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Dry spells assessment with reference to the maize crop in the Luvuvhu River catchment of South Africa

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ABSTRACT

Agricultural productivity in South Africa is negatively affected by drought as a result of frequent periodic dry spells and increasing crop water demands resulting in poor crop development and low yields. Thus, we embarked on this study which aims at investigating dry spell occurrences in relation to growing season of maize in the Luvuvhu River Catchment. Daily rainfall data (1945–2014) from 12 stations which represent the catchment fairly well was utilized in this study. Three consecutive planting dates were staggered based on three consecutive onsets of the rainy season. Dry spells were categorized into three groups: short, medium and long dry spells. The data was then subjected to theoretical distribution fitting using the Anderson–Darling goodness-of-fit test; and probabilities of occurrence were computed using a probabilistic model that best fits the data. Trend analysis was performed on the frequency of dry spells per growing period using the non-parametric Spearman's rank correlation test. Out results indicated high probabilities ($\geq$80%) of short dry spells at all the stations irrespective of the timing of planting. Further analysis revealed that a risk of yield reduction with planting following the first onset of rains was higher than that with planting following the second and third onsets. In order to minimize this risk, farmers can be advised to plant between mid-November to mid-December. Trend analysis indicated no trend for all the various dry spell lengths except for Thohoyandou with a decreasing trend and Sigonde with a weak increasing trend in long dry spells. Such findings can be used to describe drought conditions for improvement of agricultural productivity and food security, in a given area.

1. Introduction

Drought disasters occur in most climates, and the impacts vary significantly from country to country because of differences in economic, social and environmental characteristics (Sonmez et al., 2005; Li et al., 2009). In Africa, drought is considered as one of the most devastating natural disasters affecting access to water and food because most economies in the continent are reliant on agriculture. Southern Africa is not an exception, as its climates are largely arid, semi-arid and dry sub-humid with significant inter- and intra-annual rainfall variability, making farming susceptible to frequent droughts (Barron et al., 2003; Usman and Reason, 2004; Simba et al., 2012). Impacts of drought on agriculture such as reduced crop growth and development can be explained by the frequency, duration and intensity of dry spells (Usman and Reason, 2004). For that reason dry spells can serve as indicators of drought conditions during the crop growing season (Sushama et al., 2010). Consequently, information from analyses of the frequency of dry spell lengths and their probabilities could assist farmers to increase agricultural production and improve food security (Wetterhall et al., 2014).

In determining drought incidences, decisions can be better made if the probability of dry spells is computed after effective planting dates (Sivakumar, 1992). Delays in planting due to late onset of the rains may result in reduced yield, while too early planting following a “false” onset of the rain season may lead to insufficient soil moisture for proper germination (Wetterhall et al., 2014). The timing of dry spells relative to the crop physiological calendar has great influence on yield and thus, dry spell risk assessment can be predicated on the deficient

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moisture conditions during the main development stages of a crop (Reason et al., 2005). Sivakumar (1992) stated that it is essential to match the crop phenology with dry spell lengths to meet the crop water requirements during the sensitive stages of crop growth. In addition, the sensitivity of maize to the occurrence of drought is particularly high during 60–90 days after planting i.e., the flowering to grain-filling stage (Barron et al., 2003). The effects of which include delayed silking, reduced silk length, and inhibited embryo development after pollination (Lauer, 2003).

Maize (*Zea mays* L.) is a major staple crop in small-scale cropping systems in South Africa, and the yield is sensitive to the occurrence of dry spells, depending on their timing and intensity (Moeletsi and Walker, 2012a; Wetterhall et al., 2014). Maize production varies greatly from one year to another mainly due to climatic risks that affect the area, and years of poor harvest pose a negative impact on the economy of South Africa (Moeletsi et al., 2013). The objectives of this study were therefore to investigate (1) the variability and lengths of dry spells during each stage of the maize growing period and (2) the possible impact of dry spells occurrence relative to different onsets of rains on maize production. In small-scale farmer areas of the Luvuvhu River Catchment, Limpopo Province where maize production is entirely rainfed, rainfall variability can expose the crop to a range of mild to severe drought, resulting in reduced yields (Bouagila and Sushama, 2013). Thus, we selected the Luvuvhu River Catchment area as a case study.

2. Materials and methods

2.1. Description of study area

The Luvuvhu River Catchment (Fig. 1) is located in the Limpopo Province of South Africa and has an area of around 5941 km^2 (Nkuna and Odiyo, 2011). It is found within the Limpopo River Basin, between the longitudes 29.49°E and 31.23°E and latitudes 22.17°S and 23.17°S (DWAF, 2004). The catchment is within the humid subtropical climate region (Cwa – Köppen classification) characterized by warm summers and dry winters (FAO, 2005). Rainfall season in this area occurs mainly from October to April (ARC, 2015). Rainfall is strongly influenced by the topography with the mean annual precipitation ranging from less than 450 mm on the low lying plains (northern and eastern parts) to more than 1200 mm in the mountainous areas. The soil in the area is mostly sandy loam, with soil water-holding capacity varying across the selected stations with a range of 21–80 mm (Table 1). Agriculture (vegetables, citrus and a variety of sub-tropical fruits such as bananas, mangoes, avocados and nuts) is the main pillar of the economy in the area (DWAF, 2012). However, it was reported that a significant number of people in the catchment live subsistence livelihoods (DWAF, 2012).

Historical rainfall data from 12 weather stations (Table 1) at the main cultivated dryland area in the Luvuvhu River Catchment was obtained from the Agricultural Research Council (ARC, 2015) and South African Weather Service. Rainfall data of more than 30 years was considered, except for Xikundu with only eight years, as this was the longest period for which data was available for all the stations that were considered in their respective vicinity. The data was examined for quality, and missing and faulty values were patched using the ARC Stand-Alone Data Patch function which applies the Inverse distance weighting method using neighboring stations (De Nysschen et al., 2014).

2.2. Determination of onset of rainfall season

The method of determining the onset of the rainfall season employed in this study uses the same principle developed by Stern

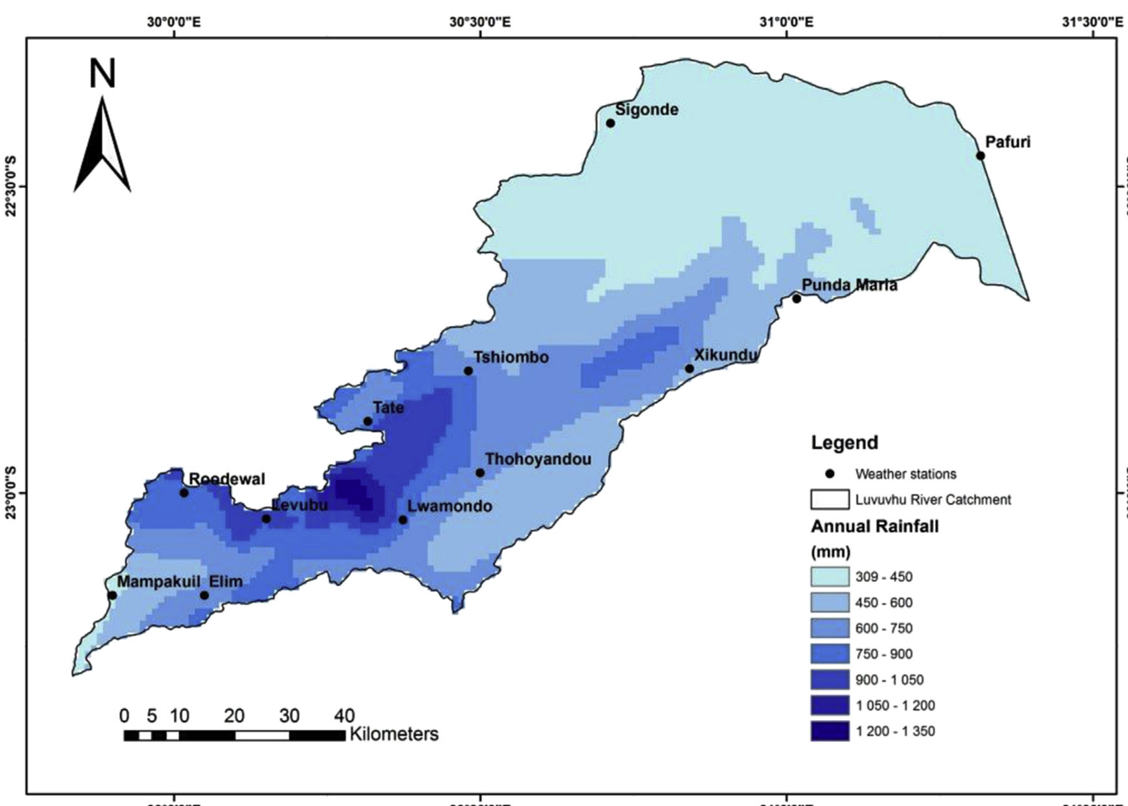

Fig. 1. Luvuvhu River Catchment long-term annual rainfall map and location of the 12 weather stations used in this study area.