Review of Literature
CHAPTER II
REVIEW OF LITERATURE

The most fundamental operations in global agricultural system are tillage and are very vital from crop production point of view. Soil tilth is a physical condition of soil in relation to plant growth. Tillage is a practice, which is earned out to loosen the soil and to produce good tilth. Tractor drawn tillage machinery have been used to create good tilth, to conserve soil water content and to increase crop yield during dry seasons. Literature regarding these parameters is reviewed under following captions:

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2.2 Agriculture in Rwanda
2.2.1 Mechanization in Rwanda
2.2.2 Fanning Systems in Rwanda
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2.2.4 Power Supply Chain
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2.1. HISTORICAL ASPECTS OF TILLAGE

Tillage is the oldest art associated with development of agriculture. Primitive man used to disturb the soil for placing seeds. Jethro Tull (1674-1741), an Englishman, is considered as father of tillage. He introduced ‘horse-hoeing husbandry’ in which crops are planted in rows and ‘horse-hoeing’ is done in between. He emphasized the need of tillage to improve the productivity of the
soil as it causes breaking of large-sized soil particles into finer ones. He held the philosophy that deeper the tillage, better is the crop growth. He believed that the soil should be finely pulverized to provide proper pabulum for the growing plants. According to him, the soil particles are actually ingested through openings in the plant roots. Tull considered tillage as a substitute for manure, and proposed a theory that plants absorb minute particles of soils. Though his theory is not correct, tillage operations are carried out to prepare a fine seed-bed for sowing crops.

Tillage operations in various forms have been practiced from the very inception of growing crop plants. To prepare a virgin or fallow land and use it for growing crops, tillage in any form is an indispensable practice even today. Tillage is one of the forms of management practices of soil, water, nutrient, crop and pests. Tillage helps to replace natural vegetation with useful crops and is necessary to provide a favourable edaphic environment for the establishment, growth and yield of crop plants.

After harvest of the crop, soil becomes hard and compact. Beating action of rain drops, irrigation and subsequent drying, movement of inter-cultivation implements and labour cause soil compaction. Further, there are weeds and stubbles after the harvest of the crop. Seeds need loose, friable soil with sufficient air and water for good germination. The field should be free from weeds to avoid competition with the crop that follows. It should also be free from stubbles to facilitate easy and smooth movement of sowing implements.

Tillage involves transference of force from one body or system to another. Force requires some energy or power. Therefore, tillage operations require power that may come from manual, animal, mechanical and other sources as well as tools, implements and equipment as aids to disturb and disrupt the normal state of the soil to a desirable extent. Tilling the soil is the most difficult and time consuming operation in field crop production. Tillage is hard work and energy-expensive. About 30% of the total cost of cultivation is for tillage operations.

Tillage was considered as an 'art' but in the recent years, research evidences have focused tillage as a 'science'. Since people began to cultivate crops, they did only what tillage was necessary to plant and to control weeds. From time immemorial, various methods of ploughing have been tried by trial and error, based on the labour availability and economic status of the farmer. As
cultivation became more sophisticated, tillage operations and equipments were altered and specialized. Powered machinery and cheap fossil fuel brought in the age of maximum tillage, loose fine seed-bed, weedless trashless fields and extensive mixing of soils with lime, plant residues and sometimes fertilizers. The cultural practices have also undergone quite a lot of changes due to the shortage and increased cost of labour and availability of machinery. A lot of cultural operations are needed to prepare the virgin soil into a good seed-bed. Tillage operations and methods of land preparation vary from place to place and even in the same place, depending upon the climate and crops cultivated (Anonymous, 2011)

2.1.1 Tilth of soil

Tilth is defined as the physical condition of the soil brought out by tillage that influences crop emergence, establishment, growth and development. It is the loose, friable, airy, powdery, granular and crumbly structure of the soil with optimum moisture content suitable for working and germination of sprouting seeds and propagates.* It indicates two properties of soil viz. the size distribution of aggregates and mellowness or friability of soil. The relative proportion of different sized soil aggregates is known as size distribution of soil aggregates. Higher percent of larger aggregates (>5 mm in diameter) is necessary for irrigated agriculture, while higher percent of smaller aggregates (1-2 mm in diameter) is desirable for dryland agriculture. A soil with good tilth is quite porous and has free drainage up to water table. The capillary and non-capillary pores should be in equal proportion so that sufficient amount of water is retained in the soil as well as free air (Anonymous, 2011)

2.2 AGRICULTURE IN RWANDA

Agriculture is an important pillar of Rwandan economy. According to National Institute of Statistics of Rwanda (2010) the agricultural sector which grew by 8%, contributed 34% of national GDP in real terms. The estimated population of Rwanda in 2009 is 10,185,435. According to FAO country report of Rwanda (2005), it was estimated that the population will rise further to 14 million by 2020. Rwanda faces serious challenges in ensuring food security for its growing population from its limited cultivable terrain.
National Institute of Statistics of Rwanda (2009) stated that Rwanda grows a range of agricultural crops over a cultivated area of 1,205,090 Ha. The major food crops grown include maize, rice, cassava, banana (cooking, beer and fruit), sweet potato, Irish potato, maize, sorghum, beans. Coffee, tea and sugarcane are the major cash crops. Vegetables such as dodo, gourds, eggplants, onions and cabbages are also widely grown. The relative changes in production of major food crops over the past 4 years are shown in Figure 2.1.

![Figure 2.1. Recent trends in production of major food- and cash crops in Rwanda. The changes arc shown in percentages. Normalized to levels of base year production in 2005.](image)

The increase in production in food crops in 2008 is mainly due to a parallel increase in area under cultivation (Table 2.1).

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Arable land (’000 Hectare)</td>
<td>2294.38</td>
<td>2294.38</td>
<td>2294.38</td>
<td>2294.38</td>
</tr>
</tbody>
</table>

(Source: Agricultural Mechanization Strategy for Rwanda, 2010)

According to National Agricultural Survey (2008), it was reported that about 84% of the total Rwandan population is dependent on agriculture, of which majority (52%) are women. A
significant proportion of the agricultural population (42.2%) receives help from family help for their field operations. In such cases, the females constituted 77.2% of help. This shows the importance of the role played by women in the handling of farm operations (kathiresan, 2010).

2.2.1 Mechanization in Rwanda

Agricultural mechanization is generally used to achieve results well beyond the capacity of human labor. It refers to application of mechanical power and technology in farm operations. Mechanization includes, but not restricted to, the use of tractors. It shall also include animal-, human-, solar-, electric- and fuel-powered energy conversions. Hence mechanization is often recognized as a means to enhance productivity of human labor in farming. Besides field operations, mechanization can be used in irrigation systems, transport, food processing and related technologies and equipment.

In several developing countries in Asia and Latin America, agricultural mechanization has made significant contributions to agricultural and rural development. Levels of production have increased, soil and water conservation measures constructed, the profitability of farming improved, the quality of rural life enhanced, and developments in the industrial and service sectors stimulated. However, until recently, mechanization efforts have stalled in Rwanda due to social disruptions in the past and the subsequent realignment of priorities. In the current context however, agricultural mechanization has become more important due to the following reasons;

• Food security: To improve food security for its growing population, the country needs to enhance its total food production. The country needs to increase its food production by increasing the area under production and by raising the productivity levels of existing lands. This requires cultivation in hitherto unutilized lands and marginal lands where there is a need for increased labor productivity.

• Urban migration: The changing lifestyles, raising incomes from non-agricultural activities and the subsequent trends in urban migration pose challenges in long term sustainability of growth in agricultural production. The general belief that agriculture
and even potential commercial farm activities involves hard physical labor and drudgery farther worsens the disenchantment amongst the rural youth.

Seasonal labor constraints: The nature of farming in Rwanda, with multiple cropping systems, increases the need for rapid land preparation and reduction in turnaround time between crops. Hence labour shortages are becoming a new trend during peak seasons, especially in areas of concentrated production such as the wet and marshlands.

- Drudgery: The excessive reliance of Rwandan farmers on human muscle, and in many cases, aged women’s muscle for the arduous tasks in farming poses serious threat on productivity and the long term sustainability of growth in agricultural production.

- Water scarcity: The climatic change and the recent drives in crop intensification require efficient management and equitable distribution of water amongst farming community. Machineries such as pumps, diesel engines and related equipments shall facilitate equitable access to water, especially for small holder farmers.

- Delicate commodity chain: In a globalized scenario, a key question is whether Rwandan farmers will be able to compete with existing gaps in commodity chain. The locally produced commodities generally (rice for instance) suffer from poor marketability. In most instances, this is due to lack of transportation and/or inept processing. Appropriate mechanization in agro processing and value addition can help increase profitability of farmers and improve rural livelihoods by generating employment opportunities.

The arguments against agricultural mechanization such as displacement of labor and the small and fragmented nature of land holdings are often due to a restricted perception that agricultural mechanization involves only the use of tractors. This is one of the fundamental dragging factors for the low levels of mechanization in Sub Saharan Africa according to Kienzle J, Cuevas R, Wall G (2006). Use of improved hand tools and animal-powered technology by small- and medium-scale farmers should be seen as an integral part of farm mechanization. Those countries that have weathered the negative perceptions in their early years of adoption (such as India, China, Brazil) are now reaping the benefits of mechanization through increase in labor productivity, increase in land productivity, and decrease in cost of production.
Farm mechanization should generally be recognized as part of a broad-based economic development strategy for national agriculture, where the short-term impacts of mechanization become less significant. Nevertheless, it is acknowledged here that care should be taken to ensure tandem movements of technological, cultural, economical and social development in order to reduce any socioeconomic consequences of mechanization and to enable well-balanced adoption of mechanization in Rwanda.

It is therefore imperative to create a policy, institutional and market environment in which farmers and other end-users in Rwanda have the appropriate choices of farm power and equipment within a sustainable delivery and support system. This forms the objective of formulating mechanization strategy.

2.2.2 Farming Systems in Rwanda

Most of the farmlands in Rwanda consist of fragmented plots of land. The average surface area of farm holding in Rwanda is 0.76 Ha. On an average, the farm holdings are spread over 4 different blocks of lands. Approximately 80% of farms have a surface area of less than 1 Ha each.

Seven types of terrain which influence mechanization options have been identified in Rwanda (Table 2.2). The eastern province is largely characterized by flat lands and shallow sloped hills. The Northern and Western provinces have steep sloped hills. The southern province consists of hills with moderate slopes. All provinces have valleys with either marshlands or wetlands. Terracing is a feature found on moderate to steep hills in the all provinces. The land adjacent to the volcano in Musanze district of the Northern Province is characterized by rocky soils. The seven terrains identified are steep hills, terraced steep hills, shallow hills, flat dry lands, marshlands, wet lands and volcanic lands.
Table 2.2: Distribution of terrains

<table>
<thead>
<tr>
<th>Province</th>
<th>Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern</td>
<td>Flat lands and rolling hills</td>
</tr>
<tr>
<td>Southern</td>
<td>Gentle hills with medium slopes, wet lands and Marshlands, terraced lands</td>
</tr>
<tr>
<td>Northern</td>
<td>Steep hills, wet lands and marshlands, terraced lands, volcanic lands</td>
</tr>
<tr>
<td>Western</td>
<td>Steep hills, wet lands and marshlands, terraced lands</td>
</tr>
</tbody>
</table>

(Source: Agricultural Mechanization Strategy for Rwanda, 2010)

The variability in the distribution of slopes in selected districts of each of the provinces is shown in Table 2.3. The eastern province has most of its slopes between 0 and 16%. This terrain is suitable for use of animal- and tractor powers. The southern province have most of the lands in the 6-40% category which makes tractor use risky but allows for two-wheel tractors, animal traction operation. Tractors with greater roll-over angles could also nevertheless be used here. Although the topography is highly variable, the Northern and Western provinces have most of their lands in the 16-40% zone with limited suitability for tractor use. There is also room for animal traction on areas with 0-16% slopes. It should be noted that all four provinces have lands with 0-16% slope and are therefore suitable for tractor use. The wide variations in topography of terrains highlight the need for site specific mechanization options in Rwanda (kathiresan, 2010).

Table 2.3: Distribution of slopes (%) in selected districts of each province

<table>
<thead>
<tr>
<th>Province</th>
<th>District</th>
<th>Sector</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-40%</th>
<th>40-60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>Bugesera</td>
<td>Nyamata</td>
<td>60.93</td>
<td>38.52</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Bugesera</td>
<td>Musenyi</td>
<td>64.09</td>
<td>34.83</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>North</td>
<td>Burera</td>
<td>Rwerere</td>
<td>9.52</td>
<td>18.69</td>
<td>68.76</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td>Burera</td>
<td>Nemba</td>
<td>10.09</td>
<td>16.56</td>
<td>70.23</td>
<td>3.11</td>
</tr>
<tr>
<td>South</td>
<td>Kamonyi</td>
<td>Kayenzi</td>
<td>9.61</td>
<td>34.16</td>
<td>58.57</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>Kamonyi</td>
<td>Ngamba</td>
<td>21.32</td>
<td>21.43</td>
<td>43.21</td>
<td>1.3</td>
</tr>
<tr>
<td>West</td>
<td>Karongi</td>
<td>Rubengeral</td>
<td>6.05</td>
<td>21.43</td>
<td>70.51</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>Karongi</td>
<td>Rubengeral</td>
<td>9.91</td>
<td>28.11</td>
<td>60.78</td>
<td>1.21</td>
</tr>
</tbody>
</table>

(Source: Agricultural Mechanization Strategy for Rwanda, 2010)

2.2.3 Current Status of Agricultural Mechanization in Rwanda

Most of the field operations in Rwanda are carried out by human labour. Use of hand tools accounts for 98.5% of all land tilled in Rwanda. Use of animal traction or tractors is isolated and
does not significantly contribute to agricultural production in Rwanda. Application of animal traction is very limited in Rwanda. Current statistics put the level of use of animals and tractors at 1.4% and 0.1% respectively. In 2008, Rwanda recorded 1,548,521 cattle. Nyagatare district in the Eastern province shows the most signs of animal traction use in the country. The impact of culture, grazing and maintenance requirements of using draft animals in on cost-benefit ratio remains to be studied. Recently MINAGRI imported a total of 66 tractors, 50 power tillers (15 HP), 2 rice transplanters and implements for ploughing and harvesting (potato) from Tong Yong Moolsan (TYM) Inc. South Korea. These machineries are currently being sold to farmers and farmer co-operatives.

Table 2.4: Current status of agricultural mechanisation

<table>
<thead>
<tr>
<th>District</th>
<th>Province</th>
<th>Hand tools</th>
<th>Animal draft</th>
<th>Motorized traction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyagatare</td>
<td>East</td>
<td>Most farmers</td>
<td>Isolated pockets</td>
<td>Very limited; Some Co-ops own and buy tractors</td>
</tr>
<tr>
<td>Ruhango</td>
<td>South</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Nyanza</td>
<td>South</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Kayonza</td>
<td>East</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Bugesera</td>
<td>East</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Rulindo</td>
<td>North</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Kirehe</td>
<td>East</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Gisagara</td>
<td>South</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Nyamagaba</td>
<td>South</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Kamonyi</td>
<td>South</td>
<td>Most farmers</td>
<td>Isolated (NGO)</td>
<td>None</td>
</tr>
<tr>
<td>Ruhango</td>
<td>South</td>
<td>All farmers</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

(Source: Agricultural Mechanization Strategy for Rwanda, 2010)

The existing level of mechanization inherently perpetuates drudgery and prevents diversification of land use patterns. The low levels of mechanization also restrict the engagement and performance of household tasks, more so by women. The rapidly changing demographic trends such as urban migration, ageing rural population, ageing farmers, and the HIV/AIDS pandemic add more concerns on labor availability (kathiresan, 2010).
2.2.4 Power Supply Chain

2.2.4.1 Hand Tools

Hand tools such as hoes, picks and shovels are sourced from China. These are imported by the wholesalers in Kigali. Retail outlets in the districts and sector level shops are procuring from the Kigali wholesalers and then selling directly to farmers. Hoes are readily available even in the remote areas at prices ranging from 1300-1500 FRW. The handles are either procured in Kigali or crafted by the farmers from tree branches cut down in their vicinity.

Farmers do not find any constraints in availing the tools from the suppliers. The supply chain is demand-driven and executed by the market. It does not need any support services from the government. Knapsack sprayers are also readily available in hardware shops in Kigali and in district centers all over the country. The sprayers are being sourced from China, India and Brazil.

Human labor, the most common farm power, is generally readily available in the country side. The recent efforts on crop intensification in the country prompt sequential cropping and synchronization of farm activities. Hence seasonal labor constraints and the subsequent increase in cost of production have begun to emerge in areas under intensive cultivation. Depending on the course of season, the minimal daily labor wages can range from 700 FRW/day to 1000 FRW. Such variability in wages during a crop season affects timely operations by small holder farmers (kathiresan, 2010).

2.2.4.2 Animal Draft inputs

The Rwandese Association for Sustainable Development (ARDI) is the only manufacturer of animal drawn equipment identified in Rwanda. The premises have only some very basic tools such as cultivator and plough with French type tool bar earners. The quality of such tools is however low. Some of the local non-government organizations (NGO) distribute the products to farmers directly. The demand for such tools is generally low due to limited use of animal draft power and unstable supply. Human capacity and skills are major constraints in the manufacturing of animal draft inputs.
Two retail stores (BrazAfric and Tasha Enterprises) located in Kigali sell animal drawn implements. These outlets import the implements from China, Uganda and Kenya. While there are no supply related constraints, the demand for such implements are low in Rwanda. Through various programs and projects in the past, some co-operatives have also accumulated drum seeders (rice), land levelers and rotary weeders (kathiresan, 2010).

2.2.4.S Tractors and related Implements

Following the import of new machineries, Ministry of Agriculture has set up a workshop facility at Kabuye, Kigali. A mobile workshop has also been set to attend to installation and problems faced by the new buyers and already existing owners of farm machineries. Tractors of other makes such as Massey Ferguson and Ford could also be found in the Eastern province. The retail outlets in the country do not sell spare parts or tractor drawn implements, as the demand is very low, although they could be sourced from Uganda and Kenya. The imports and distribution of farm machinery and farm equipment meet the existing levels of demands of the farming community. The repair and maintenance services however do not support the efficient use of farm machinery and equipment (kathiresan, 2010).

2.3 VISION 2020 OF RWANDA

Government of Rwanda aspires to fundamentally transform Rwanda into a middle income economy (with a per capita income of 900 USD), reduce the people living below poverty line to 30%, and raise the average life expectancy to 55 years by the year 2020.

To realize this vision, the government seeks to transform agriculture into a productive, high value, market oriented sector, with forward linkages to other sectors. Vision 2020 aims to modernize 50% of its agricultural land by 2020. Experience in other African countries (such as Ethiopia, Nigeria, South Africa, and Zambia) and in other developing economies of Asia and Latin America show that mechanization has transformed agriculture in recent years into a modern, progressive commercial activity. Agricultural mechanization in these countries has enabled farmers to intensify production and improve their quality of life as well as contributing to rural prosperity. Much the same could happen in Rwanda, if farmers and other end users in agriculture are provided with suitable options of mechanization.
Vision 2020 acknowledges that Rwandans can no longer subsist on land. The government recognizes the need, instead, to devise ways and means to move the population and economy from its dependence on agriculture into the secondary and tertiary sectors. Mechanization can help attenuate labor constraints and thereby allow farm- and farm dependent families to devote more time on off-farm activities, earn additional incomes, and expand their livelihood strategies. Even in areas that are heavily reliant on crop farming, significant remuneration can be made from, non-farm employment such as in small scale agro-processing industries, trading and brick-making, and thus can indirectly promote activities in other sectors.

Vision 2020 also seeks to develop an efficient private sector in all sectors and expects it to be driven by the spirits of competitiveness and entrepreneurship. Rwanda have entrepreneurs/farmers who are ready to invest in draught animals, machinery and implements for use on their farms as well as for providing mechanization services to the small-scale farmers who are unable to gather such levels of capital investments. If the tractor and irrigation markets could be expanded, the opportunities for manufacturing and/or assembling industry would also open up in Rwanda. Furthermore, mechanization can also prompt development of small-scale agro-processing industries. Thus, agricultural mechanization is consistent with the long term strategies of Rwanda (kathiresan, 2010).

2.3.1 Economic Development and Poverty Reduction Strategies (EDPRS)

EDPRS, the medium term strategy for 2008-2012 developed by the Government of Rwanda, seeks to increase economic growth through modernization of agriculture. The productive expenditures under EDPRS aims to (i) address skills shortages and (ii) modernize the agriculture.

EDPRS acknowledges that the low level of agricultural productivity in Rwanda is due to the low level of agricultural technology. EDPRS also intends to assign a greater role in policy implementation to markets and the private sector. To promote commodity chains and support the development of agribusiness, EDPRS intends to subsidize the acquisition of key inputs by farmers’ cooperatives. Under EDPRS, public investments are being directed into the construction and rehabilitation of feeder roads. It aims to reduce the employment in agriculture (% reporting as main occupation) to 70% by 2012 (from 80% in 2007).
Agricultural mechanization can act as a catalyst in all of these main programs - By reducing/eliminating the fallow period and promote crop sequencing, by minimizing the time for field operations, the farmers can find more time to improve their technical capabilities in agricultural production and by improving the quality of production commodity chains can be strengthened, by encouraging the private sector and entrepreneurship, rural financial markets can be developed and the supply of agricultural credit from private and/or public sources to both men and women can be improved (kathiresan, 2010).

2.4 SOIL TILLAGE CONCEPT

Working on the tropical soils of Nigeria, Lai (1991) reported that disking at 20 to 30 cm depth in conjunction with harrowing improved soil quality and crop yield by increasing infiltration of water into soil profile.

Li and Islam (1992) stated that possible beneficial effects of tillage on the soil physical environment include increased transmission of water into the soil profile via macro-pores.

The long term objective of judicious tillage is to improve soil quality and its capacity to perform economic, ecological and aesthetic function. In South and South East Asia, some farmers believe that in the slogan “more frequent and deeper the ploughing more the yield” (Lai, 1995).

Hill et al. (1995) found in mollisols from Iowa that tillage practice of disc ploughing combining with harrowing improves water infiltration by reducing runoff and retained more plant available soil water.

Nitant (1995) stated that one of the major advantages associated with disking and harrowing combination of tillage is greater availability of water and reduced water loss due to evaporation especially in years with low rainfall.

Hill et al. (1995) observed greater pore-space available for storage of plant available water under disking at 30 cm depth and harrowing combination tillage and utilization of total water resources appeared to be better than no tillage, simply because of higher soil water infiltration and lower soil water evaporation eventually linked to higher crop yield.
Machinery application in agriculture has been one of the most advanced developments in agricultural productions. Land preparation with tillage implements is the main mechanization operation in agriculture. Soil tillage may be defined as the mechanical manipulation of the soil aimed at improving soil conditions for crop production. It represents the most costly single item in the budget of an arable farmer. Three things are involved in soil tillage which include: the power source, the soil and the implement (Oosterhout et al, 1996).

Diaz (1996) stated that tractor tillage practice of disc ploughing at 30 cm depth followed by two passes of harrowing leads to positive change in soil water content.

Rowse et al. (1998) measured 28% increase in plant soil water retention with disc plough and harrowing tillage practice.

Land preparation or tillage is the physical manipulation of the soil with appropriate implements to loosen the surface soil layer. The main objectives of tillage are to provide an ideal environment for plant growth and specifically to prepare a seedbed which permits optimal soil water-air relations; provide good physical conditions for early root penetration and proliferation; destroy weeds and hibernating pest and disease organisms; and facilitate proper soil chemical and microbial activities (Lai, 1998).

Rowse (1998) stated that the soil physical environment is important for maintaining sustained agricultural production; a concept embodied in the presumption that good soil tilth is a precursor to high productivity.

According to Papendick (2000) tillage is defined as the physical manipulation of soil and it is intended to increase infiltration, reduce evaporation, prepare seed bed and break hard layers to facilitate root penetration.

Disc ploughing followed by harrowing has been widely claimed as highly effective practice for the conservation of soil moisture as compared to other tillage practice. It enhances water conservation through improved infiltration and reduced evaporation (Unger et al 2000).

Soil tillage is one of the fundamental agrotechnical operations in agriculture because of its influence on soil properties, environment and crop production in general. To assure normal plant growth, the soil must be in such conditions that roots can have enough air, water and nutrients (Hussain, 2001).
Tillage is one of the fundamental practices of agricultural management. It is the procedure by which man disturbs, overturns and rearranges the soil to create favorable soil physical conditions for crop growth. The tillage operations loosen, granulate, crush, or even compact the soil particles. Any tillage operations that changes soil bulk density in turn modifies pore size distribution, water holding capacity, infiltration rate, penetration, resistance and soil aeration. Different tillage practices prevail among the farming community. The way they improve the aforementioned physical properties is critical in the selection of a certain tillage practice for a specific location. However, a tillage system having better impact conducive for crop growth and economic return would be an ideal one (Khan et al., 2001).

Pikul et al. (2001) stated that tillage practices with heavy machinery physically break macro aggregates into smaller units, leading to new surfaces. These changes in soil structure act on the pore-size distribution and thus influence drainage or plant-available water content. Pore-size distribution is one sensitive soil physical property that can be used to evaluate the influence of tillage on the physical condition of the soil because it regulates the rate of water entry into the soil. It also influences soil water fluxes, which affect plant nutrient availability and plant growth. Three important phenomena related to plant nutrition, which are negatively affected by reduction in macro pores are: root growth, nutrient interception by roots, and soil drainage and aeration.

Erbach et al. (2002) conducted a three year study in Iran using combined equipments like disc plough at 15 to 20 cm and 25 to 30 cm depth and disc harrow with two passes. Based on the result of the research, the disc ploughing at 25 to 30 cm depth with two passes of harrowing is getting popularity due to its effect on soil moisture retention.

Soil tillage is a mechanical and soil stirring actions exerted on soil to modify soil conditions for the purpose of nurturing crops. The aim of these actions is to provide suitable environment for seed germinations and crop root development while suppressing weed, controlling soil erosion and maintaining adequate soil moisture (Koller, 2003).

Anderson (2003) stated that all physical parameters affecting seedling emergence and root growth, that is, soil wetness, aeration, temperature, and penetration resistance, are affected by tillage.

Jones (2004) stated that tillage suppresses evaporation loss of water by insulating and cooling the soil surface, reflecting solar energy, decreasing wind speed at or near the soil surface, and providing a barrier against water vapour movement. Tillage also influences the advance of the wetting front of specified water content into the soil.

Loosening of soil through tillage increases the relative proportion of larger pores in the tilled layer, which will drain out rapidly and restore adequate water-free porosity soon after heavy rain and/or irrigation (Lai, 2004).

Sharma et al (2004) stated that there are several objectives of tillage, of which, the most important ones are: suitable seed-bed preparation, weed control, and soil and water conservation. The other objectives include improvement of soil structure, soil permeability, soil aeration, root penetration, destruction of pests, soil inversion etc. Good seed-bed is necessary for early seed germination and initial good stand of the crop. The seed-bed should be fine for small-seeded crops and moderate for bold-seeded crops. Intimate contact between the soil particles is necessary to facilitate movement of water for quicker germination.

Proper tillage results in soil and moisture conservation through higher infiltration reduced runoff and increased depth of soil for moisture storage. When the compact soil is ploughed, it becomes fluffy and can hold more amount of water. Removal of hard pans increases the soil depth for water absorption. Surface roughness and furrow dikes slow down the velocity of runoff and provide more opportune time for infiltration of water (Sharma et al, 2004)

Iqbal (2006) informed that when a field is ploughed, the soil particles are loosely stacked in a random manner and pore space is increased. When the soil is in good tilth, the capillary and non-capillary pores would be roughly equal. This facilitates free movement of air and moisture in the soil. The pore system in un-ploughed plots is often more continuous because of earthworm activity, old root channels, and vertical cracks between pads, especially in clayey soils. The number and geometry of water-conducting pores determine the tillage.
For thousands of years of recorded history, humankind has been tilling the soil in order to increase the production of food. Soil tillage, in general, is one of the fundamental field operations in agriculture because of its influence on soil properties, environment, and crop production. (Anonymous, 2011).

2.5 REGRESSION ANALYSIS

History

The earliest form of regression was the method of least squares (French: *méthode des moindres carrés*), which was published by Legendre in 1805, and by Gauss in 1809. Legendre and Gauss both applied the method to the problem of determining, from astronomical observation; the orbits of bodies about the Sun. Gauss published a further development of the theory of least squares in 1821, including a version of the Gauss-Markov theorem.

The term "regression" was coined by Francis Galton in the nineteenth century to describe a biological phenomenon. The phenomenon was that the heights of descendants of tall ancestors tend to regress down towards a normal average (a phenomenon also known as regression toward the mean). For Galton, regression had only this biological meaning, but his work was later extended by Udny Yule and Karl Pearson to a more general statistical context. In the work of Yule and Pearson, the joint distribution of the response and explanatory variables is assumed to be Gaussian. This assumption was weakened by R.A. Fisher in his works of 1922 and 1925. Fisher assumed that the conditional distribution of the response variable is Gaussian, but the joint distribution need not be. In this respect, Fisher's assumption is closer to Gauss's formulation of 1821.

Regression methods continue to be an area of active research. In recent decades, new methods have been developed for robust regression, regression involving con-elated responses such as time series and growth curves, regression in which the predictor or response variables are curves, images, graphs, or other complex data objects, regression methods accommodating various types of missing data, nonparametric regression, Bayesian methods for regression, regression in which
the predictor variables are measured with error, regression with more predictor variables than observations, and causal inference with regression. (Freedman, 2005)

2.5.1 Definition

Regression equation is a statistical technique used to explain or predict the behavior of a dependent variable. Generally, a regression equation takes the form of \( Y = a + bX + cX^2 \), where \( Y \) is the dependent variable that the equation tries to predict, \( X \) is the independent variable that is being used to predict \( Y \), ‘\( a \)’ is the \( Y \)-intercept of the line, and ‘\( c \)’ is a value called the regression residual. The values of ‘\( a \)’ and ‘\( b \)’ are selected so that the square of the regression residuals is minimized.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. (Freedman, 2005)

2.5.2 Regression diagnostics

Once a regression model has been constructed, it may be important to confirm the goodness of fit of the model and the statistical significance of the estimated parameters. Commonly used checks of goodness of fit include the R-squared, analyses of the pattern of residuals and hypothesis testing. (Freedman, 2005)

2.6 DATA MODELING

Sanders (1995) stated that the process of designing a database involves producing the previously described three types of schemas - conceptual, logical, and physical. A fully attributed data model contains detailed attributes (descriptions) for every entity within it. Principally, and most correctly, it can be thought of as the logical design of the base data structures used to store the data.
John (2001) told that data modeling may be performed during various types of projects and in multiple phases of projects. Data models are progressive; there is no such thing as the final data model for a business or application. Instead a data model should be considered a living document that will change in response to a changing business. The data models should ideally be stored in a repository so that they can be retrieved, expanded, and edited over time.

Bekke (2005) stated that data modeling techniques and methodologies are used to model data in a standard, consistent, predictable manner in order to manage it as a resource. The use of data modeling standards is strongly recommended for all projects requiring a standard means of defining and analyzing data within an organization.

Data models provide a structure for data used within information systems by providing specific definition and format. If a data model is used consistently across systems then compatibility of data can be achieved. If the same data structures are used to store and access data then different applications can share data seamlessly (Graeme, 2005).

A simulation is the implementation of a model. A steady state simulation provides information about the system at a specific instant in time (usually at equilibrium, if such a state exists). A dynamic simulation provides information over time. A simulation brings a model to life and shows how a particular object or phenomenon will behave. Such a simulation can be useful for testing, analysis or training in those cases where real-world systems or concepts can be represented by models (Graeme, 2005).

Data models represent information areas of interest. While there are many ways to create data models, according to Graeme (2007) only two modeling methodologies stand out, top-down and bottom-up:

- Bottom-up models are often the result of a reengineering effort. They usually start with existing data structures forms, fields on application screens, or reports. These models are usually physical, application-specific, and incomplete from an enterprise perspective. They may not promote data sharing, especially if they are built without reference to other parts of the organization.
• Top-down logical data models, on the other hand, are created in an abstract way by getting information from people who know the subject area. A system may not implement all the entities in a logical model, but the model serves as a reference point or template.

Sometimes models are created in a mixture of the two methods: by considering the data needs and structure of an application and by consistently referencing a subject-area model.

2.7 TILLAGE AND CROP PRODUCTION

Soil plays a predominant role as a reservoir of microorganisms which stimulate the physical processes affecting crop establishment and yield. The capacity of soils to sustain the nutrient cycles, energy flows through soil aggregates and ability to recover from degradation and deterioration after intensive exploitation depends on the tillage techniques (Lai, 1998).

Rowse (1998) stated that quality of soil pulverization in terms of aggregate size distribution resulting from the types of tillage techniques has a pronounced effect on soil moisture retention characteristics and other physical properties that enhance suitable and stable soil structure. Soils that are structurally viable and stable for crop production can be identified by their structural properties which include infiltration rate and soil moisture retention. Soil physical properties are affected by tillage system with a residual influence on soil moisture reservoir, nutrient dynamics and crop performance.

Coarse-textured soils, characterized by low water retentivity and high permeability exhibit a sharp increase in soil strength on drying. Because of low available water storage of the root zone and high potential for leaching of mobile nutrients, crops on these soils are subjected to yield-reducing water and nutrient stresses. The problem is further exacerbated by the slow growth of roots due to high soil strength. Deep tillage of such soils helps alleviate these stresses by enlarging the root system, thus enhancing the water and nutrient uptake capacity of the crop, which results in increased yield (Rowse, 1998).
Srivastava (2002) reported that tillage affects the soil water status and also the capacity of the crop to utilize water. It alters surface and sub-surface soil conditions that govern infiltration, runoff, and evaporation of water, weed growth, crop establishment, and root growth of the crop.

Seed germination and seedling growth are greatly affected by the fineness of the soil clods. The degree of soil pulverization differs with the type of machine used, tilling method and operating condition of machine. Pulverization also differs with soil conditions such as water content or particle distribution and ground cover like straw or grass. Some soils are compact and do not allow the entry of plant roots into the soil. Soil furnishes anchorage for plant roots. Soil must be sufficiently open so that roots can penetrate easily. The soil is being constantly and uniformly moved in a forward and upward direction as the plough advances and hence pulverization takes place (David, 2002).

Srivastava (2002) confirmed through several investigations from Punjab that 30 cm deep ploughing, 25 to 30 cm apart, of sand, loamy sand, and sandy loam soils increased the yields of corn, wheat, mustard, and sunflower as compared to conventional tillage (10 cm deep disking).

Studies show that compared with other tillage practice, disc ploughing at 25 to 30 cm depth in combination with harrowing, yield of crops such as maize and beans are greater (Srivastava, 2002).

Adeoeye (2003) confirmed that optimum tillage depth is considered essential in crop production. A three year tillage study on heavy clay soil in Kenya on effect of five various tillage treatments on beans production concluded that disking at 30 cm depth followed by two passes of harrowing enhance beans production.

Adeoeye (2003) conducted three years field experiment to study the effect of three tillage depths (5, 15 and 30 cm) on soil physical properties and on yield of maize (*Zea mays*) on a clay soil and concluded increase in porosity and storage of water. The yield of maize was increased by about 17%. 

Studies have indicated that increased soil moisture under deep tillage up to 30 cm was associated with greater maize yields, particularly in years of less rainfall (Adeoye 2003).

Adeoye (2003) conducted a field experiment in a well drained, loose derived soil in Germany with a specific objective to determine if regular tillage induces differences in rooting pattern, water uptake and plant growth as compared to untilled soil. The result showed that in tilled soil a plough-sole layer at 20-30 cm depth induced higher rooting densities. The total water uptake and initial shoot growth were found to be greater at 20 to 30 cm depth of ploughing as compared to 10 to 20 cm depth. The water uptake rate was functionally related to rooting density and soil water potential.

Adeoye (2003) reported that the ploughing and harrowing combination tillage practice for crop production in south west of Nigeria under mechanized farming with a 60 hp tractor has improved soil moisture retention, aeration and smooth soil tilth significantly.

Sharma (2004) stated that summer deep ploughing improves soil structure due to alternate drying and cooling. Tillage at improper depth also damages soil structure and leads to development of hard pans. Soil permeability is increased by breaking the compacted layers. Tillage improves soil aeration which helps in multiplication of micro-organisms. Organic matter decomposition is hastened resulting in higher nutrient availability. Increased aeration also helps in degradation of herbicide and pesticide residues and harmful allelopathic chemicals exuded by roots of previous crop.

Sharma (2004) reported that roots grow into soil pores or root channels of the decomposed roots of the previous crop(s). Where such pores or channels do not exist, the growing root makes its own path by displacing the soil particles. Therefore, the purpose of tillage is to create pores larger in size than the root tip or to facilitate the displacement of soil particles by the growing root. Dense layers in the sub-soil, which develop high soil strength on drying, restrict root growth. Loosening of such layers by sub-soiling is reported to enhance root extension into deeper soil layers. Apart from mechanical impedance, root growth is also sensitive to soil wetness status, aeration, and variations in soil temperature.

Sharma (2004) confirmed the need to understand how biological, chemical and physical characteristics of soil are influenced by tillage management practices. It is also generally
accepted that the type of tillage system adopted for soil manipulation prior to planting does affect the geometry of root systems, nutrient accessibility to plants and consequently, crop establishment and growth.

Roots occupy only about a tenth of the soil mass. Breaking of hard pans and compacted layers increase depth of root penetration. In addition, root growth is unhindered when the soil mechanical resistance or soil strength is less. Roots proliferate profusely in loose soil. Increase in soil mechanical resistance decreases root growth of barley, wheat, pea, rapeseed, linseed, safflower, sunflower etc. The seminal and lateral root growth of these crops is reduced due to high soil mechanical resistance of unploughed compact soil. Thus, loosening the soil is necessary for better growth (Gajiri et al. 2005).

Gajiri et al. (2005) conducted a three year study on the effects of deep tillage on maize growth in loamy sand and sandy loam soils and concluded that tillage decreased soil strength and caused deeper and denser rooting and eventually found significant yield increase. Azzoz (2006) stated that sub-soiling or deep ploughing with harrowing can reduce soil compaction on soil with root restricting layers and yield increases following sub-soiling were attributable to great reutilization of sub-soil moisture by crops. Breaking up the hard pan enables the plant roots to penetrate lower soil regions to obtain available moisture and nutrients. The relative yield increases due to sub-soiling with the greatest benefits occurring in low rainfall region, due to the increased rooting volume created by sub-soiling. Deep tillage breaks-up high-density soil layers, improves water infiltration and movement in the soil, enhance root growth and development, and increase crop production potentials and concluded that deep fracturing and loosening of naturally formed fragipans by deep tillage up to 30 cm with harrowing was important in improving root penetration for com production.

Azzoz (2006) reported that aeration and porosity in tilled plots are 30% higher than in untilled soils.

Azzoz (2006) stated that soils with crumbly and granular clods are considered as soils with good structure. When the soil is subjected to tillage at optimum moisture, crumb structure is developed so that loss of soil by erosion is greatly reduced. Rain water is held in the large pores, between
the aggregates and also in the micro-pores of the aggregates. It is considered that soil aggregates of 1 to 5 mm in size are favourable for growth of plants. Smaller aggregates may clog the soil pores and larger ones may have large pore space between them and affect the development of rootlets of the young seedlings.

2.8 SOIL MOISTURE MIGRATION PATTERN

Refsgaard (2005) carried out a laboratory study of soil moisture migration pattern considering (x,y) plane to determine the width of water spread around the root zone and (x,z) plane as to determine the depth of water movement around the root zone of the crop.

Refsgaard (2005) while computing the maximum area under wetting surface under laboratory condition used curve expert package to fit the equations for the upper and lower parts for the graphs plotted from the transparent soil boxes and recorded the mathematical equations.

Harrold (2007) studied the soil moisture migration pattern under laboratory condition using transparent soil boxes to understand the migration pattern of water movement under laboratory condition.

Paul et al (2007) informed that water movement in the soil column compacted with the soil of the experimental field provides a workable concept about how soil moisture moves in the field towards the root zone of the crop.

Harrold (2007) conducted a study on soil moisture migration under laboratory condition using the soil from the experimental plots filled and compacted by hand in transparent soil boxes and water was allowed to flow through a pipe on the top of the soil column under constant water head.

Paul et al (2007) while studying soil moisture migration pattern under laboratory condition used dripper of different orifice sizes and allowed water to migrate in the soil boxes until the soil was wetted in the boxes and clearly visible for marking the path of water movement in the soil column.
Harrold (2007) informed that the objective of the soil moisture migration study is to find out the maximum area of wetting surface around the root zone of the crop.

Paul et al (2007) computed the wetting surface area under laboratory condition using numerical integration of Simpson’s rule and C++ language computer program.