Summary and Conclusions
CHAPTER V
SUMMARY AND CONCLUSIONS

Tillage is a practice, which is earned out to loosen the soil, to conserve soil water content and to produce good tilth. Soil tilth is a physical condition of soil in relation to plant growth. Rwanda is lying in tropical region having two dry and two rainy seasons. Average annual rainfall of 700 to 1000 mm in the study area is mostly distributed during two rainy seasons. Average diurnal temperature causes rapid evaporation and increased transpiration resulting in moisture stress for the crops grown in the dry seasons, causing an increase in mechanical impedance and restricted rooting. Because of the soil and climatic condition and restricted rooting, crops grown during dry seasons suffer water and nutrient losses leading to yield decrease. Apart from that Rwandan farmers are still using primitive tool like hand hoe for both primary and secondary tillage operations having maximum depth of 8 cm to 10 cm. The continuous ploughing at shallow depth results in development of hard pan which restricts nutrient movement and root penetration. This leads to the acute moisture deficiency problem during the dry seasons which eventually affects the crop growth and yield.

Hence, studies were designed for three years with following specific objectives, a) To study the effect of different tillage treatments on soil moisture retention during dry seasons b) To develop a multiple linear regression model for different tillage treatments with respect to soil moisture retention and weather parameters during long dry season c) To study the comparative crop performance under best tillage treatment with conventional method during dry seasons d) To study the soil moisture migration pattern under different flow rates by using computer aided packages.

In study-1, a flat land area of 85 m x 65 m was taken for the experiment plot in the research and production farm of Higher Institute of Agriculture and Animal Husbandry at Rubilizi which is in the outskirt of Kigali city of Rwanda. Tractor drawn tyne cultivator, disc plough, disc harrow and hand hoe were selected for carrying out tillage operations, since these machineries are found available in the study area. All the weather parameters pertain to the study period collected from National Airport Authority Meteorological Observatory. Soil moisture content in the field was measured by using gravimetric method.
Three factors split plot design was used in the study. Eight tillage treatments were taken as first factor. The treatments are named as T1- Ploughing with tyne cultivator for 15 cm depth, T2- Ploughing with tyne cultivator for 15 cm depth and one pass of disk harrowing, T3- Ploughing with tyne cultivator for 15 cm depth and two passes of disk harrowing, T4- Disk ploughing for 30 cm depth, T5- Disk ploughing for 30 cm depth with one pass of disk harrowing, T6- Disk ploughing for 30 cm depth and two passes of disk harrowing, T7- Hand hoe is used to prepare the soil and T8-No tillage operation in the field. Second factor considered as depth of ploughing namely 10 cm, 20 cm and 30 cm. Soil moisture content present in the experimental plots observed at different depth of ploughing at every week interval for the period of dry season, was taken as third factor. Agricultural research package (AGRES) was used to analyze the data which was collected for short and long dry seasons.

In study-2, the mean moisture content present at 10 cm, 20 cm and 30 cm depths for every weekly interval for 16 weeks (Mid May 2009 to Aug, 2009) was recorded from the eight different tillage treatments plots. Mean weekly evaporation, mean weekly ambient temperature and mean weekly relative humidity were obtained from the Kanombe Meteorological Observatory for 16 weeks. Mean soil moisture content for the depth of 10 to 30 cm was taken as dependent factor. Evaporation, temperature and relative humidity were taken as independent factors. The validity of the above equation was determined by the r² value in decimal. The r² value is multiplied by 100 to get the percent dependability of the fitting of equation. It is used to model the multiple regression equation of the following form: C1 = a₀ + a₁ C2 + a₂ C3 + a₃ C4.
Where C1 – Soil moisture content in percent - (dependent factor), C2 – Evaporation, mm - (independent factor), C3 – Ambient temperature, °C - (independent factor), C4 – Relative Humidity, percent - (independent factor), a₀, a₁, a₂ and a₃ are constants. Multiple linear regression analysis was carried for the eight tillage treatments using NCSS2007 statistical package.

In study-3, four sample plots of 16 m x 12 m each were taken up in the experimental site. Two plots were prepared by using best tillage treatment out of eight tillage treatments adopted in the study and another two plots were conventionally prepared with hand hoe. All the four plots were chosen side by side. There was a gap of 1 m between the plots as path way. The ruling varieties of maize (Pool 9) and beans (PK 10) crops were selected for the study. Both crops raised in tilled
and conventionally prepared plots separately for comparison. As per the recommendation of the Directorate of Farm production, ISAE, Rwanda basal dose application, seed rate, row spacing, plant protection measures and weeding were carried out for both crops. The man-hours involved in different farm operations, plant parameters and crop yield were recorded. The trials were carried out for both short and long dry seasons.

In study-4, three boxes made up of transparent material of size 40 cm x 30 cm x 30 cm each were used to study the migration pattern of water movement in the soil. The soil from the experimental field was collected and prepared it free from stone, weed and clods. A known volume of soil was filled in each box and compacted so as to prevent any voids present inside. However, 15 cm depth of soil layer was maintained in all the three boxes. A tank with a head of 1.20 m was permanently kept as the source of water supply for the system. Water was allowed to flow through a pipe diameter of 1 cm, from there the line was connected through three different drippers having sizes of 1.5 mm, 1.75 mm and 2 mm and kept it on top of the soil. The soil present in each box wetted by known quantity of five liter water, which allowed to pass through a dripper. The flow rate of each dripper was measured. And found that 1.5 mm size dripper delivered 0.28 lpm, 1.75 mm size dripper delivered 0.33 lpm and 2 mm size dripper delivered 0.46 lpm. The water allowed wetting the soil present in each box by a dripper with a fixed flow rate. Each time the wetting pattern was marked in the transparent side of the box with the help of a marker pen and was mapped in graph sheets in (x,y) side and (x,z) sides. The said experiment was replicated six times at every week interval and the mean values have been taken. The data set for (x,y) and (x,z) for different flow rates were analyzed with computer aided packages like Excel curve expert 1.3 research package and C++ for arriving the equations to simulate the curve of soil moisture migration.

The data processed and interpretation offered in the proceeding chapter was summarized and the relevant conclusions useful to the academic and farmers point of view are given below:

1. During the short dry season, the ANOVA showed that 8 different treatments adopted in the experiment, different depth of tillage like 10 cm, 20 cm and 30 cm adopted in the experiment, the moisture content measured in 12 weeks and the interaction of 3 depths
and 12 weeks were highly significant at 1% level. Similarly, interactions of the two factors like depth and tillage treatments and the three factors like depth, week and tillage treatments are not significant. It is also found that coefficient of variation in the experiment is 4.11%, which is less than 30%. Hence, this experiment can be accepted.

2. During the short dry season, it is found that the soil having 20 to 30 cm depth is holding high moisture content and the 10 to 20 cm is having medium moisture content. The top soil of up to 10 cm depth is having low moisture content because of dry climate. It was also found that T6 (Disk ploughing with 2 Harrowing) is holding the highest moisture content due to pulverization of soil particles and the lowest is T8 (no tillage) because soil was not disturbed.

3. During the short dry season, it is found that the combined effect of D3W12 (20 to 30 cm depth of soil and 12th week) was holding the highest moisture content and the poorest moisture were recorded for the D1W3 (up to 10 cm depth of soil and 3rd week) and D2W3 (10 to 20 cm depth of soil and 3rd week). The combined effect of W12T6 (Week 12 and Disk ploughing with 2 harrowing) was holding the highest moisture content and the poorest moisture was recorded for W2T8, W3T7 and W3T8 (Week 2 and no tillage, week 3 and hand hoe, week 3 and no tillage).

4. During the long dry season, the ANOVA showed that different treatments adopted in the experiment, different depth of tillage like 10 cm, 20 cm and 30 cm adopted in the experiment, the moisture content measured in different weeks, the two factor interaction of depth and tillage treatments, the two factor interaction of weeks and treatments are highly significant at 1% level. Similarly, the two factor interaction of depth and weeks and three factor interaction of depth, week and tillage treatments are not significant. It is also found that coefficient of variation in the experiment is 4.19%, which is less than 30%. Hence, this experiment can be accepted.

5. During long dry season, it is found that the soil having 20 to 30 cm depth is holding high moisture content and the 10 to 20 cm is having medium moisture content. The top soil of
up to 10 cm depth is having low moisture content because of dry climate. It was also found that the ranking of moisture content based on weeks showed that 1st week has the highest moisture content and the lowest was in the 15th week.

6. During the long dry season, the combined effect of Depth and Weeks showed that the highest soil moisture retention was found at D3T6, the second highest is seen at D3T3. Third rank of moisture level was found in D2T6 D3T1 D3T4 D3T5 D3T8. The combined effect of week and tillage treatments showed that the highest soil moisture retention is found at W1T6, the second, third, fourth highest soil moisture are seen for W2T6, W1T3 and W3T6 respectively.

7. During the long dry season, it is found that the evaporation is varying within the range of 3.3 ±1.0 mm, the atmospheric temperature is within the range of 21.8±1.3 °C, the relative humidity varies within the range of 68.25±16.1% and the rainfall is 0.5 mm only.

8. During long dry season, the statistical modeling of soil moisture with available weather parameters using multiple linear regression analysis was carried out for T1 to T8 treatments and the model is is given by C1 = a0 + a1 C2 + a2 C3 + a3 C4. Where in C1 is soil moisture content in percent, C2 is evaporation in mm, C3 is ambient temperature in °C, C4 is relative humidity in percent and the empirical constants are a0, a1, a2 and a3. The value of a0 varies from 48.7 to 60.7, a1 varies from -1.5 to -2.4, a2 varies from -1.4 to -1.9 and a3 varies from 0.075 to 0.117.

9. During the short dry season, a comparative crop performance studies were conducted. In tillage operations 89 % and 92 % of man – hour saved for maize and beans crops respectively under tilled plot when compared with conventional plot. Similarly in case of sowing around 16.4 % and 19.4 % saving in man-hour found in tilled plot for maize and beans crop respectively when compared with conventional plot. It was observed that 18.3% of man-hour saved for maize crop under tilled condition compared to conventionally cultivation. The same (18.6%) was found in case of beans crop. The yield in the tilled plot of maize crop was 5484 kg/ha and the conventionally prepared plot was
4765 Kg/ha. The percentage increase in yield of beans was found to be 12.8% in the tilled plot compared to the conventionally prepared plot.

10. During the short dry season, a comparative crop performance studies were conducted for the plant height of maize crop in the tilled plot and conventionally prepared plot, it was found that the plant height at 15 DAS was 9 cm and 7.5 cm respectively and then the height of the crop in both plots increasing in a curve linear form almost at the same rate of growth up to 75 DAS to a height of 110 cm and 102 cm. Similarly for beans, the height of the plant was 20.1 cm and 14.8 cm at 15 DAS. The plant height increased to 137 cm and 99 cm at 75 DAS for the tilled plot and conventional plot.

11. During the short dry season, it was found that the yield of maize in best tilled field is compared with the conventional tilled field. The yield recorded in the best tilled field of maize crop is 105.3 Kg and the conventionally prepared field is 91.5 Kg for the same area of 16 m x 12 m. The percentage increase in yield of maize is found to be 15.1% in the best tilled field. Similarly, the yield in the best tilled field of beans crop is 38.9 Kg and the conventionally prepared field is 34.5 Kg for the same area. The percentage increase in yield of beans is found to be 12.8% in the best tilled field.

12. During the long dry season, the number of man hours needed for seed bed preparation for maize crop in the tilled plot was 1.0 and for the conventionally prepared plot was 8.5 man hours. Similarly in case of beans, for seed bed preparation, 0.8 man hours observed for tilled plot and 9 man hours for conventionally prepared plot. Hence, the man-hour needed for seed bed preparation found less i.e. 88 % for maize crop and 91% for beans crop under tilled plot compared with conventional plot. The number of man hours saved for sowing in tilled plot for maize crop was 15.8 % and 19% for beans as compared with conventional plot. Similarly in case of weeding operations for maize and beans crops there was a saving of 23 % and 21 % man-hour respectively in tilled plot as compared with conventional plot.
13. During the long dry season, a comparative crop performance studies were conducted for the plant height of maize crop in the tilled plot and conventionally prepared plot, it was found that the plant height at 15 DAS of sowing was 8.1 cm and 7.3 cm respectively. Thereafter, the height of the crop in both plots are increasing in a curve linear form almost at the same rate of growth. The plant height at 75 DAS was found to be 103 cm and 102 cm. Similarly for beans, the height of the plant was 19 cm and 14 cm at 15 DAS. The plant height increased to 130 cm and 94 cm at 75 DAS for the tilled plot and conventional plot.

14. During the long dry season, the percentage increase in yield of maize was found to be 13.7% in the tilled plot compared to the conventionally prepared plot. The percentage increase in yield of beans was found to be 14.9% in the tilled plot compared to the conventionally prepared plot.

15. Under the laboratory condition, it was found that when the head of water is same, the wetting surface area due to water migration in (x,y) plane is increasing as the hole sizes are increased from 1.50 mm to 2 mm with the flow rate of 0.28 lpm to 0.46 lpm respectively. This (x,y) plane determines the width of water spread around the root zone of the crop. The maximum surface area around the root zone is 114.09 cm$^2$ obtained for 2 mm hole size. Similarly, the maximum surface area around the root zone is 114.12 cm$^2$ obtained for 1.75 mm hole size.

**RECOMMENDATION FOR FUTURE WORK**

1. Rwanda is completely relying on rainfed agriculture. Irrigation systems and dams are not developed. High crop yield can be achieved only by soil moisture conservation during the two dry seasons. This soil moisture conservation studies in different tillage treatments is first of its kind in Rwanda. Similar studies are needed in different agro climatic conditions and different soil types of Rwanda.

2. The present study used tyne cultivators, disk ploughs, disk harrows and hand hoe. There is a need to study other tillage tools like mould board plough, rotary plough, chisel
plough and sub soilers etc. Hence, it is recommended that more such studies has to be carried out to recommend suitable tillage practices for Rwandan farmers to increase the yield of the crop.

3. The Ministry of Agriculture and Animal Resources, GoR now started the task force on Irrigation and Mechanization. Extension of tractors and tillage tools are being carried out through Village Mechanization Service Centres. It is recommended that the ministry has to start modern farm machinery research, training and testing centre to cater the needs of the farming community.