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Low - Cost Irrigation Technology, in the Context of Sustainable Land Management and Adaptation to Climate Change in the Kilimanjaro Region

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Abstract
Unsustainable land management and poor adaptation to climate change limits agricultural production in different districts in Kilimanjaro Region. The aim of this study was to train farmers on different aspects of Sustainable Land Management (SLM), improve water use efficiency (WUE) through rehabilitation of traditionally managed irrigation schemes and installation of precision irrigation systems in order to compare their performance without such systems and to assess the impact of the interventions on crop yield and water use productivity. Data were collected during land survey and farmers training in selected areas in Kilimanjaro Region using land survey and farmers training techniques. The data showed increased area under irrigation, improved crop yield, farmer income, water use efficiency and production and productivity in drip irrigation system demonstrated plots compared with furrow or gravity irrigation methods. Improved intake and main canal in Ngalachu irrigation scheme had overall all measured parameters but less compared with drip irrigation. Water saved by drip irrigation was greater by between 33 % and 50 % compared with furrow irrigation methods. The data also showed that crop yields and total revenue in drip irrigation were greater by between 25 % and 60 % and 167 % and 400 % respectively compared with the furrow irrigation methods. These results suggest that farmers using drip irrigation systems were able to realize skills and knowledge, less water loss and greater WUE, higher crop yields, higher incomes compared with places without drip irrigation systems or furrow irrigation methods. However, more time is needed to test these technologies in the field so as to have more meaningful results. It is recommended that the technologies as well as rehabilitation of traditional irrigation schemes be up scaled to a larger area and assess their impact to farmers. Targeted agronomic practices such as the choice of appropriate crop/cultivar (i.e. high value crops) for a specific environment as well as planting and harvesting times, adequate plant nutrition, soil management, and weed control should be observed by both farmers and extension staff since such agricultural practices can significantly contribute to improve WUE and farmers income through increased gross margins.
Keywords: Climate change, water use efficiency, canal, total revenue, water harvesting, land, management

1.0 Introduction

The effects of climate change such as rise in temperature and changes in rainfall are undeniably clear with impacts already affecting ecosystems, biodiversity and people in Kilimanjaro Region. The Initial National Communication has reported that the mean annual temperatures will increase by 2.1˚C to 4˚C in the northern parts of the country by 2100. This increase will markedly be observed particularly during the cool months. During the same period of time, annual precipitation is expected to increase by 10 %. Climate projections indicate that northern parts of the country would experience increased rainfall ranging from 5 – 45 % (Mwandosya et al., 1998). During the past five decades, there has been a steady increase in temperature, adversely affecting almost all sectors of the economy. Mount Kilimanjaro, the highest mountain in Africa, for example, is undergoing rapid transformation since 1912. The snow-capped mountain is losing its glacial top at an alarming rate; and it is expected that within the next 10 - 20 years, the summit will be bare (Thompson et al., 2007). For the past four years, climate change has affected rainfall pattern across many parts in the Pangani Basin which were recorded as below the annual average. The situation has affected the water supply in many places in Kilimanjaro Region attributed to unusual seasonal short rains in the months of September through December and long rains during the months of March to June. As a result, places along the Pangani basin like Tengeru, Korogwe, Kahe, Moshi, Handeni and Kilimahewa- Kihurio had in the last year received only 50, 80, 4, 50, 90 and 52 % of their respective average annual rainfall (NBS, 2012).

Drastic decline of rainfall pattern and increased temperature (Jones and Kiniry, 1986) has led to severe effect on socio-economic livelihood of people living within the basin such as decline in domestic water supply, decreased irrigation water and increased water conflicts, decline in crop yields and lack of electricity. As a result, the average yield decrease in the north eastern highlands was 22 %. These results suggest that climate change may significantly influence future crop yields in Kilimanjaro including maize. For example, due to effects of climate change, the discharge of Nsere Springs which is a source of the Moshi Urban Water Supply and Sewerage Authority (MUWSA) have declined from the normal discharge of 11,000 m^3 day^{-1} in 2008 to 7,000 m^3

day^{-1} in 2012. The decline in discharge in the source has consequently led to water rationing in Moshi Township by MUWSA. The situation was much worse at Hale and Nyumba ya Mungu Dam in Tanga and Kilimanjaro regions respectively. For example, the minimum operational level required for the generation of hydro-electricity at Nyumba ya Mungu was 683.35 m above mean sea level compared with what was recorded recently (2012) as 682.68 m above mean sea level, a 0.67 m below minimum operational level. Crop yields in the same cultivated area have also declined as a result of climate change. "Maize production declined from 385,665 tons (2009/10) to 144,468 tons (2010/11); paddy yields declined from 71,602 tons (2009/10) to 60,368 tons (2010/11); millet from 1965 tons (2009/10) to 925 tons (2010/11); while beans production declined from 72,484 tons (2009/10) to 52,905 tons (2010/11).

Irrigation in Kilimanjaro Region has been practiced since the late Iron Age (Sutton, 2004; Stump, 2006). Using their indigenous knowledge in water management, farmers diverted water from rivers, lakes or any other source by using locally available materials such as stones or plant debris into traditional furrows for irrigation (Goldsmith & Hildyard, 1984; Adams, 1992; Goldsmith, 1998). However, due to the traditional nature of the furrows, significant conveyance water losses due to high seepage and poor WUE have been experienced. Taken together, climate change impacts can be addressed through improved WUE, lining of traditional furrows, construction and/or spot improvement of traditional intakes, use of modern irrigation water saving technologies such as drip irrigation system and cultivation of drought tolerant crops. According to the National Irrigation Master Plan of 2002 (NIMP, 2002), the total potential area for cultivation in Kilimanjaro Region is 120,042 ha corresponding to 454 irrigation schemes. Of the total, 92,989 ha are traditional, 2,069 ha are rain-water harvesting (RWH), 16,250 ha are modern, and 8,734 ha are improved traditional irrigation schemes (Fig. 1). This data suggests that significant impact on WUE can be achieved by rehabilitating the traditional schemes in Kilimanjaro region leading to great amount of water saved.

Unsustainable land management and poor adaptation to climate change limits agricultural production in Kilimanjaro Region (IPCC, 2001). Unsustainable land management includes practices that leads expansion of cultivated fields and diminishing of natural vegetation cover; insufficient amounts of organic material or soil organic carbon and nutrients; burning of organic material (harvest residue, brush fires); soil degradation such as soil erosion (wind and water), compaction, crusting; overuse or inefficient use of water resources; soil erosion and salinization; overgrazing and increase in undesirable plants; free grazing, unclear land use rights (Dregne and Kassas, 1991; Oldeman, 1998; Wood et al., 2000; MA,2005). Sustainable development ensures the satisfaction of economic, social and cultural needs of the present generation without undermining the needs of future generations (Bruntland Report, 1987; UNCED, 1992). In this case, sustainable agriculture and rural development means using and conserving natural resources and directing technological and institutional change to meet the current and future needs of stakeholders. This kind of development conserves soil, water and the genetic resources of flora and fauna, protects the environment, applies appropriate technology and is economically and socially viable (FAO, 1991). However, studies have indicated some barriers to achieve sustainable land management in Kilimanjaro Region. They include weak incentives for adoption of SLM, weaknesses in the policy, planning and institutional environment that influence SLM, and, inadequate skills at all levels required for promoting and/or adopting SLM. The objective of this study was, therefore, to support the development of improved traditional irrigation through the introduction of water harvesting techniques supplemented by water conservation systems like drip irrigation.

2.0 Materials and Methods

2.1 Description of study site

Kilimanjaro Region is located in north-eastern Tanzania just South of the equator (2˚25"and 4˚15" S; 36˚25" and 38˚18"E) and consists of seven administrative districts (Fig. 2) namely Rombo (1,442 km^2), Hai (2,111 km^2), Moshi Rural (1,713 km^2), Moshi Municipality (58 km^2), Mwanga (2,698 km^2), Siha (1,158km^2) and Same (5,186 km^2), all sub-divided into 26 Divisions, 121 Wards and 449 Villages. Moshi Rural land area covers 1,713 km^2 and has a population of 466,737 giving it a slightly higher population density of 272 people km^{-2}. The population growth rate is also slightly higher at 1.9 % but the average household size is lower at 4.3 people (PHC, 2012).

The morphology of the upper areas of Mt. Kilimanjaro is formed by glaciers which reached down to an altitude of 3000 m above mean sea level during the ice age (Downie & Wilkinson, 1972; Hastenrath, 1984). However, the majority of the soils in the region are of volcanic origin, generally rich in Mg and Ca. The FAO/UNESCO Soil Map identifies four main soil groups in Kilimanjaro region all of which display great variation in fertility. These are: Humic nitosols and associated humic andosols; Chromic cambisols and associated eutric cambisols; Orchric andosols and associated chromic cambisols and vitric andosols; Mollic andosols and associated eutric nitosols.

According to National Housing census (PHC, 2012), the population in Kilimanjaro region was estimated to be 1,640,087 (i.e. 793,140 M and 846,947 F), a population density of 124 persons km^{-2} with sex ratio of 94 (PHC, 2012). However, the population density in the region varies dramatically from up to 650 persons km^{-2} in the Chagga home gardens to less than 50 persons km^{-2} in the lowlands. The average household size is 4.3 and 84 % of households are male headed (URT, 2006). It has the highest percentage of literacy in Tanzanian rural areas of 86 % (URT, 2006). Compared with other regions, Kilimanjaro is the smallest in Tanzania covering an area of 13,209 km^2. The topography of the area ranges from Kibo peak, the highest point on the African continent (5,986 m a.m.s.l.) to the lowlands of the Maasai steppe (700 – 900 m a.m.s.l.).

The climate on the southern slopes of Mt. Kilimanjaro is characterized by a bimodal rainfall, where the ‘long’ rains (*Masika*) occur from March to May and the ‘short’ rains (*Vuli*) are between October and November. The quantity of rainfall depends on altitude. Total annual rainfall primarily depends on the success of the short rains (*Vuli*) and the onset, intensity and duration of the long rains (*Masika*). Total mean annual rainfall (mm) for different stations in Kilimanjaro Region is shown in Fig. 3

2.2 Irrigation Area in Kilimanjaro Region

Kilimanjaro region has a total cultivated area of 120,042 ha of which 53,875 ha (44.9 %) are irrigated. Relative to the total, the irrigated area is 6.9 %, 1.3 %, 21.6 %, 0.2 %, 4.4 % and 1.2 % in Hai, Siha, Moshi Rural, Rombo, Mwanga and Same respectively (Fig.1). The corresponding beneficiaries are shown in Fig. 4.

2.3 Identification of the Demonstration Sites

In order to select a representative traditional irrigation schemes for rehabilitation in the region, a criterion was established. For a district to qualify for selection, it should have large per cent of irrigated area compared with other districts. Moshi District was therefore selected since it has more than 40 % of irrigated area. Furthermore, for a traditional irrigation scheme in the District to be selected, it should have an irrigable area of between 20 ha - 100 ha. Based on these criteria, Msawaro irrigation scheme and Ngalacho main canal were selected as they were similar based on the initially set criteria. However, since only one irrigation scheme was required for rehabilitation, further criteria were set to select one out of the two candidate schemes after field visit. The additional criteria were such as possession of water use permits, presence of Irrigators’ Organization (IO) and availability of reliable water for irrigation. Based on these criteria, Ngalachu main canal was selected.

In addressing land degradation and improvement of irrigation water use efficiency (WUE), establishment of demonstration plots on drip irrigation system in selected sites in Hai, Moshi Rural, Mwanga and Same districts were initiated. For a scheme to be considered in these Districts, communities should have low income generation and interest to climate change adaptation. Other criteria used included eagerness and willingness of farmers, assured irrigation water supply throughout the year, availability of an area that can be used as a training ground for other farmers and suitability of the site in terms of land terrain. Based on these criteria, Longoi (Hai District), Kisangesangeni (Moshi District), Kwamboa (Mwanga District) and Mabilioni (Same District) were selected. These schemes were used as demonstration plots which were further replicated elsewhere in the region.

2.4 Topographical Survey and Designs of the Selected Demonstration Plots

2.4.1 Drip irrigation system

Detailed topographical surveys and designs were undertaken in the selected areas with a view to adopting low-cost, environmentally-friendly and efficient gravity and drip irrigation systems in the demonstration plots. Detailed topographical survey for the proposed drip irrigation followed 10 m x 10 m grids for drip-irrigation demonstration plots ranging from 400 m^2 to 500 m^2 to produce drawings at a scale of 1:240 with 0.25 m contour interval. The collected data were processed to prepare maps, drawings and topographical survey report. During topographical survey, two bench marks were established along Longoi, Kisangesangeni, Kwamboa and Mabilioni drip irrigation schemes. For effective customized drip irrigation system for different crops such as maize, beans, vegetables and tomatoes, certain inputs are required as shown in Table 1. These inputs enabled a complete design of drip irrigation system with detailed field layout; emitter selection and placement; size and length of mainline, sub-main and lateral pipes; material and cost estimates. Detailed design works included design assumptions; production of drawings, bill of quantities and design report.

2.4.2 Gravity or furrow irrigation

Topographical survey was carried out and three bench marks were established along Ngalachu main canal. This was done by first establishing a baseline almost parallel to direction of flow of Msaranga River pegged at 10 m intervals from the baseline. Lines pegged perpendicular to the baseline at 10 m intervals were then established whereby existing details were picked by an automatic level machine. The observed data were booked and drawn at a scale of 1:100 with 0.25 m contour interval. Permanent survey marks were established along Ngalachu main canal. Ngalachu intake site cross sections were similarly established at 10 m intervals and drawn at a scale of 1:100 Vertical and Horizontal scales respectively. Likewise, Ngalachu main canal (NMC) detailed profile was done at 50 m intervals from Msaranga River to the farm pond area at 0 m to 2,278 m chainage. The profile map, drawn at a scale of 1:2,000 Horizontal and 1:100 Vertical scales, showed the existing foot path crossings, critical seepage areas and any other man-made and natural features. Permanent survey marks were established along the main canal at 50 m, 1,000 m and 2,250 m chainage. However, NMC cross sections taken at 200 m intervals and the existing pond were drawn at 1:100 Vertical and Horizontal scales. Layout map showing NMC, Msaranga River, village settlements, and the existing Ngalachu pond were drawn at a scale of 1:2,500.

Topographical survey data were used as input during the design of proposed infrastructure. The designs of the proposed weirs and intakes; improvement of the canal systems and associated control structures were carried out. This includes preparation of final designs, bill of quantities, preliminary cost estimates and construction plan. The design of the main canal systems included provision of adequate in field control and regulating structures i.e. culverts, tail escapes, division boxes, etc. Lining of canal sections was designed where seepage losses were likely to be excessive and where the canals traverse difficult terrain.

2.5 Establishment of Demonstration Plots

Drip irrigation system installation was demonstrated on each of the four (4) selected plots in Longoi, Kisangesangeni, Kwamboa and Mabilioni irrigation schemes (Table 2). The demonstration was done in step by step in one of the group member's field that was used as training ground for the whole group. The construction steps included a raiser, a tank and laying down the main supply pipe across the selected plots, connecting micro-drip lines along the plots and installation of drip irrigation system along plot (Figs. 5-1 and 5-2). Water for irrigation was pumped from a nearby earthen canal or shallow well and stored in a tank from which it was released by gravity to irrigate crops in the study area. The vegetables were transplanted immediately after the installation of the irrigation system.

2.6 Training of Farmers

One of the outcomes of the project is institutional capacity building for adoption and adaptation of sustainable land management (SLM). Under this outcome, a series of training sessions on improved irrigation system to the target groups in selected sites were carried out (Table 3). The trained beneficiaries included Ngalachu, Longoi, Kisangesangeni, Kwamboa and Mabilioni irrigation groups. Three training modules were prepared covering aspects of improved irrigation systems; strengthening of irrigator's organizations and new technologies such as drip irrigation methods. The training module on improved irrigation systems was aimed at creating awareness of different improved irrigation systems and their important components and roles for systems sustainability. Training methodology included theory and group work, a combination that aimed at increasing understanding through promoting interaction of the farmers. Fully involvements of the farmers were expected to build-up sense of ownership and hence increase their level of participation in various activities that need their support. In order to bring sustainable impacts, staffs from respective districts were fully involved in the training sessions so that they can later make necessary follow-ups to the trained farmers to ensure they practice what was covered during the training sessions.

2.7 Data Collection

Water use data (m^3 ha^{-1} yr^{-1} or l ha^{-1} yr^{-1}) and crop yield (t ha^{-1}) were collected from the commonly practiced gravity irrigation system, i.e., furrow and drip irrigation methods in the selected irrigation schemes. In this arrangement, data from furrow and drip irrigation systems in the selected pilot area and the surrounding locations were collected using a previously designed data collection template. For comparison, data on water use (m^3 ha^{-1} yr^{-1} or l ha^{-1} yr^{-1}) and crop yield (t ha^{-1}) were similarly collected from the newly constructed drip irrigation system in the selected pilot areas (Table 4).

2.8 Data Analysis

Data was analysed using excel computer program. Various analyses performed include total revenue and average yield. Total revenue was computed as the product of adjusted average crop yield (t ha^{-1}) by the market or farm gate price.

3.0 Results and Discussion

3.1 Training of Farmers

After farmers have had theoretical training, they fully participated in the installation of drip system in the field (Fig. 5) following a defined protocol till the end of the process. These protocol included *construction of a raiser for installation of the tank, preparation of the tank and installation on the raiser, laying down the main supply pipe across the selected plots, connecting micro-drip lines along the plot and installation of drip irrigation system along the plots*. Full participation of all farmers in these steps gave them an opportunity to see different components of drip system and its layout as explained in theory.

3.2 Establishment of Drip Irrigation System Demonstration Plots

Irrigation water supply is a major constraint in Kilimanjaro Region where natural rainfall and stored soil water is insufficient to meet water requirement needed for successful crop production (Hassan et al., 2002). Efficient use of water during irrigation is becoming increasingly important especially where surface or gravity irrigation is practiced. Alternative water application methods such as drip irrigation system may contribute substantially to the best use of land, water for agriculture and improved irrigation efficiency (Abd El-Kader et al., 2010). Results in this study showed that furrow or gravity irrigation lead to greater conveyance loss and low WUE. Recently, the trend has been towards conversion of gravity or surface irrigation to drip irrigation which is considered to be a more efficient delivery system. Previous reports have indicated that drip irrigation has greater water economy under good management conditions, has the potential to increase yields of crops even with reduced irrigation water application, reduces evaporation and deep percolation and controls soil water content more precisely (Sanders et al. 1989; Kadam, 1993; Acar, 2001).

High-frequency water management by drip irrigation minimizes soil as a storage reservoir for water, provides at least daily requirements of water to a portion of the root zone of each plant, and maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Tiwari et al., 1998; Singh and Rajput, 2007; Al-Harbi et al., 2008; Zotarelli et al., 2009). Some studies have consistently shown that drip irrigation reduces water use by 30 to 70 % and raises crop yields by 20 to 90 % (Postel et al., 2001). Other advantages of drip irrigation are: Efficient water use up to 95 %; reduced labour cost; easy and efficient application of fertilizer and other chemicals; reduced salinity hazards; better phytosanitary conditions; simultaneous performance of other cultural practices and can be used on uneven or sloping areas (Polak et al. 1997a, b; Narayanamoorthy and Deshpande 1998; Narayanamoorthy 1999).

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3.3 Water Use Efficiency and Crop Yields in Different Irrigation Methods

Results from this study showed that there was improved WUE and crop yield increase in drip irrigation compared with furrow irrigation methods (Table 3). Furrow irrigation is the conventional method widely used to irrigate most of the vegetable crops grown in Kilimanjaro. However, this method uses more water compared with other high-tech water-saving irrigation methods such as drip irrigation systems which have higher application efficiency. The data showed that WUE in drip irrigation was greater by between 33 % and 50 % compared with furrow irrigation methods suggesting that drip irrigation is the most effective way to supply soil water, nutrients and increased yields of crops including fruits and vegetables (Tiwari et al., 1998a, b). The greater conveyance water loss or low WUE in furrow irrigation was probably due to water seepage into the soil from the sloping surfaces and bed of the canal which accounts for 98.37 % as reported by Badenhorst et al. (2002).

High WUE and increased crop yields through drip irrigation compared with furrow methods have similarly been reported by other workers. For example, review of literature showed irrigation efficiency with drip systems ranges from 75 - 95% compared with 25 - 50% for furrow irrigation methods (Smajstrla, et al., 1988; Sanders, 1990; Maisiri et al., 2005; Ngouajio et al., 2007). Similarly, WUE of 80 - 90 % and water savings of between 45 % and 60 % has been reported by Sabah and Safa (1983); Yaseen, et al. (1992); Chandio, et al. (1995); FAO (1997); and Babar, et al. (2008) as major benefit of drip irrigation system compared with only 50 % observed from surface irrigation methods. Comparing drip and furrow irrigation systems in vegetables production, Sivanappan and Padmakumari (1980) found that there was savings of 67 % to 80 % of the costly irrigation water than surface irrigation methods suggesting that vagaries of climate change can be alleviated and more area can be put under irrigation. The data also showed that crop yields and total revenue in drip irrigation were greater by between 25 % and 60 % and 167 % and 400 % respectively compared with the furrow irrigation methods. The differences in crop yield and total revenue in drip compared with furrow irrigation systems may be attributed to effective supply of soil water and nutrients to satisfy the crop water and nutrient requirements. Similar results have been reported by Khade (1987) where it was shown that under drip irrigation yield of okra was higher by 60 % with water savings of 40 % compared to furrow irrigation. In another study, Tiwari et al. (1998) reported that highest yield of okra *(Abelmoschus esculentus)* was 14.51 $t.ha^{-1}$ with 72 % yield increase was obtained when drip irrigation was used meet 100 % crop water requirement compared with furrow irrigation. Likewise, a study by Panigrahi et al. (2010) indicated that replenishment of crop water requirement by 100 % during tomato production by drip irrigation increased yield by 15.4 % compared with conventional furrow irrigation practiced by most of the farmers. On the other hand lining of canals can save water through improved conveyance and WUE that could be used for irrigating additional irrigated area. For example, Jadhav et al. (2014) showed that by converting unlined sections of main canal into lined sections, then, the 0.263 Mm^3 of water can be saved sufficient to irrigate additional area of 30 ha. Similarly, if both the unlined sections of canal network are converted into lined sections then the 0.376 Mm^3 of water can be saved from which about 43 ha additional area can be irrigated through improving conveyance efficiency up to 75 per cent. The findings suggest that application of drip irrigation system can effectively improve WUE, save significant amount of water, increase area under irrigation, improve farmer's income and alleviate poverty through comparable total revenues. For quick cost recovery and significant gross margins, farmers were advised to grow or cultivate high value crops such as sweet/bell peppers (*Capsicum annuum)*, tomatoes (*Solanum lycopersicum*) and night shade (*mnavu*) under the guidance of the village extension officer who also participated in the training. In all, establishment of demonstration plots for drip irrigation in different districts in Kilimanjaro Region will definitely improve knowledge and skills, water use efficiency, crop yield, farmer's income and dissemination of modern irrigation technology to a wider scale of farmers

4.0 Conclusion

In conclusion, results have shown that farmer's capacity building, improved water use efficiency through rehabilitation of traditionally managed irrigation schemes and installation of drip irrigation systems can significantly contribute to sustainable land management and relief to climate change. The data also showed that improved WUE saved irrigation water that would have otherwise got lost, area under irrigation, increased crop yields (quality and quantity) and improved farmers income. Increasing the amount of water used by the crop per unit of water applied requires substantial investment in management and innovative design of integrated water delivery and application schemes that assist farmers to efficiently allocate limited water resources thus, directly affecting WUE. However, more time is needed to test these technologies in the field to have more meaningful results. It is recommended that the technologies as well as rehabilitation of traditional irrigation schemes be up scaled to a larger area and assess their impact to farmers. Targeted agronomic practices such as the choice of appropriate crop/cultivar (i.e. high value crops) for a specific environment as well as planting and harvesting times, adequate plant nutrition, soil management, and weed control should be observed by both farmers and extension staff since such agricultural practices can significantly contribute to improve WUE and farmers income through increased gross margins.

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Table 1: Data inputs used to make an effective customized drip micro irrigation system

S/No	Description of input	Units	Quantity
1	Crop	Type	Maize/Beans /vegetable/tomato
2	Maximum design discharge	m^3/hr	3.750
3	Area	m^2	480
4	Friction Coefficient (C)		150 (Ref ,Larry G.James pg 215 table 5.7)
5	Pipe selected	Nos	PE pipes
6	Length of drip line (LD)	m	12
7	Spacing between lateral (SL)	m	0.75
8	Spacing between emitter (Se)	m	0.3
9	Crop water requirement (CWR)	mm/day	6 (from literature)
10	Soil type		clay loam
11	infiltration rate	mm/hour	7
12	Working pressure	m	1.5
13	Emitter classification		inline emitter
14	Working hours per day	hr	2
15	Number of emitter per plant	No	1
16	Desired soil wetted area	%	60

Table 2: Types of irrigation systems and their corresponding irrigated areas and crop yields in the selected areas in Kilimanjaro Region

S/No	Scheme	Location		Area (ha)	Type of irrigation	Crop yields ($t.ha^{-1}$)			
		Lat.	Long.			Maize	Beans	Tomatoes	Banana
1	Longoi	3°26’16’’ S	37°16’16’’E	300	Furrow and basin				
2	Mabilioni	4°35’44’’ S	37°56’55’’E	24	Furrow	2.5		6.0	
3	Kwamboa	3°35’35’’ S	37°40’30’’E	14	low pressure sprinklers	2.0	1.0	6.0	5.0
4	Kisangesangeni	3°26’43’’ S	37°27’47’’E	300	Furrow	1.5	0.5	6.0	-
5	Ngalachu	3°18’56’’ S	37°23’43’’E	89	Furrow/Night storage Reservoir				
6	Msawaro	3°18’20’’ S	37°22’30’’E	75	Furrow				

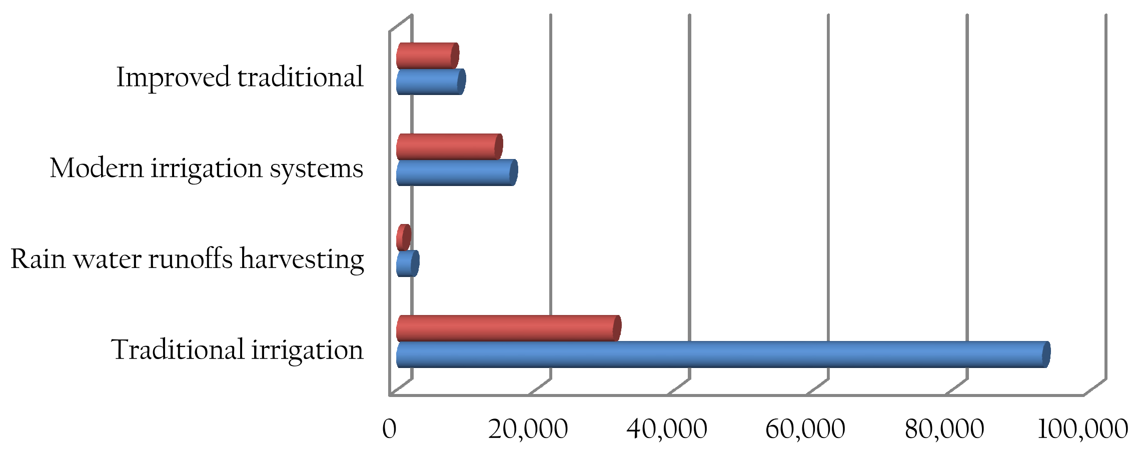
Table 3: Types of irrigation systems, beneficiaries and total farmers trained in the selected areas in Kilimanjaro Region

S/No	Scheme	Location		Beneficiaries	Total farmers trained	Type of irrigation
		Lat.	Long.			
1	Longoi	$3^0$26’16’’S	$37^0$16’16’’E	233	15	Furrow and basin
2	Mabilioni	$4^0$35’44’’S	$37^0$56’55’’E	150	15	Furrow
3	Kwamboa	$3^0$35’35’’S	$37^0$40’30’’E	60	15	low pressure sprinklers
4	Kisangesangeni	$3^0$26’43’’S	$37^0$27’47’’E	450	15	Furrow
5	Ngalachu	$3^0$18’56’’S	$37^0$23’43’’E	1500	30	Furrow/Night storage reservoir
6	Msawaro	$3^0$18’20’’S	$37^0$22’30’’ E	900	-	Furrow

Table 4: Water use ($l.ha^{-1}.yr^{-1}$), Yield ($t.ha^{-1}$) and Total Revenue ($TZS.ha^{-1}.yr^{-1}$) by furrow irrigation versus drip irrigation methods

Scheme	No of farmers	Crop	Water Use ($l.ha^{-1}$ $day^{-1}.yr^{-1}$)		Crop yield ($t.ha^{-1}.yr^{-1}$)		Total Revenue ($TZS.ha^{-1}.yr^{-1}$)	
			Furrow irrigation	Drip irrigation system	Furrow irrigation	Drip irrigation system	Furrow irrigation	Drip irrigation system
Kisangesangeni	27	Tomato	4,800,000	1,600,800	12.0	36.0	6,000,000	18,000,000
Longoi	15	Green pepper	5,160,000	1,720,000	7.2*	12.0*	4,200,000	7,000,000
	15	Night shade	ND	ND	4.5	18.0	3,000,000	12,000,000
Kwamboa	60	Chinese cabbage	720,000	360,000	ND	3.4*	ND	690,000

Note: ND = Not determined; * = bundle units. In Mabilioni irrigation scheme the farmers had sweet pepper as their first crop under drip irrigation. Unfortunately, the crop was seriously infested by birds resulting in failure to get yield figures that could be compared with the baseline figures under furrow irrigation. For Ngalachu irrigation scheme, farmers were yet to produce any crop following rehabilitation works; hence no yield figures could be obtained for comparison with the baseline figures before rehabilitation.



	Traditional irrigation	Rain water runoffs harvesting	Modern irrigation systems	Improved traditional
Irrigated Area (ha)	31,139	850	14,095	7,791
Irrigation Potential (ha)	92,989	2,069	16,250	8,734

Fig 1: Potential areas for irrigation, Irrigated and uncultivated areas in different districts in

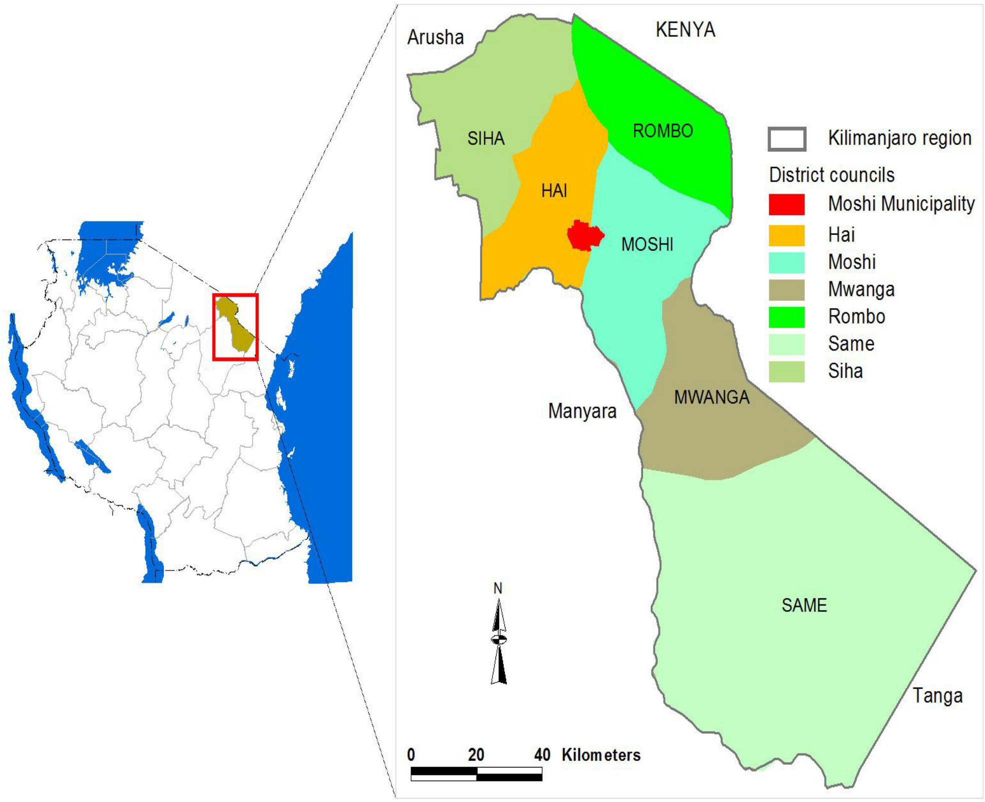
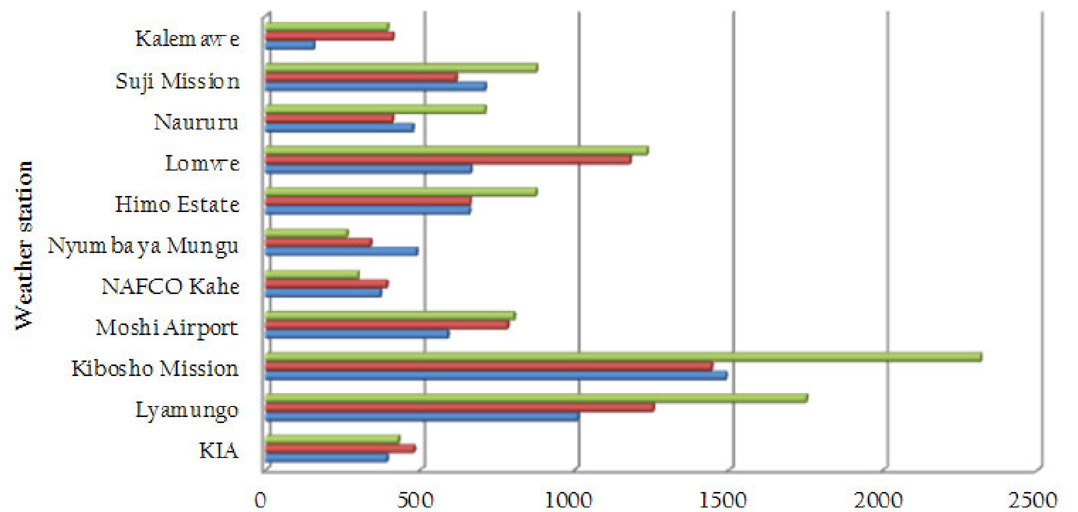


Fig. 2: Location map for Kilimanjaro region and the respective administrative districts



	KIA	Lyamungo	Kibosho Mission	Moshi Airport	NAFCO Kahe	Nyumba ya Mungu	Himo Estate	Lomwe	Naururu	Suji Mission	Kalemawe
2014	429.6	1750.6	2315.1	804.2	298.7	262.5	874.3	1235.1	709.3	876.7	394.6
2013	479.9	1254.7	1443.5	783.1	391.5	339.3	661.8	1179.7	409.9	616.2	411.2
2012	392.5	1010.2	1490.1	589.2	370.9	487.9	659.5	664.2	476.1	710.4	155.4

Rainfall (mm)

Fig 3: Total mean annual rainfall (mm) for different stations in Kilimanjaro Region

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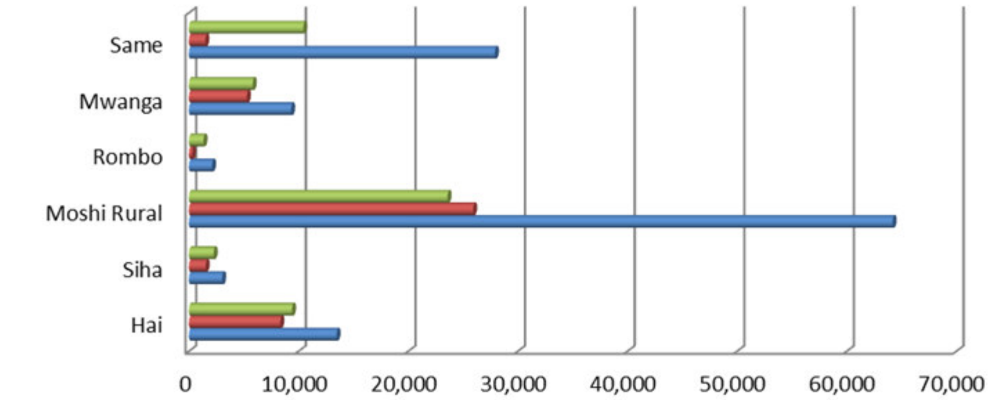

	Hai	Siha	Moshi Rural	Rombo	Mwanga	Same
No. of beneficiaries	9407	2261	23588	1330	5819	10439
Irrigated area (ha)	8,333	1,531	25,932	296	5,285	1,498
Cultivated area (ha)	13,471	3,032	64,190	2,109	9,324	27,916

Fig.4: Cultivated, Irrigated areas and beneficiaries in different districts in Kilimanjaro Region

Fig 5-1: Protocol for installation of drip irrigation system the case of Kwamboa

Fig 5-2: Protocol for the installation of drip irrigation system at Mabilioni demonstration plot: A) Preparation of plot for installation of drip irrigation system; B) Participation of farmers in installation of drip irrigation system; C) Demonstration plot for drip irrigation system at Mabilioni village ready for planting; D) Uprooting seedlings from nursery; E) Farmers participation in transplanting in drip irrigation demonstration plot at Mabilioni scheme; F) Inspection of drip irrigation system after transplanting of vegetable seedlings at Mabilioni demonstration plot