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On-Farm Demonstration and Evaluation of Rooftop Water Harvesting and Low-Cost Drip Irrigation System in Moisture Deficit Areas of Daro Labu District, Eastern Ethiopia

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Abstract
The efficient use of water is seen as a key to crop production in semi-arid and arid areas of Ethiopia. For smallholder farmers, low-cost drip irrigation systems provide a means of maximizing return on their cropland by increasing the agricultural productivity per unit of land; and through increasing cropping intensity during the dry season. The experiment was conducted in 2012-2014 cropping seasons in moisture deficit areas of Daro Labu district Sororo peasant association (PA), Eastern Ethiopia. The study was conducted to evaluate and demonstrate rooftop water harvesting practice in combination with low-cost drip irrigation system in moisture deficit areas and increase the productivity of farmers using harvested water with water saving drip irrigation technology. It was also aimed to improve farmers' awareness, knowledge and skill of utilizing water harvesting practices and water saving technologies. One farmer, who actively participates and has house roofing with corrugated iron sheets, was selected. On roof, side collectors and gutters were tied and appropriate site selected to place plastic tank for storage. The collected water during rainy season was stored in the two plastic tankers (total capacity of 8000 liters) for irrigating off-season for high value crop tomato (Cochoro variety) during three years of practice. The plastic tank and gutters were found from nearby as a suppliers and low-cost drip set which operates with gravity installed at 1m height above the ground level to supply water for the crop was obtained from district bureau of agriculture. The plot area on which tomato was cultivated varied depending on rain fall amount and variability during three years of practice. The marketable yield obtained varied from 5.24 to 39.06 t ha^{-1} with average value of 25.76 t ha^{-1} and corresponding gross income varied in between 78, 600 to 313, 405 ETB per hectare. Further, farmers' mini field day was organized to assess their reaction towards the technologies that over 73% said they are affordable and 77% reported their operation is simple and can be handled with minimum training. Thus, the technologies are found important and recommended to be used in moisture deficit areas for both as supplementary and complementary irrigation.
Keywords: low-cost, drip irrigation, rooftop water harvesting, water use efficiency

1. Introduction

It is well known that the pressure on land is increasing every day due to population growth, causing more and more use of marginal lands for agriculture. But, agriculture is only possible when there is availability of water. By water harvesting during rainy seasons, water availability can be increased. Currently, the terminology of 'water harvesting' is used to indicate the collection of any kind of water for domestic, agricultural, or other purposes. Water is harvested and directed either onto crop fields, or into various types of natural or man-made storage structures. A large variety of storage technologies are used in Eastern and Southern Africa and many of these are described and illustrated in Ngigi (2003), Mati (2006), and Aulachew *et al.* (2006). For water harvesting structures to be successful, the communities have to participate in the planning and construction of the structures and accept responsibility for their operation and management.

The major reason for the low and inconsistent rate of growth in agricultural production is as a result of high uncertainty and unpredictable rainfall, combined with low soil fertility (FAO, 2003). Even in years of 'average' rainfall, a shortfall during critical periods of crop growth often leads to extensive crop failure. Therefore, water storage is absolutely crucial for stabilizing and increasing crop yields (FAO, 2003). The harvested water can be stored in many ways: large and small dams, aquifers, on-farm storage tanks, and in the root zone of the crops itself.

To increase agricultural production and living standard in dry lands of Ethiopia, greater priority must be given to enhancing efficiency of water collection and utilization (Hillel, 2001; Sandra, *et al.,* 2001; Hune and Paul, 2002). Drip irrigation system, thus, can achieve 90-95% efficiency by reducing evaporation and deep percolation and its distribution of water is uniform (Bresler, 1990; Brouwer, 1990; Baker, *et al.,* 1993). Ideally, well designed drip system applies nearly equal amount of water to each plant, meets its water requirement and is economically feasible (Clark, 1990; Fekadu and Teshome, 1997; Mizyed and Kruse, 2008). Thus, it has been often promoted as an efficient technology that can conserve water, increase crop production, and improve crop quality (Frederick and Troeh, 1980; Jensen, 1983; Michael, 1997; Hacham, 2001; Isaya, 2001).

Since quantity and availability of rainwater in time in a given area is the prime factor that largely determines the performance of rain-fed agriculture, its improved efficiency can substantially augment the countries food security achieving endeavors (Michael & Teklu, 2006). In line with this, research project/demonstration was initiated to tackle the problem of moisture deficit in Daro Labu district, West Hararghe zone which is resulted from low rainfall amount, high rainfall variability in space and time and decreasing reliability from time to time (Eshetu et al., 2010).

Harvesting water from roof-top catchment and utilizing the collected water for irrigation in combination with water saving irrigation systems like low-cost family drip sets are among the primary and viable options to cope up with existing low moisture problem in midlands and lowlands of Western Hararghe zone, Eastern Ethiopia. Development of rainwater harvesting practice and its use with water saving technologies for enhanced agricultural production in those areas is the most efficient and also sustainable since development of other water resources like ground water, diversions from rivers and construction of large dam could not be feasible. In addition, the current housing condition of population in the region, allows collection of runoff from corrugated iron sheet roof and the existing farmers' practice in tanker/hand dug pond is the potential to be tapped. Therefore, this study was intended to demonstrate and evaluate rooftop water harvesting practice and low-cost drip irrigation system for increased productivity and improve farmers' level of awareness, knowledge and skill on utilizing those technologies.

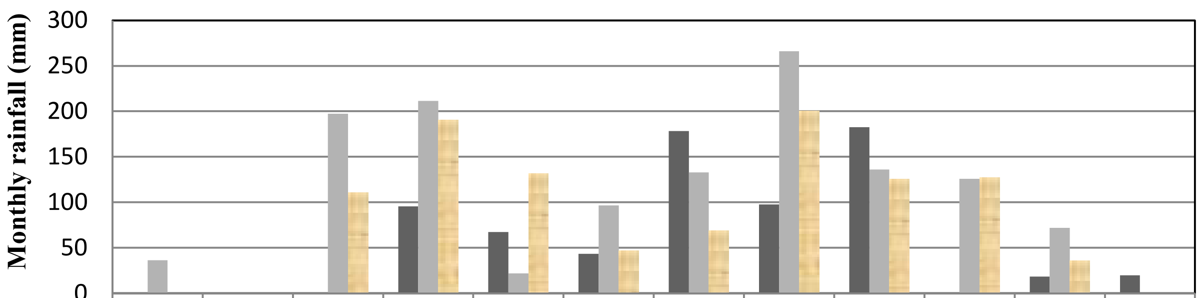
2. Materials and method

2.1. Site Description:

The field experiment was conducted in Western Hararghe zone of Eastern Ethiopia, in Daro Labu district. It is located at 444 km to the east of Addis Ababa and 125 km from Chiro (Zonal Capital) to the south on a gravel road that connects to Arsi and Bale Zones. Its latitudinal and longitudinal positions are $40^0$19.114' North and $08^0$35.589' East respectively. The area has bimodal type of rain fall distribution with annual rainfall ranging from 900-1300mm (average annual rainfall of 1094mm) and ambient temperature of the district varies from 14 to 26^{o}C with an average of 20^{o}C (summarized for Mechara metrological station from 2009-2014 which was found at about 15 kms away from study site). The monthly total rainfall distribution and mean monthly temperature during experimental period is depicted in figures 1 & 2.

The nature of rain fall in the area is very erratic and unpredictable causing tremendous erosion. The altitudinal range for Daro Labu district is in between 1350 to 2450 m.a.s.l with total area coverage of 434,280 ha and the predominant production system is mixed crop-livestock production with peculiar sub-systems. The major crops grown in the area includes from cereals like teff, sorghum, maize and finger millet; lowland pulses like haricot bean and soya bean; vegetables like tomatoes, cabbage and hot pepper; tuber crops like sweet potatoes and potatoes to tree and fruit crops like coffee, mango and avocado. The major soil type of the area is Nitisol with texture of sandy loam clay which is reddish in color (McARC, 1998)

Monthly rainfall distribution at Mechara station



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	0	0	0.2	95.6	67.3	43.3	178.3	97.7	182.4	0	18.3	19.7
2013	36.2	0.6	197.3	211.3	21.7	96.7	133	266.1	135.9	125.8	71.8	0
2014	0	0	110.6	190.4	131.8	47	68.9	200.5	125.3	127.2	35.5	0

Figure 1: Monthly rainfall pattern in 2012, 2013 & 2014 at Mechara meteorological station

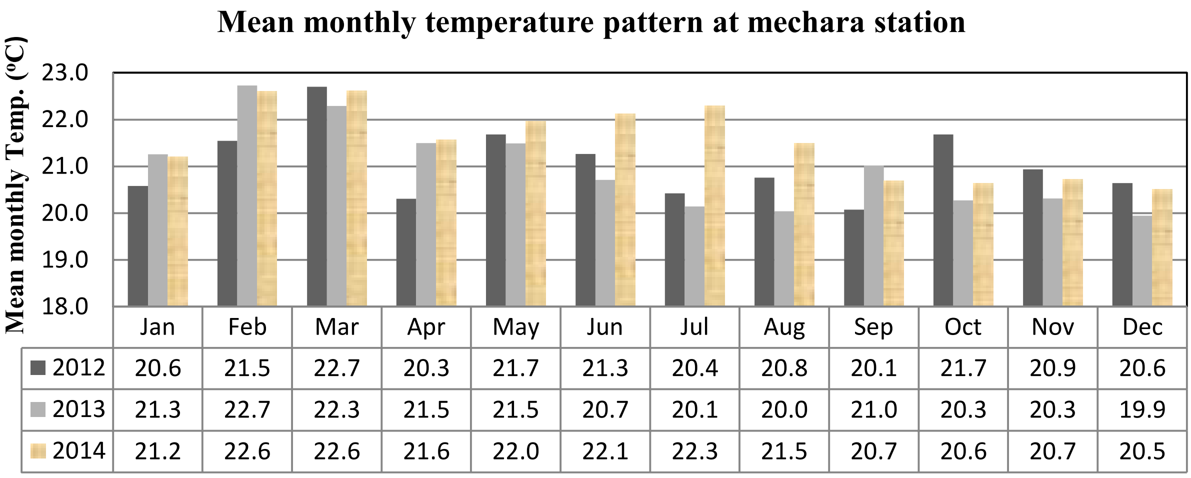


Figure 2: Mean monthly temperature pattern in 2012, 2013 & 2014 at Mechara meteorological station

2.2. Experimental Design:

The demonstration and evaluation of roof top water harvesting for cultivating tomato was made at Sororo PA of Daro Labu district-on farm, for three consecutive years (2012 up to 2014) on one farmer as a demonstration, who actively participates and have house with corrugated iron sheet roof. On roof, side collectors and gutters were tied and appropriate site selected to place plastic tank storage. The collected water during rainy season was stored in the two tankers (8000 liters total capacity) for using during off-season for high value crop tomato (Cochoro variety) during three years of practice. The plastic tank and gutters was found from nearby suppliers and low-cost drip set which operates with gravity installed at 1m height above the ground using barrel to supply water for tomato. The land on which tomato seedlings transplanted was prepared and the study plots used were 16m^2, 72m^2 and 42 m^2 respectively during three years of practice (Table 1). The data on yield (t ha^{-1}), total selling price (birr), water productivity (kg/m^3) and farmers' perception towards the technologies were taken. Mini-field day was arranged during the second year of practice which involved 22 participants (Figure 3).

Figure 3: Installed drip lines and discussion with farmers to assess their perception towards the technologies, 2013

3. Results and discussion

Table1: Summarized information on demonstration and evaluation of rooftop water harvesting with drip irrigation system in Daro Labu district, Eastern Ethiopia

Period of the year	Tomato variety	Planting area (m^2)	Total amount of water harvested (m^3/ha)	Yield (t ha^{-1})	Water use efficiency (kg/m^3)	Gross Income (ETB/ha)
2012	Cochoro	4mx4m	5000	39.06	7.82	312,500
2013	"	7mx8m	1111	32.99	29.70	313,405
2014	"	6mx7m	1904.8	5.24	2.75	78,600
Average			2671.9	25.76	13.4	234,835

Table 2: Perception of farmers and expert opinion on rooftop water harvesting and low-cost drip irrigation

system technologies (2013)

Groups/stakeholders	No participated		Assessment parameters	
	Male	Female	Affordability	Technical knowhow
Farmers	13	2	Affordable (n=10)	Easy to use (n=12)
DAs	2	1	Affordable (n=2)	Easy to use (n=1)
Experts from BoA	2	-	Affordable (n=2)	Easy to use (n=2)
Researchers	2	-	Affordable (n=2)	Easy to use (n=2)
Total	19	3	Affordable (73%) (n=16)	Easy to use 77% (n=17)

The study revealed that the yield was better during the first (39.06 t ha^{-1}) followed by second (32.99 t ha^{-1}) years of practice due to favorable climate, but it was much decreased on the third year (5.24 t ha^{-1}) (Table 1) since severely affected by fusarium wilt; one of the most devastating disease (Mes et al., 1999) which might be caused by higher mean temperature in 2014 (Figure 2) and consecutive planting on the same plot without crop rotation. Gross income gained from sell of produced tomato using low-cost drip irrigation system also varied with yield and is in between 78, 600 to 312, 500 ETB/ha. The use of highest water level (5,000 m^3) relatively gave maximum fruit yield; but the highest water use efficiency (WUE) was recorded at the lowest water amount used (1,111 m^3). The least WUE (2.75 kg/m^3) was recorded during the third year due to the lowest economical yield gained. The overall mean yield of tomato gained and WUE during three cropping seasons were 25.76 t ha^{-1} and 13.4 kg/m^3 respectively, with corresponding average gross income of 234,835 ETB (~11,200 USD) (Table 1). As compared to average yield of tomato which varied from 6.5-24 t ha^{-1} (Gemachis *et al.,* 2012) in Ethiopia, the yield obtained from low-cost drip irrigation system by using harvested water from rooftop where rainfall amount is found not sufficient to meet the crop requirement is promising. The increase in crop yield is justified by the more efficient drip irrigation system where the limited amount of water is supplied effectively to the root zone of the crop.

Studies revealed that, drip irrigation increased the yield of tomato and water use efficiency (WUE) by 19 and 20% (Fekadu and Teshome, 1997) as compared to furrow irrigation; and others found it significantly reduced the irrigation water requirement of a crop as it supply water only to root zone of the crop (Bogle, 1986; Raina *et al.,* 1998). It is also reported that use of harvested water from rooftop for irrigating vegetables by low-cost drip irrigation systems like bucket/drum kits increased farmers gross income in Kenya that they gained over 18,000 USD/ha (Ngigi, no date) which is comparable with the income found by this study. Furthermore, farmers and expert perception towards the technologies was also assessed based on cost of obtaining the technologies and their ease of operation that over 73% said they are affordable and 77% reported their management is simple and can be handled with minimum training (Table 2).

4. Conclusion and Recommendation

Water saving irrigation technologies need to be tested under local environments and particular agricultural production systems. Thus, the main challenge confronting both rain fed and irrigated agriculture is to improve WUE and sustainable water use for agriculture. Drip irrigation was found increased fruit yield of tomato and improved WUE due to consumption of less water. Generally, practicing rain water harvesting and using the collected water as supplementary or as complementary irrigation for double cropping is the better way of increasing agricultural crop production in moisture deficit areas of Western Hararghe Zone, as low rainfall amount, high rainfall variability in space and time and decrease in reliability is the major impediment to the productivity of rural poor in these areas.

As this study reveals, water harvesting technology combined with water saving drip irrigation system is found effective in moisture deficit areas like Daro Labu district and similar agro ecologies; especially for producing high value crops (onion, tomato etc) which have high return per plot of land and per drop of water during off-season or to supplement rain fed crops. But, it needs careful planning for wise use of harvested water (increasing water use efficiency) to ensure increased production.

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References

Awulachew, S.B.; Menker, M.; Abesha, D.; Atnafe, T.; Wondimkun, Y. (Eds.). 2006. Best practices and technologies for small scale agricultural water management in Ethiopia.

Proceeding of a MoARD/MoWR/USAID/IWMI symposium and exhibition held at Ghion Hotel, Addis Ababa, Ethiopia 7-9 March, 2 006. Colombo, Sri Lanka: International Water Management Institute.190pp.

Baker, D. M., Rain S. R., Robertson, M. S., 1993. A preliminary investigation of irrigation systems for sugar cane production. Bed fold, London.

Bogle O, Hartz (1986). Comparison of drip and furrow irrigation for Muskmelon production. Hortic. Sci., 21: 242-244.

Bresler, E. R., 1990. Drip irrigation technology in semi-arid regions: International co-operation. *Journal of irrigation Engineering and Rural planning*, 19:48-62. Nairobi, Kenya.

Brouwer, C., 1990. Design of Trickle irrigation systems. Department of irrigation and civil engineering, Agricultural University Combater, TNAU press, India.

Clark, W., 1991. Crops and Drops. Land and water development division, Rome, Italy.

Eshetu A, Yasin E, Desalegn M, Dulo H, Alemayo D (2010). Survey of land uses and management system in Western Hararghe Zone, Eastern Ethiopia: *Five years (2006/7-2010/11) research achievement report*, Mechara agricultural research center. pp. 18 (unpublished).

FAO (Food and Agriculture Organization of the United Nations), 2003. A perspective on water control in southern Africa: Support to regional investment initiatives. Land and Water Discussion Paper 1. FAO, Rome, Italy

Fekadu Y. and Teshome T., 1997. Effect of drip and furrow irrigation on the yield of tomato in Dire Dawa. Agriculture water Management 35, Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Frederick R. Troeh , 1980. Soil and water conservation for productivity and environmental protection. Prentice-Hall, Englewood cliffs. New Jersey, USA.

Gemechis A.O., Paul C.S. and E. Bezabih, 2012. Tomato production in Ethiopia: constraints and opportunities

Hachum, A., 2001. Water harvesting indigenous knowledge for future of the drier environments, ICARDA, Aleppo, Syria.

Hune Nega and Paul M. Kimeu, 2002. Water harvesting techniques. RELMA, Ministry of Agriculture, Addis Ababa, Ethiopia.

Isaya, R. F., 2001. Small-scale drip irrigation systems. RELMA, Nairobi, Kenya.

Jensen M. E., 1983. Design and operation of farm irrigation systems. ASAE monograph, Revised printing No. 3.

Mati, B. M., 2005. Overview of Water and Soil Nutrient Management Under Smallholder Rain-fed Agriculture in East Africa. Working Paper No. 105. Colombo, Sri Lanka: International Water Management Institute (IWMI).

McARC (Mechara agricultural research center), 1998. Farming system characterization of Daro Labu and Bokie districts in Western Hararghe Zone (unpublished report)

Mes JJ, Wit R., Testerink CS, de Groot F., Haring MA, Cornelissen BJC., 1999. Loss of a Virulence and Reduced Pathogenicity of a Gamma-irradiated of *Fusarium oxysporum* f. sp. *lycopersici***.** Phytopathology 89**:** 1131-1137.

Michael, A. M., 1997. Irrigation theory and practice. Ashanti printers, Delhi, India.

Mikael & Teklu, 2006. Irrigation and rain fed crop production system in Ethiopia.

Mizyed, N. and E. G., Kruse, 2008. Emitters discharge variability of subsurface drip irrigation in uniform soils: Effect on application uniformity. Trans. of the ASAE, 26: 451-458.

Ngigi, S.N., 2003. Rainwater harvesting for improved food security: Promising technologies in the Greater Horn of Africa. Greater Horn of Africa Rainwater Partnership and the Kenya Rainwater Association, Nairobi, Kenya.

Ngigi, S.N. (no date). Rainwater harvesting for supplemental irrigation: promising technology for enhancing food security in Semiarid Areas

Postel Sandra, P. Polak, F. Gonzales and J. Keller, 2001. Drip Irrigation for Small Farmers. A New Initiative to Alleviate Hunger and Poverty. Water International, Vol. 26 (1) 3-13.

Raina JN, Thakur BC, Bhandaria R (1998). Effect of drip irrigation and plastic mulch on yield, water use efficiency and benefit-cost ratio of pea cultivation. Indian J. Soil Sci.