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Full Length Research Paper

Drought monitoring for Masvingo province in Zimbabwe: A remote sensing perspective

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The research was aimed at analysing and monitoring the seasonal occurrences of drought in Masvingo province of Zimbabwe so as to determine the areas that are prone to drought episodes. The Vegetation Condition Index which shows how close the Normalized Difference Vegetation Index **of the current time is to the minimum** Normalized Difference Vegetation Index **calculated from the long-term record for that given time was used to monitor drought occurrence over the Province. Time series of dekadal SPOT** Normalized Difference Vegetation Index **images of Masvingo province were also used to compute seasonal Vegetation Condition Index maps from 2005-2010. The resulting Vegetation Condition Index maps were then classified as follows: Severe, Moderate and Mild. Results showed that droughts occur in Masvingo province at least at some place every rainy season but on average the droughts are mild rather than severe or moderate. The occurrence and the spatial distribution of drought in Masvingo was also found to be random but some parts of Chiredzi, Mwenezi and Bikita districts are more frequently beset by severe droughts than any other parts of the province.**

Keywords: drought monitoring, Masvingo province, Vegetation Condition Index, remote sensing.

INTRODUCTION

Drought is any period of moisture deficiency that deviates from climatic normals at a given location or region (Warren and Khogali, 1992, Hulme, 1996). Droughts are normal recurring climatic phenomena that affect people and the landscapes. They occur at many scales (locally, regionally, and nationally) for periods varying from weeks to decades (Glantz; 1987 and Wilhite, 1993) It is becoming increasingly unusual for drought not to occur somewhere in Zimbabwe each year. The dependence of Zimbabwe's economy on rainfed agriculture emphasizes the importance of drought monitoring to the country (Richardson, 2007). It is therefore important to identify the extent of the areas prone to severe drought conditions in order to study the possible consequences of drought on annual crop production and livelihoods of local communities (Unganai; 1994, Tadesse et al., 2008).

Most food shortages that occur in Zimbabwe are attributed to drought conditions though there are limited monitoring mechanisms to map the affected areas as well as its severity. Most of the studies done in the Masvingo province on drought were mainly focused on drought mitigation, development of Early Warning Systems (EWS) and the impact of drought on the national economy and food supply Bohle et al, 1994; Mogotsi and Nyangito, 2012; UNDP, 2012. No initiative has been taken to analyse the occurrence of droughts over the total area of the province for long periods of time so as to determine the areas that are more vulnerable to droughts of different magnitudes. Ideally this is the information that is required to strengthen the Early Warning Systems, drought mitigation systems, food aid to vulnerable areas and to build drought resilient communities.

The spatial and temporal variability and multiple impacts of droughts present challenges for mapping and monitoring at all geographical scales. Operational drought monitoring requires repetitive measurements at the same location day after day, month after month, and year after year. It is more accurate when the variable of interest is recorded directly at a series of ground stations where the event under study is happening. Ideally, ground stations would be uniformly located and closely spaced in order to get the best information. However, in most cases the costs associated with a dense spatial coverage are high and developing countries rarely have the economic and human resources necessary to realize

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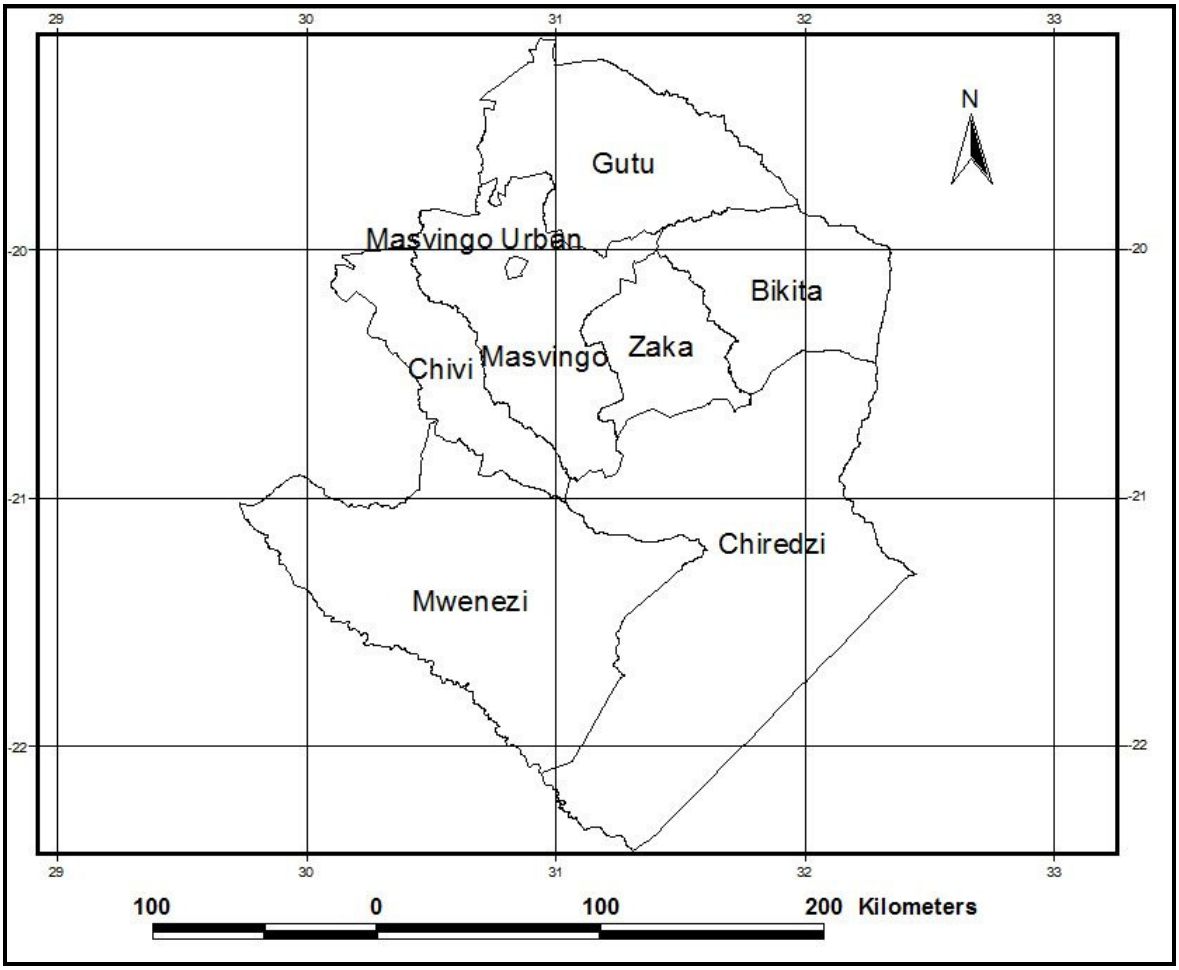

Figure 1. The location of Masvingo Province, and the districts found within the province

this ideal situation (Unganai and Kogan, 1998). Remotely sensed images become an important data source which is objectively collected, and covering large spatial extents. Satellite information is especially appropriate over remote areas or in locations where weather stations or other ground observations are sparse or non-existent (Thiruvengadachari and Gopalkrishana, 1993). In the case of Masvingo Province of Zimbabwe, only four sparsely located weather stations are operated by the Zimbabwe Meteorological Department over an area of 56,566 km². These stations are Masvingo Airport, Buffalo Range, Zaka and Makhoholi, and are inadequate for drought monitoring hence there is need to use satellite based drought monitoring systems to monitor drought

The use of long term series of vegetation indices derived from satellite imagery in vegetation monitoring and classification of land cover is a widespread technique (DeFries and Townshend, 1994; Maselli et al, 1998) and relationships between such indices and green biomass have been proven by many authors (Goward et al., 1985; Tucker et al., 1985; Peters et al., 1997). The relationships between Normalised Difference Vegetation Index (NDVI) and rainfall have been widely investigated (Davenport and Nicholson, 1993). NDVI is a general measure of the state and health of vegetation (Tucker, et al 1985) and is one of the most widely used indices for monitoring droughts from landscape to global scales (Goward et al., 1985and Peters et al., 1997). Most of the drought monitoring vegetation indices are derived from NDVI including the Vegetation Condition Index (VCI) used in this study. VCI shows how close the NDVI of the current time is to the minimum NDVI calculated from the long-term record for that given time (Liu and Kogan, 1996).

The study was therefore aimed at mapping the areas of drought occurrence in Masvingo province of Zimbabwe from the 2005/2006-2009/2010 seasons.

MATERIALS AND METHODS

Study area

Figure.1 shows the location of the study area. Masvingo

province is divided into seven administrative districts which are; Gutu, Masvingo, Bikita, Zaka, Chivi, Mwenezi and Chiredzi. The province occupies the drier south-east Lowveld of Zimbabwe and has an area of 56,566 km² and a population of approximately 1.3 million in 2002, (CSO, 2002).

The province is predominantly semi-arid; rainfall is minimal, highly variable/erratic and uncertain making the province prone to droughts. Although most of the province is generally dry, it has some of the most agriculturally fertile soils, inland water bodies and river systems (Save, Runde, Mwenezi, Mutirikwi and Limpopo river systems dominate the drainage system in the province). The province's vegetation is dominated by drought tolerant and sturdy vegetation like *Colophospermum mopane* trees, and several grass species.

MATERIALS

We used decadal (10-day composite) SPOT NDVI data from 2005-2010 which was made available by AMESD, (2011). For the purposes of processing of the NDVI data, we used the Integrated Land and Water Information Systems (ILWIS) Geographic Information System (ITC, 2005).

METHOD

Time series of dekadal NDVI images of Masvingo Province were extracted from the SPOT-VGT ten daily synthesis archive (AMESD, 2011). A dekad is equals to 10 days (Delli, et al, 2002). The time series of images at 1 km resolution were retrieved for the period December 2005 April 2010. The satellite data was already pre-processed and ready for use, courtesy of the convenient SPOT downloading policy means.

In order to create time series NDVI data for Masvingo province, the SPOT-VGT images were first imported into ILWIS GIS and the Map List function used to group images from the same dekad from the 2005-2010 seasons. Next, we calculated the long-term maximum as well as the long-term minimum NDVI for all dekads of the rainy season from December–April over the Masvingo Province was then done using the Map List Statistics Operation. We then calculated the Vegetation Condition Index (VCI) for the rainy seasons from the year 2005-2010, starting from the first dekad of December 2005 and ending with the third dekad of April 2010. The following formula was used;

$$VCI_j = \left(\frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right) \times 100 \quad \text{..... (1)}$$

Where $NDVI_j$ is the NDVI for the dekad, $NDVI_{min}$ is the minimum long term NDVI for the dekad and $NDVI_{max}$ is the long-term maximum NDVI for the dekad (Kogan, 1995).

Averaging the VCI for all the dekads of a season produced the average state of vegetation for the season. The condition of the vegetation is measured as a percentage and different degrees of a drought severity are indicated by VCI values below 50% .To determine the areas which experienced drought during the rainy seasons from the 2005-2010 seasons we needed to select and classify pixels that have an average VCI of less than 50%. Drought is one of the major natural hazards facing the world yet there is no universally accepted definition of it (Agnew and Anderson, 1992; Wilhite, 1993), but only operational definitions exist. In order to come up with nominal class lists for drought, the following classification was used: VCI less than 36% was classified as severe drought, VCI of between 36%-45% was classified as moderate while VCI of between 45-49%was classified as a mild drought. Areas that had a VCI of 50% or more were treated as non-drought areas.

RESULTS

Figure 2 shows the spatial temporal variations of the different magnitudes of drought in Masvingo province between 2005/2006 and 2009/2010 seasons. It can be noted that for every season under consideration, a part of the province experienced a drought.

It can also be noted that the 2005/2006 and 2006-2007seasons had the most severe droughts for Masvingo province, with Chiredzi, Mwenezi and Bikita districts being the most affected (Figure 2).The 2007-2008 and 2009-2010 seasons' droughts were the most widespread, though they were mainly in the mild class with pockets of severe droughts occurring in Mwenezi, Chiredzi and Masvingo districts. The 2008-2009 season was the best (good vegetation health) with only a few areas that were affected by drought.

Figure 3 show the average drought conditions for Masvingo province from 2005-2010. The figure shows the areas that are prone to drought and the magnitude of drought that is more frequent.

It can be noted that when averaged over the entire period of study, the province suffers from "scattered mild droughts", unlike the seasonal maps which show the dominance of severe and moderate droughts. Specifically, parts of Mwenezi, Chiredzi, Bikita and Masvingo districts are shown here to be more prone to the mild droughts, with isolated cases of severe drought.

DISCUSSION

The seasonal occurrence of drought shows that Mwenezi and Chiredzi districts are more likely to be affected by severe droughts than other districts. In other Districts of the Province, droughts range from severe to mild and

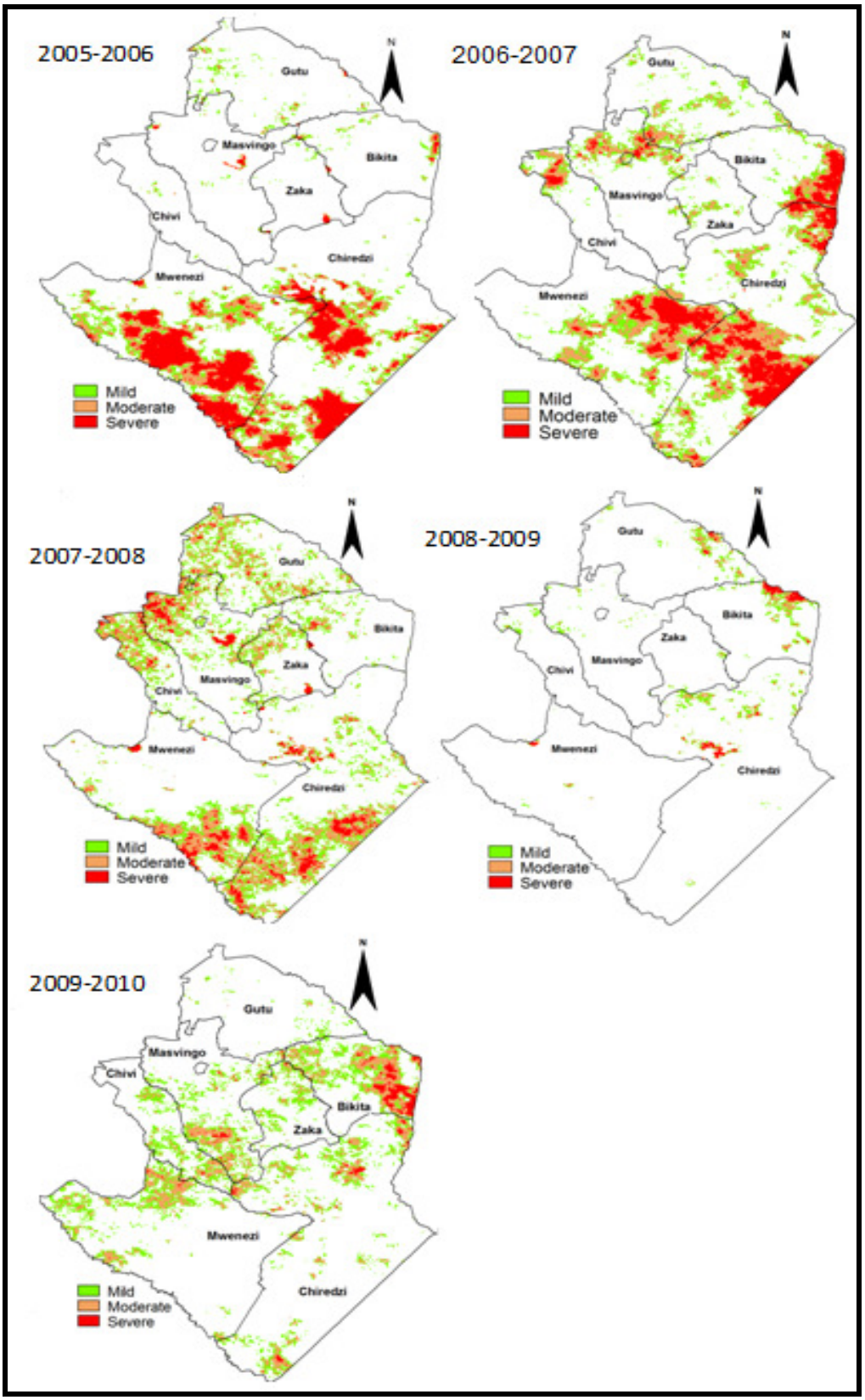

Figure 2. Drought occurrence in Masvingo Province from 2005-2006 season to 2009-2010 season. The black lines show the boundaries of the districts, with the names written inside each district.

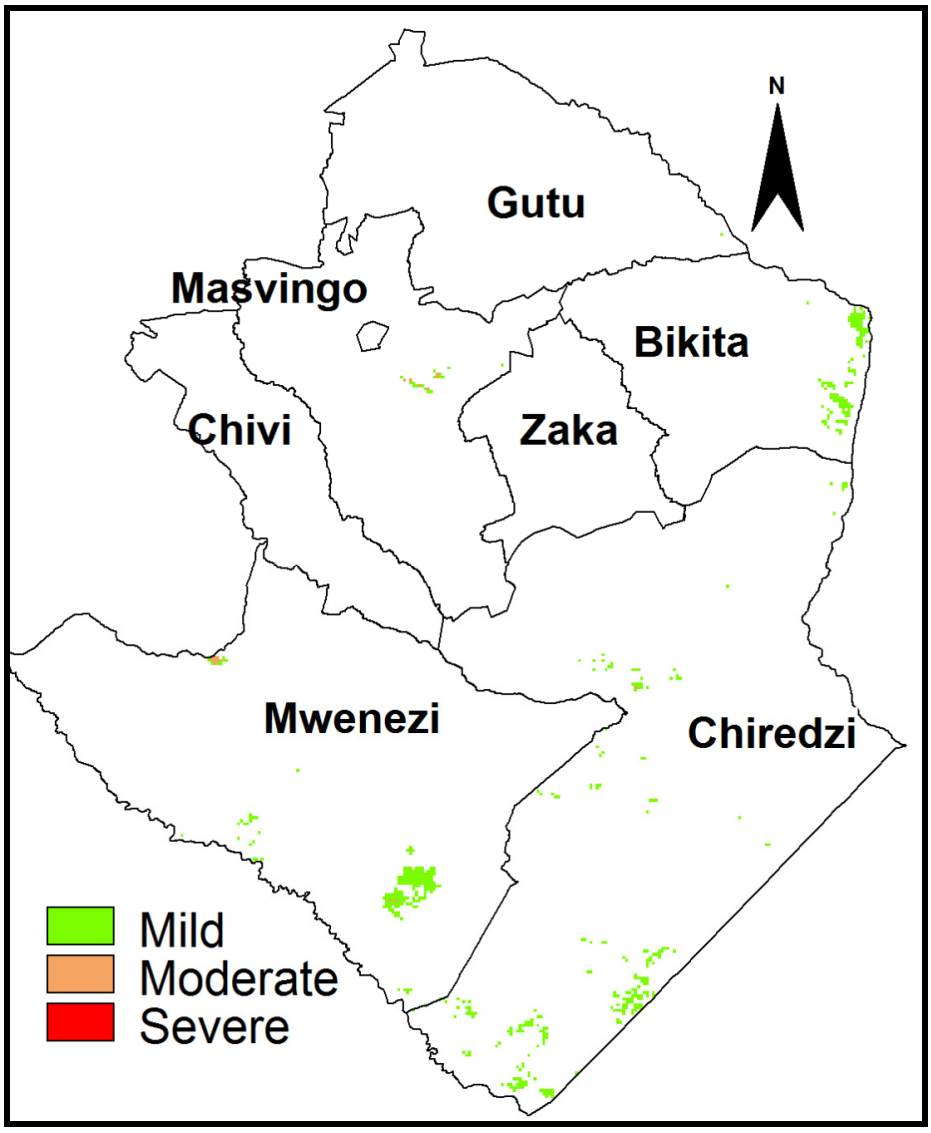

Figure 3.The drought proneness and severity in Masvingo province from 2005-2010

occur randomly hence some form of crop production that is adapted to drought conditions like small grains can do well in these areas.

The drought pattern of the Masvingo province indicates that the food shortages and poor harvests cannot be attributed to drought alone. This is because not all areas are affected by continuous droughts for years except for some parts of Chiredzi and Mwenezi districts. This observation supports the view that the decline in agricultural output was mainly due to inappropriate government policies rather than drought (Richardson 2007). Nash and Endfield (2002), noted that perceptions about the increasing severity of droughts are also often influenced by the tendency for humans to compare recent drought years to previous wet periods during their lifetimes. Thus perceptions about droughts increasing in their frequencies and severity in Zimbabwe may be due to a comparison of the dry 1980's and 1990's to the wet 1970's. This was corroborated by Mazvimavi, (2010), who sought to determine if rainfall patterns had significantly changed in Zimbabwe. Based on rainfall records at 40 stations, and covering the period from 1892 to 2000, he concluded that there was no evidence of changes in the median, high or low rainfall during the beginning (October to December), mid-to-end (January to March), of the rainy season and for the whole year.

However, it should be noted that recently, there has been high inter-annual variability of rainfall in most parts of Southern Africa (O'Hare et al, 2005). This was confirmed by Simba (2012), who observed that dryspell events at Buffalo Range weather station in Chiredzi and Zaka station were increasing in length and frequency.

This may mean that the intra seasonal variations are averaged out by the total for the annual rainfall resulting in a “normal” rainfall season. We therefore recommend that further studies should focus on the intra-seasonal variability of drought occurrence, with special emphasis on the time of occurence and length of the mid season dry spells. An understanding of the dry spells is important because they are most relevant to agricultural activities and are the major determinants of rainfed agricultural output.

CONCLUSIONS

It can be concluded that droughts occur annually in Masvingo province, though the severity and spatial distribution varies. We also conclude that Chiredzi, Mwenezi and Bikita districts are more frequently affected by moderate to severe seasonal droughts than other parts of the province. However, on the long-term basis, the province is on average mostly affected by mild drought conditions, with a few isolated cases of severe and moderate droughts.

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