CHAPTER VI

6.0 SUMMARY AND CONCLUSION

Occurrence of timely rainfall in sufficient quantity is the prime requirement for successful rainfed agriculture. Insufficient rainfall during dry season attracts the need of in-situ soil moisture conservation, water harvesting and supplemental irrigation. The study has been conducted in ISAE terraced farm at Rubirizi with the objective of assessing the possibilities for having an additional crop yield by appropriate crop and water management plan.

The study explores the best technical option to resolve the constraints related to water management in rainfed farming. Comparative study of in-situ soil moisture conservation techniques in terraces and unterraced field with maize crop had been conducted from June 2007 to October 2007. Analysis of rainfall and crop water demand indicates that crop suffered by soil moisture stress due to insufficient rainfall. Bench terrace increased the average soil moisture content in 90 cm soil depth by more than 50 percent than that of unterraced land. Within the bench terraced field compartment bund increased average soil moisture by 19.5 percent higher than plain bed with a coefficient of variation of 20.4 percent and ridges & furrows increased by 27.9 percent with coefficient of variation of 28.6 percent. This indicates that in-situ moisture conservation measures are effective to increase soil moisture compared to plain bed. It is also found that mean soil moisture fluctuation in the soil profile is moderately more at 60cm depth compared to 30 cm irrespective of type of conservation technique.

Performance of ridges & furrows, compartmental bund and plain land was evaluated in terms of soil moisture conservation. The study reveals that Compartment bund performed well in both 30 cm and 60 cm soil depths followed by ridges & furrows because of consistent soil moisture as evidenced by less coefficient of variation. Higher moisture content in these two
techniques is due to water barrier to harvest rainwater. Average soil moisture content for compartment bund and ridges & furrows varied between 16 to 17 percent and 13 to 14 percent for plain bed at both 30 and 60 cm soil depths.

In all the three techniques, actual soil water during the entire study period remained below field capacity posing soil moisture stress. No maize yield was recorded in all the techniques because the soil water depleted to 60 percent and above from the beginning of the study period inferring the need of supplementary irrigation. Plain bed exhibited lowest degree of fluctuation of deficit water indicating poorly influenced by rain fall as compared to ridges & furrows and compartmental bund. In terms of efficiency of moisture conservation during the study period, ridges & furrows performed well with 85.8 percent followed by compartment bund with 75.9 percent in terraced field. Unterraced field conserved moisture very poorly with 13.9 percent efficiency inferring importance of bench terraces for soil moisture conservation.

Shaxson et al. (1989) and Hudson (1992) advocated aiming at land husbandry rather than at soil and water conservation, the difference being that land husbandry involves an integrated set of land management practices intended to increase or maintain land productivity. What semi-arid Africa needs is a regreening of the landscape (Stroosnijder, 1992). Not a narrow focus on ‘more crop per drop’ but rather a focus on ‘more biomass per drop’. Planting trees, shrubs provide good run off reduction and soil water storage particularly in hill lands, thus reducing soil degradation. Soil degradation and soil water storage are interrelated.

A general problem in semi-arid areas is the lack of soil organic amendments, including mulch (Aklilu et al., 2007). However, water conservation and water harvesting result in a greater share of the rainfall for green biomass. By enhancing GWUE, water conservation practices will not only provide more available water for food crops but also for grasses, shrubs and trees, part
of which can be used as mulch. Mulching will create a win-win situation, because the mulch will not only reduce evaporation but also contribute to the maintenance of soil organic matter, thus enhancing the physical quality of soils.

Development of dry land or rainfed areas does not mean that no irrigation development at all takes place as part of the programme. Giving one or two light irrigations to a crop at certain critical stages of water stress during its growth cycle is now recommended in dry farming. Evidently dry land agriculture needs to be given the most attention in regions where there is little scope for additional development of irrigation sources. In India, DANIDA helped to improve dry land through soil and water conservation and water harvesting measures, including providing a bore well for every 10 ha of land cultivated. There is tremendous potential for improving production in rainfed agriculture through supplemental irrigation by micro irrigation systems using conjunctive use of ground water and runoff water harvesting. It is suggested to adopt lift irrigation for hill land agriculture. This needs further studies on ground water exploration to ensure its availability. Detailed analysis is needed for feasibility of lift irrigation with different crops under different altitudes to derive suitable policy for hill land irrigation. Feasible zones of altitudes for different crops should be demarcated on hill land based on its economical viability.

This research suggests that a promising avenue of upgrading rainfed agriculture is through water harvesting and supplemental irrigation that enables mitigation of dry spells. Such measures involve adding a blue water component, through tapping of surface runoff and ground water, to the rainfed system, i.e., developing rainfed farming into a more blended blue-green system by adding a small irrigation component. Carried out at large scale may have implications on downstream blue water availability. However, it is not certain that an increase in return flow of evapotranspiration in rainfed agriculture upstream automatically results in reduced water
availability downstream. Finally it is argued that some of the most exciting opportunities for water productivity enhancements in rainfed agriculture are found in the domain of integrating components of irrigation management within the context of rainfed farming, e.g., supplemental or micro irrigation and conjunctive use of ground water for dry spell mitigation. The most suitable technology available for rainfall management in rainfed farming is determined through a rational analysis of rainfall, identification of the critical irrigation periods of the crops grown, estimation and collection of excess runoff into designed tanks after taking into account effect of soil and water conservation measures including insitu moisture conservation, and adopting a suitable irrigation system.

Experiments conducted in 2008 and 2009 reveal that maize straw mulch combined with Broad Bed and furrow (BBF) land configuration on bench terrace yielded 4.15tons ha\textsuperscript{-1} of grain when supplied with 182mm of supplemental irrigation by drip irrigation with one lateral for two plant rows. Maize straw mulch performed well in both BBF and CB with irrigation water use efficiency of 10.15 and 10.38kg m\textsuperscript{3} respectively when irrigated with 27 mm net supplemental irrigation.

Effects of irrigation regime, land configuration and mulching are significant for dry grain, biomass yield and number of grains per row. Irrigation regime has no significant effect on number of grain rows per cob. Land configuration and mulching have no significant effects on cob perimeter whereas interaction effect of mulching with irrigation regime is not significant. In 2008, weight of 100 grains did not vary significantly due to combined effect of irrigation regime, land configuration and mulching but in 2009 irrigation regime had significant effect.

It is observed that 61 percent of crop water demand was met by direct rain water and 39 percent was to be served by ground water through supplemental irrigation. In year 2009, drip
irrigation with 120cm lateral spacing saved 53 per cent water for 31 per cent yield reduction when applied with 43 percent of actual water demand under organic manure application of 15tons ha\(^{-1}\). Maximum average irrigation water use efficiency of 17.5 kg m\(^{-3}\) was obtained in drip lateral spaced at 120cm and an average of 75 percent irrigation water can be saved for 33.6 percent yield reduction compared to check basin irrigation. Under water scarce conditions, it is recommended to use drip irrigation with 120cm lateral spacing and apply irrigation from flowering stage of crop under organic manure dose of 15MT ha\(^{-1}\) to achieve maximum water use efficiency by practicing deficit irrigation.

Maximum production of 5.4 tons ha\(^{-1}\) and 4.8 tons ha\(^{-1}\) respectively were obtained in basin and drip irrigation. The difference in yield was due to the quantity of irrigation water applied and it is clear that the increase in water supplied lead to the increase in yield.

Relationship between irrigation water and grain yield can be expressed by quadratic equations which represent the characteristic feature of the three irrigation methods in terms of grain yield response to irrigation water under soil and climatic conditions of Rubirizi. For drip irrigation the relationship has steep slope than that of basin irrigation inferring grain yield is more sensitive to irrigation water under drip irrigation than basin irrigation.

Irrigation method, irrigation regime and organic manure application have significant effect on dry grain yield and biomass yield but interaction effect of organic manure with irrigation method was not significant. Basin irrigation followed by drip irrigation performed well in terms of grain yield but in terms of water use efficiency, drip irrigation with laterals spaced at 120cm performed better compared to other irrigation methods under organic manure dose of 15tons ha\(^{-1}\).

Drip irrigation laterals spaced at 60cm can save 54 per cent of water for 19.6 per cent yield reduction under organic manure application of 15tons ha\(^{-1}\). Laying one drip lateral for two rows
of maize is economical and resulted highest irrigation water use efficiency of 19.2kg m\(^{-3}\) producing 3.5tons ha\(^{-1}\) of dry grain yield in 2009. Analysis of rainfall, crop water demand and insitu moisture conservation reveals exciting opportunities for water productivity enhancements by integrating components of water management within the context of rain-fed farming through water harvesting and supplemental or micro irrigation for dry spell mitigation.

Hence from these studies it is concluded that the supplemental drip irrigation integrated with BBF with maize straw mulching of 10 tons ha\(^{-1}\) shall be followed to get the higher crop yield in terraced hill lands of Kigali. Further the use of one drip lateral to cater two rows of maize crop along with application of organic manure at the rate of 15tons ha\(^{-1}\) is recommended for higher water use efficiency. Economic analysis infers that that for non commercial crop like maize, supplemental irrigation adopting expensive drip irrigation with ground water becomes if it is marketed as fresh cobs which is in much demand for human consumption through out the year in Rwanda.

**Future line of recommendations**

Based on the results observed, the following recommendations have been formulated for future adoption.

- With supplemental irrigation during flowering stage, high yielding long varieties can be cultivated provided adequate availability of water is ensured.
- High organic manure dose of 15tons ha\(^{-1}\) is recommended for newly constructed terraces on laterite soils in Rubirizi but still there is a scope for increasing the organic manure application rate.
- Deficit irrigation by drip irrigation can be practiced to get high water use efficiency
- Economic feasibility of drip irrigation system with one drip laterals for two rows of maize crop need to be studied in comparison with other horticultural crops.
• Under conditions of water scarcity, irrigation is to be scheduled at 45 percent maximum allowable depletion of available soil water during the non-critical stages of growth of maize grown in sandy loam soils in sub-tropical regions in order to obtain maximum grain yield and above ground dry matter as well as maximum field water use efficiency and net return.

• The plant extracts most of the soil water from 0-40 cm soil profile in case of maize. Therefore, only 0-40 cm of soil profile is to be considered for scheduling of irrigation water for maize crop grown in sandy loam soils in the sub-tropical regions and under water scarcity conditions.