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Rainwater harvesting for supplemental irrigation of onions in the southern dry lands of Ethiopia

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ABSTRACT

Agricultural water scarcity is a major limiting factor for crop production in dry land regions of sub-Saharan Africa (SSA). Despite notable efforts of developing macro-catchment rainwater harvesting (RWH) techniques, few studies have evaluated the performance of RWH for deficit supplemental irrigation of crops. We examine the agro-meteorological risks such as late onset, early cessation, overall low rainfall amounts and long dry spells during the growing season and evaluate the potential of macro-catchment RWH for supplemental irrigation of onion in the southern dry lands of Ethiopia. Field experiments were undertaken during 2012 and 2013 to evaluate the effects of 50% ETc, 75% ETc and 100% ETc irrigation levels on yield and water productivity of onion during dry and wet seasons. The harvestable yield and water productivity of onion under 75% ETc irrigation were not significantly lower than that under 100% ETc irrigation during both the dry and wet seasons. Thus, deficit supplemental irrigation of onion at 75% ETc can be implemented with macro-catchment RWH to reduce the risks of crop failure and significant yield declines in dryland areas.

1. Introduction

Most residents of sub-Saharan Africa (SSA) earn their living from rainfed agriculture (Rockstrom, 2009; UNCCD, 2009). Rainfed agriculture in SSA will remain vital for food security in the future as well (Cooper et al., 2008). In the arid, semi-arid and dry sub-humid regions of the SSA, food insecurity associated with agricultural drought affects a large portion of the population (Rockstrom et al., 2002). In these areas, rainfall has extreme temporal variability manifested in terms of unpredictable onset windows (too early or late onsets), early cessation and variable mean seasonal and annual rainfall distribution patterns (Barron et al., 2003). Crop production is mainly affected by higher seasonal rainfall variability that results in critical and long intra-seasonal dry spells (Biazin and Sterk, 2013; Barron et al., 2003). In eastern Africa, intra-seasonal dry spells caused severe crop yield reduction once to twice in 5 years (Barron et al., 2003; Biazin and Sterk, 2013). Also, once within 10 years annual drought incidence caused total crop failure (Biazin et al., 2012; Rockstrom, 2000). Water stress is one of the main limiting factors for crop production in rainfed farming systems of dry agro-ecological zones in SSA.

The southern Rift Valley of Ethiopia is a drought-prone area (Biazin and Stroosnijder, 2012; IPMS, 2005; Seleshi and Camberlin, 2006; Tilahun, 2006), due largely to the variable distribution pattern of the rainfall and unproductive loss of the seasonal precipitation (Biazin and Stroosnijder, 2012; Tilahun, 2006). A substantial proportion, some times more than 50%, of the seasonal rainfall may be lost in the form of soil evaporation and surface runoff in the dry lands of Ethiopia (Biazin and Stroosnijder, 2012; Welderufael et al., 2008). Hence, rainwater harvesting (RWH) techniques hold a significant potential for shifting the non-productive rainwater losses in to productive use, thus improving rainwater-use efficiency and sustaining rainfed agriculture in the region. RWH is irreplaceable in areas where both surface water and groundwater sources of irrigation are not possible.

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The SSA is the birthplace of many indigenous RWH techniques – some of which have been introduced to west Asian drylands (Biazin et al., 2012). The most commonly applied macro-catchment RWH techniques in SSA encompass traditional open ponds, cisterns, micro-dams, sand dams and spate-irrigation systems. The use of RWH systems for supplemental irrigation of rainfed crops has been widely considered as a key strategy to minimize the risks of crop failure induced by dry spells (Biazin et al., 2012; Rockstrom et al., 2010). However, few studies have examined the performance of macro-catchment RWH techniques for supplemental irrigation of dryland crops in SSA (Barron and Okwatch, 2005; Kahinda et al., 2007).

Oweis and Hachum (2003) define supplemental irrigation as 'the addition of small amounts of water to essentially rainfed crops during times when rainfall fails to provide sufficient moisture for normal plant growth, in order to improve and stabilize yields'. According to Shan et al. (2002), limited irrigation or deficit irrigation is a system of dryland cultivation in which limited water is supplied to the crop in an irrigation network to supply part, but not all of the water needed for crop growth. A review of research results by Geerts and Raes (2009) confirmed that deficit irrigation could increase water productivity for various crops without causing severe yield reductions. However, proper implementation of deficit irrigation requires precise knowledge of crop response to drought stress caused by agro-meteorological risks across different regions. Hence, there is a need to undertake more scientific studies to examine the probabilities of agricultural water scarcity for crops caused by late onset of the rainfall, critical dry spells, early cessation of the rainfall seasons and critically low rainfall amounts in a given region. Thus there is a possibility of addressing these challenges through supplemental irrigation using RWH from excess surface runoff during the rainfall seasons.

In the southern dry lands of Ethiopia, absence or limited surface and ground water availability is a critical challenge against developing supplemental and full irrigation for food and cash crops (IPMS, 2005; Rebeka, 2006). In response to this, the development of macro-catchment RWH techniques for supplemental irrigation has been considered as a viable option by governmental and non-governmental development organizations. Various efforts have been put in place to promote RWH interventions (Rebeka, 2006). Smallholder households have been harvesting excess runoff in macro-catchment rainwater ponds and use that to grow high value vegetables including onion (*Allium cepa*), pepper (*Cupsicum annunm*) and tomatoes (*Lycopersicon esculentum* Mill.) during the short and long rainy seasons (IPMS, 2005).

Despite notable efforts of developing and promoting rainwater harvesting techniques in southern Ethiopia, no empirical studies have examined the agro-metrological risks or evaluated the potential of RWH for supplemental irrigation of locally grown high value vegetables such as onion. We examine the agro-meteorological risks such as late onset, early cessation, overall low rainfall amounts and long dry spells during the growing season and evaluate the potential of RWH for supplemental irrigation of onion in the southern dry lands of Ethiopia.

2. Material and methods

2.1. Description of the study area

This study was conducted at Halaba Special district, which is part of the Southern Nations, Nationalities and Peoples (SNNP) region of Ethiopia (Fig. 1). The study site is located at about 7° 17′ N and 38° 06′ E with an altitudinal range from 1554 to 2149 m above sea level. It has a mean annual rainfall of 994 mm with bimodal distribution, small and long rainfall seasons (Fig. 2). The small rainy season, also known as *Belg*, ranges between February and May and provides about 39% of the annual rainfall. The long rainy season, also known as *Kiremt*, ranges between June and September and provides about 47% of the annual rainfall. Farmers can produce two crops per year if they grow short-maturing crops such as teff and haricot bean during the short rainy season and harvest before the beginning of the long rainy season when they can produce other crops such as maize and wheat. The monthly rainfall is also characterized by its high annual variability (Fig. 2). Agricultural water scarcity is a major limiting factor for crop production in the area. The mean annual temperature is between 18 and 21 °C. The long-term mean monthly reference evapotranspiration (ETo) values exceed the mean monthly rainfall values, except during July and August.

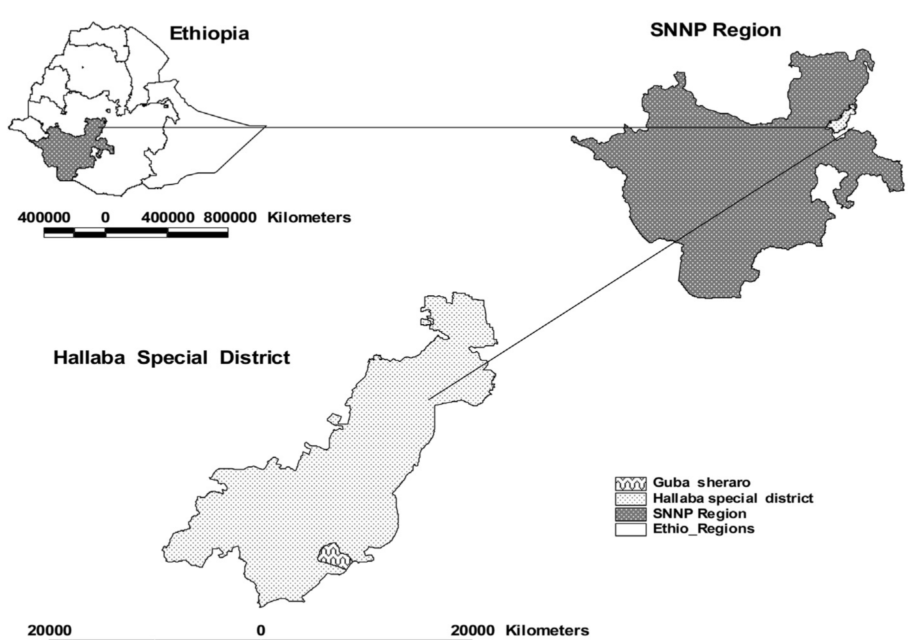

Fig. 1. Location of the Guba Sheraro, the study area at Halaba district, in the Southern Nations, Nationalities and Peoples region of Ethiopia.