Environmental Development 19 (2016) 36–48

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

Local climate variability and crop production in the central highlands of Ethiopia

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ARTICLE INFO

Article history:
Received 31 January 2016
Received in revised form
10 June 2016
Accepted 10 June 2016

Keywords:
Climate variability
Crop production
North Shewa, Ethiopia

ABSTRACT

The aim of this study was to understand the association of crop production with climate variability in the central highlands of Ethiopia. We used monthly rainfall and temperature data from 132 points each representing a pixel of 10×10 km, which are reconstructions based on station records and meteorological satellite observations. Production data of five major crops for the main cropping season, locally known as Meher, were collected for the period 2004–2013 for three districts (Baso Werana, Efratana Gidim and Menz Gera Meder) from the Central Statistical Agency (CSA). The production data are at the Enumeration Area (EA[1]) level and hence the best available dataset on crop production. Therefore, there is no published local scale study, as is attempted here, on local scale climate variability and crop production in the country insofar as it is known to the authors. Correlation analysis shows that crop production and cultivated area are positively correlated with rainfall, but negatively associated with maximum and minimum temperatures except for one of the districts, Basona Werana, where production of all crops are positively associated with the minimum temperature. Production of four out of five crops in Basona Werana and three out of five crops in both Efratana Gidim and Menz Gera Meder, showed declines over the period of study; regression results indicating rainfall to be the most important determinant of production levels. It is concluded that current climate variability has a significant influence on crop production in the area and any unfavorable change in the local climate in the future will have serious implications for household level food security. Efforts to adapt to the ongoing climate change should begin from tackling the current climate variability and take a climate risk management approach for adapting to the ongoing climate change.

1. Introduction

Climate variability plays a great role in agricultural production having a direct impact from the start of land preparation to the final harvest (Akinseye et al., 2013; Mesike and Esekhade, 2014). Rainfall in particular is a critical climatic element. While non-climatic factors like availability and access to farm inputs, land quality, tenure security, infrastructure, market and policy can be managed by farmers or the government in the short- or long-term, little could actually be done to

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[1] Enumeration Areas (EAs) are small spatial units from which crop production data are collected by the Central Statistical Agency of Ethiopia as a basis to estimate national level production. The data are therefore the best available on crop production. On average an EA consists of 150–200 households.

http://dx.doi.org/10.1016/j.envdev.2016.06.002
2211-4645/

drastically change the influence of climate, particularly rainfall. Mesike and Esekhade (2014) note that rainfall has always dictated how land is used and plays a dominant role in agriculture exerting a direct impact on production and spatial distribution of crops.

In countries like Ethiopia where agriculture is dependent on rainfall, the influence of climate variability on crop production is generally large. Previous studies have shown that variability in Ethiopia's agricultural GDP is clearly correlated with rainfall variability (World Bank, 2006; Bewket, 2009). Segele and Lamb (2005) also note that the characteristics of the main rainy season (June – September, known as *Kiremt*) rainfall are the most important determinants for agricultural activity from the perspective of its amount and geographical coverage. On the other hand, the frequent droughts in the past 30 years were caused by shortages of rainfall.

Whereas rainfall variability has always been a major challenge to Ethiopia, *Kiremt* rainfall is less variable in most parts of the country compared to the short rainy season (March–May, known as *Belg*) which is highly variable (Shanko and Camberlin, 1998; Bewket and Conway, 2007; Ayalew et al., 2012; Mengistu et al., 2013). Abebe (2006) notes that *Belg* rainfall is highly variable and its impact on agriculture of this variability is higher in the onset period than the cessation period. The sensitivity of agricultural production to current climate variability is a very important indicator of the vulnerability of Ethiopian smallholder farmers to ongoing climate change.

Many studies have shown the importance of rainfall variability in explaining crop production fluctuations at different spatial scales. At the global level, estimates are that climate variability accounts for roughly a third of observed crop yield variability (Ray et al., 2015). At the continental level, climate variability is widely recognized to be a major driver of crop production fluctuations particularly in Africa, where agriculture is predominantly small scale and rainfed (Jones and Thornton, 2003; IPCC, 2014). For instance, Rowhani et al. (2011) and Afifi et al. (2014) reported that intra-annual and inter-annual variability of rainfall and temperature had significant impacts on crop production and thereby food security of communities in Tanzania. In Nigeria, rainfall variability was found to have a significant influence on crop production (Adamgbe and Ujoh, 2013; Akinseye et al., 2013; Yamusa et al., 2015). In Uganda, variations in rainfall and temperature had significant effects on crop production (Mwaura and Okoboi, 2014).

There are only a few studies on the effects of climate variability on crop production in Ethiopia (Admassu, 2004; Lemi, 2005; Bewket, 2009). These studies are either at national or regional scales which mask local scale variability. Admassu (2004) studied the impact of rainfall variation on crop production for the whole of Ethiopia. The results of this study show no significant correlation between total annual, *Kiremt* and *Belg* rainfall, and production of those crops (barley, maize, sorghum, tef and wheat) in most parts of the country. Lemi (2005) investigated correlations between crop yields and rainfall covering some parts of the country (former provinces of Gojjam, Gonder, Harargie and Keffa). His results show that significant correlation exists between rainfall and yields of crops during the two seasons and noted the significant impact of rainfall variability on crop yields in almost all provinces. Bewket (2009) studied the relationship between rainfall variability and crop production in the Amhara region, and reported existence of significant correlations between crop production and rainfall and concluded that farmers are vulnerable to food insecurity partly due to rainfall variability in the region. Regardless of scale, high correlation coefficients between rainfall and crop production have been found by these researches.

Teka et al. (2012) investigated relationships between rainfall variability and crop and livestock production in eastern Tigray, northern Ethiopia. They found a positive correlation between livestock holding size and crop yield with rainfall amount. Another study was the work of Rosell and Holmer (2007) on implications of rainfall change for *Belg* harvest in South Wollo, north-central Ethiopia. They found significant effect of rainfall variability on food security of communities and changes in farming situation in the past 40 years. However, they only used agricultural data obtained from farmers' interviews on what they could remember in the study years rather than using actual data on crop or livestock production.

There is no local scale study, as is attempted here, on local scale climate variability and crop production in the country insofar as it is known to the authors. In this study, unlike the previous researches, crop production data are at the EAs level and climatic data are at a spatial resolution of 10×10 km. The general objective of the study is to analyse the influence of current climate variability on crop production in the central highlands of Ethiopia by using three districts as case study sites. The specific objectives are: i) to assess inter-annual variability and trends in crop production, and ii) investigate correlations of crop production with rainfall and produce a surface map showing the spatial patterns of the associations.

2. Materials and methods

2.1. Description of the study area

The study covers three districts (*Woredas* in Amharic), namely Menz Gera Meder, Basona Werana and Efratana Gidim, of the North Shewa Administrative Zone of the Amhara National Regional State (ANRS) of Ethiopia (Fig. 1). According to the Central Statistical Agency (CSA) (2013) the total population of the three districts is 371,890 out of which 188,820 are males and 183,070 are females. Menz Gera Meder is in the *Dega* (highland) agroecological zone while Basona Werana and Efratana Gidim are in the *Weyna Dega* (midland) and *Kolla* (lowland) agroecological zones, respectively. Elevation ranges from 1140 m asl in Efratana Gidim to 3554 m asl in Menz Gera Meder. Some 37% of the total area of the three districts is mountainous, 21% is rugged terrain and 42% is plain lands. Based on the FAO/UNESCO soil classification system, Vertisols cover about 37% of the districts, Nitosols cover about 24%, Chernozems cover about 30% and others some 9%. The major land use types