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RESEARCH ARTICLE

Vegetation Health and vegetative drought conditions: Case Study of AVHRR/VIIRS Data in Tigray Region, Ethiopia

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ABSTRACT

In this study, weekly mean of vegetation health index (VHI) for Tigray region from 1982 to 2016 was compared with mean VHI during 2017. The Vegetation Health index (VHI) is based on a combination of products extracted from vegetation signals, namely the Normalized Difference Vegetation Index (NDVI) and from the brightness temperatures, both derived from the NOAA Advanced Very High-Resolution Radiometer (AVHRR) sensor. The data and images have 4 km spatial and 7-day composite temporal resolution. VH is calculated based on strong inverse correlation between NDVI and land surface temperature, since increasing land temperatures are assumed to act negatively on vegetation and consequently to cause stress. The VHI values range from 0 to 100, the low values representing stressed vegetation health conditions, middle values representing fair health conditions, and high values representing optimal or above-normal vegetation health conditions. Vegetative drought conditions were calculated using vegetation health conditions as proposed by Kogan. Extreme Drought<10 VHI, Severe Drought<20 VHI, Moderate Drought<30VHI, Mild Drought <40 VHI, No Drought>40 VHI. The results showed during 1985, 1990 – 91, 2009 and 2015-16 there was large area covered under drought conditions in Tigray Region. Drought conditions were found in Tigray region during 32nd week to 42nd week of 2017. Results shows eastern and south eastern part of Tigray has not been as much affected as western and central part of Tigray during 2017.

Key words: VCI; VHI; TCI; AVHRR; Tigray

1) INTRODUCTION

The new millennium has started with a series of large-area droughts which have had grim consequences for the affected countries and regions [1].

Drought is one of the most frequent climate-related disasters occurring across large portions of the African continent, often with devastating consequences for the food security of agricultural households [2].

Ministry of Environment and Forest, Ethiopia [3] reported, Drought causes significant impact in the agriculture Sector-Oxfam $1.1 billion per year, over the years (2007-2010), 66% of the total budget of MoARD went to the DRMFSS.

UN report published on 27 October 2015 at UN News " Ethiopia is experiencing its worst drought in 30 years according to the United Nations, with levels of acute need across all humanitarian sectors having already exceeded levels seen in the Horn of Africa drought of 2011, and which are projected to become far more severe in 2016".

Drought struck Ethiopia in 1888, leading to the historic deadly famine of 1888/89. About one-third of the population died because of famine, and 90% of the animals perished due to drought and drought related impacts. The 1957/58 drought and its related impacts led to famine in Tigray province and the 1972/73 famine caused by drought claimed 200,000 lives in Wollo province. Although the famine caused by drought of 1984–85 remains well known to the world community, less serious, nonetheless significant droughts, occurred in the years 1987, 1988, 1991–92, 1993– 94, 1999, and 2002. The geographical location and topography, the spatial and temporal distribution of rainfall in Ethiopia has given rise to three main seasons, these seasons are Kiremt, Belg and Bega [4].

Many studies have been conducted to analyze drought characteristics in Ethiopia based on meteorological and hydrological variables. Desalegn et al. [5] analyzed drought using Standardized precipitation index for temporal and spatial analyses of meteorological drought in the Awash River Basin.

Hellden and Eklundh [6] studied on the potential of NOAA satellite data for operational early warning and food security monitoring at a national level. They used NOAA NDVI 15-day composites (1981-1985) to analyze and

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compare precipitation data including time series records from more than 200 stations. As a result, they found strong relationship between satellite vegetation index anomalies and precipitation anomalies.
The rationale of this paper is to investigate weeks with lower vegetation health index using AVHRR/VIIRS data and to classify drought affected areas in Tigray region during 2017.
AVHRR-based Vegetation Condition Index (VCI) that has showed to be useful for drought detection and tracking. Validations showed that the VCI has excellent ability to detect drought and to measure time of its onset, intensity, duration, and impact on vegetation. The VCI provides accurate drought information not only for well-defined, prolonged, widespread, and intensive droughts, but also for very localized, short-term, and non-well-defined droughts. In addition to the VCI, the AVHRR-based observations in thermal bands were used to develop the Temperature Condition Index (TCI). This index is used to determine temperature-related vegetation stress and also stress caused by an excessive wetness [7].
Several authors have used the combined responses of reflected (e.g. NDVI, VCI) and thermal (e.g. LST, brightness temperature) products of the NOAA-AVHRR to provide a more ecological and physical interpretation of remotely sensed data for examining vegetation conditions [8, 9, 10, 11].
NDVI and LST time series have potential to describe the various dynamics of dry conditions [12].
The VH are indices, which range from 0 to 100 characterizing changes in vegetation conditions from extremely poor (0) to excellent (100) [13].
Research done by Owrangi et al., [14] on the topic entitled "Drought Monitoring Methodology Based on AVHRR Images and SPOT Vegetation Maps" shows the good validation results by comparing NDVI values of NOAA-AVHRR with SPOT-Vegetation maps. Pearson correlation shows R around 0.87.
In recent years, the developed indices Based on AVHRR Images have been used successfully in detecting vegetation stress resulting from droughts in different part of the globe [15, 16, 17, 18].
Multiyear observations, the NDVI was converted into the Vegetation Condition Index (VCI), which was applied successfully for drought monitoring and assessment of the vegetation condition in the United States [17] and some other countries [16].
The validation results clearly indicate the utility of VCI–TCI as a sole source of information about vegetation stress and consequently drought as a major cause of the stress. Moreover, they were also useful for real-time assessments and diagnosis of vegetation condition and weather impact on vegetation. This information is especially beneficial if weather data is not available and/or nonrepresentative due to sparsity of a weather-observing network. If real-time weather information is reliable, it should be combined with the AVHRR-derived characteristics and used as a comprehensive tool for monitoring vegetation stress, drought estimates, and weather impact assessment [19].

Objectives

1. To compare long term, mean weekly VHI and 2017 in Tigray Region.
2. To investigate percent of area in different vegetative drought categories during 1982 to 2017 in Tigray Region.
3. To identify vegetative drought affected areas in Tigray during 32^{nd} to 43^{rd} weeks of 2017.

2) MATERIALS AND METHODS

Study Area

Tigray region was chosen as the study areas (Fig. 1). Tigray Region is the northernmost of the nine regions of Ethiopia [20]. which is geographically situated between 12°14'10.795"N - 14°54'47.612"N and 36°25'48.181"E - 40°0'18.685"E.
Administratively, Tigray is bounded by Eritrea in the North, Afar in the East, Amahara in the South border, and Sudan lies in the West. Landforms in the research areas are dominated by mountainous terrain.

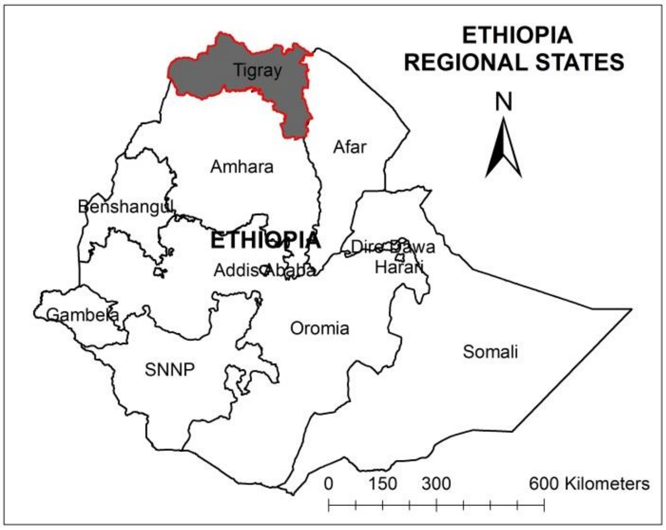


Figure 1: Location of study area (Tigray region)

Methodology

In this research, Vegetation health Index and droughts were identified from long term sequence of AVHRR (1981-2012)/ VH Blended VIIRS (2013-present) data. Multispectral and thermal data were used to construct Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) data.
Vegetation condition Index (VHI), Temperature condition index (TCI) and Vegetation Health Index (VHI) proposed by Kogan (1995) and adopted in this work are as follows:

(1) $VCI (\%) = 100 * (NDVI - NDVI_{min}) / (NDVI_{max} + NDVI_{min})$
(2) $TCI (\%) = 100 * (T_{max} - T) / (T_{max} - T_{min})$
VHI that was used for drought mapping. VHI is computed and expressed as:
(3) $VHI = \alpha VCI + (1-\alpha) TCI$

Where α is the relative contribution of VCI and TCI in the VHI. In most published analyses, α has been assigned a value of 0.5, assuming an even contribution from both elements in the combined index, due to the lack of more accurate information [20].

3) RESULTS AND DISCUSSION

Figure 2 shows percent of area in different vegetative drought categories in Tigray Region during 1982 to 2017. Bars show around 10 % area of Tigray has always been drought conditions. Tall bars show large are coverage under droughts in Tigray region. During 1985, 1990 – 91, 2009 and 2015-16 there was large area covered under drought conditions.

Figure 3 shows compare of drought conditions between long term average and 2017. Red line shows ten weeks with lower VHI than long term average.

Figure 4 shows drought conditions during 32nd week to 42nd week of 2017 in Tigray region. Results shows eastern and south eastern part of Tigray has not been as much affected as western and central part of Tigray.

Figure 5 & 6 shows Drought affected area in Tigray during 32nd to 43rd weeks of 2017.

Figure 7 & 8 show number of Kebeles under Drought conditions in Tigray Region 32nd to 43rd weeks of 2017.

4) CONCLUSION

This study attempts to identify the spatio-temporal extent of drought over Tigray region using satellite-borne remote sensing data based on Vegetation Health Index (VHI). As a result, it was found that this index can be successfully used to identify the spatio-temporal extent of agricultural drought. In addition, it can also be employed to explain drought severity classes in the research areas through composite analysis of both vegetation health by vegetation condition and temperature condition of vegetation. The results of VHI estimates can contribute to monitoring onset of agricultural drought as early warning system.

The detailed spatial assessment of drought evolution is required for a better understanding of the possible impacts of recurrent drought on agriculture, food production, soil degradation, human settlements and migrations, as well as energy production and water resources management across Ethiopia.

Figure 2: Tigray Region - Percent of area in different drought categories during 1982 to 2017

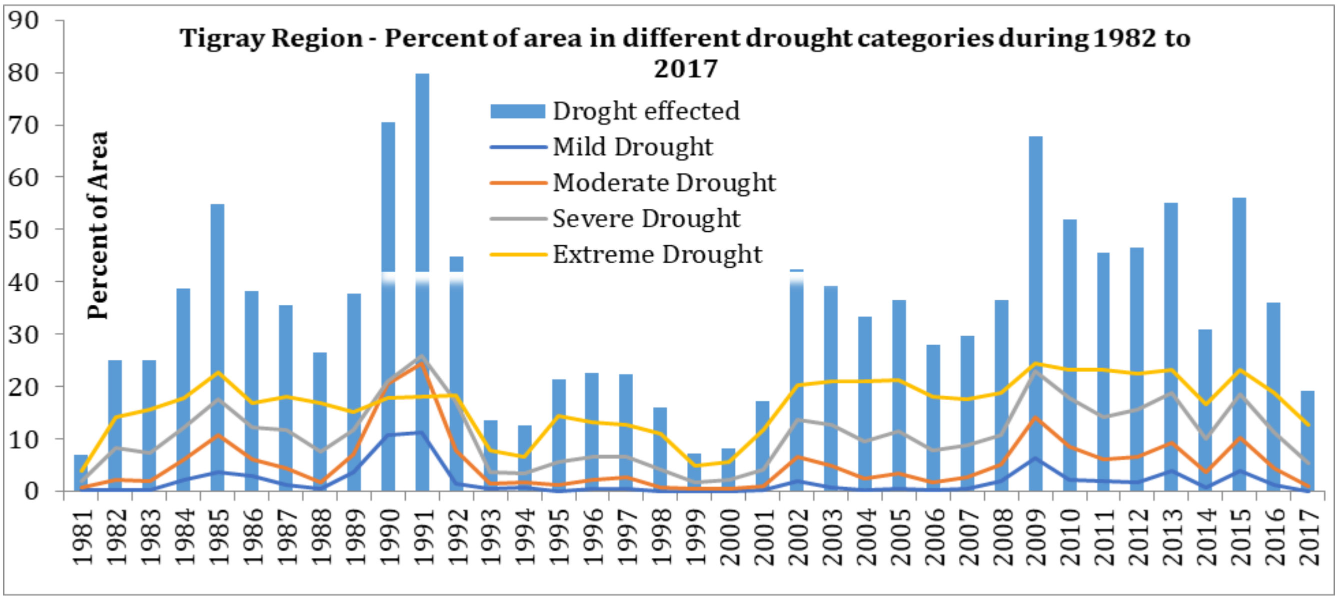


Figure 3: Compare of long-term average drought with 2017.

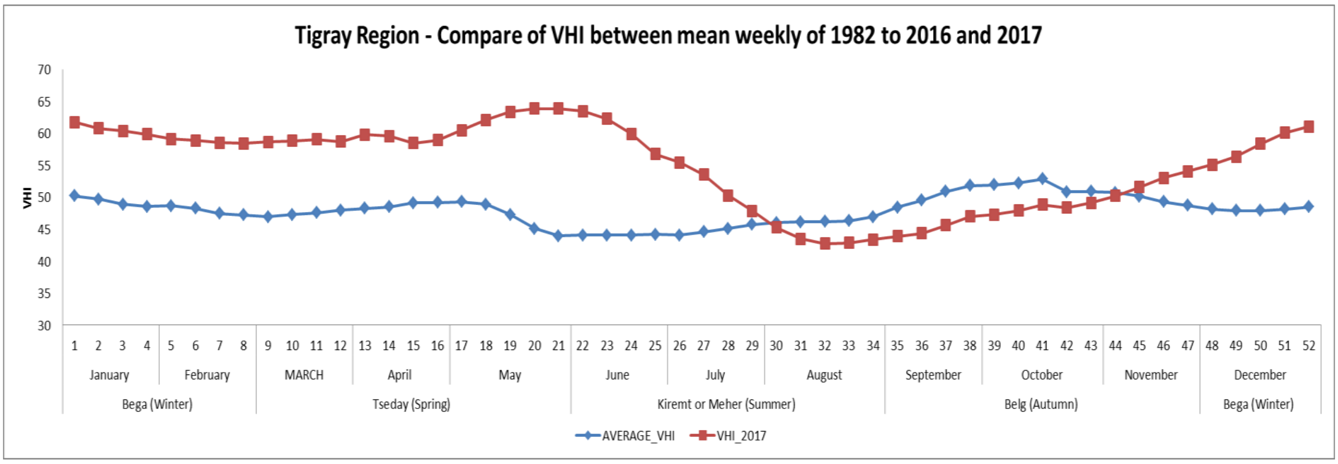


Figure 4: Tigray – VHI/ drought condition in 2017.

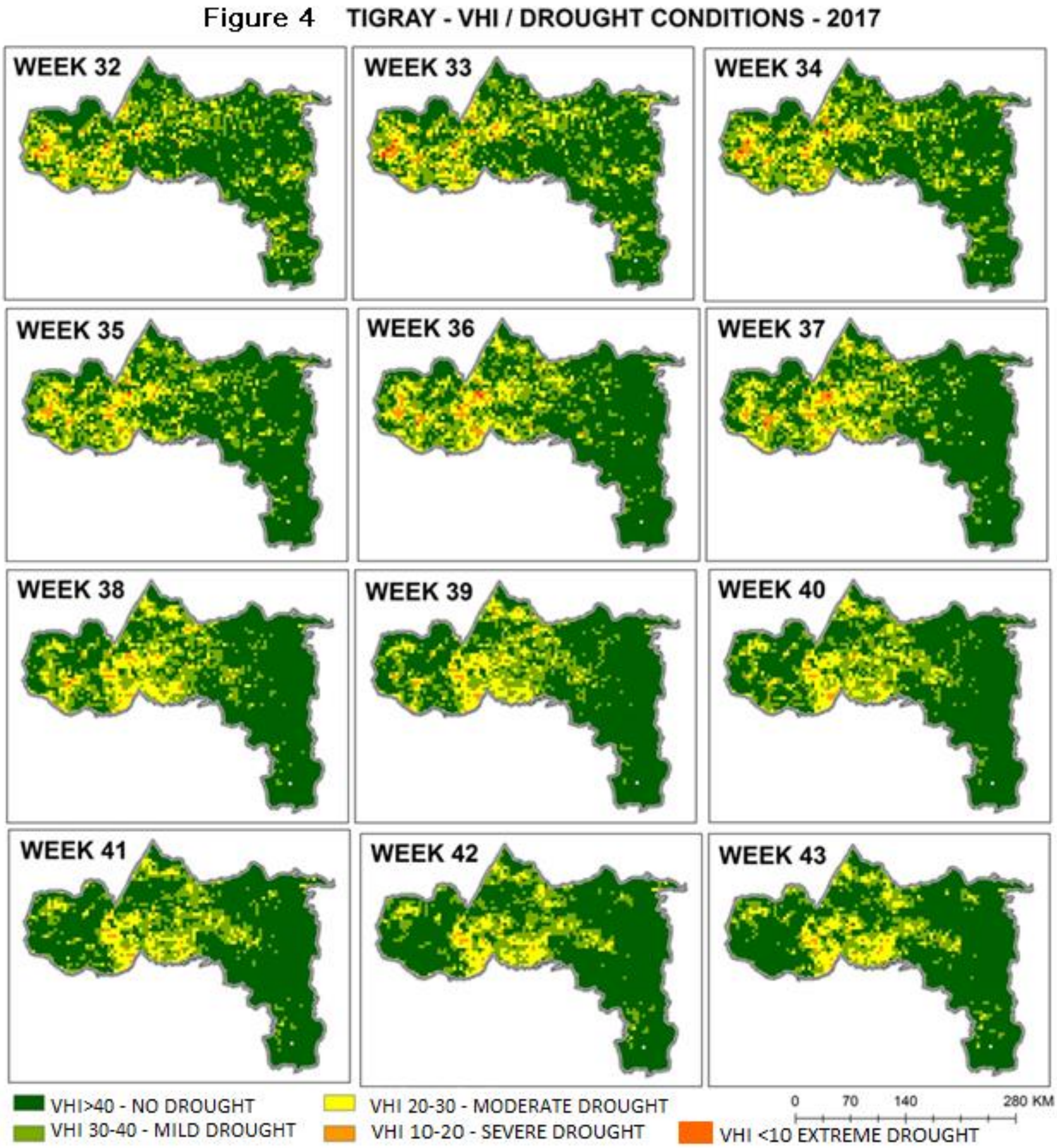


Figure 5: Drought affected area in Tigray 32nd to 43rd weeks of 2017

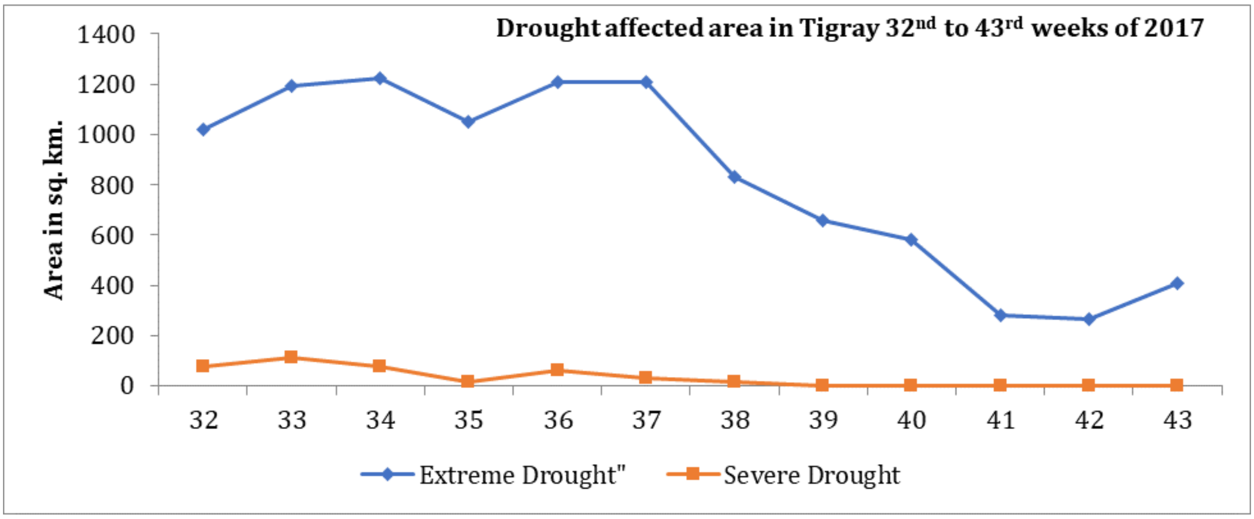


Figure 6: Drought affected area in Tigray Region 32nd to 43rd weeks of 2017

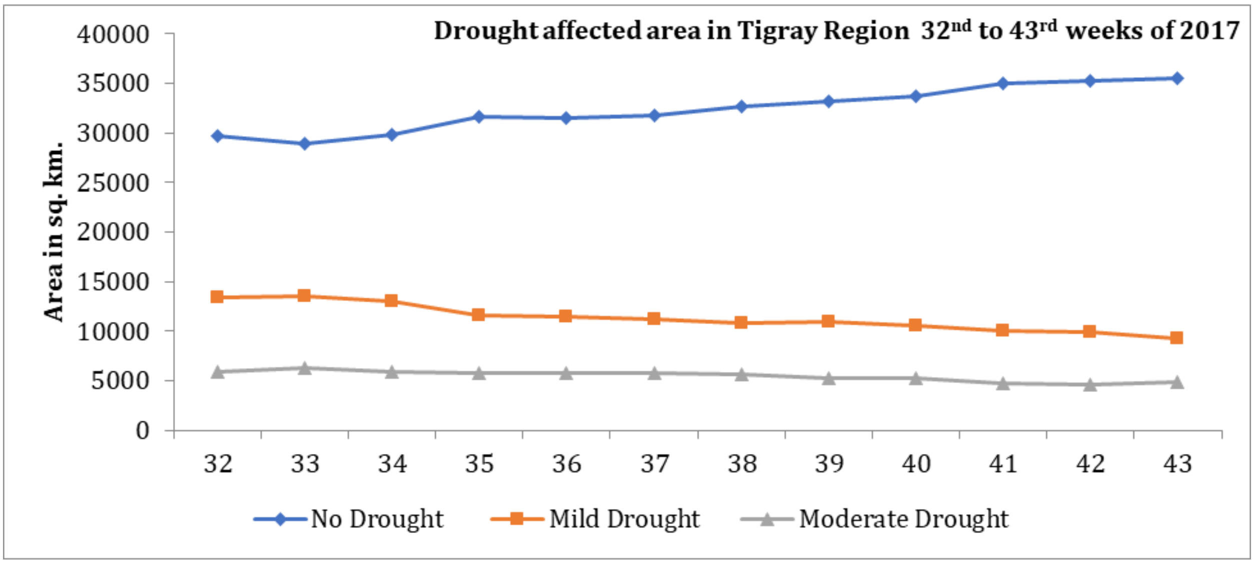


Figure 7: No of Kebeles under Drought conditions in Tigray Region 32nd to 43rd weeks - 2017

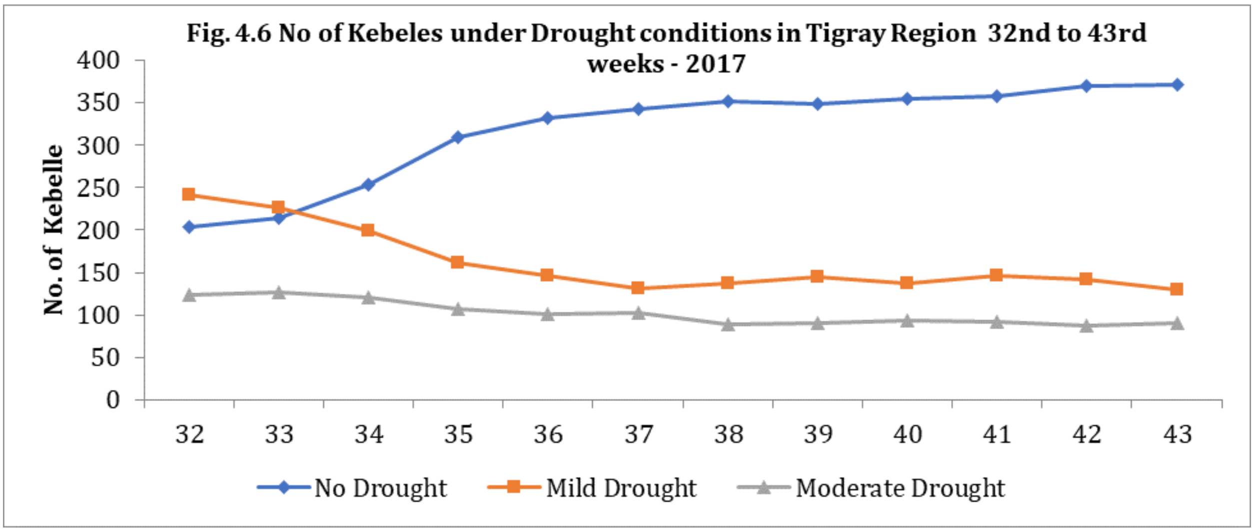
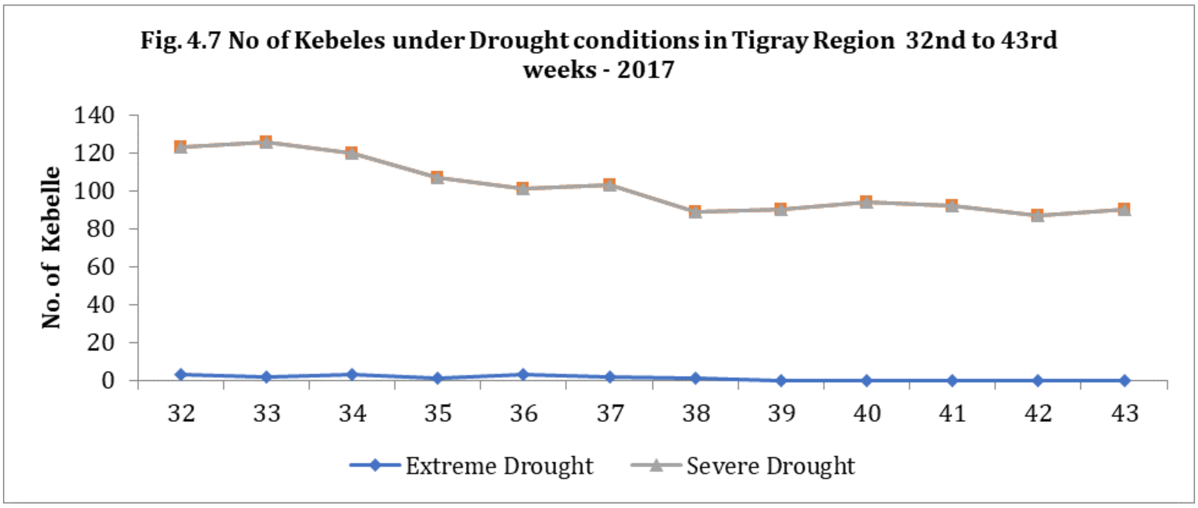


Figure 8: No of Kebeles under Drought conditions in Tigray Region 32nd to 43rd weeks - 2017



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