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Climate change, human impact and hydro-meteorological hazard in Dire Dawa district, Ethiopia

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Background

Records of drought in Ethiopia date back to 250 B.C. and since then droughts have been a recurring phenomenon in different parts of the country at different times. Recent studies have shown that the frequency of drought has increased over the past few decades, especially in the lowlands. Drought episodes are commonly followed by food insecurity leading to several casualties and substantial livestock reduction. Climate change prediction will worsen the already severe land degradation and will accelerate deforestation, loss of biodiversity and desertification with negative repercussions on food production and supply. During the last decades, in several parts of Ethiopia, such as the Dire Dawa district, the effects of climate change were paired and exacerbated by deforestation, overgrazing and poor land management. This led to an impressive increase in the frequency of devastating flash floods that repeatedly inundated the town of Dire Dawa, causing several fatalities and relevant property damage. The town of Dire Dawa and its surroundings (Fig. 1) are therefore experiencing a combination of hydro-meteorological extremes (droughts and floods), the frequency and intensity of which increased in the last decades, substantially limiting the economic development of the area.

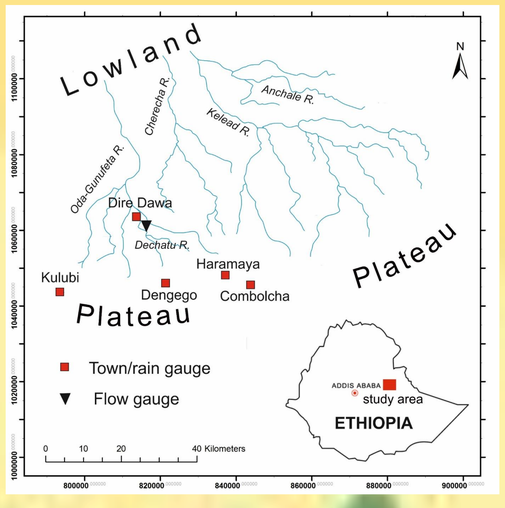

Figure 1. *The study area of Dire Dawa*

Drought assessment methods

The occurrence of droughts in the study area was investigated by the Standard Precipitation Index (SPI) (Fig. 2) and other parameters, such as the Z score or the aridity index, and a new parameter based on the number of days of rainfall onset delay with respect to the traditional seeding time (Rd).

In Ethiopia, farmers follow a millennial tradition of adaptation to rainfall seasonality and sow their crops at the end of February (just before the beginning of the spring small rains) and at the end of June-beginning of July for the summer big, monsoon-type rain crops.

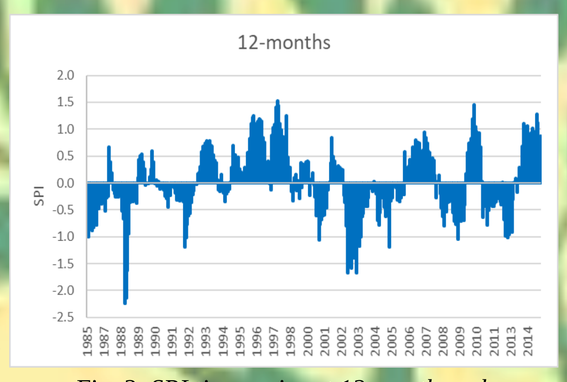

Fig. 2. *SPI time series at 12-month scale*

The sooner the rainfall comes the better it is for seed germination. Instead, if the rain comes several days after the seeds placement, their germination may be at risk or significantly reduced. Moreover, a bird of the francolin family, rather common in Ethiopia, is able to find the seeds also under two-three centimeters of soil. Though farmers use different means to keep these birds away, the longer the time between sowing and germination the more seeds are eaten by these birds. On the base of such considerations, a new, very simple parameter was developed to take into account the delay of rain onset with respect to sowing. For each of the study meteo-stations, the number of days to reach a rainfall amount of 20 mm after March 1 and July 1 were counted and then summed. Time series diagrams of rain delay data (Rd) for both the small spring and big summer rains and their sum were constructed and the occurrence of peaks was compared with droughts/famine occurrence since 1955 for Dire Dawa and Haramaya and since 1981 for the other meteo-stations, respectively, with the exception of Combolcha for which data was not sufficient (Table 1). From the comparison with the historical drought series, cumulative rain delays in excess of 40-50 days (depending on annual precipitation) can be considered as indicative of drought conditions.

Drought study results

According to a few authors and international institutions (Edossa et al. 2010; Degefu & Bewket 2015), in Ethiopia, major droughts have occurred in 1957-1958, 1964-1966, 1972-1974, 1982-1984, 1987-1988, 1990, 1999, 2000, 2002-2003, 2006, 2009 and 2011. This sequence is compared with the peaks of the aridity/drought parameters considered in this study, i.e. SPI, the UNEP's (1992) Aridity Index (Ai), the Z-score (Z) and the rain delay (Rd) (Table 1). **The results indicate the best performance is given by Rd with about 65 % of matches (Fig. 3) (Table 1).**

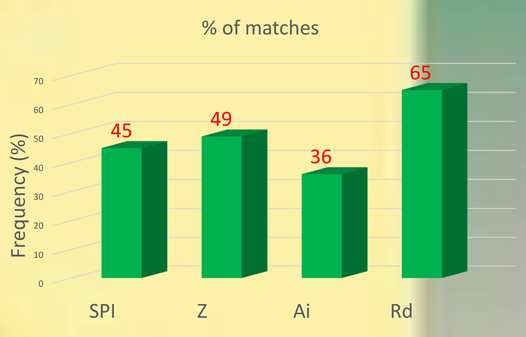

Fig. 3 *Correct predictions by the different drought indices considered in this study*

Table 1 - Results of different indices (see text for explanations) matching drought/famine episodes (■ = matches: ▬ = doesn't match; md = missing data).

		1957-58	1964-66	1972-74	1982-84	1987-88	1990	1999	2000	2002-03	2006	2009	2011	Total (%)
Dire Dawa	SPI	md	md	md	md	■	▬	▬	■	■	■	■	■	75
	Z	■	■	■	■	■	■	▬	■	■	▬	■	▬	75
	Ai	■	■	■	■	■	■	■	■	■	■	md	md	83
	Rd	■	■	■	■	■	▬	▬	■	▬	▬	▬	■	58
Haramaya	SPI	md	md	md	md	▬	▬	▬	■	■	▬	▬	▬	25
	Z	■	■	▬	■	▬	▬	▬	▬	▬	■	▬	▬	33
	Ai	md	md	▬	▬	▬	▬	▬	md	▬	md	▬	md	0
	Rd	■	■	■	■	▬	■	▬	■	■	md	■	■	82
Dengego	SPI	md	md	md	md	■	■	▬	▬	■	▬	▬	■	50
	Z	md	md	md	■	■	▬	▬	▬	■	md	▬	■	50
	Ai	md	md	md	■	▬	md	▬	▬	▬	md	md	md	25
	Rd	md	md	md	■	md	▬	▬	■	▬	■	■	■	63
Kulubi	SPI	md	md	md	md	■	▬	▬	▬	▬	■	■	■	50
	Z	md	md	md	▬	■	▬	■	▬	■	▬	■	▬	44
	Rd	md	md	md	■	■	▬	▬	md	▬	md	■	■	57
Combolcha	SPI	md	md	md	md	■	▬	▬	▬	■	▬	▬	▬	25
	Z	md	md	md	md	■	▬	▬	▬	■	▬	■	▬	43
Total match (%)		100	100	67	82	67	25	12	50	62	42	57	61	

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Flash floods in Dire Dawa

In 2006, the town of Dire Dawa experienced a typical flash flood that, following the heavy rain on the upland areas of eastern Harerge highlands, within a few hours turned the dry bed of the Dechatu River into a swelling and devastating river that caused several casualties and property damage for millions of Euros. The problem of flash floods in the semi-arid area of Dire Dawa is not new, but their frequency has significantly increased in the last decades (Alemu 2009; DDAEPA 2011). This study aims are: 1) to analyse the recent trends of rainfall intensity in the study area to ascertain if the increased frequency of flash floods can be associated with an increase of daily precipitation amounts (Fig. 4); 2) to estimate peak discharges for the Dechatu River in the recent decades and assess the evidence for changing flood behavior (Fig. 5); 3) to discern the role of climate change compared to that of to land use change and human impact in general, i.e. a situation that is common in many dry lands of developing countries.

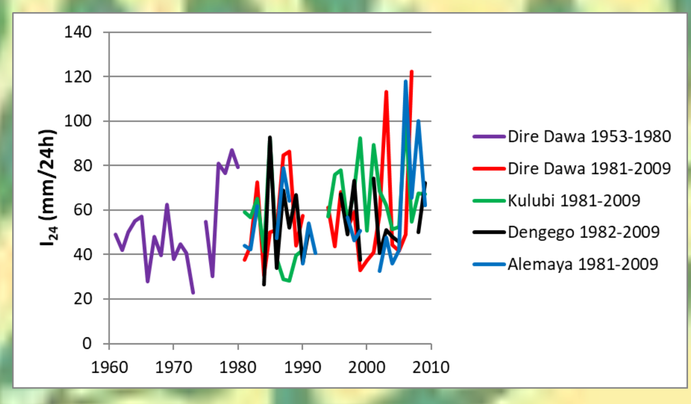

Fig. 4. *Inter-annual variation of daily rainfall intensity in the study area*

The return time interval for a daily rainfall intensity I_{24} = 100 mm/24h was calculated using the Gumbel method for 18 meteo-stations uniformly distributed across Ethiopia. The results of this analysis show that for 50% of the meteo stations the probability of a rainfall intensity of 100 mm/24h is less than one in 20 years. In the Dechatu R., rainfall intensities of the same order of magnitude of those that generated the devastating flood of August 2006 have a high probability to occur given the short return time ranging from 14 to 21 years calculated for Dire Dawa and the neighbouring mete-stations.

The interannual variation of daily rainfall intensity shows a marked increasing trend, with a substantial jump in the last two decades (Fig.4).

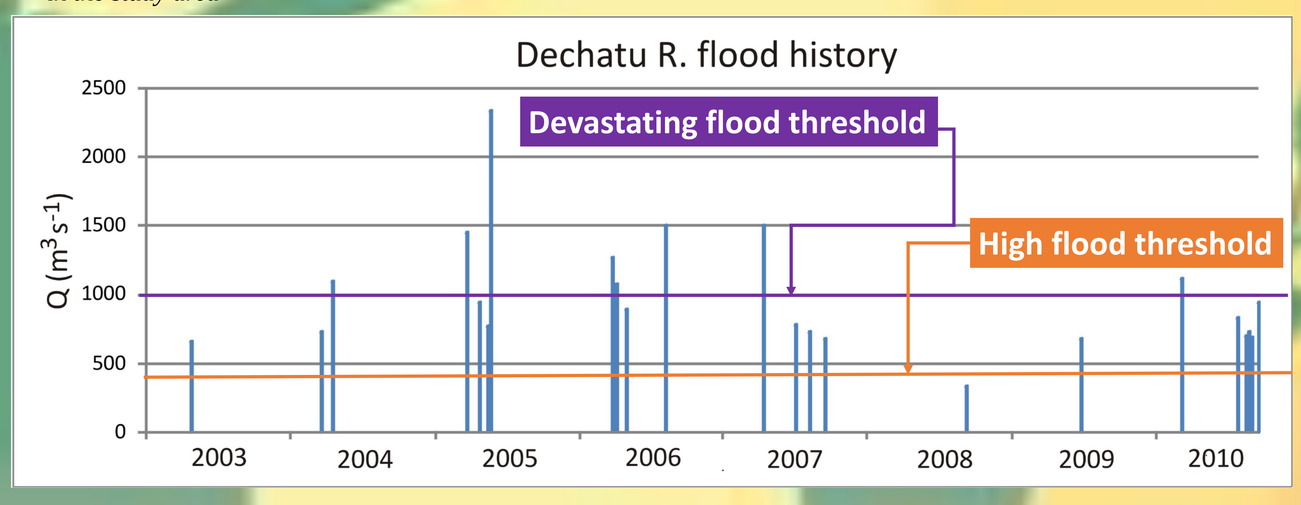

Fig. 5. *The floods larger than 300 $m^3 s^{-1}$ were calculated from flow level data, filed survey of the cross-section and bed material grain size and by using the Darcy-Weisbach uniform flow equation. Two other very high floods occurred after 2010.*

In the study area, land use/cover changed significantly from 1985 to 2006 and a nick point can be identified in the first years following the change of Government (DERG) in Ethiopia that formally occurred in 1992. Late land management plans of the DERG forced the farmers to set up cultivations also on the on steep slopes of the Dechatu headwater and, though soil countermeasures such as terracing and eucalyptus tree plantations were implemented through the food for work program, the local farmers considered the natural constraints and limitations too hard to cope with and making such cultivations scarcely remunerative and rewarding. After the fall of the DERG regime in 1991, these cultivations were abandoned and grown trees were cut and sold for daily consumption. Presently, only little cultivation is taking place due to the limitations of soil degradation severity. This important land management transformation, consisting substantially in crop and conservation practices abandonment has left the slopes, especially in the river headwaters, devoid of any efficient soil maintenance and water conservations practices, de facto giving rise to conditions that favour higher than before overland flow volumes.

The runoff generated by a rainfall of 100 mm in 24 hours was calculated by the curve number method for the land use/cover referred to 1985 and 2006. According to this method, **the change of land use/cover observed in 2006 is responsible for a runoff increase of about 4.5%.**

Fig. 6. *The 2016 high flood of the Dechatu R. in Dire Dawa.*

Conclusions

1) The semiarid area od Dire Dawa, likewise many other parts of Ethiopia, is subjected to recurring droughts. The rain delay parameter proved to be the best to identify droughts and to be used as a simple early warning method to inform farmers of the drought risk and to let local administrators to deploy timely countermeasures.
2) The increased frequency of devastating floods in the town of Dire Dawa (Fig. 6) is the result of a combination of factors: the increased rainfall intensity in 24 hours recorded in the area and a marked land use change that following the fall of the DERG government resulted in the abandonment of the steeper land and of the old soil and water conservation implementations.

Fig. 7. *The river bed area is extensively occupied by the local people, including a permanent open air market. That has increased remarkably the number of casualties during the past floods.*