Remote Sensing and GIS Based Agricultural Drought Risk Assessment in East Shewa Zone, Central Rift Valley Region of Ethiopia

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Abstract
Drought is one of the most complex naturally occurring disasters that results in serious human life, environmental, social and economic costs around the world. In order to monitor agricultural drought risk, GIS and remote sensing have a significant role. This research was conducted in East Shewa Zone of Oromia Region of Ethiopia with the objective of mapping agricultural drought risk using GIS and remote sensing. Ten years decadal SPOT NDVI datasets were downloaded from VITO website. In order to compute the Standardized Precipitation Index (SPI), rainfall data was obtained from meteorological stations of the study area. The result of drought severity index indicated that 2005 and 2009 were years of drought while 2013 identified as wet year. On the other hand based the result of SPI, 2005 and 2009 were years of droughts while 2012 wet year. The result also showed that there is good correlation (r = 0.7) between long term NDVI and seasonal rainfalls. The results were supported by the interviews and focus group discussions. Based on the result drought risk map, 5.1% of the zone are under extreme drought risk, 31.9% severe drought, 27.1% moderate drought and 32.5% are under mild drought. Thus, it is only the remaining 3% of the East Shewa Zone that are not vulnerable to drought. Our findings showed that we can use GIS and remote sensing for drought assessment in regions where there are scarce ground observation data. Future research may focus on camparson of ground observation data and sattellite derived data.
Keywords: Drought risk, GIS, NDVI, Remote sensing, SPI, SPOT.

1. Introduction

Drought is one of the most complex naturally occurring disasters that results in serious human life, environmental, social and economic costs around the world. Due to its cumulative impacts and widespread over large geographical areas, drought is stronger than other natural disasters (Temesgen *et al*., 2004; Wilhite, 2007; Khalil *et al*., 2013; Golian *et al*., 2015). According to Dai (2011) large amount of droughts have been occurred in different parts of the continents in the past three decades. This implies that both developed and developing nations are under the impact of drought. Agriculture is the dominant economic activity in developing countries. It is very much sensitive to weather and climate variables like temperature, precipitation, light and weather extremes, such as droughts, floods and severe storms (Molua, 2002; Adger *et al.,* 2003; Demeke *et al*., 2012). This indicates that any fluctuation in the variables, largely affects agricultural production. Agricultural drought in developing countries is very disastrous causing suffering, population displacement, food shortage, loss of life, land degradation, death of animals, reduction of agricultural output, diminishing of rivers and lakes, deteriorations of water conditions, wildfires and permanent vegetation failure (FAO, 2011; Huang *et al.,* 2013; Kapoi and Alabi, 2013). Ethiopia as one of the sub-Saharan African countries has been experiencing different degree of droughts in the last decades. The recently released report of Intergovernmental Panel for Climate Change (IPCC) indicated that as a result of climate change and variability, drought conditions are projected to be harsher in the future (IPCC, 2014). Similarly Houghton (2002) revealed that the intensity and frequency of drought are likely to increase in several regions which further amplify the need for the current study. In fact, several studies have been carried out to monitor agricultural drought using remote sensing and GIS techniques including Huailiang *et al.* (2009), Huang *et al.* (2013) and Abbas *et al.* (2014) in China, Kapoi and Alabi (2013) in Kenya, Muthumanickam *et al*. (2011) and Himanshu *et al.* (2015) in India, Khalil *et al*. (2013) in Egypt, Gedif *et al.* (2014) in Tigray, Ethiopia. However, none of them explicitly focused on agricultural drought risk assessment in East Shewa Zone, Central Rift Valley Region of Ethiopia. Therefore, this research was carried out with the objectives of generating agricultural drought risk map based on its severity levels using Normalized Difference Vegetation Index (NDVI) and Standardized Precipitation Index (SPI) and examining the relationship between rainfall and Normalized Difference Vegetation Index (NDVI) in the study area.

2. Materials and Methods

2.1 Study Area

Most parts of the present East Shewa Zone, study area of this research, were under the Yerer and Kereyu Awraja before 1988. Geographically, this East Shewa Zone extends from longitudes of 7º 33’50”N to 9º 08’56”N and latitudes of 38º 24’ 10”E to 40º 05’ 34”E with total area of 9178 km^2. This indicates that the zone is entirely found in tropical zone having its associated climate. It is also found in the rift system and has elongated shape. With respect to its relative location, the Zone has physical contact with three regional states of Ethiopia namely: Southern Nations Nationalities of Peoples, Afar and Amhara National Regional States of Ethiopia.

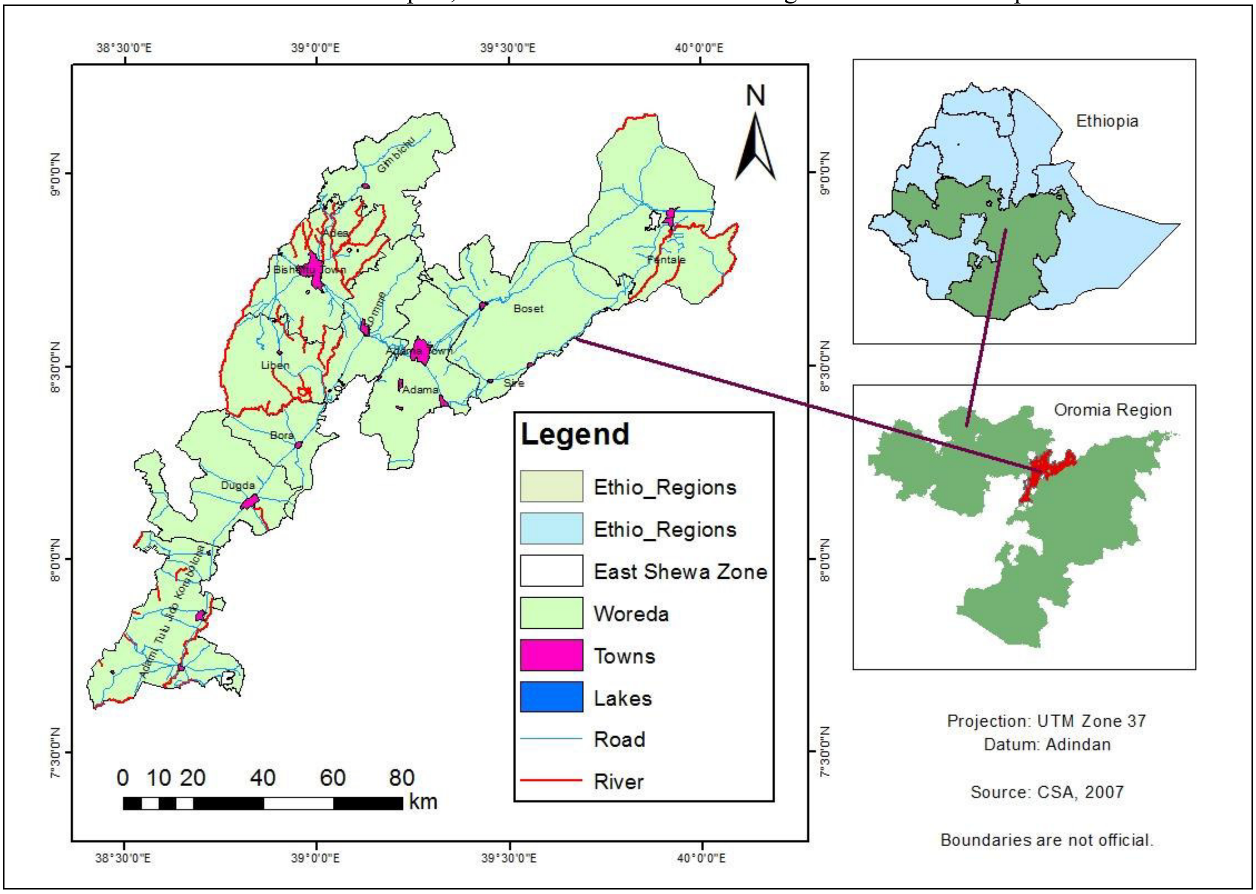

Figure 1: Location Map of East Shewa Zone

2.2 Data Source

Ten years decadal SPOT Vegetation NDVI datasets were downloaded from http://www.vito-eodata.be/[1] for the study period 2005 – 2013. The 2014 image was downloaded from Copernicus Global Land Service (http://land.copernicus.eu/global[2]). The NDVI data set contains 10-days maximum value NDVI composites at 1km resolution. The ten day composites are distributed and generated by Vlaamse Instelling voor Technologish Onderzoek (VITO) using maximum value composites (MVC) algorithm. For the Standardized Precipitation Index (SPI), rainfall data was obtained from meteorological stations of the study area. For the analysis, Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI) and Standardized Precipitation Index (SPI) were utilized. Agricultural drought risk mapping of study area was generated by integrating NDVI, VCI and SPI according to their degree of influence using weighted overlay. In this process, software packages including ERDAS Imagine 2014, ArcGIS 10.2 and Vegetation extraction tool were employed to achieve the objectives of this research.

3. Results and Discussions

3.1 Relationship between Seasonal Rainfall and NDVI

The relationship between seasonal rainfall and NDVI was done for exploring the potentials of NDVI in showing drought conditions on the ground. It is established truth that when there is drought, there will be decrease in the amount of rainfall, which is usually expressed in SPI (McKee et al., 1993; UNCCD, 1999; Wilhite, 2005; Dai, 2011). Here, since the relationship between precipitation and vegetation status varies within growing season of months, Pearson correlation analyses between rainfall amount and NDVI were done. Figure 2 presents the linear

[1] http://www.vito-eodata.be/PDF/portal/Application.htm
[2] http://land.copernicus.eu/global

regression analysis and scatter plots for the average rainfall and NDVI for the years 2005 to 2014. As it can be observed, there is good correlation between long term NDVI and seasonal rainfalls (r = 0.70).

According to other studies, such as Chopra (2006) in Gujrat, India the coefficient of determination between long term NDVI and seasonal rainfall was 0.4. On the other hand, study conducted in East Shewa Zone by Legesse (2010) for the period between1996 – 2008 has revealed that 42% of NDVI variability was explained by seasonal rainfall. Whereas the study carried out by Sultan (2014) in Sire district of Oromia Region of Ethiopia showed that 59% of NDVI variability was attributed to the seasonal rainfall.

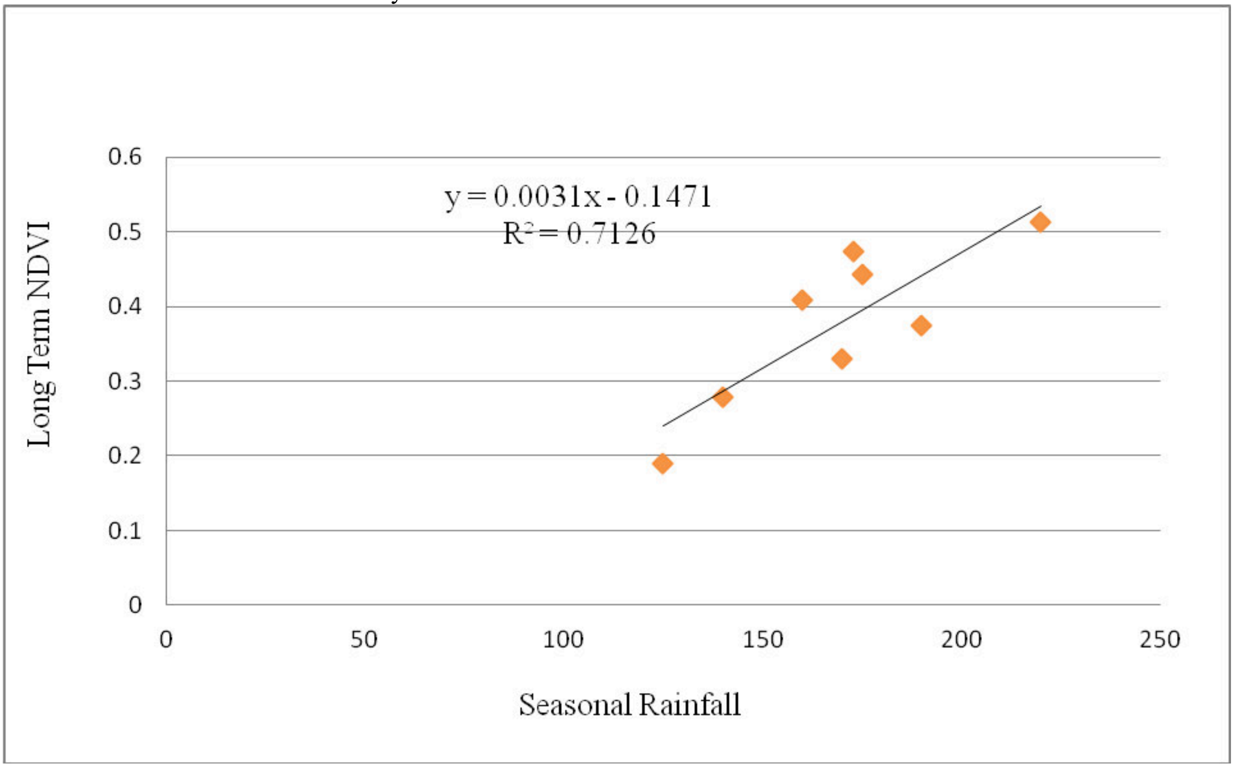

Figure 2: Relationship between long term NDVI and seasonal rainfall (2005 – 2014)

3.2 Pattern of Drought Severity Index and Standardized Precipitation Index (SPI)

As it can be understood from the figure 3, agricultural seasons of 2012 and 2013 years have drought severity index above zero indicating that they were relatively wet years. However, that of 2012 year was taken as the wettest year as its drought severity index is about 0.02. Even though the severity varies from year to year, in all the remaining years the value of drought severity index was below zero indicating some level of drought conditions. As it can be seen from the tempral profile of the study area, 2005 and 2009 years were conssidered as the drought periods. It is also possible to conclude that the level of vegitation was sparse during the specified periods. This finding is inline with the finding obtained by Sultan (2014) in Sire district which is geographically closer to the present study area. However, Legesse (2010) in his study on agricultural drought using NOAA NDVI data in East Shewa zone identifed 2000 and 2002 as drought years. Of course, the author only considered the time between 1996 to 2008. In fact, the current study and Legesse's finding have identified 2008 as wet year.

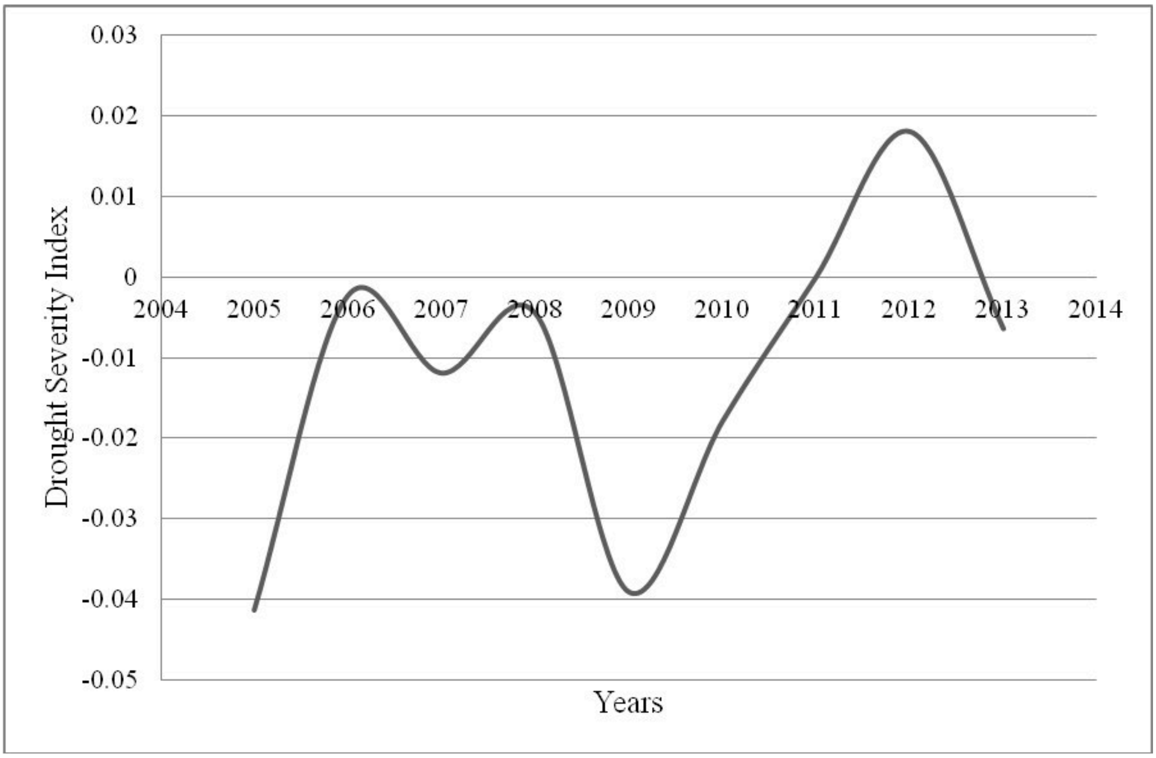

Figure 3: Temporal Pattern of Drought Severity Index of 2005 – 2014.

As it is indicated in the figure 4, the SPI value is above zero for the years 2007, 2008, 2010, 2011 and 2012. Though in these years the value of SPI is above zero, the level of drought was not exactly equal in all years. For instance, the highest value of SPI was recorded in 2012 and followed by 2008 year. This implies that the wettest year over the past ten years was 2012 and follwed by 2008. The growing season of both years were characterized by having relatively excess moisture. Simalrly, in 2005, 2006 and 2009 the value of SPI is below zero indicating some level of drought in these years indicating insuffiecient moisture. Although the years were identified as drought conditions, the nature and severity of the droughts were not simimar. For example as it can be concluded from the figure 4, the level of drought was the highest in 2005 followed by 2009.

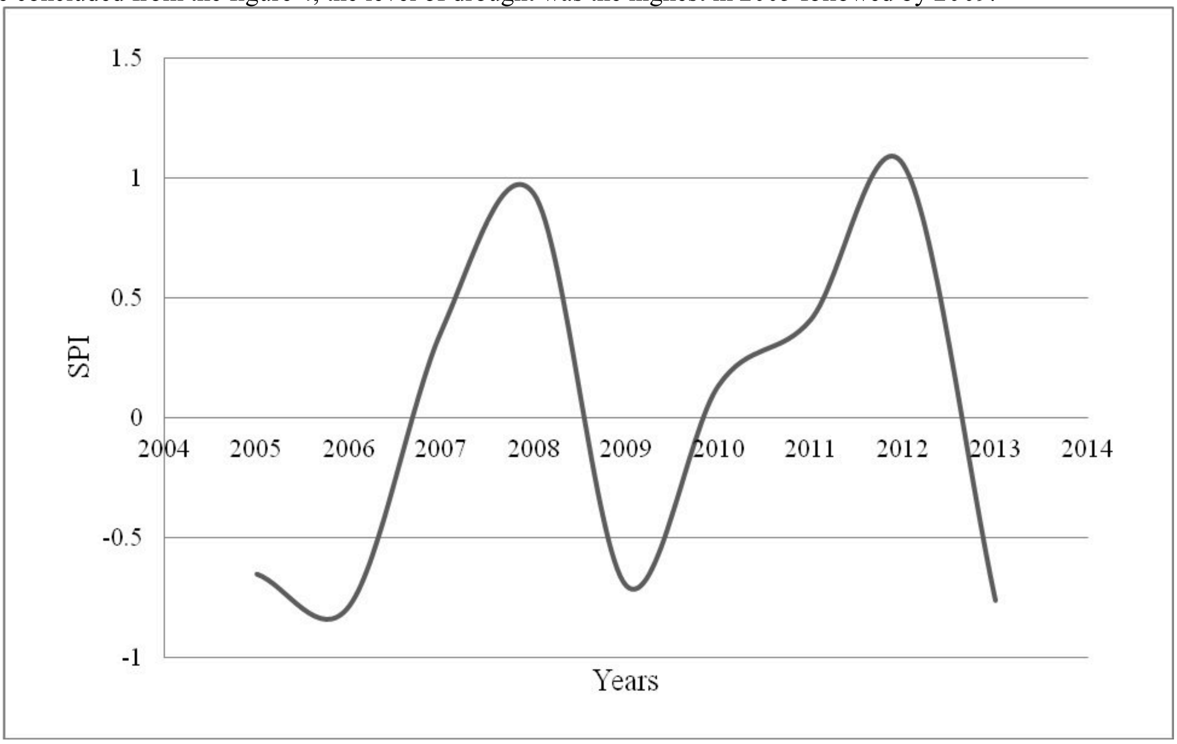

Figure 4: Temporal pattern of SPI f or growing season of 2004 – 2014

3.3 Identification of Drought Severity

According to Song and Saito (2004) drought severity class is done based on the value of its NDVI like extreme drought with NDVI less than -0.25, severe drought between -0.1 to -0.25, moderate drought 0.1 to -0.1, mild drought 0.1 to 0.25 and no drought with NDVI greater than 0.25. Accordingly, agricultural drought risk map has been developed by integrating drought severity index, vegetation condition index and standardized precipitation index as indicated in the figure below.

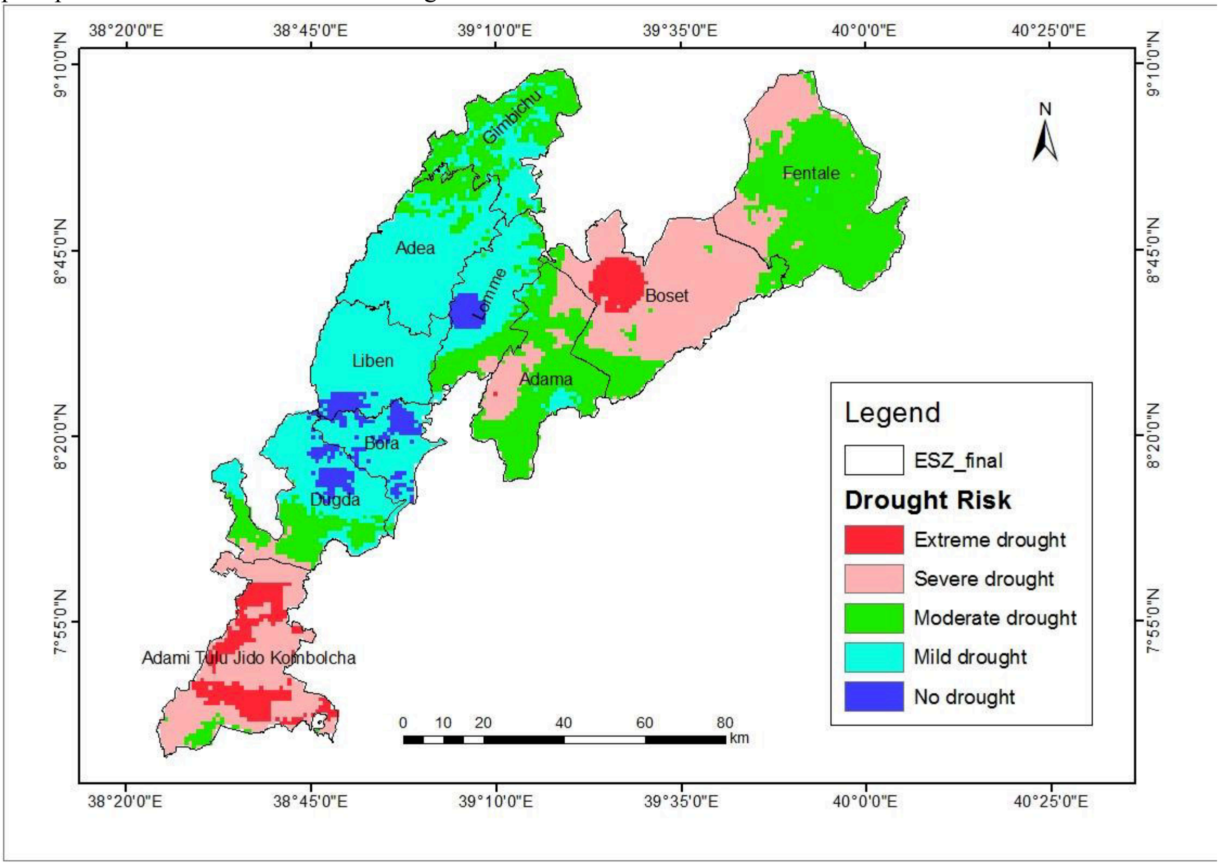

Figure 5: Agricultural drought risk map

Table 1: Drought severity level

Drought severity level	Area (sq.km)	Area (percent)
Extreme drought	466.7	5.1
Severe drought	2923.8	31.9
Moderate drought	2484.4	27.1
Mild drought	2988.6	32.5
No drought	314.5	3.4
Total	**9178**	**100**

According to the result obtained from the integrattion of indices, the East Shewa Zone is classified into fives classes ranging from extremly drought to no drought. Based on the result indicated in the (Fig 5), the percentges of the area affected by drought is about 97%. As it can be seen from the (Table 1 and Fig 5) among these, 5.1% of the zone are under extreme drought risk, 31.9% severe drought, 27.1% moderate drought and 32.5% are under mild drought. Thus, in this case it is only the remaining 3% of the East Shewa Zone that are not vulnerable to drought (Table 1 & Fig 5). As it can be seen from the figure 5, most of central and western part of East Shewa Zone is categrized into mild drought while north eastern and southern part of the study area is catagorized into severe and moderate drought risk.

4. Conclusion

In this study we used GIS and remote sensing for drought assessment in regions where there are scarce ground observation data. During considered years (2005 – 2014) in almost all parts of study area, the value of drought severity index was very low suggesting that there is low ground vegetation cover. Using drought severity index, 2006 and 2009 were identified as drought years as their larger areas are under the influence of drought. However, according to the result of SPI, 2005 and 2009 were identified as drought years. The variations may be associated to lag time of NDVI response. In addition during these years large volume of relief distributions were carried out for the communities of the zone. On the other hand 2008 and 2012 were identified as wet years. The relationship between long term NDVI and seasonal pattern of rainfall for the whole study area during the period of 2005 – 2014 shows good correlation (r=0.7) between them. Using the weighted overlay analysis, the drought risk map of the study area was constructed. Accordingly only 3% of the study areas are not vulnerable to drought while the remaining 97% were under different level of drought risk. From this research, we concluded that GIS & RS technologies are used for drought risk assessment of a given region. Future research may focus on comparison between satellite based and ground station data for drought risk monitoring.

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