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Assessing drought risk and irrigation need in northern Ethiopia

A. Araya[a,*], Leo Stroosnijder[b]

[a] Mekelle University, Department of Crop and Horticultural Sciences, P.O. Box 3057, Mekelle, Ethiopia
[b] Wageningen University, Land Degradation and Development Group, Droevendaalsesteeg 4, 6708PB Wageningen, The Netherlands

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ABSTRACT

Long-term climate data of four stations in the northern Ethiopia were analyzed in combination with information from local farmers and documented materials. From this analysis, a suitable drought-assessing technique was developed and site-specific needs for supplementary irrigation were explored. Results showed that our technique for assessing drought and crop failure corresponded well with farmer observations. The three major causes of crop failure (dry spells, short growing period and "total lack of rain") which were explicitly listed and ranked by the local farmers were found to match the analyzed data well. The agro-meteorological variables with the most severe consequences were "short growing period" and "total lack of rain". To prolong the growing period, supplementary irrigation is recommended in the month of September for three of the stations (Maychew, Mekelle and Adigudom) because: (1) rain frequently stops in early September or late August and crops have no other source of water for the rest of the growing period; (2) sufficient surface runoff can be harvested in July and August to be stored in farm ponds and used in September; (3) more cultivable land can be irrigated if supplementary irrigation is scheduled only for the month of September; and (4) giving supplementary irrigation in September can cut yield reduction by over 80% and crop failure by over 50%, except at Alamata. At Alamata, supplementary irrigation must be scheduled for July. The conditions experienced during the famine years of the early 1980s were primarily caused by the continued total rain failure over multiple years. Giving supplementary irrigation in July or September would probably not have mitigated the effects of these droughts, especially at Alamata and Maychew stations.

1. Introduction

The Ethiopian economy is based on agriculture. It is also the source of income for about 80% of the labor force in Ethiopia (Bewket and Conway, 2007). Natural rainfall is the major source of water for agriculture. Assessing seasonal or dekadal[1] rainfall characteristics based on past records is essential to evaluate drought risk and to contribute to development of drought mitigation strategies such as supplementary irrigation.

Rainfall variability has been reported to have significant effect on the country's economy and food production for the last three decades. There have been reports of rainfall variability and drought-associated food shortages (Tilahun, 1999; Bewket and Conway, 2007). In most cases, what determines crop production in semi-arid areas of Africa is the distribution rather than the total amount of rainfall, because dry spells strongly depress the yield (Barron et al., 2003; Segele and Lamb, 2005; Meze-Hausken, 2004).

Early onset of the rainy season leads to crop germination, since most farmers sow in dry soil. If a long dry spell follows, the seedlings die – a "false start" (Ati et al., 2002; Raes et al., 2004; Kipkorir et al., 2007) – and often the crop must be resown. The major causes of crop failure in northeastern Ethiopia are frequent dry spells of about 10 days length, as well as a shorter growing period due to replanting or late onset and/or early cessation of rain (Segele and Lamb, 2005; Araya et al., 2010b). Reliable estimation of onset and cessation of rain could help optimize rainwater use in semi-arid areas (Sivakumar, 1992; Ati et al., 2002; Raes et al., 2004; Kipkorir et al., 2007; Mugalavai et al., 2008).

Dry-spell analysis has been carried out in various parts of Africa. Many authors define a dry spell as *n* consecutive days without appreciable rainfall (Stern, 1980; Sivakumar, 1992; Sharma, 1996; Ceballos et al., 2004; Gong et al., 2005). In many studies, days with rainfall less than 0.1 mm per day are considered a dry spell. The severity of dry spells depends on their frequency and duration and on the crop stage during which they occur. However, sometimes such analysis may not be useful for assessing whether the crop water demand will be met, for three reasons: (i) it does not consider the evaporative demand of the atmosphere; (ii) a day of rainfall with little agronomic effect may be counted as a wet day and (iii) effective rainfall is not considered.

* Corresponding author. Tel.: +251 914 722576; fax: +251 344 409304.
E-mail addresses: arayaalemie@gmail.com, arayaalemie@yahoo.com (A. Araya).

[1] We use the term dekad for a period of 10 days.

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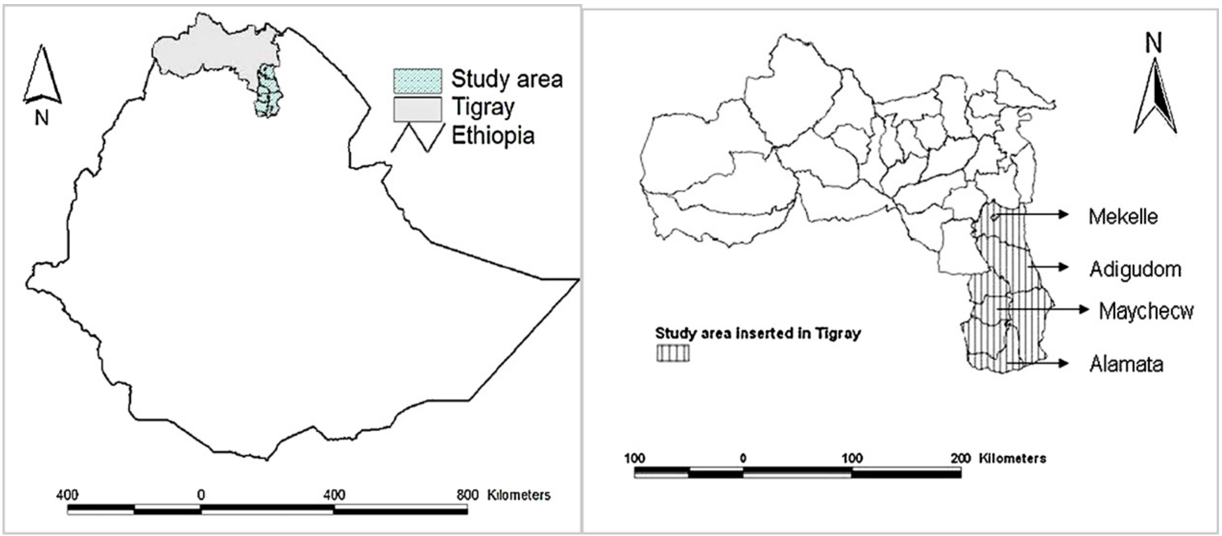

Fig. 1. Map of the study area in Tigray region in north Ethiopia.

Given that agriculturists are mainly concerned with actual crop water stress, the analysis would be more meaningful if it considered dry spells in relation to meeting crop water demand (Barron et al., 2003). Moisture deficit and the crop-growing risks and suitability of rain-fed agriculture can be evaluated on the basis of relationships between rainfall and reference evapotranspiration (Tilahun, 2006; Araya et al., 2010b). However, effective rainfall, not total rainfall has to be considered, because in semi-arid northern Ethiopia a substantial amount of the rainfall is lost as runoff (Araya and Stroosnijder, 2010). Crop water stress becomes severe when the available water meets less than half the crop water demand (Doorenbos and Kassam, 1979). Thus, one way of analyzing dry spells is to describe the dekadal effective rainfall in relation to the dekadal reference evapotranspiration. A dry spell in our case is thus any dekad in which effective rainfall is less than 50% of the dekadal reference evapotranspiration, whereas a wet spell is any dekad in which effective rainfall exceeds 50% of the dekadal reference evapotranspiration.

There are many definitions of drought, but from the viewpoint of local people, drought is any season with low rainfall in relation to crop water demand that results in poor crop harvest or total crop failure and/or livestock suffering or dying from because of feed shortages as a consequence of poor rainfall distribution/amount. Dry spells affect a crop when only a small amount of soil water is available to the crop due to reduced soil water holding capacity.

A dry spell can occur at the start, mid, or late season of the crop. When dry spells occur at the late season stage of the crop, the growing season is shortened. Late season drought has been reported to reduce yields significantly at Mekelle in northern Ethiopia (Araya et al., 2010b). Despite the risk of drought and the vulnerability of the people to the recurrent drought, little has been done to develop techniques for assessing drought risk and to determine how and which variables are related to crop failure circumstances in the northern Ethiopia.

There are various techniques for assessing and predicting drought. Each has merits and limitations (Alley, 1984; Guttman, 1991; Heddinghaus and Sabol, 1991; Guttman, 1998). In this study we set out to develop a simpler technique that can be used to assess the occurrence of past drought (crop failure) years easily and adequately for northern Ethiopia.

Drought can be mitigated by various agronomic and water conservation methods and with supplementary irrigation. The objectives of this paper are: (1) to analyze critically the quality of past growing seasons in northern Ethiopia in order to elucidate the main causes of crop failures; (2) to develop a simple suitable drought assessment technique and (3) to study the probability of occurrence of drought and indicate site-specific time and quantity recommendations for supplementary irrigation as a drought-coping strategy. Data from four rainfall stations in northern Ethiopia, each with 30–46 years of observation, and on two major crops: barley (*Hordium vulgare*) and teff (*Eragrostis tef*) were studied.

2. Materials and methods

2.1. Site and data description

The study site is located in northern Ethiopia (longitude 39°5′–39°8′ and latitude 12°3′–13°7′) and has four climate stations (Fig. 1). The climate is characterized by bimodal rainfall. About 70–80% of the rain falls in the *Kiremt* season (June–September) (Araya et al., 2010b). There is great inter-annual spatial and temporal rainfall variation. The mean minimum and maximum temperature range is from 8 °C to 30 °C, with small annual variations. In all months except the month of August, the dekadal reference evapotranspiration exceeds the mean dekadal rainfall.

In this area, the agriculture is mixed crop and livestock farming. Land degradation and deforestation are among the major problems caused by human factors in the area (Hurni, 1990; Nyssen et al., 2000; Meze-Hausken, 2004). The fertility of the agricultural lands is deteriorating. In this area of Ethiopia the soils are shallow (<0.5 m) and have poor water-holding capacity.

The major crops in the study area are barley, teff, sorghum, chick pea and wheat. Early-maturing and drought-resistant crop cultivars are widely grown (Meze-Hausken, 2004). The growing period starts in early July and ends in early to late September, with a rainy period of a maximum of 80 days (Araya et al., 2010b). More than 95% of the arable land is cultivated with out irrigation.

The site was chosen not only due to availability of relatively long series of meteorological data but also because recurrent drought is common in this part of the country. As the farmers in this area have frequently experienced drought, their perceptions of drought and crop failure are valuable to consider when analyzing climatic data.

Daily weather data such as rainfall, sunshine, temperature, humidity and wind were obtained from the Ethiopian