

STATISTICAL RELATIONSHIP BETWEEN ONSET DEKAD OF RAINING SEASON AND  
NORMALIZED DIFFERENCE VEGETATION INDEX: AN INDICATOR OF ACUTE FOOD  
INSECURITY LEVELS IN DISTRICTS OF ZAMBIA

By

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## **DEDICATION**

This dissertation is dedicated to God Almighty, my beloved parents Mr. and Mrs. John Hamakala, my siblings and niblings, my beloved Wife Veronica Nambeye, my Children and my beloved family at large.

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## **ABSTRACT**

Agricultural drought conditions driven by delayed onset of the rainy season is one of the main contributing factors to Acute Food Insecurity (AFI). A number of studies on AFI severity in Zambia have been done at national level but no assessment of severity of AFI at district level has been done. This study investigated the statistical relationship between the delays in the Onset of the rainy season and peak Normalized Difference Vegetation Index (NDVI) and associated it with the AFI levels in the districts of Zambia using AFI classification of the Disaster Management and Mitigation Unit (DMMU), Zambia. The NDVI data for districts of Zambia were downloaded from USGS EROS's FEWS NET's Data warehouse. The rainfall data for districts of Zambia were downloaded from the Climate Hazards Group InfraRed Precipitation (CHIRPS) website, Climate Hazards Centre, University of California, Santa Barbara. CHIRPS data has been assessed against the Zambia Meteorological Department's station observations for its capability in reproducing rainfall climatology. The rainy season onset was determined for seasons from 2005/06 to 2020/21 using prevailing criteria for determining onset in the Southern African region. Peak NDVI for districts of Zambia for each of the mentioned seasons was determined at the end of the raining season. The Pearson Correlation Coefficient was employed to investigate the relationship between onset dekad of a rainy season and NDVI. The Districts of Zambia were put in 3 bins based on AFI modes (AFI-2 bin 1, AFI-3 bin 2 and AFI-4 bin 3). For each bin, an empirical Pearson correlation was computed. The proportion of districts in each bin of AFI levels were utilized to partition correlations range from -1 to +1 into three subintervals. If correlation between seasonal onset dekad anomalies and standardized peak NDVI for a district falls in subinterval 1, the district is likely to experience AFI level 4, if correlation falls in the subinterval 2, the district is likely to experience AFI of level 3 and if correlation falls in subinterval 3 then district is likely to experience AFI level 2. The results showed that CHIRPS data captured the monthly climatology of the rainy season for the districts of Zambia reasonably well. It was found that there is a negative relationship between onset occurrence (early or delayed onset) and peak NDVI. Each district in the study was assigned an AFI severity level using DMMU's AFI data, It was noted that districts of Zambia generally experienced only three levels of AFI severity namely 2 (stressed), 3 (crisis) and 4 (emergency) out of five classified levels where level 5 refers to Catastrophe or Famine. Districts were binned together according to their AFI levels. Pearson correlation coefficient between anomaly in onset dekad and peak NDVI were computed using data for districts in each of the three bins for AFI levels 2, 3 and 4. The correlations were -0.265 for level 4, -0.09 for level 3 and 0.01 for level 2. The empirical correlations confirmed that delay in onset of rainy season is negatively correlated with low vegetation index leading to AFI of different levels. Subinterval 1 is [-1, -0.96) subinterval 2 is [-0.96, 0.1) and subinterval 3 is [0.1, 1]. This early warning system for assessing the AFI levels in the districts of Zambia for a delayed onset season can be improved as more DMMU disaster related data, longer climate and NDVI daily time series data are available in future. It can enable government to plan and organize resources required to provide AFI stricken communities a relief aide according to the severity way before a disaster situation becomes grave due to delay in onset of rainy season.

*Key words: Onset Dekad, CHIRPS, NDVI and AFI.*

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## **Acronyms and Abbreviations**

AFI	Acute Food Insecurity
NDVI	Normalized Difference Vegetation Index
ZMD	Zambia Metrological Department
CHIRPS	Climate Hazards Infrared Precipitation with ZMD Station data
SSA	Sub Saharan Africa
IPC	Integrated Food Security Phase Classification.
EoS	End of Season (Maximum NDVI or peak NDVI)
DMMU	Disaster Management and Mitigation Unit
ODA	Onset Dekad Anomaly
SP-NDVI	Standardized Peak Normalized Difference Vegetation Index
EWS	Early Warning Systems
WRSI	Water Requirement Satisfaction Index

## CHAPTER 1: INTRODUCTION

### 1.1. Background

Global warming is the slow increase in the average temperature of the earth's atmosphere. Over the last 100 years, the average temperature of the earth's atmosphere has risen about 1<sup>0</sup> Celsius which has adversely impacted the entire globe. Regional impacts of global warming include increase in frequency, intensity and duration of extreme weather events such as heat waves, dry and wet spells, delayed onset and early cessation of the rainy season and reduced number of wet days. Extreme weather events pose an increased threat to food production, buildings, road infrastructure and human health. Early warning of extreme rainfall events in the seasonal food production chain can save human lives, livestock and livelihoods, and, therefore, can mitigate the adverse impacts of the extreme weather events. Climate-driven drought is one of the main contributing factors to acute food insecurity (AFI) (Shukla et al 2021). Timely and appropriate interventions through early warning of anomalous seasons can reduce impacts of AFI related disasters. Onset Dekad can be used as a critical indicator to provide alerts of seasonal drought development in the most food-insecure regions of Sub-Saharan Africa (SSA) (Shukla et al 2021).

The research required daily weather observations for districts of Zambia. However, Zambia Meteorological Department (ZMD) has only 39 weather stations which do not cover all districts. Hence internationally constructed observed rainfall data were sought. These data sets are created by world renowned climate and meteorological institutes by integrating in situ and satellite observations. One such data set is Climate Hazards Infrared Precipitation with ZMD Station data (CHIRPS), created by the United States Geological Survey (USGS) and it was employed in this study.

The Normalized Difference Vegetation Index (NDVI) is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green cover on an area of land (Jagadish, Sameer & Kailash, 2019). NDVI can be used as a timely tool to access the heterogeneity in crop fields remotely and quite early (Jagadish, Sameer & Kailash, 2019). This study investigated statistical relationships between shift in rainy season Onset Dekad and peak normalized difference vegetation index (NDVI) as an indicator of AFI.

## 1.2. Overview of AFI in Zambia

The Disaster Management and Mitigation Unit (DMMU) is a statutory body of the Government of Zambia under the Office of the Vice President. The Institution draws its authority, functions and powers from the Disaster Management Act No. 13 of 2010. One of the many mandates of DMMU is to put in place appropriate measures to respond to negative impacts of climate change. In this regard, every year, an annual report is prepared, documenting the acute food insecurity situation in the districts of Zambia. DMMU adopted the Integrated Food Security Phase Classification (IPC), a multi partner initiative of the United States Agency of International Development (USAID) which classifies AFI into five phases. The AFI Phases 1 to 5 adopted from IPC (2020) report were published by IPC Global Support Unit on Acute Food Insecurity Analysis in Zambia. The description of the phases of AFI are given in the *Table 1.2.1*.

*Table 1.2.1: IPC Phase Description*

<b>AFI - Phase</b>	<b>AFI - Phase Description</b>
Phase 1 None/ Minimal	Households are able to meet essential food and non-food needs without engaging in typical and unsustainable strategies to access food and income.
Phase 2 Stressed	Households have minimally adequate food consumption but are unable to afford some essential non-food expenditures without engaging in stress-coping strategies.
Phase 3 Crisis	Households either: have food consumption gaps that are reflected by high or usual acute malnutrition; or  Are marginally able to meet minimum food needs but only by depleting essential livelihood assets or through crisis-coping strategies.
Phase 4 Emergency	Households either: have large food consumption gaps that are reflected in very high acute malnutrition and excess mortality; or  Are able to mitigate food consumption gaps but only by employing emergency livelihood and asset liquidation.
Phase 5 Catastrophe/ Famine	Households have an extreme lack of food and/or other basic needs even after full employment of coping strategies starvation, death, destitution and extremely critical acute malnutrition levels are evident.  For famine classification, the area needs to have extreme critical levels of acute malnutrition and mortality.

*Source: IPC (2020) Report of USAID*

Some of the statistics reported in annual reports of DMMU on food insecurity stated that around 1.42 million people (22% of the analyzed population) faced high levels of acute food insecurity (IPC Phase 3 or ) between July and September 2020 that included 1.24 million people in Crisis (IPC Phase 3) and nearly 190,000 people in Emergency (IPC Phase 4). Out of the 64 districts analyzed, 37 were classified in crisis (IPC Phase 3), while 27 were classified in Stressed (IPC Phase 2) (IPC, 2020).

The IPC (2021) report indicated that between July and September 2021, about 1.18 million people in Zambia faced high levels of acute food insecurity. The highly food insecure population required urgent humanitarian assistance to reduce food gaps, protect and restore livelihoods and prevent acute malnutrition. The situation had particularly deteriorated in the Western province, where five districts were classified in Crisis (IPC Phase 3) (IPC, 2021).

Further, IPC (2022) report showed that over 1.35 million Zambians (10% of the analyzed population) experienced severe food insecurity (IPC Phase 3 - Crisis) between July and September 2022, due to high food prices and climatic shocks. Most of these shocks occurred during the flowering and grain filling periods for most staple crops between December 2021 and March 2022.

### **1.3. Problem Statement**

Since 2015, Sub-Saharan Africa (SSA) has experienced an unprecedented rise in acute food insecurity (AFI) (Shukla et al, 2021). Zambia has not been spared by this crisis as stated by the Integrated Food Insecurity Phase Clarification (IPC) reports of the Disaster Management and Mitigation Unit (DMMU) for the years 2020, 2021 and 2022. IPC (2022) report stated that 91 districts were analyzed out of 116 in the country and established that 14 districts were classified in IPC Phase 3 (Crisis), 76 districts were classified in IPC Phase 2 (Stressed) and 1 district was in IPC Phase 1 (Minimal) during the period April to September, 2022. This was due to climatic shocks such as prolonged dry spells, flooding, reduced livelihood opportunities due to restrictions linked to COVID-19, pests and diseases, and high input and food prices (IPC, 2022). This situation requires urgent interventions to reduce food gaps, protect and restore livelihoods, and prevent acute malnutrition. Since agricultural drought conditions driven by delayed onset of the rainy season is one of the main contributing factors to AFI (Shukla et al 2021), therefore, timely and appropriate

early warning of drought development is called for to mitigate devastating impacts of AFI. Statistical relationship between the shifts in the Onset Dekads of cropping season and peak Normalized Difference Vegetation Index (NDVI) can be investigated to serve as an early warning for drought development. AFI related disasters occur in different parts of the country with varying levels of severity. A number of studies on drought forecasts in Zambia have been done at national level. This study aims to design an early warning indicator for AFI severity in the districts of Zambia based on potential statistical relationship between the shifts in the Onset Dekads and peak Normalized Difference Vegetation Index NDVI.

#### **1.4. Aim of the study**

The aim of this study is to investigate potential statistical relationship between the shifts in the Onset Dekads and peak Normalized Difference Vegetation Index (NDVI) which can be utilized as an early warning indicator for occurrence of Acute Food Insecurity in the districts of Zambia.

#### **1.5. Specific objectives**

1. To assess the ability of Climate Hazards Infrared Precipitation Station (CHIRPS) data in representing the rainfall climatology of Zambia.
2. To determine the onset dekad of rainy seasons based on the established definition used in Southern Africa and Peak NDVI month for seasons under study for districts of Zambia.
3. To investigate the statistical relationship between the shift in Onset Dekad and peak NDVI for districts of Zambia.
4. To assign the AFI risk levels classified by the IPC to the districts of Zambia based on statistical relationship found in 1.5.3.

#### **1.6. Research questions**

1. Is the CHIRPS data able to reproduce the rainfall climatology of Zambia?
2. How do we determine rainy season onset and peak NDVI for districts of Zambia?
3. How is shift in onset correlated with the peak NDVI for district of Zambia?
4. How do we assign the levels of AFI phases to the disaster stricken districts based on correlations between shift of Onset Dekad and peak NDVI?

## **1.7. Significance of the study**

Early warning indicator based on correlation between shift in Onset Dekad of the rainy season and peak NDVI for each district of Zambia will provide an opportunity to come up with effective mid-season responses to AFI and, therefore reduce the adverse impacts of drought related disasters in districts of Zambia.

## **1.8. Definitions of Operational terms**

### ***1.8.1. Pentad***

Five days period in meteorology is called a pentad. CHIRPS data is constructed for six pentads per month. The first pentad in a month is the average of daily values from 1 to 5 days of a month, and the second pentad is the average of daily values for days 6,7,8,9 and 10.

### ***1.8.2. Dekad***

A month is divided into three dekads. The average of daily values for days 1 to 10 is the value for the first dekad, the average of values for days from 11 to 20 is the value for dekad two and average of values for days 21 to 30 is the value for dekad 3.

### ***1.8.3. Onset Dekad***

Onset Dekad is a simple heuristic method designed to coincide with the planting date by farmers (Shukla et al 2021). To determine the Onset Dekad of a rainy season in Zambia, the search for Onset Dekad starts from 1<sup>st</sup> October as traditionally cropping season starts any time during or after October. It searches for the first dekad with at least 25 mm of rainfall, followed by two dekads, with total rainfall of at least 20 mm. If both thresholds are met, the first dekad of that three-dekad series would be considered the Onset Dekad. If either threshold is unmet, a search for the Onset Dekad continues. This scheme for identifying Onset Dekad was originally proposed by Agriculture, Hydrology, Meteorology (AGRHYMET) Regional Research Centre, Niger. It, is widely used in the Southern African region (Shukla et al, 2021).

## **1.9. Summary Structure of the study**

Chapter 1 of this study is Introduction and it gives the background, overview of AFI in Zambia and problem statement. Further, the chapters states the aim, objectives, research question, significance of the study, definitions of operation teams and Summary Structure of the study.

Chapter 2 explored the literature CHIRPS data, onset of a raining season, Cessation dates, Acute Food Insecurity and Research Gap. Chapter 3 gives the road map of how the study was conducted. It states the study design and data acquisition as well as preparation. The chapter states the methods of data analysis and data analysis tools as well as comments on the ethical issues. Chapter 4 presents the results and discussions in answering the research questions to achieve the research objectives. Chapter 5 provides the conclusions and recommendations based on the research objectives of this study. Finally the study ends with the list of references and the appendices for easy reference.

## CHAPTER 2: LITERATURE REVIEW

### 2.1. Introduction

Published studies which assessed the ability of CHIRPS data in representing the rainfall patterns or climatology of various countries and regions were searched and reviewed. Further, literature on the definition of onset and cessation dates of a raining season, acute food insecurity in Africa and globally, relationship between Onset Dekad and peak NDVI and assignment of the relationship to the levels of AFI were reviewed.

### 2.2. Ability of CHIRPS Data

In trying to assess the ability of CHIRPS data in representing the rainfall climatology, various published studies were reviewed. Naikson et al (2022) conducted a study to compare the CHIRPS rainfall data with the observed rainfall data in the North Sumatra region of Indonesia. The Results indicated that the CHIRPS data has a low correlation with the observed data.

Mulungu & Mukama (2022) conducted a study to assess the CHIRPS data against ground observations at Ruvu subbasin in Tanzania for the period 1981-2015. The study showed that CHIRPS monthly data correlated well with ground rainfall observations with Pearson correlation coefficient  $r > 0.7$ .

Medina et al (2022) conducted a study, to assess the performance of CHIRPS rainfall data in comparison with data from 50 rain gauges in Northern Argentina for the period 1982–2019 and established that CHIRPS dataset represents well the inter-annual variability in wetter months.

Sulugodu & Deka (2019) conducted a study with the aim of evaluating the effectiveness of CHIRPS satellite rainfall data in comparison with Indian Meteorological Department (IMD) gridded rainfall data. The study established that CHIRPS rainfall data showed better performance in comparison with IMD constructed gridded data by using the various statistical indices in evaluating the performance of the flow forecasting models.

In summary, studies have shown that CHIRPS data has the ability to represent the local rainfall at various regions of the world as established by Naikson et al (2022), Mulungu & Mukama (2022), Medina, et al (2022) and Sulugodu & Deka (2019).

### 2.3. Onset and Cessation Dates

Several methods exist for calculating the date of onset of the rains that may be taken as the start of the growing season. (Ati et al., 2002) discussed five methods which are relatively easy to apply on a large scale. These methods are traditional technique (Ramadan method), accumulated rainfall totals techniques (Walter) and (Sivakumar), rainfall–evapotranspiration relationships techniques (Kowal) and (Benoit). Walter’s method gave quite early onsets and Sivakumar’s method gave very late onsets, thereby seriously shortening the growing season. Kowal’s and Benoit’s determinations fell most often in between the results of Walter’s and Sivakumar’s methods in their performance. To avoid incorrectly predicting the growing season’s onset as far as possible, but to prevent an unacceptable shortening of the growing season, Ati et al (2002) used a combination of Kowal’s and Sivakumar’s criteria to develop an improved technique. This proved to work well for determining the Onset Dekad in the study area (Sudan Savanna of Northern Nigeria).

The methods based on accumulated rainfall totals assume that, after a particular level of rainfall is reached, the probability of a long dry spell that leads to crop failure is relatively small (Ati et al., 2002). Based on Nigerian data, Ati et al (2002) cited Walter (1967) who described the Onset Dekad (OD) as;

$$OD = \frac{D(50.8 - F)}{R}$$

where  $D$  is the number of days in the first month of the season with effective rain (MER) when totals equal or exceed 50.8 mm.  $F$  is the accumulated rainfall total of previous month;  $R$  is the total rainfall in the MER. He postulated that the model can only be accepted if it is not followed by a month with less than 50.8 mm of rainfall. If it is less, the rainfall of the MER is disregarded and the formula becomes

$$OD = \frac{D(50.8 - F_X)}{R_X}$$

where  $F_X$  is the rainfall of the succeeding month,  $R_X$  is the rainfall of the second month after MER. Ati et al (2002) through Sivakumar (1988) described the Onset Dekad in the Southern Sahelian climate zones of West Africa as the date after 1<sup>st</sup> May when rainfall accumulated over three consecutive days was at least 20 mm and when no dry spell within the next 30 days exceeded 7 days.

Kapila et al (2022) published a study that aimed at providing improved knowledge and evidence on seasonal rainfall trends in Zambia using CHIRPS data for the period 1983-2019 with the purpose of drawing inferences on the length of the crop growing season. The study revealed that the average rainy season Onset Dekads are 19<sup>th</sup>, 17<sup>th</sup>, and 16<sup>th</sup> of November and an average rainfall withdraw date for Zambia is 19<sup>th</sup> March. The study also observed that rainy seasons are getting shorter with the late-onset that has been found across all agro-ecological regions of Zambia.

Hachigonta et al (2008) found that there is substantial inter-annual variability in the Onset Dekad of the rainy season over the northern part of Zambia. A strong gradient exists between the south and the north of Zambia in terms of total seasonal rainfall amount, mean Onset Dekad and mean cessation date.

Byakatonda et al (2019) found that uncertainties in rainfall events such as length of the rainy season and frequency of dry spells have increased in the recent past, consequently exacerbating climate related risks which are projected to be higher in semiarid environments of Botswana. The study further revealed a higher coefficient of variation in Onset Dekad as compared to the cessation of rains. Deeper analysis of the study revealed that the town of Pandamatenga in Botswana experiences the earliest onset which is on 28<sup>th</sup> of November while Tsabong experiences the latest onset which is on 14<sup>th</sup> of January. The study also revealed that the earliest cessation in Botswana is observed at Tshane on 22<sup>nd</sup> of February and the latest on 30<sup>th</sup> of March at Shakawe.

Muhammad & Aishetu (2013) revealed that peasant farming is the most important economic activity in many parts of Africa's semi-dry and dry sub-humid environments, and a key impediment to its success has remained largely the erratic rainfall regime, especially since the great Sahelian drought of 1969–1973. Therefore there is urgent need to put in place reliable forecast schemes to aid peasant farming. Consequently, a scheme should be adopted for determining the effective onset of rains and commencement of intensive planting across the region.

Pham-Thanh et al., (2022) conducted a study on the performance of European Centre for Medium-Range Weather Forecasts (ECMWF) to predict the Onset Dekad in Vietnam and established that, the sub-seasonal to seasonal (S2S) ensemble hind casts of ECMWF are used to evaluate the predictability of the rainy season Onset Dekads (RSODs) over five climatic sub-regions of Vietnam.

Pham-Thanh & Phan-Van, (2022) published a study on a criteria to determine the Rainy Season Onset Dekad (RSOD) for the Central Highlands and Southern Vietnam. In this study, Pham-Thanh & Phan-Van, (2022) proposed and applied a new approach to determine RSOD based on daily rainfall Station data from 1979 to 2015. This approach is based on the similarity between station-based RSODs and regional-scale RSOD signal, obtained by applying Multi variable Principal Component Analysis (MPCA). The results showed that these selected criteria can capture reasonably the heterogeneity of the start of the rainy season on both regional and local-scale in the Central Highlands and Southern Vietnam.

Vasubandhu & Jayasankar (2023) published a study on the regional diagnosis of onset and demise of the rainy season over tropical and subtropical Australia and introduced a novel strategy to robustly diagnose the onset and demise of the rainy season using daily observed rainfall over seven specific regions across Australia, as demarcated by the Natural Resource Management (NRM) agency of Australia. The results indicate that the spread of the ensemble in the diagnosis of the onset and demise dates of the rainy season is higher in the subtropical region than the tropical region.

#### **2.4. Acute Food Insecurity**

While climate change is a complex, interdisciplinary topic, perhaps the most important effect of climate change on the developing world is the issue of food security. Ddumba, et al (2012) presented some simple mathematical models for assessment of climate-change-induced food insecurity in the equatorial region of Africa. The study established that the primary effect of future climate change in equatorial Africa will be a shift of the timing of the rainy season and an increase in the incidence of violent rain events which will be a driver of potentially disastrous low yields which eventually will affect the food security.

Amekudzi et al (2015) showed in a study on variability in rainfall onset, cessation and length of rainy season for the agro-ecological zones of Ghana that the high variability in onset and cessation dates of the rainy season over Ghana have adverse effects on rain-fed agricultural practices, disease control, water resource management, socio-economic activities and food security.

Kiran & Jabbar (2022) conducted a study on policy-oriented food insecurity estimation and mapping at district levels in Pakistan. The results of the study indicated that the policy makers

should consider both the density of affected population and incidence of food insecurity in terms of Integrated Food Security Phase Classification (IPC) for targeted interventions.

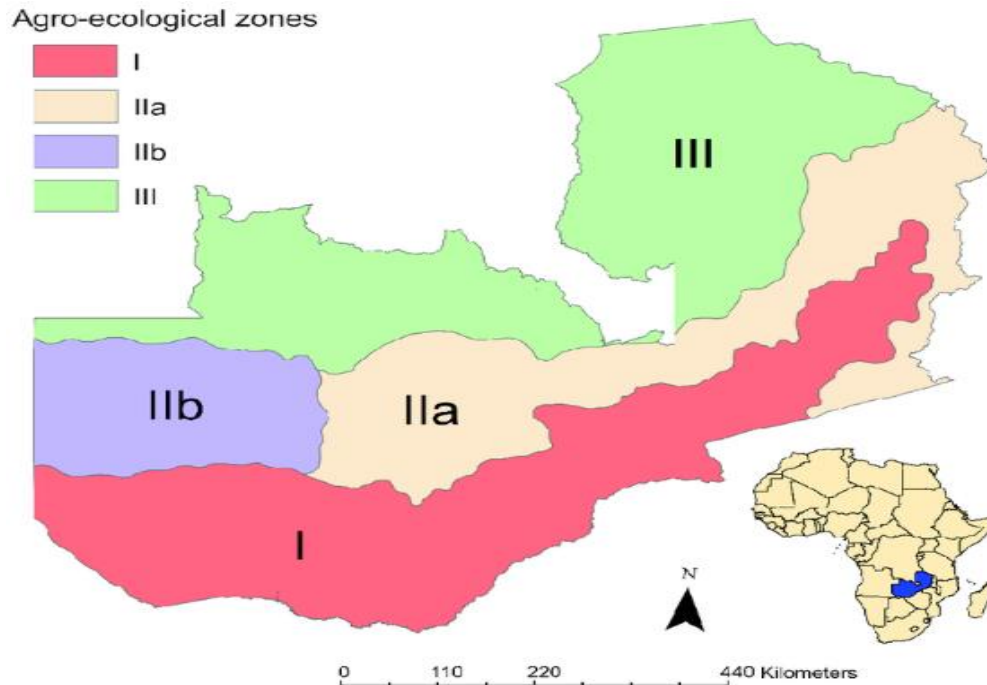
### **2.5. Research Gap**

Agricultural drought conditions driven by delayed Onset of the rainy season is one of the main contributing factors to AFI (Shukla et al 2021). A number of studies on drought forecasts in Zambia have been done at national level. Timely and appropriate early warning of drought development is called for at districts level to mitigate devastating impacts of AFI because AFI related disasters occur in different parts of the country with varying levels of severity.

## CHAPTER 3: DATA AND METHODOLOGY

### 3.1. Description of Study Area

This was conducted in the districts of Zambia. Zambia is divided into three major agro-ecological regions based on rainfall patterns, soil types, and agricultural practices as shown in *Figure 3.1*.



*Figure 3.1: Agro-Ecological Regions in Zambia*  
Source: Phiri, et al (2021)

#### 3.1.1. Region III is Northern Agro-Ecological Region

It is primarily known for its high rainfall and fertile soils, making it suitable for a variety of crops where annual rainfall exceeds 1,000 mm. It includes among other districts like Mansa, Nchelenge, Mwanabombwe, Kasama, Mbala and Nakonde (Mtambo, et al, 2007).

#### 3.1.2. Region II is Central Agro-Ecological Region

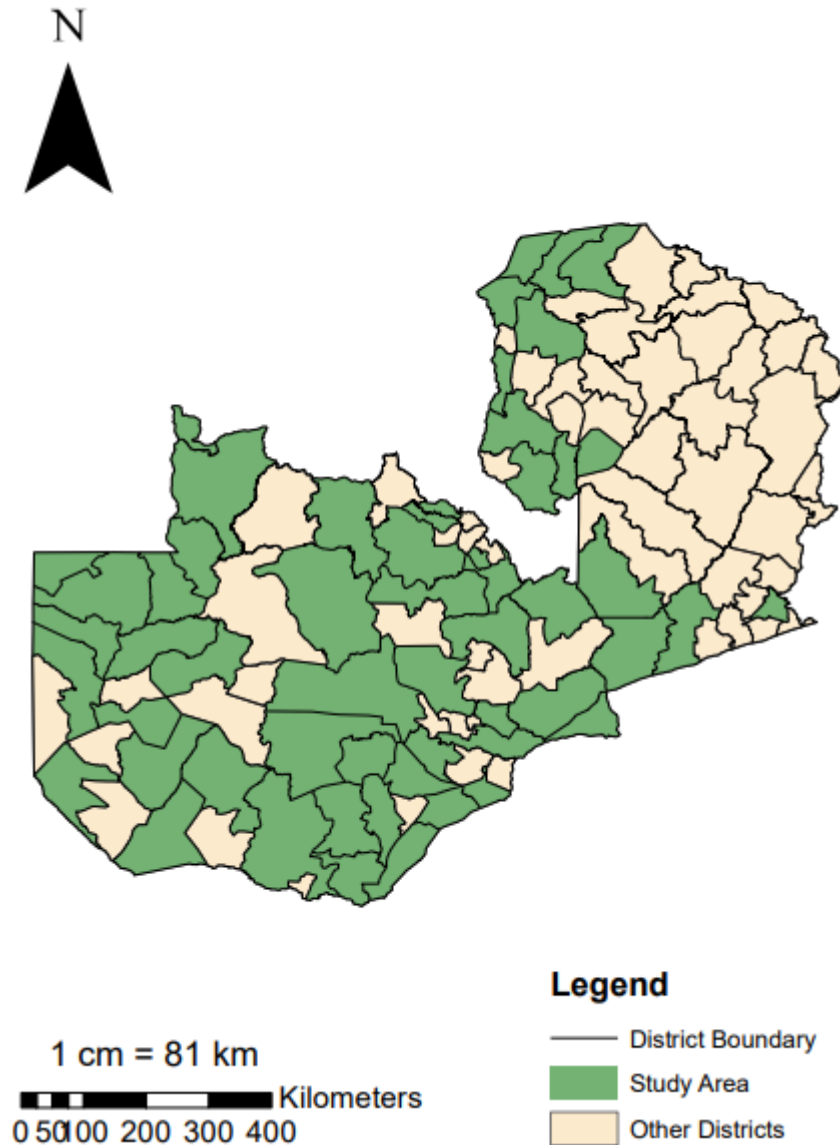
It serves as a transitional zone between the northern and southern regions of Zambia. The region receives annual rainfall between 800 to 1,000 mm. It includes Kabwe, Kapirimposhi, Mkushi, and Lusaka among other districts (Mtambo, et al, 2007).

#### 3.1.3. Region I is Southern Agro-Ecological Region

It is characterized by lower rainfall levels compared to the other two regions, with averages ranging from about 600 mm to 800 mm per year. Among other districts, it includes Choma, Livingstone, Monze and Mongu, (Mtambo, et al, 2007).

### 3.2. Study Design

This research employed a case study design on districts of Zambia. Fifty-seven (57) districts were included in the study. The constraint arose from the availability of climate data at district level. All districts for which both climate data (CHIRPS) and vegetation index (NDVI) were available for 16 cropping seasons were included. *Figure 3.2* showing the districts in green that were included in this study.



*Figure 3.2: Districts Included in the study*

### 3.3. Philosophical perspective

This study was anchored on *Objectivist Epistemology* philosophical perspectives. Under *Objectivist Epistemology* philosophical perspectives, knowledge is obtained through objective

observation and measurement. This study employed quantitative methods to ensure reliability and generalizability of results on statistical relationship between onset decade of a rainy season and NDVI as an indicator of AFI to the districts of Zambia.

### **3.4. Data Acquisition and Preparation**

The cropping seasons included for statistical analysis were from 2005/2006 to 2020/2021 because the NDVI data was available only from 2003 onwards for the study domain. Therefore, a period of sixteen (16) cropping seasons were included in this study. The CHIRPS and NDVI data is generated at daily time steps at the source. In meteorological and climatological context, each month is divided into six pentads, 1-5days (pentad 1), 6-10 days (pentad 2), 11-15 days (pentad 3), 16-20 days (pentad 4), 21-25 days (pentad 5) and 26 to end of month (pentad 6). Further, each month is divided into three dekads, 1-10days (dekad 1), 11-20 days (dekad 2) and 21 to end of month (dekad 3). In this research, daily values of CHIRPS rainfall and NDVI are aggregated at time step of a dekad.

#### **3.4.1. Rainfall Data from the Zambia Meteorological Department**

The daily rainfall data for Livingstone and Lusaka Districts was accessed from the Zambia Meteorological department for the period *1990 to 2019*.

#### **3.4.2. CHIRPS Rainfall Data**

The CHIRPS data for generating the Onset Dekad of the rainfall seasons included in the study were downloaded from USGS EROS's Early Warning eXplorer, FEWS NET's Data warehouse ([https://earlywarning.usgs.gov/fews/ewx\\_lite/index.html?region=af](https://earlywarning.usgs.gov/fews/ewx_lite/index.html?region=af)) at a time step of pentad.

#### **3.4.3. NDVI Data**

NDVI data were downloaded from USGS EROS's Early Warning eXplorer, FEWS NET's Data warehouse ([https://earlywarning.usgs.gov/fews/ewx\\_lite/index.html?region=af](https://earlywarning.usgs.gov/fews/ewx_lite/index.html?region=af)) at a time step of dekad.

#### **3.4.4. AFI Data**

Acute Food Insecurity (AFI) classification was obtained from Integrated Food Security Phase Classification website managed by Disaster Management and Mitigation Unit (DMMU), Zambia (<http://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1152117/>). The AFI incidence data in the districts of Zambia was obtained from the AFI reports of 2018, 2019, 2020 and 2021 from the same website (<http://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1152117/>).

### **3.5. Methods**

This section presents methods and criteria of data processing that were employed to answer research questions stated in section 1.6 .

#### **3.5.1. Assessment of CHIRPS data**

Zambia is divided into three major agro-ecological regions based on rainfall patterns, soil types, and agricultural practices. Region III is Northern Agro-Ecological Region: it is primarily known for its high rainfall and fertile soils, making it suitable for a variety of crops where annual rainfall exceeds 1,000 mm. It includes among other districts like Mansa, Nchelenge, Mwanabombwe, Kasama, Mbala and Nakonde. Region II is Central Agro-Ecological Region which serves as a transitional zone between the northern and southern regions of Zambia. The region receives annual rainfall between 800 to 1,000 mm. It includes Kabwe, Kapiri Mposhi, Mkushi, and Lusaka among other districts. Region I is Southern Agro-Ecological Region and it is characterized by lower rainfall levels compared to the other two regions, with averages ranging from about 600 mm to 800 mm per year. Among other districts, it includes Choma, Livingstone, Monze and Mongu, (Mtambo J., Madder M., & Bortel W., Chaka G., Berkvens D., Backeljau T., 2007).

To assess the ability of CHIRPS data in representing the rainfall climatology of Zambia, it was assumed that if one randomly selected district from each of the three major agro-ecological regions showed reasonably good agreement, then CHIRPS data could be utilized to cover all districts of Zambia. Therefore, the following steps were followed for Lusaka, Livingstone and Mansa districts:

- a. Compute the mean monthly total rainfall for Lusaka, Livingstone and Mansa districts using ZMD data.
- b. Compute the mean monthly total rainfall for Lusaka, Livingstone and Mansa districts using CHIRPS data.
- c. Plot the data of mean monthly totals of ZMD data and CHIRPS data for both Lusaka, Livingstone and Mansa districts and check for agreement.
- d. The Pearson correlation coefficient between seasonal totals of ZMD data and CHIRPS data covering seasons was employed to check the strength of the agreement.

### 3.5.2. Onset Dekad

The traditional Onset of the rainy season in districts of Zambia as identified using the established criterion in the Southern African region at large as defined in Section 1.8.3. This criterion is as follows;

- a. Determine the climatological rainfall month of Onset for Zambia.
- b. Convert the CHIRPS data from pentad to dekad time step.
- c. Starting from the first dekad of the climatological rainfall month, search for the dekad with at least 25 mm of rainfall followed by two dekads with a total of at least 20mm of rain.
- d. If criterion (c) is met, then, the first dekad with at least 25 mm rainfall is the Onset Dekad of that rain season, otherwise, the search continues.

### 3.5.3. Peak NDVI

To identify the peak NDVI for a district in a cropping season, the following criteria were employed:

- a. For each month, in the cropping season, the largest NDVI out of NDVI's of the three dekads was identified as the NDVI value for that month.
- b. Temporal means for each month over the period of analysis were computed (that is, the mean of October NDVI from 2005/2006 to 2020/2021 was computed. Similarly, the means for November, December, January, February, March and April NDVI were computed).
- c. Using the time series of mean monthly NDVI values, the month with the highest mean NDVI was identified as the month of peak NDVI.
- d. The monthly NDVI value for the month of peak NDVI for each of the seasons from 2005/2006 to 2020/2021 was regarded as peak NDVI for that cropping season.

#### 3.5.3.1. Standardized Peak NDVI

To standardize the peak NDVI for a district in a cropping season, the following criteria was employed:

- a. For each month, in the cropping season, the largest NDVI out of the three dekads was identified as the NDVI value for that Month say ( $NDVI_{Oct}$ ,  $NDVI_{Nov}$ , ...,  $NDVI_{Apr}$  for 2005/2006).
- b. The mean  $\overline{NDVI_{Month}}$  and the variance ( $Var(NDVI)$ ) for each month over the period of analysis were computed (that is, the mean and variance of October NDVI from 2005/2006

to 2020/2021 was computed. Similarly, the means and variances for November, December, January, February, March and April NDVI were computed).

- c. Using the NDVI, means and variances, the NDVI for each month were standardized using the formula;

$$\text{Standardized NDVI}_{Month} = \frac{NDVI_{Month} - \overline{NDVI}_{Month}}{\sqrt{Var(NDVI_{Month})}}$$

- d. Using the time series of mean monthly NDVI values, the month with the highest mean NDVI was identified as the month of the standardized peak NDVI.
- e. The monthly standardized NDVI value for the month of standardized peak NDVI for each of the season from 2005/2006 to 2020/2021 was regarded as standardized peak NDVI for a given cropping season.

#### 3.5.4. Assignment of AFI Levels to Districts

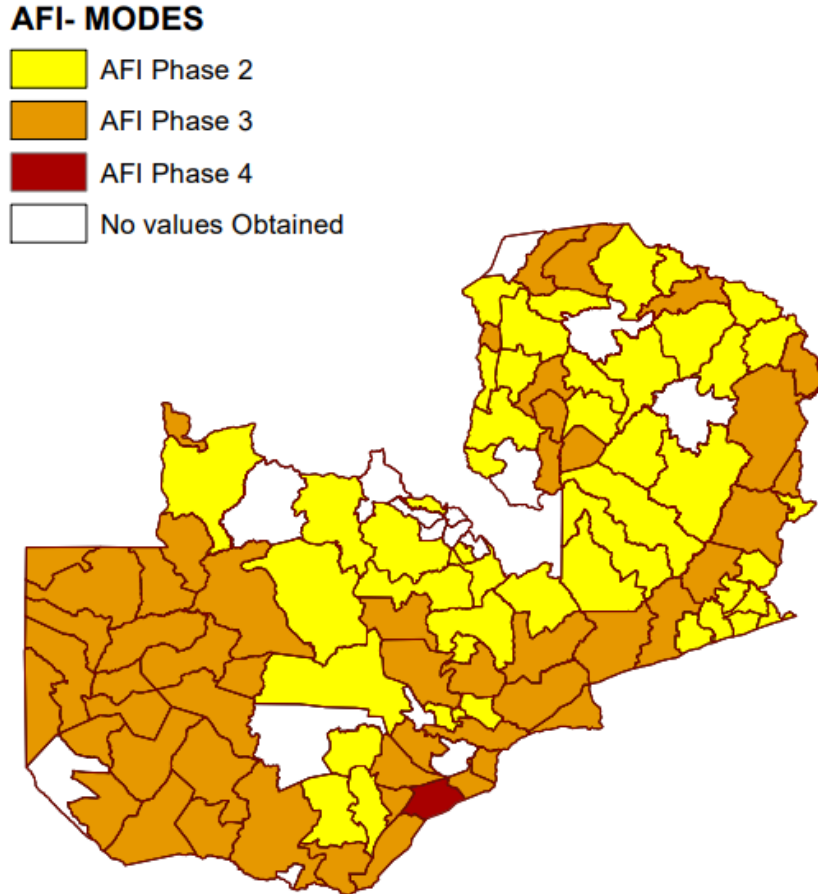
Data on the AFI risk levels of the disaster-stricken districts of Zambia has been classified and reported by the Disaster Management and Mitigation Unit (DMMU) since the year 2018. Hundred and eleven (111) districts were included in the operations of DMMU during the period from 2018 to 2022. DMMU assigns AFI status to each of these districts bi-annually. Table 3.5.4 presents the summary on the number of districts affected by each AFI level during the five reporting seasons.

*Table 3.5.4: Number of Districts affected by five levels of AFI from 2018 to 2022*

Seasons	AFI-1	AFI-2	AFI-3	AFI-4	AFI-5	Total AFIs
<b>May - Sep 2018</b>	10	46	2	0	0	58
<b>Oct 2018 - Mar 2019</b>	4	35	19	0	0	58
<b>May - Sep 2019</b>	1	39	45	2	0	87
<b>Oct 2019 - Mar 2020</b>	0	26	58	3	0	87
<b>Feb to Mar 2021</b>	0	12	53	0	0	65
<b>Jun - Sep 2022</b>	1	69	15	0	0	85
<b>Total Occurrence of AFI Levels</b>	16	227	192	5	0	440

The Mode AFI level of each district during the period 2018-2022 is assigned as the AFI level of that district. If there two Modes for a district, the worst AFI mode was picked and assigned as the

AFI level of that district. Figure 3.5.4 show the Mode AFI level assigned to each district. The names of the districts are shown in *Appendix 4.5.1*.



*Figure 3.5.4: Mode AFI Status*

### 3.5.5. Statistical Relationship between Onset Dekad and Peak NDVI

Pearson correlation coefficient between seasonal Onset Dekad and peak NDVI for each district was computed using the seasons from 2005 to 2022. The computations were done using the formula.

$$r = \frac{\sum_{i=2005}^{n=2022} (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=2005}^{n=2022} (O_i - \bar{O})^2} \sqrt{\sum_{i=2005}^{n=2022} (P_i - \bar{P})^2}}$$

Where;

$r$  is the Pearson correlation coefficient between seasonal Onset Dekad and peak NDVI for each district in *Figure 3.2* .

$O_i$  is the difference of the  $i$ th seasonal onset dekad from the mean onset dekad based on rainfall data from 2005 to 2022 for each district in *Figure 3.2* .

$\bar{O}$  is the average seasonal onset dekad for period from 2005 to 2022 for each district in *Figure 3.2* .

$P_i$  is the peak NDVIs for the  $i$ th season where seasons run from 2005 to 2022 for each district in *Figure 3.2* .

$\bar{P}$  is the average peak NDVI based on period from 2005 to 2022 for each district in *Figure 3.2* .

Districts with the same AFI level Mode were binned together. For each bin, the Pearson coefficient correlation between seasonal Onset Dekad and peak NDVI were computed as empirical correlations. The correlations of district falling in the bin of each AFI-level were presented in a box plot.

### 3.5.6. Development of Early Warning Signal for Severity of AFI

The Pearson correlation coefficient range of -1 to +1 was partitioned into subintervals by using the proportion of correlations range of each AFI determined in 3.3.5. The proportion of districts in each bin of AFI levels were utilized to partition correlations range from -1 to +1 into three subintervals using the intervals .

$$-1 \leq r \leq l_4 \dots\dots\dots \text{AFI-4 Interval}$$

$$l_4 < r \leq l_3 \dots\dots\dots \text{AFI-3 Interval}$$

$$l_3 < r \leq l_2 = 1 \dots\dots\dots \text{AFI-2 Interval}$$

Where;

$$l_4 = -1 + 2P_4$$

$$l_3 = l_4 + 2P_3$$

$$l_2 = l_3 + 2P_2 = 1$$

$P_4$  is the number of districts with AFI-4 mode out of Total number of districts ( $P_4 = 1/49$ )

$P_3$  is the number of districts with AFI-4 mode out of Total number of districts ( $P_3 = 26/49$ )

$P_2$  is the number of districts with AFI-4 mode out of Total number of districts ( $P_2 = 22/49$ )

### **3.6. Data Analysis Software**

In this study, various statistical software for data analysis and geo spatial mapping were employed based on the required analysis techniques. Software that were used are ArcGIS, Microsoft Excel and Python.

### **3.7. Ethical issues**

All the sourced data and materials were used for academic purposes only. High levels of integrity were observed in this study. The sources of materials and data are acknowledged in the study.

## CHAPTER 4: RESULTS AND DISCUSSION

### 4.1. Introduction

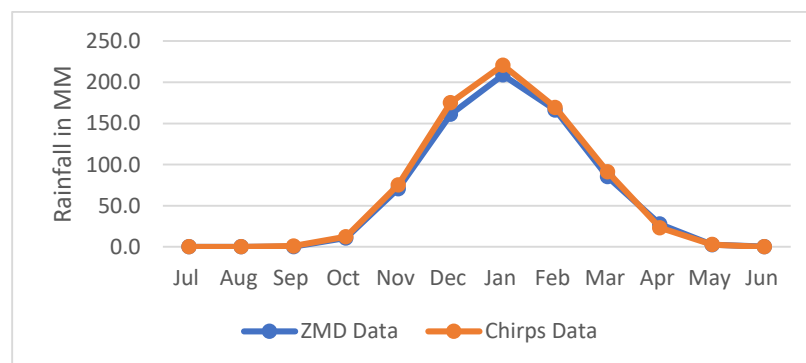
This chapter presents results based on data analysis methodology outlined in Chapter 3 in order to achieve specific objectives of the study. The chapter has four sections (4.2, 4.3, 4.4 and 4.5). The first section (4.2) presents results on the ability of CHIRPS data in representing the rainfall climatology of Zambia. The second section (4.3) presents results on onset and cessation dekads and peak NDVI for rainy seasons in the districts of Zambia. The third section (4.4) presents results on the correlations between Onset Dekad and peak NDVI in the districts of Zambia. The fourth section (4.5) presents assignment of correlations range for each of AFI risk phases or risk levels for districts of Zambia. The last section (4.6) presents the discussion of findings.

### 4.2. Findings on the Ability of CHIRPS Data

Since Zambia is divided into three Agro-Ecological Regions, one district from each Agro-Ecological Region was randomly picked to assess the ability of CHIRPS data in Zambia. Lusaka from Central Agro-Ecological Region, Livingstone from Southern Agro-Ecological Region and Mansa from Northern Agro-Ecological Region districts were analyzed to assess the agreement between Climate Hazards Centre Infrared Precipitation Station (CHIRPS) data and the observed rainfall ZMD Station data by the Zambian Meteorological Department (ZMD) in the rainfall climatology of Zambia.

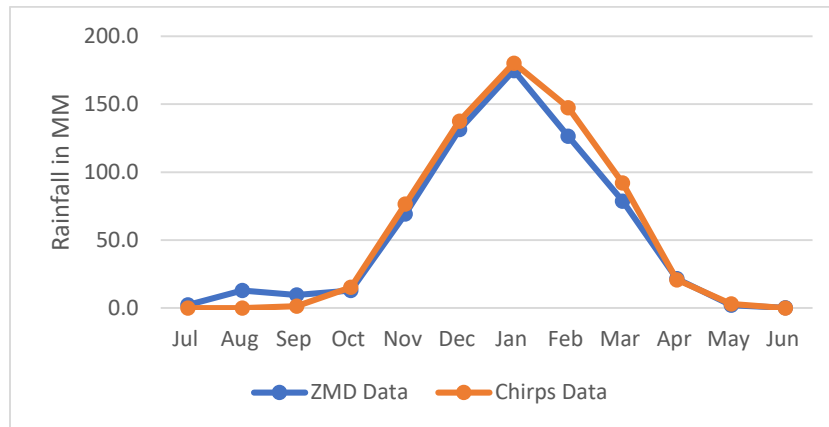
#### 4.2.1. Ability of CHIRPS data to Represent Rainfall Climatology in Zambia

The CHIRPS data and ZMD rainfall monthly data in millimeters (MM) for Lusaka, Livingstone and Mansa districts for the period of 1990 to 2019 were analyzed. The results are shown in *Figure 4.2.1.1*, *Figure 4.2.1.2* and *Figure 4.2.1.3*.



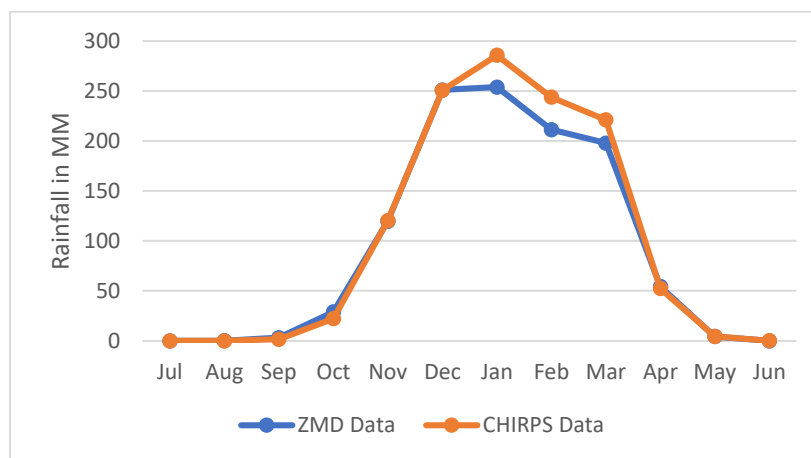
*Figure 4.2.1.1: Mean Monthly rainfall of CHIRPS and ZMD Data for Lusaka Districts for years from 1990 to 2019*

The plot in *Figure 4.2.1.1* show that the pattern of mean monthly rainfall cycle in Lusaka was the same for both CHIRPS and ZMD Station data for the period 1990 to 2019. Both datasets indeed captured the shape of the monthly rainfall well by reproducing the October-April climatological rainy season for Zambia. The peak of rainy season for both CHIRPS and ZMD data was in the month of January.



*Figure 4.2.1.2: Mean Monthly Rainfall of CHIRPS and ZMD Data for Livingstone District for years from 1990 to 2019*

Similarly, in assessing the agreement between the CHIRPS monthly data and ZMD monthly data for Livingstone district in Southern province, a period of 1990 to 2019 was utilized. The results are shown in *Figure 4.2.1.2*. The plot show that the pattern of mean monthly rainfall cycle of Livingstone for both CHIRPS and ZMD data for the period 1990 to 2019 are in agreement.



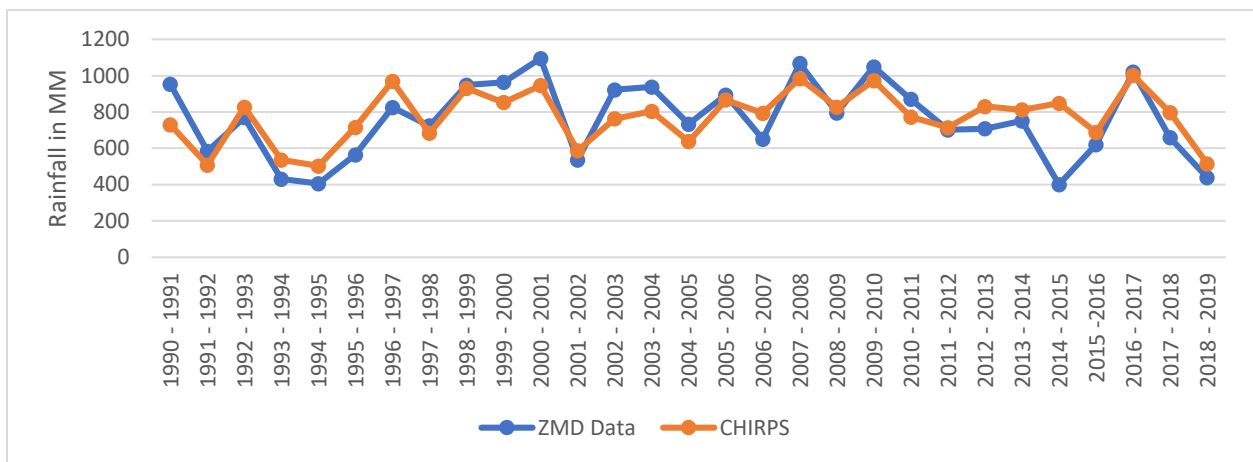
*Figure 4.2.1.3: Mean Monthly Rainfall of CHIRPS and ZMD Data for Mansa District for years from 1990 to 2019*

Furthermore, in assessing the agreement between the CHIRPS monthly data and ZMD monthly data for Mansa district in Luapula province from Northern Agro-Ecological Region, a period of 1990 to 2019 was utilized. The results are shown in *Figure 4.2.1.3*. The plot show that the pattern

of mean monthly rainfall cycle of Mansa for both CHIRPS and ZMD data for the period 1990 to 2019 are in agreement.

#### 4.2.2. Inter Annual Variability in CHIRPS and ZMD Data from 1990 to 2019

The annual total rainfall for years from 1990 to 2019 for each of the two datasets CHIRPS and ZMD for Central Agro-Ecological Region represented by Lusaka district, Southern Agro-Ecological Region represented by Livingstone district and Northern Agro-Ecological Region represented by Mansa district are shown in *Figure 4.2.2.1*, *4.2.2.2* and *4.2.2.3* respectively.



*Figure 4.2.2.1: Inter Annual rainfall variability in CHIRPS and ZMD Data for years from 1990 to 2019 for Lusaka.*

The time plots in *Figure 4.2.2.1* confirm reasonably good agreement in inter annual rainfall variability in the two datasets except ZMD is showing drier seasons during 1993/94 to 1996/97, 2006/07, 2012/13 to 2014/15 and 2017/18 to 2018/19 compared to CHIRPS data. Further, CHIRPS shows drier seasons during 1999/2000 to 2000/01, 2002/03 to 2004/05 and 2010/11 compared to ZMD for Central Agro-Ecological Region represented by Lusaka district.

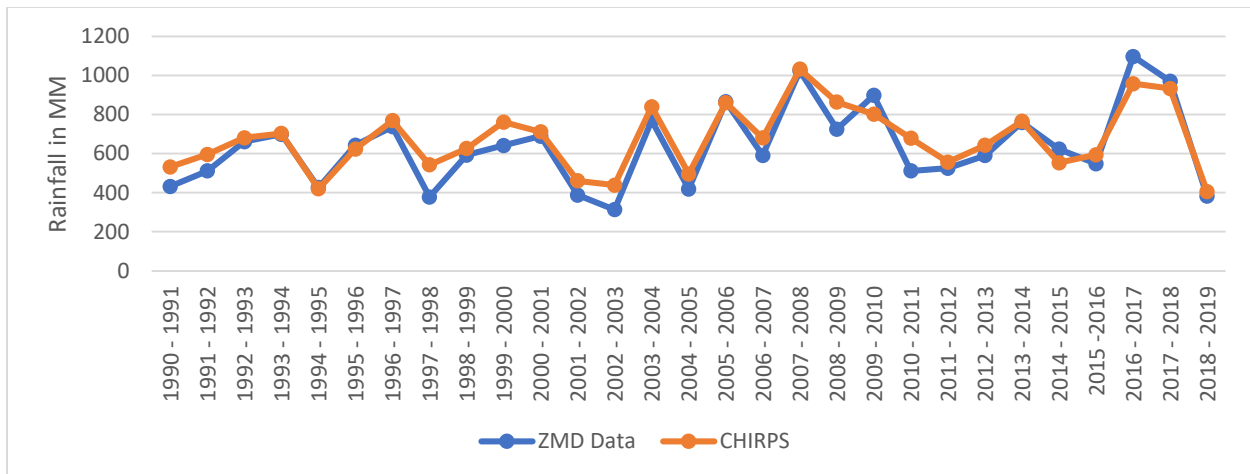


Figure 4.2.2.2: Inter Annual rainfall variability in CHIRPS and ZMD Data for years from 1990 to 2019 for Livingstone.

Similarly, the time plots in Figure 4.2.2.2 confirm reasonably good agreement in inter annual rainfall variability in the two datasets except ZMD is showing drier seasons during 1990/91 to 1991/92, 1997/98 to 1999/2000, 2001/02 to 2002/03, 2004/05, 2006/07, 2008/09 and 2010/11 to 2012/13 and 2015/16 compared to CHIRPS data. Also, CHIRPS shows drier season only during 2014/15 compared to ZMD for Southern Agro-Ecological Region represented by Livingstone district.

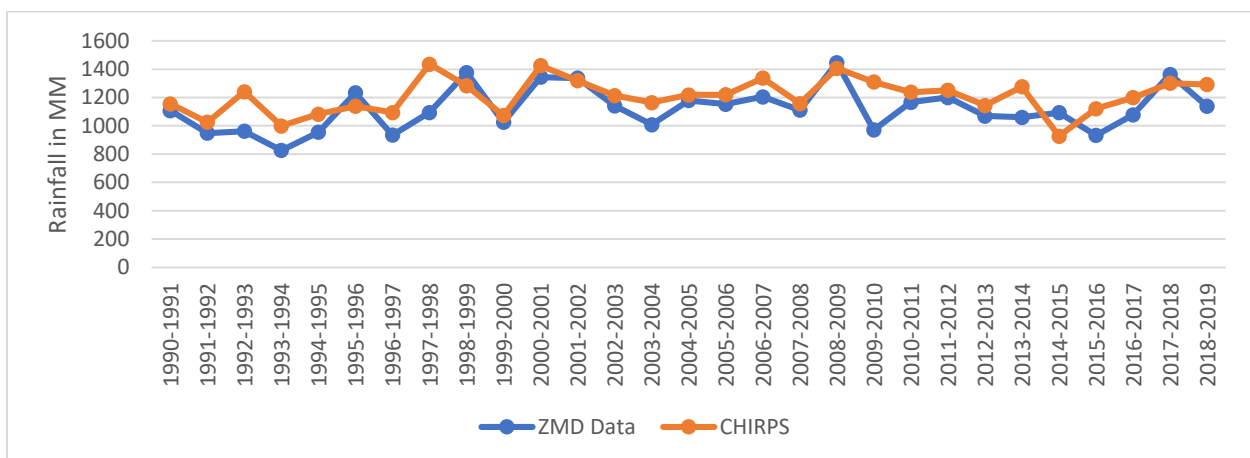


Figure 4.2.2.3: Inter Annual rainfall variability in CHIRPS and ZMD Data for years from 1990 to 2019 for Mansa.

Further, the time plots in Figure 4.2.2.3 confirm reasonably well agreement in inter annual rainfall variability in the two datasets except ZMD is showing drier seasons during 1991/92 to 1994/95, 1996/97 to 1997/98, 2002/03 to 2007/08, 2009/10 to 2013/14, 2015/16 to 2016/17 and 2018/19 compared to CHIRPS data. Similarly, CHIRPS shows drier season only during 2014/15 compare to ZMD for Northern Agro-Ecological Region represented by Mansa district.

#### **4.2.3. Correlation between Annual Total Rainfall in CHIRPS and ZMD Data**

Furthermore, in comparing CHIRPS and ZMD Station data, a correlation analysis at 5% level of significance was employed to measure the strength of the relationship between CHIRPS and ZMD annual rainfall for years from 1990 to 2019 for each Agro-Ecological Region.

The Pearson Correlation coefficients between annual total rainfall in CHIRPS and ZMD data for Central Agro-Ecological Region represented by Lusaka district is  $r = 0.765$  with two tailed significance at 5%, indicating that there is a strong positive correlation between CHIRPS and ZMD total annual rainfall for Central Agro-Ecological Region.

Pearson Correlation coefficient between CHIRPS and ZMD data for total annual rainfall for Southern Agro-Ecological Region represented Livingstone district is  $r = 0.926$  with two tailed significance at 5% indicating that there is a strong positive relationship between CHIRPS and ZMD data for Southern Agro-Ecological Region.

Pearson Correlation coefficient between CHIRPS and ZMD data for total annual rainfall for Northern Agro-Ecological Region represented by Mansa district is  $r = 0.638$  with two tailed significance at 5% indicating that there is a strong positive relationship between CHIRPS and ZMD Station data for Northern Agro-Ecological Region.

Therefore, the results in sections 4.2.1, 4.2.2 and 4.2.3 show that the (CHIRPS) data is in agreement with ZMD Station data for all the three Agro-Ecological Regions represented by Lusaka, Livingstone and Mansa districts. These findings suggest that CHIRPS data has the ability to represent the climatology of Zambia and hence CHIRPS data were used for further analysis in all the districts in green color shown in *Figure 3.2*.

#### **4.3. Onset Dekad Anomalies and Peak NDVI for Districts of Zambia**

The methods described in Sections 3.2.2 and 3.3.3 for determining onset dekad and peak NDVI were applied for each district in *Figure 3.2*. October is used as the climatological rainfall onset month for Zambia (Shukla et al 2021). The first dekad of October is assigned number 1, second dekad is assigned number 2 and so on until the last dekad of April (as the last month of the climatological rainy season of Zambia) is assigned number 21. The mode (most frequent dekad) of onset dekads for seasons from 2005 to 2021 for each district is used as the climatological onset dekad and seasonal anomalies are calculated from climatological onset dekad. Similarly, peak NDVI for each season and each district are calculated and standardized. Onset dekad and peak

NDVI for Lusaka province are shown in *Table 4.3.1.1*. For all other districts, summary results by province are presented with more details by districts in the appendix.

#### **4.3.1. Onset Dekads Anomalies and Peak NDVI for Districts of Lusaka Province**

Five (5) districts were considered in the analysis of the onset dekad and Peak NDVI for Lusaka province. These districts are Lusaka, Chongwe, Kafue, Luangwa and Rufunsa.

##### **4.3.1.1. Onset Dekad Anomalies and Peak NDVI for Lusaka District**

In Lusaka province, Lusaka district among others was analyzed. The seasonal onset dekad anomalies (ODA) and standardized peak NDVI (SP-NDVI) for Lusaka district are presented in *Table 4.3.1.1* and *Figure 4.3.1.1*, which show that November and December were the onset months of the rainy season in Lusaka district for seasons from 2005 to 2021.

Peak NDVIs for each season from 2005 to 2021 were also computed. SP-NDVIs for seasons from 2005 to 2021 are shown in *Table 4.3.1.1* and *Figure 4.3.1.1*. It is noted from *Figure 4.3.1.1* that (ODA) and SP-NDVI are negatively correlated.

*Table 4.3.1.1: Onset Dekad and Peak NDVI for Lusaka District*

Season	Onset Dekad	Anomaly Onset Dekad	Peak NDVI	SP-NDVI
2005-2006	4	-1	0.6036	0.448564
2006-2007	5	0	0.5637	0.142004
2007-2008	4	-1	0.5676	0.171968
2008-2009	5	0	0.5679	0.174273
2009-2010	5	0	0.587	0.321022
2010-2011	6	1	0.5773	0.246495
2011-2012	4	-1	0.5657	0.15737
2012-2013	6	1	0.5603	0.115881
2013-2014	6	1	0.555	0.07516
2014-2015	8	3	0.5507	0.042122
2015-2016	8	3	0.5326	-0.09694
2016-2017	5	0	0.5519	0.051342
2017-2018	5	0	0.5435	-0.0132
2018-2019	7	2	0.4653	-0.61402
2019-2020	5	0	0.4694	-0.58252
2020-2021	7	2	0.5088	-0.2798

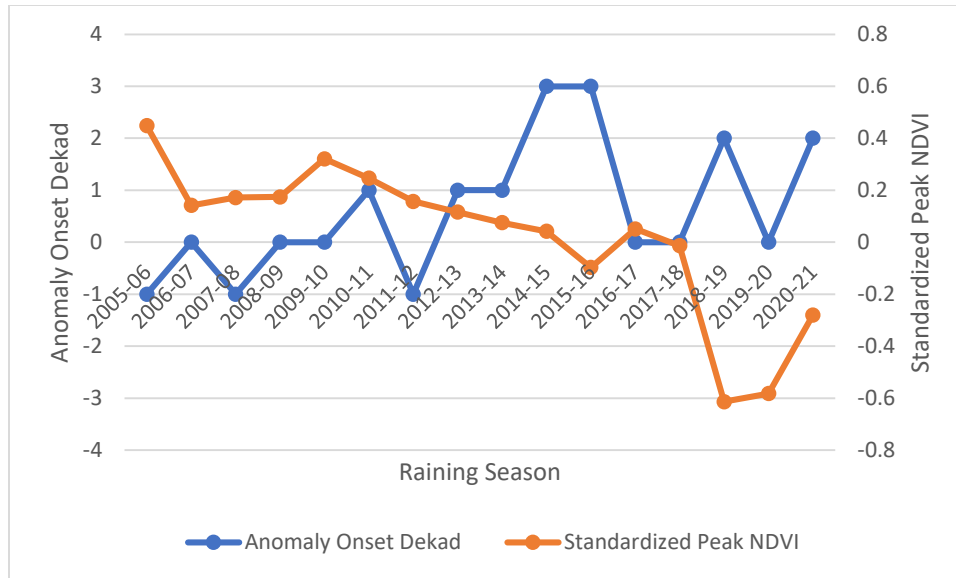


Figure 4.3.1.1: ODA and SP- NDVI for Lusaka District

#### 4.3.1.2. Onset Dekad and Peak NDVI for Chongwe District

Figure 4.3.1.2 and Table 4.3.1.2 present the case of Chongwe district from 2005 to 2021.

Table Figure 4.3.1.2: Onset Dekad and Peak NDVI for Chongwe District

Year	Onset Dekad	Anomaly Onset Dekad	Peak NDVI	SP-NDVI
2005-2006	6	1	0.7506	0.105491
2006-2007	5	0	0.7437	0.06573
2007-2008	4	-1	0.7314	-0.00515
2008-2009	5	0	0.7189	-0.07718
2009-2010	5	0	0.7238	-0.04895
2010-2011	4	-1	0.7365	0.024239
2011-2012	4	-1	0.7256	-0.03857
2012-2013	6	1	0.7421	0.056509
2013-2014	6	1	0.7276	-0.02705
2014-2015	8	3	0.7389	0.038069
2015-2016	6	1	0.7376	0.030578
2016-2017	5	0	0.7287	-0.02071
2017-2018	5	0	0.7251	-0.04145
2018-2019	6	1	0.6942	-0.21952
2019-2020	5	0	0.6993	-0.19013
2020-2021	7	2	0.7927	0.348097

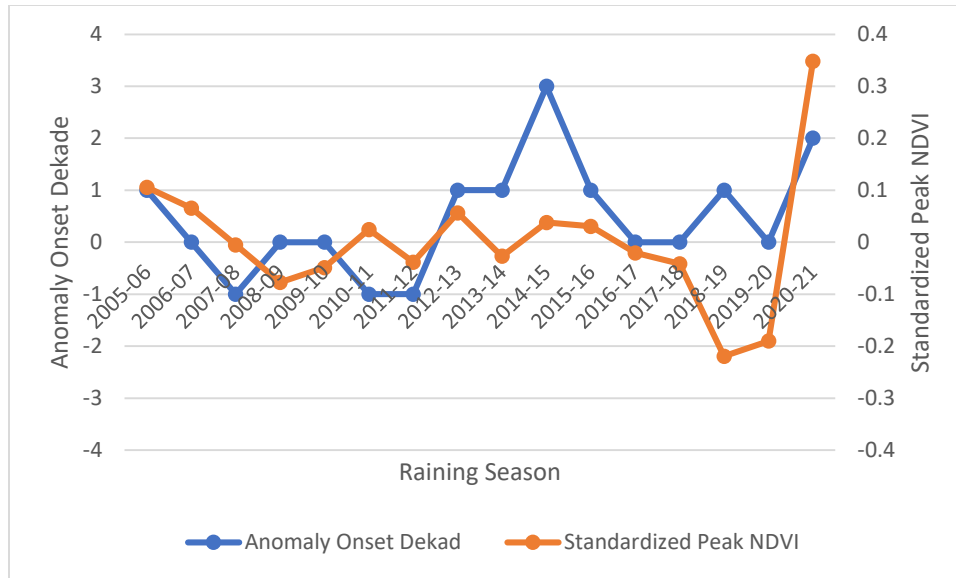


Figure 4.3.1.2: ODA and SP- NDVI for Chongwe District

#### 4.3.1.3. Onset Dekads and Peak NDVI for Kafue District

Figure 4.3.1.3 and Table 4.3.1.3 present the case of Kafue district from 2005 to 2021.

Table 4.3.1.3: Onset Dekad and Peak NDVI for Kafue District

Season	Onset Dekad	Anomaly Onset Dekad	Peak NDVI	SP- NDVI
2005-2006	6	1	0.7718	0.100815
2006-2007	5	0	0.7508	-0.01672
2007-2008	4	-1	0.7489	-0.02736
2008-2009	5	0	0.7516	-0.01224
2009-2010	5	0	0.7637	0.05548
2010-2011	4	-1	0.7457	-0.04527
2011-2012	4	-1	0.7576	0.021338
2012-2013	6	1	0.764	0.057159
2013-2014	6	1	0.7598	0.033652
2014-2015	8	3	0.76	0.034771
2015-2016	6	1	0.7467	-0.03967
2016-2017	5	0	0.7705	0.093539
2017-2018	5	0	0.7585	0.026376
2018-2019	6	1	0.7045	-0.27586
2019-2020	5	0	0.7063	-0.26579
2020-2021	7	2	0.8002	0.259769

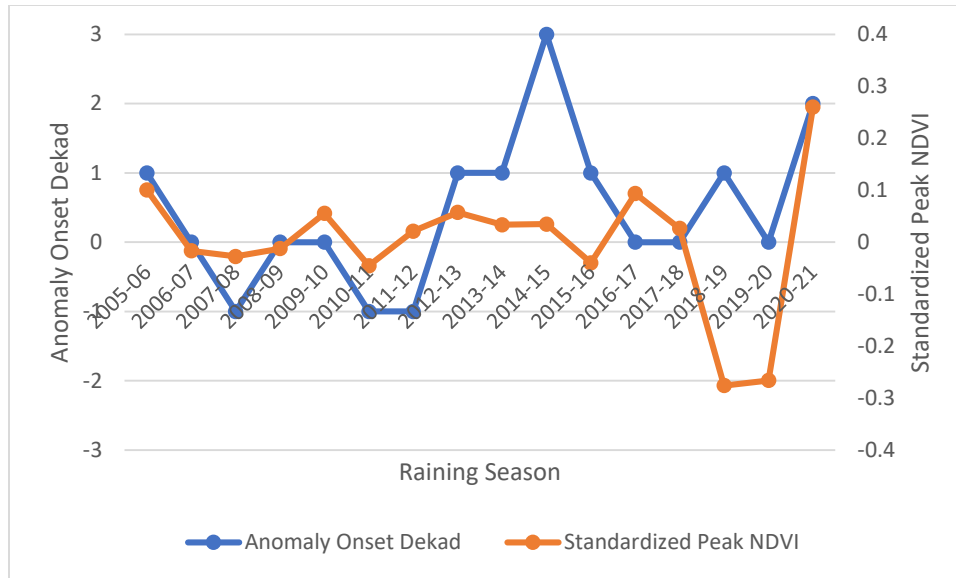


Figure 4.3.1.3: ODA and SP-NDVI for Kafue District

#### 4.3.1.4. Onset Dekad and Peak NDVI for Luangwa District

Furthermore, in Lusaka province, Luangwa district among others was also analyzed, and the results in Figure 4.3.1.4 and Table 4.3.1.4 showed that November and December were the climatological Onset months of the rainy season in Luangwa district from 2005 to 2021.

Table 4.3.1.4: Onset Dekad and Peak NDVI for Luangwa District

Season	Onset Dekad	Anomaly Onset Dekad	Peak NDVI	SP-NDVI
2005-2006	6	1	0.7672	-0.04365
2006-2007	5	0	0.7775	0.012593
2007-2008	4	-1	0.7676	-0.04146
2008-2009	5	0	0.7816	0.03498
2009-2010	5	0	0.7777	0.013685
2010-2011	6	1	0.7652	-0.05457
2011-2012	6	1	0.7955	0.110878
2012-2013	7	2	0.7935	0.099958
2013-2014	7	2	0.7794	0.022967
2014-2015	8	3	0.7644	-0.05894
2015-2016	6	1	0.7467	-0.15558
2016-2017	5	0	0.7889	0.07484
2017-2018	5	0	0.7896	0.078663
2018-2019	6	1	0.7458	-0.1605
2019-2020	5	0	0.7557	-0.10644
2020-2021	7	2	0.8068	0.17258

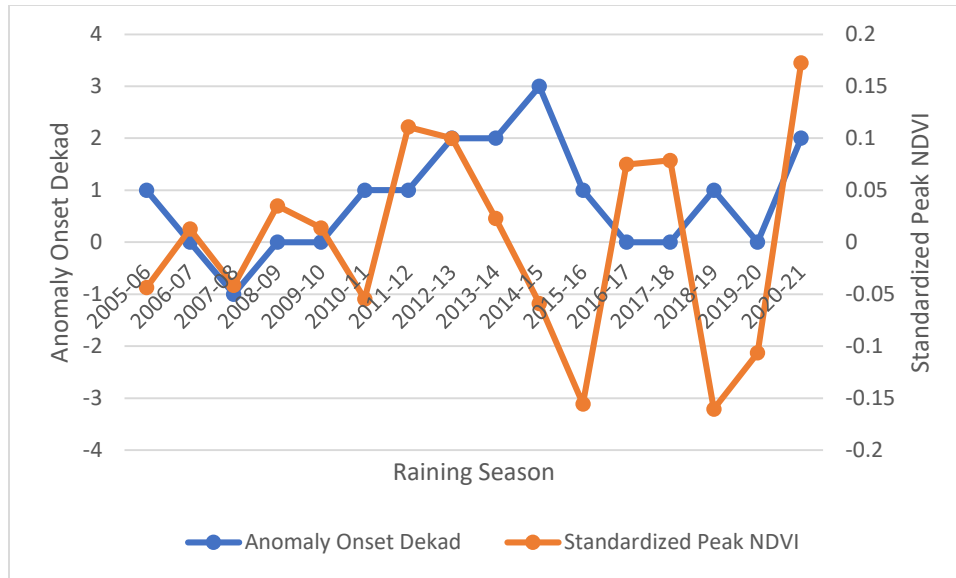


Figure 4.3.1.4: ODA and SP-NDVI for Luangwa District

#### 4.3.1.5. Onset Dekad and Peak NDVI for Rufunsa District

Last but not the least, in Lusaka province, Rufunsa District among others was also analyzed, and the results in Figure 4.3.1.5 and Table 4.3.1.5 showed that November and December were the climatological onset months of the rainy season in Rufunsa district from 2005 to 2021.

Table 4.3.1.5: Onset Dekad and Peak NDVI for Rufunsa District

Season	Onset Dekad	Anomaly Onset Dekad	Peak NDVI	SP-NDVI
2005-2006	6	0	0.7598	-0.02378
2006-2007	5	-1	0.7729	0.048772
2007-2008	4	-2	0.7572	-0.03818
2008-2009	5	-1	0.7434	-0.11461
2009-2010	5	-1	0.7557	-0.04649
2010-2011	6	0	0.7706	0.036033
2011-2012	6	0	0.7583	-0.03209
2012-2013	7	1	0.7698	0.031603
2013-2014	7	1	0.7918	0.153445
2014-2015	8	2	0.7697	0.031049
2015-2016	6	0	0.771	0.038249
2016-2017	6	0	0.7594	-0.026
2017-2018	5	-1	0.77	0.032711
2018-2019	6	0	0.7396	-0.13565
2019-2020	5	-1	0.7331	-0.17165
2020-2021	7	1	0.8032	0.216582

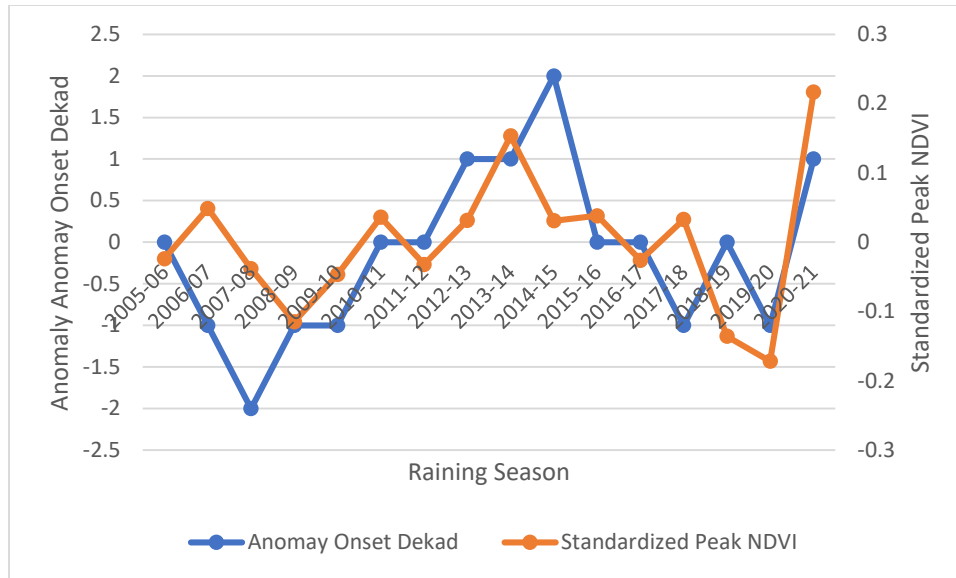


Figure 4.3.1.5: ODA and SP-NDVI for Rufunsa District

#### 4.3.1.6. Summary of Onset Dekads and Peak NDVI for Districts of Lusaka Province

In summary, five (5) districts in Lusaka Province, were analyzed for their onset dekad of the rainy season. The mode onset dekad for Rufunsa is dekad 6 whereas the other four districts mode dekad is 5 as shown in Table 4.3.1.6 and Figure 4.3.1.6 indicating that the onset dekad for different districts although in the same province are different. Provinces of Zambia are quite large, hence the onset of rainy season in the districts occur during different dekads.

Table 4.3.1.6: Summary of Onset Dekad and Peak NDVI for Districts of Lusaka Province

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Lusaka	Chongwe	5	0.7323
2	Lusaka	Kafue	5	0.7538
3	Lusaka	Luangwa	5	0.7752
4	Lusaka	Lusaka	5	0.5481
5	Lusaka	Rufunsa	6	0.7641

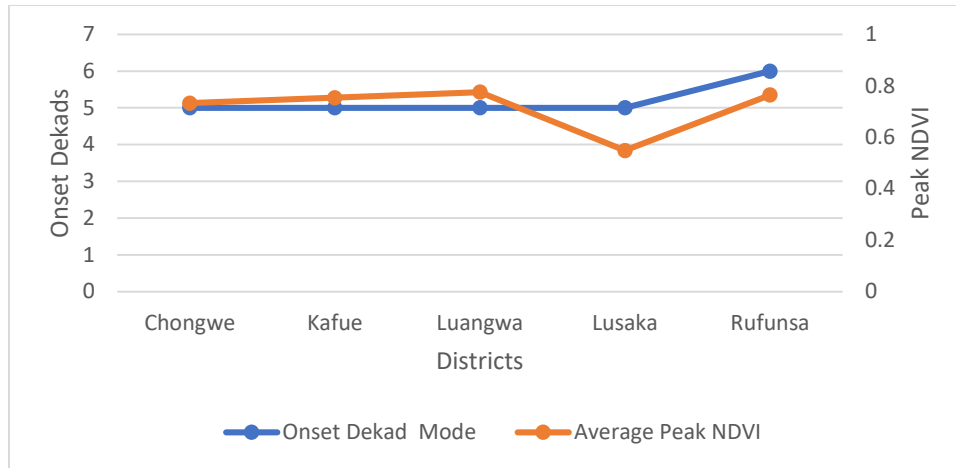


Figure 4.3.1.6: Mode Onset Dekad for Districts of Lusaka Province

The anomalies in the seasonal onset dekads and standardized peak NDVI for districts in the other nine provinces are presented in the appendix. The average peak NDVI with more than 0.5481NDVI is in March suggesting to be the end of rainy season with a health vegetation.

#### 4.3.1.7. Summary Onset Dekad and Peak NDVI for Districts of Central Province

In Central Province, five (5) districts were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in *Appendices 4.3.2*.

Table 4.3.1.7: Summary Onset Dekad and Peak NDVI for Districts of Central Province

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Central	Chibombo	5	0.7090
2	Central	Kapiri Mposhi	4	0.7295
3	Central	Mkushi	6	0.7447
4	Central	Mumbwa	4	0.7569
5	Central	Serenje	5	0.7438

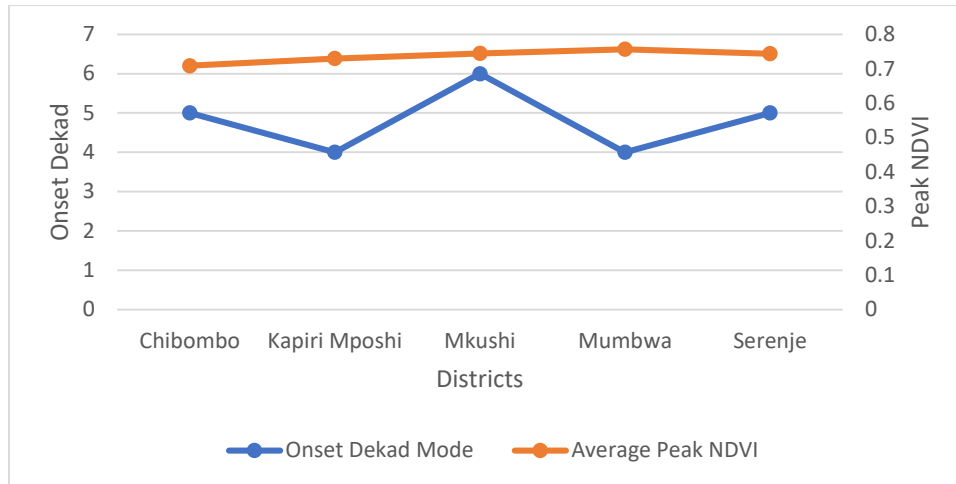


Figure 4.3.1.7: Summary Onset Dekad for Districts of Central Province

The results in Table 4.3.1.7 and Figure 4.3.1.7 show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 4<sup>th</sup> dekad for Kapiri Mposhi and Mumbwa districts, 5<sup>th</sup> dekad for Chibombo and Serenje, districts and 6<sup>th</sup> dekad for Mkushi. The average peak NDVI with more than 0.7090 is in March suggesting to be the end of rainy season with a health vegetation.

#### 4.3.1.8. Summary Onset Dekad and Peak NDVI for Districts of Coperbelt Province

Five (5) districts in Coperbelt Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in Appendices 4.3.3.

Table 4.3.1.8: Summary of Onset Dekad and Peak NDVI for Districts of Copperbelt

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Copperbelt	Chingola	5	0.7243
2	Copperbelt	Luanshya	4	0.7279
3	Copperbelt	Lufwanyama	4	0.7834
4	Copperbelt	Masaiti	5	0.7688
5	Copperbelt	Mpongwe	5	0.7741

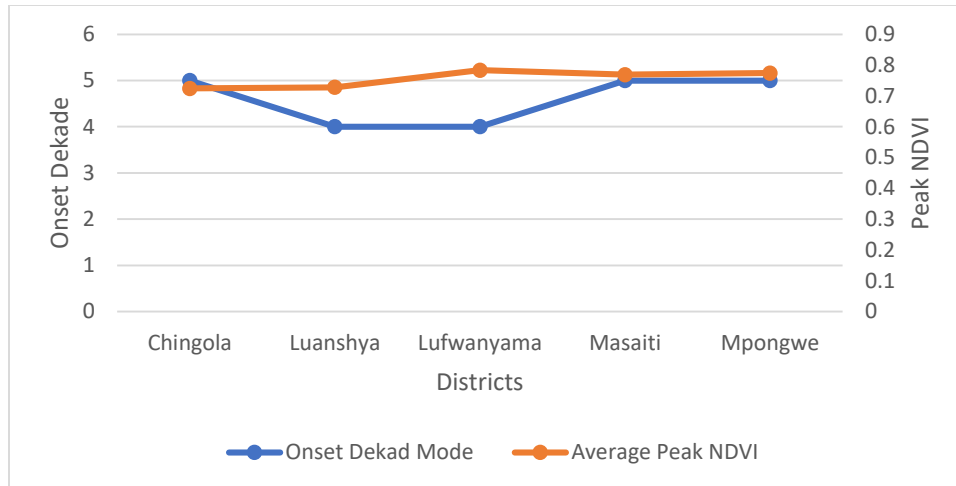


Figure 4.3.1.8: Summary of Onset Dekad and Peak NDVI for Districts of Copperbelt

The results in Figure 4.3.1.8 and Table 4.3.1.8 shows that the climatological Onset Dekad of the rainy season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 4<sup>th</sup> dekad for Luanshya and Lufwanyama districts and 5<sup>th</sup> dekad for Chingola, Masaiti and Mpongwe. The average peak NDVI with more than 0.7243 is in March suggesting to be the end of rainy season with a very Health vegetation.

#### 4.3.1.9. Summary Onset Dekads and Peak NDVI for Districts of Eastern Province

Three (3) districts in Eastern Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in Appendices 4.3.4

Table 4.3.1.9: Summary of Onset Dekad and Peak NDVI for Districts of Eastern Province

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Eastern	Chipata	6	0.7534
2	Eastern	Nyimba	5	0.7871
3	Eastern	Petauke	5	0.7464

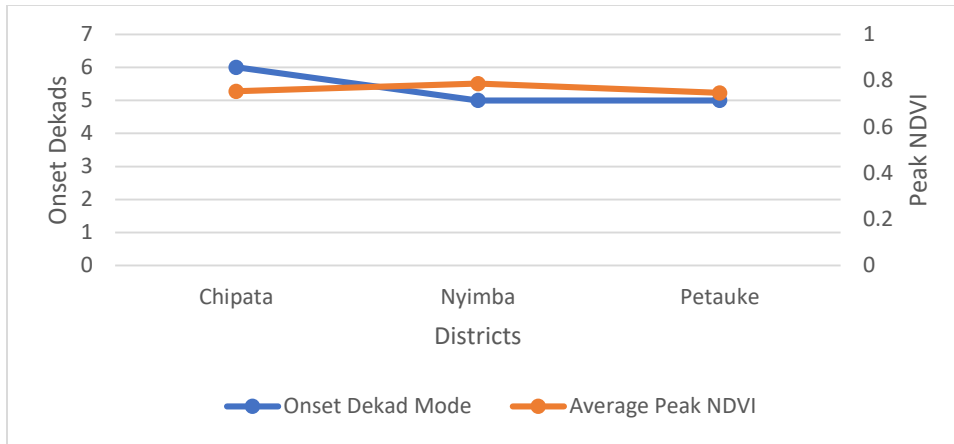


Figure 4.3.1.9: Summary of Onset Dekad and Peak NDVI for Districts of Eastern Province

The results in Figure 4.3.1.9 and Table 4.3.1.9 show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 5<sup>th</sup> dekad for Nyimba and Petauke districts and 6<sup>th</sup> dekad for Chipata district. The average peak NDVI with more than 0.7464 is in March suggesting to be the end of rainy season with a very Health vegetation.

**4.3.1.10. Summary Onset Dekads and Peak NDVI for Districts of Luapula Province**

Eight (8) districts in Luapula Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in Appendices 4.3.5

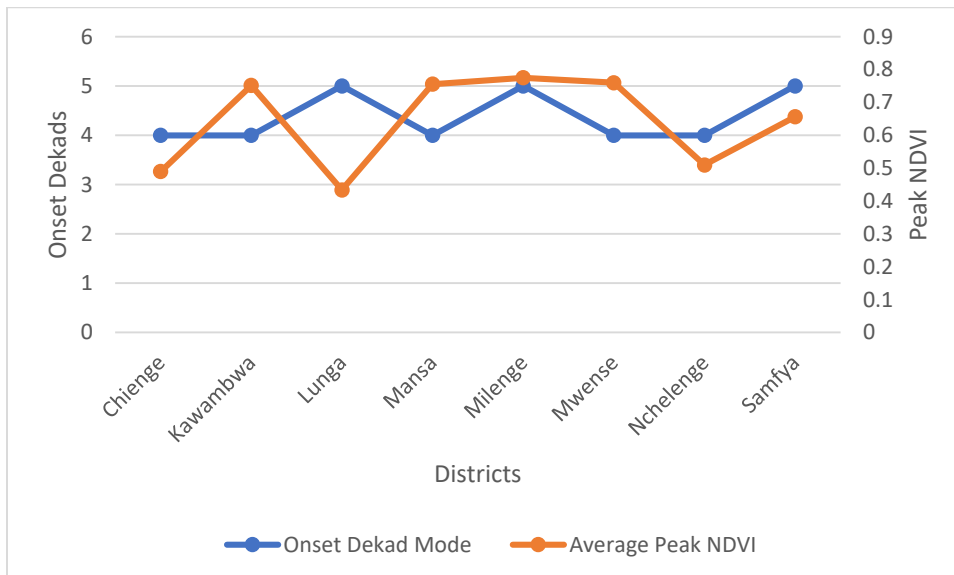


Figure 4.3.1.10: Summary of Onset Dekad and Peak NDVI for Districts of Luapula Province

Table 4.3.1.10: Summary of Onset Dekad and Peak NDVI for Districts of Luapula Province

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Luapula	Chienge	4	0.4898
2	Luapula	Kawambwa	4	0.7516
3	Luapula	Lunga	5	0.4337
4	Luapula	Mansa	4	0.7555
5	Luapula	Milenge	5	0.7751
6	Luapula	Mwense	4	0.7601
7	Luapula	Nchelenge	4	0.5096
8	Luapula	Samfya	5	0.6564

The results in *Figure 4.3.1.10* and *Table 4.3.1.10* show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 4<sup>th</sup> dekad for Chienge, Kawambwa, Mansa, Mwense and Nchelenge Districts. Further, for Lunga, Milenge and Samfya, the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 5<sup>th</sup> dekad. The average peak NDVI with more than 0.4337 is in March suggesting to be the end of rainy season with moderate health vegetation.

#### 4.3.1.11. Summary Onset Dekad and Peak NDVI for Districts of Northern Province

Two (2) districts in Northern Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in *Appendices 4.3.6*.

Table 4.3.1.11: Summary of Onset Dekad and Peak NDVI for Districts of Northern Province

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Northern	Kaputa	4	0.6981
2	Northern	Nsama	5	0.7453

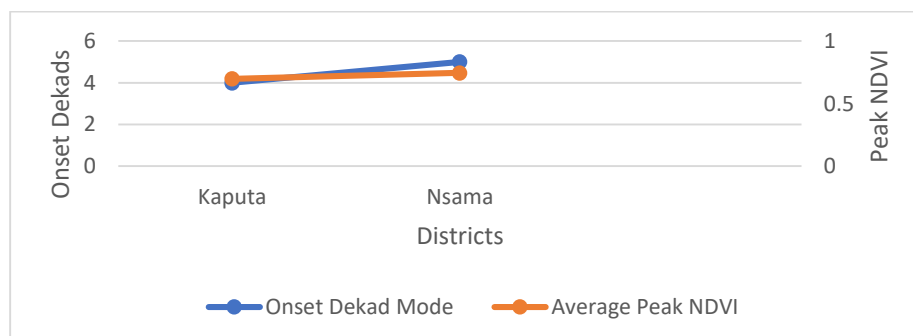


Figure 4.3.1.11: Summary of Onset Dekad for Districts of Northern Province

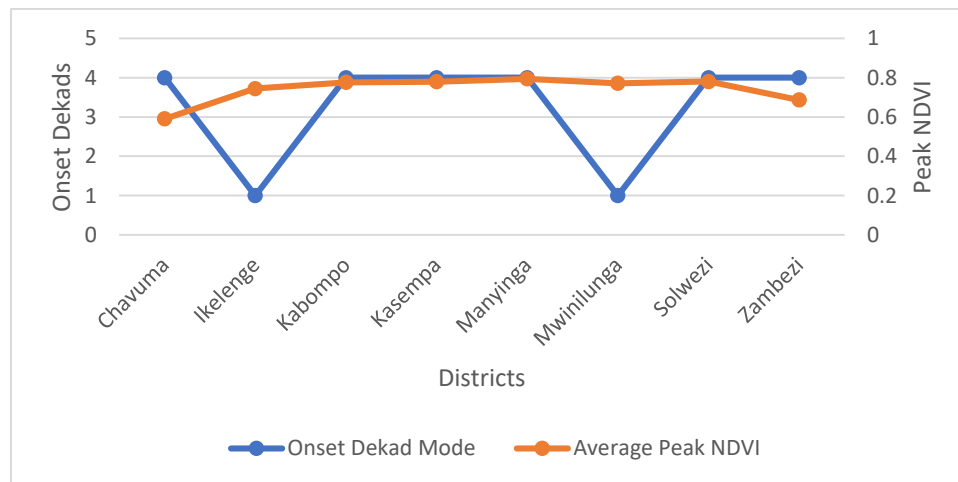
The results in *Figure 4.3.1.11* and *Table 4.3.1.11* show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from 1<sup>st</sup> dekad to the 4<sup>th</sup> dekad for Kaputa district and 5<sup>th</sup> dekad for Nsama District. The average peak NDVI with more than 0.6981 is in March suggesting to be the end of rainy season with a health vegetation.

**4.3.1.12. Summary Onset Dekad and Peak NDVI for Districts of North Western Province**

Eight (8) districts in North Western Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in *Appendices 4.3.7*.

*Table 4.3.1.12: Summary of Onset Dekad and Peak NDVI for Districts of Northern Province*

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	North-Western	Chavuma	4	0.5909
2	North-Western	Ikelenge	1	0.7444
3	North-Western	Kabompo	4	0.7759
4	North-Western	Kasempa	4	0.7798
5	North-Western	Manyinga	4	0.7940
6	North-Western	Mwinilunga	1	0.7712
7	North-Western	Solwezi	4	0.7800
8	North-Western	Zambezi	4	0.6865



*Figure 4.3.1.12: Summary of Onset Dekad and Peak NDVI for Districts of Northern Province*

The results in *Figure 4.3.1.12* and *Table 4.3.1.12* show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has not shifted from the 1<sup>st</sup> dekad for Ikelenge and Mwinilunga. Further, the climatological Onset Dekad of the rain season has shifted from 1<sup>st</sup> dekad

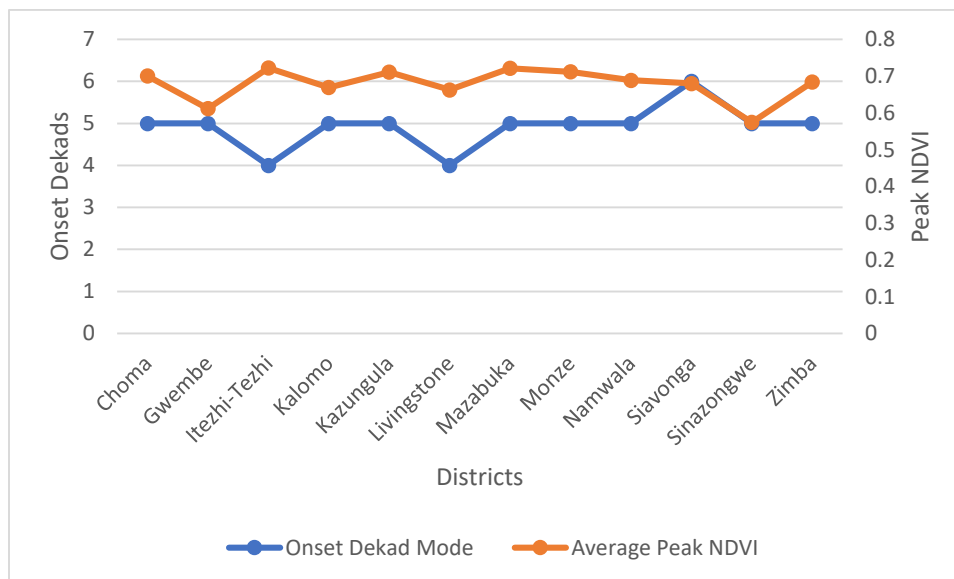
to the 4<sup>th</sup> dekad for Chavuma, Kabompo, Kasempa, Manyinga and Solwezi Districts. The average peak NDVI with more than 0.5909 is in March suggesting to be the end of rainy season with a moderate health vegetation.

**4.3.1.13. Summary Onset Dekads and Peak NDVI for Districts of Southern Province**

Twelve (12) districts in Southern Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in *Appendices 4.3.8*.

*Table 4.3.9.13: Summary of Onset Dekad and Peak NDVI for Districts of Southern Province*

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Southern	Choma	5	0.7005
2	Southern	Gwembe	5	0.6119
3	Southern	Itezhi-Tezhi	4	0.7225
4	Southern	Kalomo	5	0.6692
5	Southern	Kazungula	5	0.7111
6	Southern	Livingstone	4	0.6628
7	Southern	Mazabuka	5	0.7216
8	Southern	Monze	5	0.7118
9	Southern	Namwala	5	0.6887
10	Southern	Siavonga	6	0.6801
11	Southern	Sinazongwe	5	0.5745
12	Southern	Zimba	5	0.6839



*Figure 4.3.1.13: Summary of Onset Dekad and Peak NDVI for Districts of Southern Province*

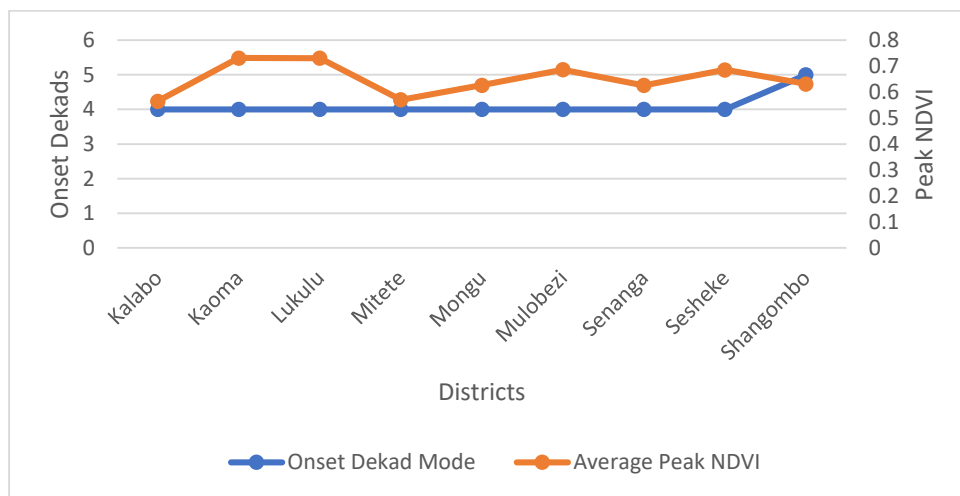
The results in *Figure 4.3.1.13* and *Table 4.3.1.13* show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has not shifted from the 1<sup>st</sup> dekad to 4<sup>th</sup> dekad for Itezhi-Tezhi and Livingstone districts. Further, the Onset Dekad shifted from the 1<sup>st</sup> dekad to 5<sup>th</sup> Dekad for Choma, Gwembe, Kalomo, Kazungula, Mazabuka, Monze, Namwala, Sinazongwe and Zimba Districts. Finally, the Onset Dekad shifted from the 1<sup>st</sup> dekad to the 6<sup>th</sup> dekad for Siavonga District in Southern Province. The average peak NDVI with more than 0.5909 is in March suggesting to be the end of rainy season with a moderate health vegetation.

**4.3.1.14. Summary Onset Dekad and Peak NDVI for Districts of Western Province**

In summary, Nine (9) districts in Western Province, were analyzed on their Onset Dekad of the rain season and Peak NDVI. More detailed results by districts are given in *Appendices 4.3.9*.

*Table 4.3.1.14: Summary of Onset Dekad and Peak NDVI for Districts of Western Province*

No.	Province	District	Onset Dekad Mode	Average Peak NDVI
1	Western	Kalabo	4	0.5649
2	Western	Kaoma	4	0.7312
3	Western	Lukulu	4	0.7309
4	Western	Mitete	4	0.5706
5	Western	Mongu	4	0.6269
6	Western	Mulobezi	4	0.6866
7	Western	Senanga	4	0.6260
8	Western	Sesheke	4	0.6860
9	Western	Shangombo	5	0.6313



*Figure 4.3.1.14: Summary of Onset Dekad and Peak NDVI for Districts of Western Province*

The results in *Figure 4.3.10.10* and *Table 4.3.10.10* show that the climatological Onset Dekad of the rain season for the period 2005 to 2021 has shifted from the 1<sup>st</sup> dekad to 4<sup>th</sup> dekad for Kalabo, Kaoma, Lukulu, Mitete, Mongu, Mulobezi, Seneanga and Sesheke Districts. The Onset Dekad shifted from the 1<sup>st</sup> dekad to the 5<sup>th</sup> dekad for Shangombo District in Western province. . The average peak NDVI with more than 0.5909 is in March suggesting to be the end of rainy season with a moderate health vegetation for all the districts in the province.

#### **4.4. Relationship between Onset Dekad and Peak NDVI for districts of Zambia**

Figures 4.3.1.1 to 4.3.1.4 indicate that generally delay in the onset of a rainy season (positive ODA) is associated with a negative SP-NDVI. This empirical relationship agrees with the fact that there is water deficit in a delayed onset rainy season (positive onset anomaly) which results in less dense plant growth leading to negative SP-NDVI. Hence a linear relationship between ODA and SP-NDVI is assumed and the Pearson correlation coefficient was calculated between these two variables using data for seasons from 2005/06 to 2020/21 for each district.

##### **4.4.1. AFI Status and correlations between ODA and SP-NDVI for Districts of Zambia**

AFI status of districts of Zambia has been published bi-annually by DMMU since 2018. So far the reporting has been done only six times. There are a few gaps in information in the data set. In each report, a district is assigned a number from 1,2,3,4 and 5 according to AFI status of the district during that particular half year period. Number 1 indicates very little food insecurity whereas 5 indicates very severe AFI as explained in *Table 1.2.1* in Chapter 1. The mode of AFI level for each district is classified as the AFI status of that district. In a situation of two modes, the worse AFI level is assigned to that district. Table 4.4.1 summarizes the district correlations and AFI status.

*Table 4.4.1* presents the correlation between ODA and SP-NDVI and AFI status for districts available in the study.

*Table 4.4.1: AFI status and correlations between ODA and SP-NDVI*

<b>BIN</b>	<b>District</b>	<b>Correlation between ODA and SP-NDVI</b>	<b>AFI Status</b>
1	Solwezi	0.073063833	2
1	Luanshya	0.23435505	2
1	Lufwanyama	0.166377521	2
1	Masaiti	0.186588643	2
1	Mpongwe	0.172371122	2
1	Chipata	-0.0247848	2
1	Mkushi	0.454808959	2

1	Mansa	0.109890909	2
1	Lusaka	-0.436851008	2
1	Mwense	-0.017376735	2
1	Nchelenge	0.276426137	2
1	Kasempa	-0.119099848	2
1	Mwinilunga	-0.354929258	2
1	Namwala	-0.448185117	2
1	Itezhi-tezhi	0.339624261	2
1	Kapiri mposhi	0.368203117	2
1	Serenje	0.60387012	2
1	Mumbwa	0.048689715	2
1	Kawambwa	-0.015472628	2
1	Chongwe	0.374055402	2
1	Kafue	0.261472644	2
1	Kalomo	-0.304987015	2
2	Chibombo	0.129773996	3
2	Petauke	0.325192737	3
2	Chavuma	0.033839158	3
2	Zambezi	0.098099079	3
2	Kazungula	0.017565405	3
2	Monze	-0.437674985	3
2	Ikelenge	0.173915875	3
2	Manyinga	0.11035248	3
2	Zimba	0.188989782	3
2	Kalabo	-0.556260844	3
2	Samfya	0.299007966	3
2	Luangwa	0.101328798	3
2	Kabompo	0.195416212	3
2	Kaputa	-0.175612983	3
2	Mazabuka	-0.087083701	3
2	Siavonga	-0.127404652	3
2	Sinazongwe	-0.151785904	3
2	Kaoma	-0.166258734	3
2	Lukulu	-0.605105785	3
2	Mitete	-0.649743733	3
2	Mongu	-0.156174182	3
2	Mulobezi	0.333517887	3
2	Senanga	-0.001683904	3
2	Sesheke	0.189931138	3
2	Lunga	-0.097937708	3
2	Shangombo	0.00246558	3
3	Gwembe	-0.265462997	4

#### 4.4.2. Bins of Districts According to the AFI Status

The districts included in the study were binned together according to their AFI status. Only three AFI levels (AFI-2, AFI-3 and AFI-4) out of five defined AFI levels have been experienced as shown in Table 4.4.1. Bin 1 contains 22 districts which were classified AFI level 2, Bin 2 contains

26 districts which were classified AFI level 3 and Bin 3 contains 1 district which was classified AFI level 4.

The range of correlations between ODA and SP-NDVI for districts in each bin is shown in Figure 4.4.2 which confirms that correlations are towards the negative end of interval [-1, 1] for higher AFI levels (more severe AFI situation).

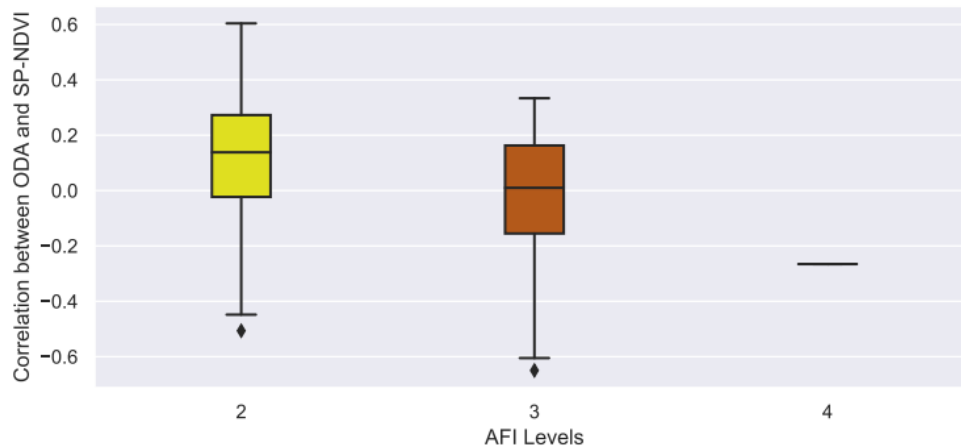


Figure 4.4.2: Box plot of correlations between ODA and SP-NDVI for districts in Bin 1(AFI Level2), Bin 2(AFI Level3) and Bin 3(AFI Level 4)

#### 4.4.3. Correlations between ODA and SP-NDVI for Bins

The Pearson correlation coefficient was calculated based on merged seasonal ODA and SP-NDVI for all the districts and all the seasons under study (2005/06 to 2020/21) for each Bin as shown in Table 4.4.2.

Table 4.4.3: Correlation between ODA and SP-NDVI for AFI BINS

Bin	AFI Level	Number of Districts	Correlation Coefficient between ODA and SP-NDVI
1	2	22	0.010296917
2	3	26	-0.014635695
3	4	1	-0.265462997

#### 4.5. AFI Risk levels Assignment for the districts of Zambia

A total of 49 districts were used to develop a system to determine AFI levels for districts of Zambia. These districts had all three types of data available namely climate, NDVI and AFI. It was found that 45% of the districts had AFI level 2, 53% of the districts had AFI level 3 and 2% of the districts had AFI level 4 (Table 4.4.3). Accordingly, to develop an AFI level assignment

system, the correlations interval  $[-1,1]$  was divided into three subintervals using the proportion of districts in each bin as explained in section 3.3.6. Subinterval 1 is  $[-1, -0.96)$ , subinterval 2 is  $[-0.96, 0.1)$  and subinterval 3 is  $[0.1, 1]$ . If the correlation between seasonal ODA and SP- NDVI for a district falls in subinterval 1 , the district is likely to experience AFI level 4, if the correlation falls in the subinterval 2, the district is likely to experience AFI of level 3 and if the correlation falls in subinterval 3 then the district is likely to experience AFI level 2. *Table 4.5* presents the correlation ranges for each of the three levels of AFI experienced in Zambia.

*Table 4.5: AFI assignment System for the districts of Zambia*

<b>Range of Correlations (r) Between ODA and SP-NDVI</b>	<b>AFI Level</b>
$-1 \leq r \leq -0.96$	4
$-0.96 < r \leq 0.1$	3
$0.1 < r \leq 1$	2

Table 4.4.3 show that the empirical correlation for AFI level 2 is 0.01029 which does not lie in the assigned range 0.1 to 1 of correlations for AFI level 2 disaster (Table 4.5). However, the empirical correlation for AFI level 3 is -0.0146 which lies in the assigned range -.96 to 0.1. Again, the observed correlation for AFI level 4 does not fall in the assigned range from -1 to -0.96. This discrepancy is attributed to the fact that the study is constrained by very limited data. There was only one district in bin 3. In subsequent years, when more AFI data is available, the agreement between empirical correlations and theoretical ranges of correlations for AFI levels is likely to improve. Also as climate change is getting more intense, AFI level 5 might be experienced in future in Zambia.

#### **4.6. Discussion of Findings**

This section presents a discussion on relating results of this study with the results from other studies, interpreting the meaning of results and the implications in real life among other issues in respect to specific objectives. The section has four parts, the first part presents discussion of findings on assessment of CHIRPS data against the observed rainfall Station data of ZMD taking Lusaka and Livingstone as sample stations. The second part presents discussion of findings on the criteria to determine Onset Dekadof a raining season as well as the peak NDVI for the districts of Zambia. The third Part presents discussion on the correlations between Onset Dekad and peak NDVI for the districts of Zambia. Last but not the least part presents discussion on the assignment

of AFI risk levels to the districts of Zambia based on Onset Dekad and peak NDVI of a rainy season.

#### **4.6.1. Discussion on Ability of CHIRPS data in reproducing Zambia Rainfall**

The patterns of monthly rainfall cycle in Central Agro-Ecological Region in Zambia represented by Lusaka, Southern Agro-Ecological Region in Zambia represented by Livingstone district, and Northern Agro-Ecological Region in Zambia represented by Mansa district were the same for both CHIRPS and ZMD Station data for the period 1990 to 2019. These results are in line with in line with Mulungu & Mukama (2022) who established that CHIRPS data were proved to be the same as ground rainfall data observations during 1990–2015 in Ruvu subbas in Tanzania. The peak of rainy season for both CHIRPS and ZMD Station data was in the month of January for all the three Agro-Ecological Region. CHIRPS data for all the three Agro-Ecological Region indeed captured the October-April climatological rainy season for Zambia. The findings are also in line with Naikson et al (2022)'s study on validating the CHIRPS rainfall estimation data with observation rainfall data at the Central MKG Region I Medan that established that CHIRPS was able to detect rain events based on a threshold of 1 mm.

The Pearson Correlation coefficients between CHIRPS & ZMD Station data for Central Agro-Ecological Regions shows a strong positive relationship at 5% level of significant which is in line with, Mulungu & Mukama (2022) who showed that CHIRPS monthly data correlated well with ground rainfall observations with Pearson correlation coefficient greater than 0.7. There is a strong relationship between CHIRPS and ZMD Station data in Zambia.

These results suggest that CHIRPS is a good estimator of ZMD Station data in Zambia. CHIRPS is able to reproduce the climatology of Zambia. ZMD station data is limited to about 39 stations in Zambia with a lot of missing data, CHIRPS data is a good option in place of ZMD Data for further investigations of rain patterns in Zambia.

#### **4.6.2. Discussion on Onset Dekad and Peak NDVI for districts of Zambia**

The climatological Onset Dekad of the rain season in the districts of Zambia for the period 2005/06 to 2020/21 has shifted from 1<sup>st</sup> dekad to either 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup> or further Dekad which is in agreement with Ddumba, Kayanja, & Stastna (2012) who established that the primary effect of future climate change in equatorial Africa will be a shift of the timing of the rainy season and an increase in the incidence of violent rain events. These results are also in line with Kapila, Kabwe

& Mubanga (2022) who established that the onset date of the rain season in Zambia are 19<sup>th</sup> 17<sup>th</sup> and 16<sup>th</sup> November. Further, the Peak NDVI for the districts in Zambia for the period 2005 to 2021 was in the month March which is considered to be the EoS which is also in agreement with Kapila, Kabwe & Mubanga (2022) who revealed that on average, 19<sup>th</sup> March experiences the latest cessation of the rainy season.

These results means that the climatology of Zambia has reduced by at least two months. The climatology of Zambia is October to April, but these results shows that the rains effectively start toward the end of November and stops in March. All the faming that depend of rain irrigation should consider the option of medium and early maturity seeds for a better crop yield.

#### **4.6.3. Discussion on Correlation between ODA and SP-NDVI for districts of Zambia**

AFI 2 bin 1 had a positive weak correlation between ODA and SP-NDVI of 0.010296917 while AFI 3 bin 2 AFI 4 bin 3 had a weak negative correlations between ODA and SP-NDVI of -0.014635695 and -0.265462997 respectively. These results are expected to improve as Zambia generates more data on AFI. The results are in line with Shukla et al (2021) that revealed that the Onset Dekad can effectively explain much of the inter-annual variability in peak NDVI in the regions with the highest AFI risk level, particularly where the median of correlation (across all the Administrative Unit 2) varies between -0.42 to -0.68.

The positive correlations between ODA and SP-NDVI, points to low AFI and the negative correlations between ODA and SP-NDVI points to high AFI. These results means that, the more the rains delays to start, the poor the health of the vegetation which leads to the poor cropping environment and eventually affecting the crop yield. The crop yield affects the AFI of the district, province and the country at large.

#### **4.6.4. Discussion of AFI risk levels assignment to the districts of Zambia**

Using *Table 4.5* as a key or tool to assignment of AFI risk levels in this study, 70% of the district in *Figure 3.2* were assigned to AFI level 2 which means that generally, most of the Households in those districts are expected to have minimally adequate food consumption but are unable to afford some essential non-food expenditures a situation referred to as (**Stressed**). This is in line with Ddumba, et al (2012) that established that the primary effect of future climate change in equatorial Africa will be a shift of the timing of the rainy season and an increase in the incidence of violent rain events which will be a driver of potentially disastrous low yields which eventually will affect

the food security. Similarly, 30% of the district in *Figure 3.2* were assigned to AFI level 3 which means Households either have food consumption gaps or are marginally able to meet minimum food needs a situation referred as **(Crisis)**. These findings are in line with IPC (2021) reports which showed that 37 out of 64 districts that were analyzed by DMMU on AFI were classified in Crisis (IPC Phase 3). Therefore, as indicated by Kiran & Jabbar (2022), policy makers should consider both the density of affected population and incidence of food insecurity in terms of Integrated Food Security Phase Classification (IPC) for targeted interventions.

The results suggest that most districts are able to have three meals a day although not able to meet the nonfood needs. A few districts are struggling to meet the food needs. With the delay in the onset of the rainy season, most district are likely experience challenge to meet the food needs. Therefore, the study provides and early warning system for early response to this crisis.

## **CHAPTER 5: CONCLUSIONS AND RECOMENDATIONS**

### **5.1. Introduction**

This chapter presents the conclusions and recommendations in respect to specific objectives. The chapter has two sections (conclusions and recommendations) with further four sub-sections. The first sub-section covers the ability of CHIRPS data in representing the rainfall climatology of Zambia. The second sub-section covers the onset of a raining season as well as the peak NDVI for the districts of Zambia. The third section statistical relationship between onset dekad and peak NDVI for the districts of Zambia. Last but not the least sub-section presents discussion on an early warning system to determine AFI levels in the districts of Zambia much before a drought stricken season ends to allow timely action to reduce sufferings of communities.

### **5.2. Ability of CHIRPS data Conclusion in the districts of Zambia**

The CHIRPS data has the ability to reproduce the October-April climatological rainy season for all districts in Zambia. The peak of rainy season for both CHIRPS and ZMD Station data was in the month of January. There is a strong positive relationship between CHIRPS & ZMD Station data suggesting a strong similarity between CHIRPS & ZMD Station data at 5% level of significance. Hence, it was concluded that CHIRPS data has the ability to represent the rainfall climatology of Zambia.

### **5.3. Conclusion on Onset Dekad Anomalies and Peak NDVI for Districts of Zambia**

In the districts of Zambia, the climatological onset dekad of the rain season has shifted from 1<sup>st</sup> dekad to further dekads except for Ikelenge and Mwinilunga districts where the onset dekad has remained 1<sup>st</sup> dekad of the raining season. Further, the EoS or cessation of the rain season has shifted from April to Mar of the Climatological year because the Peak NDVI for the districts were in the month March for all districts in *Figure 3.2*. There has been AFI different levels of severity in the districts of Zambia in the past few years, driven by delayed onset and EoS of rainy season. The AFI is classified into five levels. Level five refers to very severe AFI that is total catastrophe. Many times, the severity of AFI in the districts is felt much after the cropping season ends and consequently adequate aide to communities is delivered late.

### **5.4. Relationship between Onset and peak NDVI Conclusions for districts of Zambia**

The study has empirically concluded that for a rainy season, any shift in Onset Dekadis negatively correlated with the peak NDVI. Furthermore, it is seen that the lower the correlation between Onset Dekadshift and peak NDVI is, the worse the AFI level. Further it was concluded that, empirically,

AFI 2 in bin 1 has a positive correlation of 0.010296917 while AFI 3 in bin 2 and AFI 4 in bin 3 has a negative correlation -0.014635695 and -0.265462997 respectively between ODA and SP-NDVI as shown in *Table 4.4.1*. A positive correlation between ODA and SP-NDVI means little stress on AFI where as a negative correlation between ODA and SP-NDVI means more stress on AFI. Therefore, the positive the ODA, the lower the NDVI, the strong the negative correlation between ODA and SP-NDVI and the high the AFI risk.

### **5.5. AFI risk levels assignment Conclusions to the districts of Zambia**

This study has attempted to devise an early warning system empirically which can assess the severity of AFI in districts of Zambia much before the cropping season ends. This early warning system can allow national disaster aid agencies such as DMMU to prepare adequately and timely much needed assistance to AFI stricken districts. After applying the devised early warning system to the districts in *Figure 3.2*, 70% of the districts were assigned to AFI level 2 subinterval 3 (0.1, 1] where the households in those districts are expected to have minimally adequate food consumption but are unable to afford some essential non-food expenditures a situation referred to as **(Stressed)**. Further, 30% of the district in *Figure 3.2* were assigned to AFI level 3 subinterval 2 (-0.96, 0.1] where households either have food consumption gaps or are marginally able to meet minimum food needs a situation referred as **(Crisis)**. No districts were assigned to AFI level 4 subinterval 1 [-1, -0.96] The AFI occurs at different levels of severity in the national districts. So far, no study has addressed AFI severity at district level. The proposed early warning system addresses the AFI severity at district levels in Zambia.

### **5.6. Recommendations**

- 5.6.1. Zambia Meteorological Department has limited rainfall data. It has less than 40 stations for which longer than 30 years daily rainfall time series is available. CHIRPS data can be used for any study requiring rainfall daily data for the districts of Zambia.
- 5.6.2. Research is needed to modify existing criteria for onset of rainy season in Southern Africa, particularly in Zambia on the face of climate change which has altered rainfall patterns.
- 5.6.3. The early warning system developed in this research to determine AFI levels in the districts of Zambia during a delayed rainfall season is constrained by limited data on rainfall, NDVI and DMMU droughts reports. There is need to revise the results after about five years when more data is available.

5.6.4. Policy makers should consider early warning system for both the density of affected population and incidence of food insecurity in terms of Integrated Food Security Phase Classification (IPC) for early targeted interventions.

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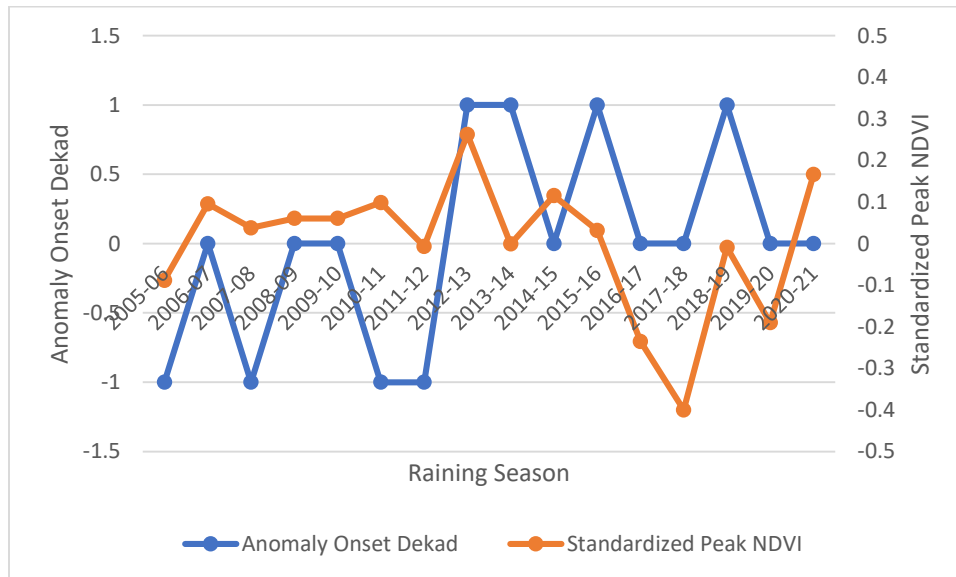
**Appendices**

**Appendices 4.3.2: Onset Dekads and Peak NDVI for Districts of Central Province**

**Appendix 4.3.2.1 Onset Dekads and Peak NDVI for Chibombo district**

*Table 4.3.2.1: Onset Dekad and Peak NDVI for Chibombo District*

Year	Onset Dekad	Onset Anomaly	Feb - Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.6945	-0.08822
2006-2007	5	0	0.7247	0.09567
2007-2008	4	-1	0.7152	0.037824
2008-2009	5	0	0.7189	0.060354
2009-2010	5	0	0.7189	0.060354
2010-2011	4	-1	0.7252	0.098715
2011-2012	4	-1	0.7079	-0.00663
2012-2013	6	1	0.7521	0.262511
2013-2014	6	1	0.7088	-0.00115
2014-2015	5	0	0.7279	0.115155
2015-2016	6	1	0.7142	0.031735
2016-2017	5	0	0.6703	-0.23558
2017-2018	5	0	0.6433	-0.39998
2018-2019	6	1	0.7075	-0.00906
2019-2020	5	0	0.6777	-0.19052
2020-2021	5	0	0.7363	0.166304
2021-2022	6	1	0.7094	0.002507

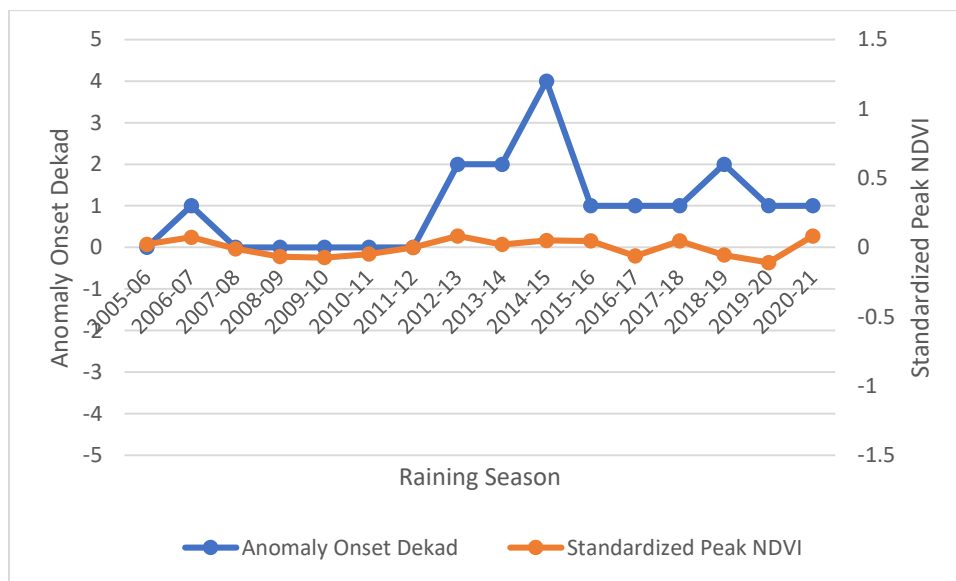


*Figure 4.3.2.1: ODA and SP-NDVI for Chibombo District*

**Appendix 4.3.2.2: Onset Dekads and Peak NDVI for Kapiri Mposhi district**

*Table 4.3.2.2: Onset Dekad and Peak NDVI for Kapiri Mposhi District*

Year	Onset Dekad	Onset Anomaly	Mar- Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7333	0.022284
2006-2007	5	1	0.742	0.072885
2007-2008	4	0	0.7277	-0.01029
2008-2009	4	0	0.7181	-0.06612
2009-2010	4	0	0.7168	-0.07368
2010-2011	4	0	0.7212	-0.04809
2011-2012	4	0	0.7294	-0.0004
2012-2013	6	2	0.7437	0.082773
2013-2014	6	2	0.7332	0.021702
2014-2015	8	4	0.738	0.04962
2015-2016	5	1	0.7374	0.04613
2016-2017	5	1	0.7189	-0.06147
2017-2018	5	1	0.7375	0.046712
2018-2019	6	2	0.7201	-0.05449
2019-2020	5	1	0.7106	-0.10975
2020-2021	5	1	0.7436	0.082191



*Figure 4.3.2.2: ODA and SP-NDVI for Kapiri Mposhi District*

**Appendix 4.3.2.3: Onset Dekads and Peak NDVI for Mkushi district**

Table 4.3.2.3: Onset Dekad and Peak NDVI for Mkushi District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	0	0.7376	-0.04049
2006-2007	5	-1	0.7569	0.069183
2007-2008	4	-2	0.7481	0.019178
2008-2009	5	-1	0.7458	0.006109
2009-2010	4	-2	0.7396	-0.02912
2010-2011	6	0	0.7477	0.016905
2011-2012	4	-2	0.7177	-0.15357
2012-2013	7	1	0.7529	0.046454
2013-2014	6	0	0.7673	0.128281
2014-2015	8	2	0.7474	0.0152
2015-2016	6	0	0.7565	0.06691
2016-2017	5	-1	0.7186	-0.14845
2017-2018	5	-1	0.7513	0.037362
2018-2019	6	0	0.7279	-0.09561
2019-2020	5	-1	0.7208	-0.13595
2020-2021	7	1	0.7795	0.197606

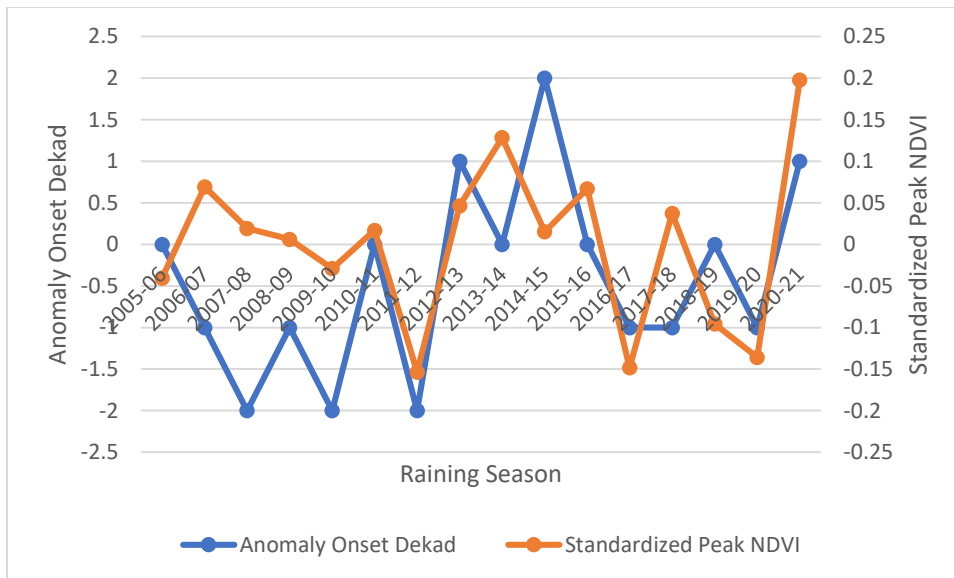
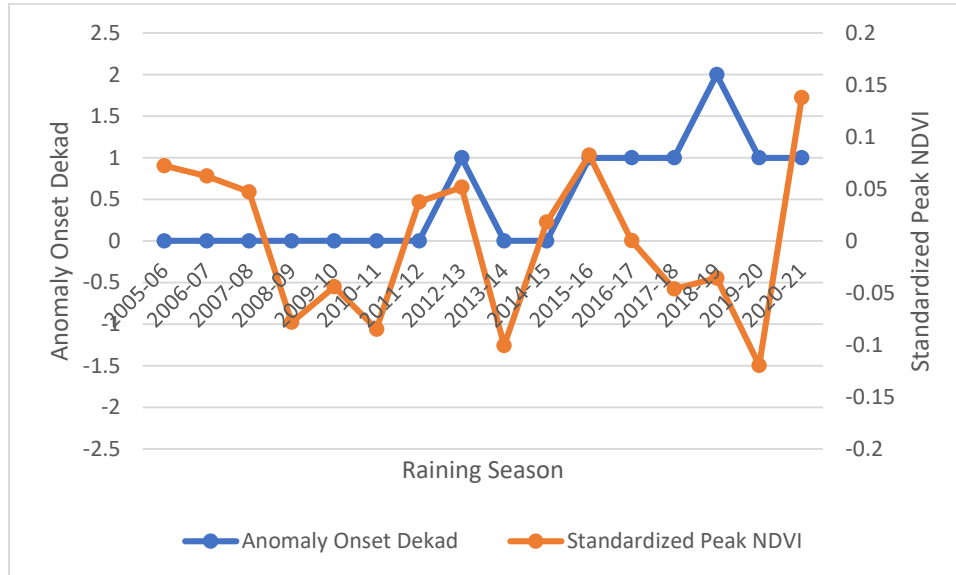


Figure 4.3.2.3: ODA and SP-NDVI for Mkushi District

**Appendix 4.3.2.4 Onset Dekads and Peak NDVI for Mumbwa District**

*Table 4.3.2.4: Onset Dekad and Peak NDVI for Mumbwa District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7698	0.072395
2006-2007	4	0	0.768	0.062313
2007-2008	4	0	0.7653	0.04719
2008-2009	4	0	0.7429	-0.07828
2009-2010	4	0	0.749	-0.04411
2010-2011	4	0	0.7417	-0.085
2011-2012	4	0	0.7636	0.037668
2012-2013	5	1	0.7661	0.051671
2013-2014	4	0	0.7389	-0.10068
2014-2015	4	0	0.7601	0.018064
2015-2016	5	1	0.7716	0.082477
2016-2017	5	1	0.7569	0.00014
2017-2018	5	1	0.7486	-0.04635
2018-2019	6	2	0.7505	-0.03571
2019-2020	5	1	0.7355	-0.11973
2020-2021	5	1	0.7815	0.137929

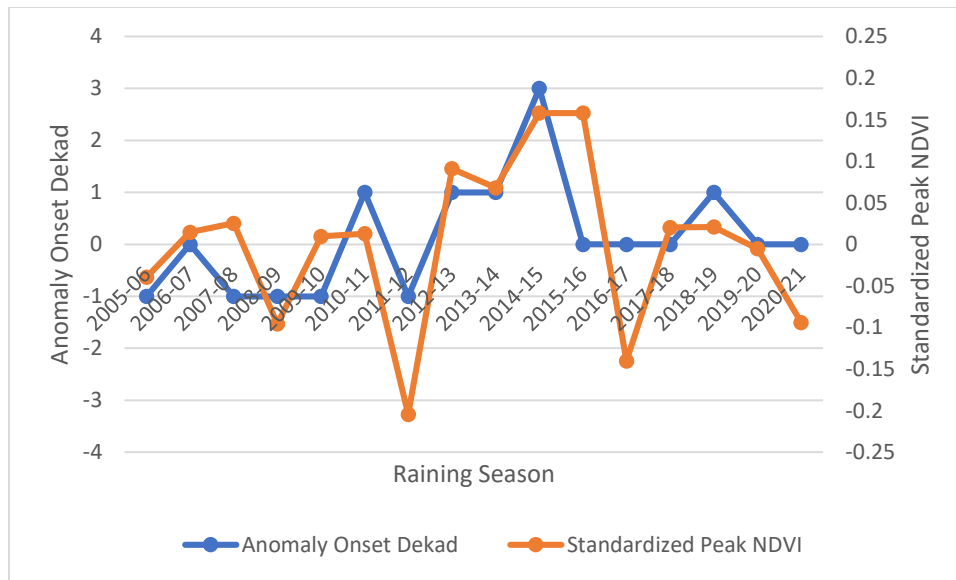


*Figure 4.3.2.4: ODA and SP-NDVI for Mumbwa District*

**Appendix 4.3.2.5: Onset Dekads and Peak NDVI for Serenje District**

*Table 4.3.2.5: Onset Dekad and Peak NDVI for Serenje District*

Year	Onset Dekad	Onset Anomaly	Mar- Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7369	-0.0394
2006-2007	5	0	0.7464	0.01465
2007-2008	4	-1	0.7483	0.025459
2008-2009	4	-1	0.727	-0.09572
2009-2010	4	-1	0.7455	0.009529
2010-2011	6	1	0.7461	0.012943
2011-2012	4	-1	0.7079	-0.20438
2012-2013	6	1	0.7598	0.090884
2013-2014	6	1	0.7558	0.068128
2014-2015	8	3	0.7716	0.158016
2015-2016	5	0	0.7716	0.158016
2016-2017	5	0	0.7192	-0.1401
2017-2018	5	0	0.7474	0.020339
2018-2019	6	1	0.7475	0.020908
2019-2020	5	0	0.7429	-0.00526
2020-2021	5	0	0.7273	-0.09401



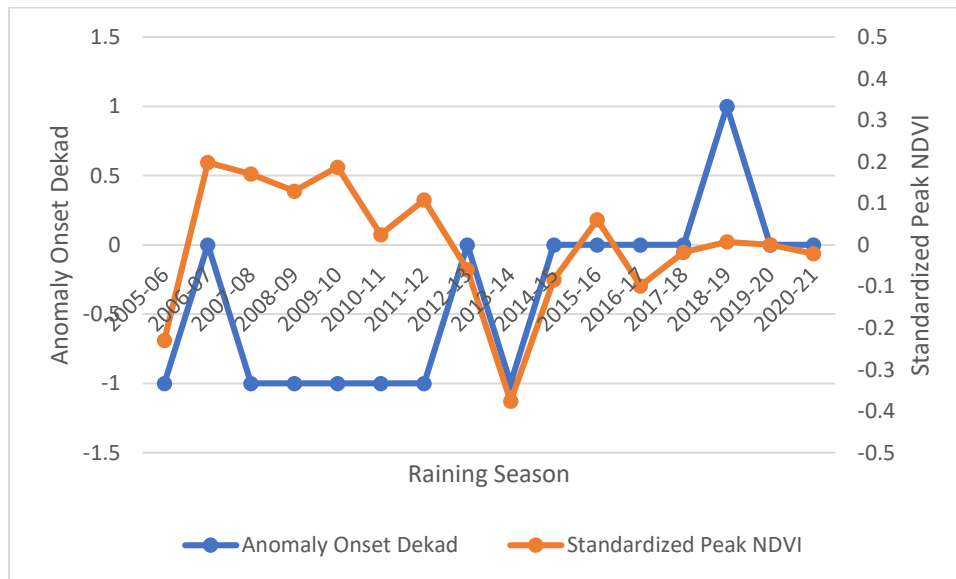
*Figure 4.3.2.5: ODA and SP-NDVI for Serenje District*

**Appendices 4.3.3: Onset Dekads and Peak NDVI for Districts of Copperbelt Province**

**Appendix 4.3.3.1: Onset Dekads and Peak NDVI for Chingola District**

*Table 4.3.3.1: Onset Dekad and Peak NDVI for Chingola District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.6848	-0.22913
2006-2007	5	0	0.7584	0.198279
2007-2008	4	-1	0.7536	0.170404
2008-2009	4	-1	0.7465	0.129173
2009-2010	4	-1	0.7565	0.187245
2010-2011	4	-1	0.7285	0.024644
2011-2012	4	-1	0.7429	0.108267
2012-2013	5	0	0.714	-0.05956
2013-2014	4	-1	0.6595	-0.37605
2014-2015	5	0	0.7098	-0.08395
2015-2016	5	0	0.7347	0.060649
2016-2017	5	0	0.7073	-0.09847
2017-2018	5	0	0.7212	-0.01775
2018-2019	6	1	0.7255	0.007223
2019-2020	5	0	0.7243	0.000254
2020-2021	5	0	0.7206	-0.02123

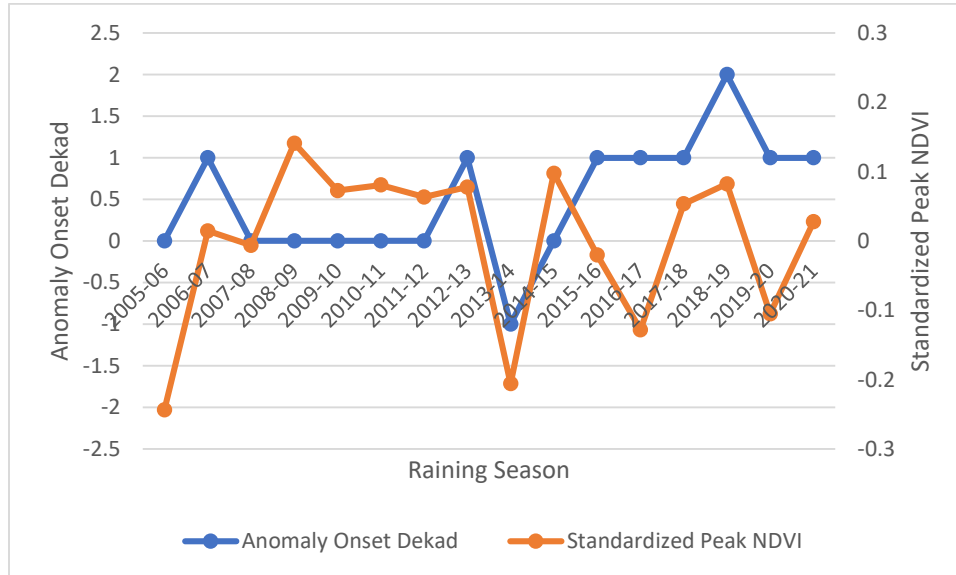


*Figure 4.3.3.1: ODA and SP-NDVI for Chingola District*

**Appendix 4.3.3.2: Onset Dekads and Peak NDVI for Luanshya District**

*Table 4.3.3.2: Onset Dekad and Peak NDVI for Luanshya District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.6859	-0.24391
2006-2007	5	1	0.7304	0.014441
2007-2008	4	0	0.7268	-0.00646
2008-2009	4	0	0.7522	0.141003
2009-2010	4	0	0.7404	0.072497
2010-2011	4	0	0.7418	0.080625
2011-2012	4	0	0.7388	0.063208
2012-2013	5	1	0.7413	0.077722
2013-2014	3	-1	0.6924	-0.20617
2014-2015	4	0	0.7447	0.097461
2015-2016	5	1	0.7244	-0.02039
2016-2017	5	1	0.7058	-0.12838
2017-2018	5	1	0.7371	0.053339
2018-2019	6	2	0.7421	0.082367
2019-2020	5	1	0.7098	-0.10515
2020-2021	5	1	0.7327	0.027794

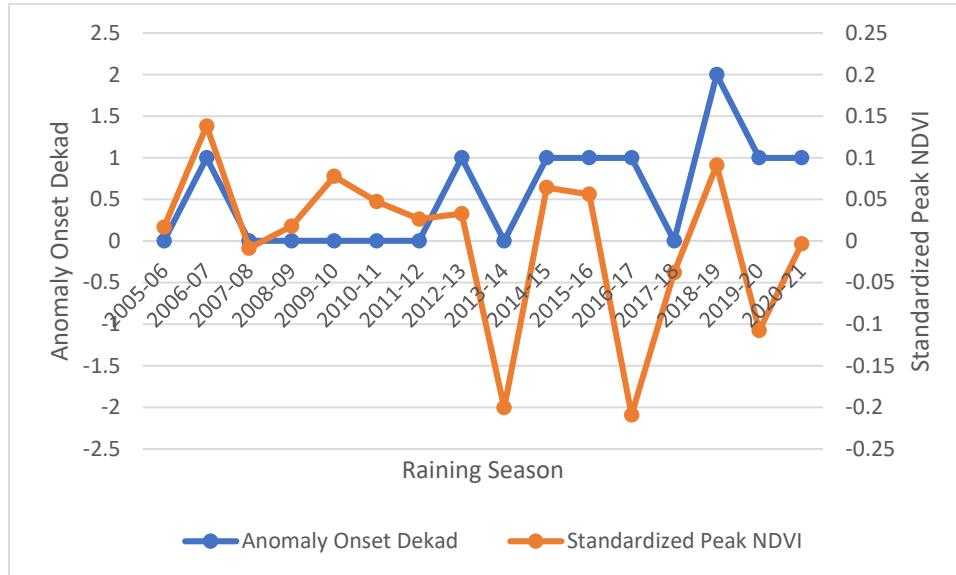


*Figure 4.3.3.2: ODA and SP-NDVI for Luanshya District*

**Appendix 4.3.3.3: Onset Dekads and Peak NDVI for Lufwanyama District**

*Table 4.3.3.3: Onset Dekad and Peak NDVI for Lufwanyama District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7865	0.016578
2006-2007	5	1	0.809	0.138125
2007-2008	4	0	0.7818	-0.00881
2008-2009	4	0	0.7867	0.017658
2009-2010	4	0	0.7978	0.077621
2010-2011	4	0	0.7922	0.04737
2011-2012	4	0	0.7883	0.026301
2012-2013	5	1	0.7895	0.032784
2013-2014	4	0	0.7463	-0.20059
2014-2015	5	1	0.7953	0.064116
2015-2016	5	1	0.7938	0.056013
2016-2017	5	1	0.7447	-0.20923
2017-2018	4	0	0.7764	-0.03798
2018-2019	6	2	0.8003	0.091126
2019-2020	5	1	0.7635	-0.10767
2020-2021	5	1	0.7828	-0.00341

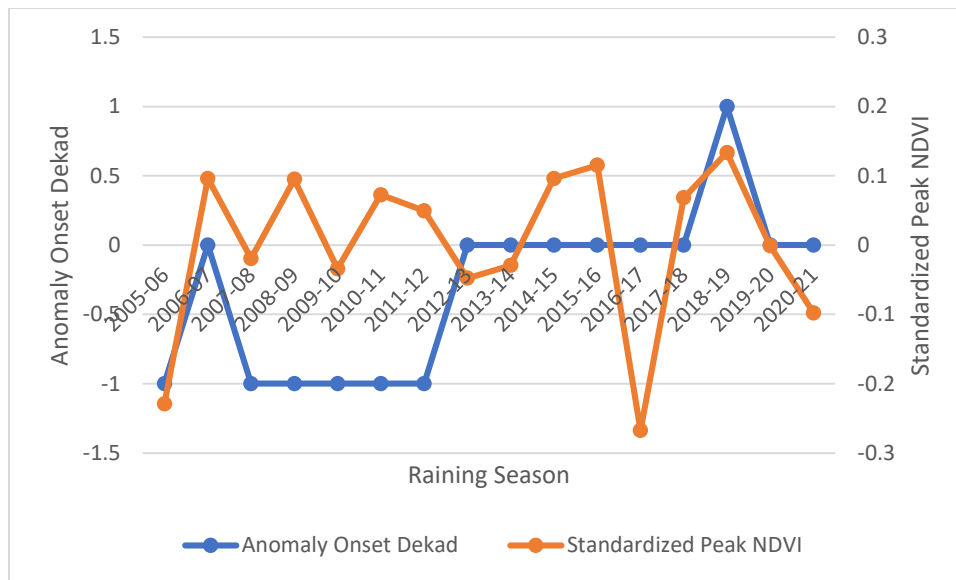


*Figure 4.3.3.3: ODA and SP-NDVI for Lufwanyama District*

**Appendix 4.3.3.4: Onset Dekads and Peak NDVI for Masaiti District**

*Table 4.3.3.4: Onset Dekad and Peak NDVI for Masaiti District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7271	-0.22913
2006-2007	5	0	0.7863	0.096109
2007-2008	4	-1	0.7653	-0.01926
2008-2009	4	-1	0.7861	0.09501
2009-2010	4	-1	0.7626	-0.0341
2010-2011	4	-1	0.782	0.072485
2011-2012	4	-1	0.7778	0.049411
2012-2013	5	0	0.7601	-0.04783
2013-2014	5	0	0.7635	-0.02915
2014-2015	5	0	0.7863	0.096109
2015-2016	5	0	0.7898	0.115338
2016-2017	5	0	0.7201	-0.26759
2017-2018	5	0	0.7812	0.06809
2018-2019	6	1	0.7931	0.133468
2019-2020	5	0	0.7686	-0.00113
2020-2021	5	0	0.751	-0.09783



*Figure 4.3.3.4: ODA and SP-NDVI for Masaiti District*

### Appendix 4.3.3.5: Onset Dekads and Peak NDVI for Mpongwe District

Table 4.3.3.5: Onset Dekad and Peak NDVI for Mpongwe District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7782	0.022736
2006-2007	5	0	0.7967	0.124091
2007-2008	4	-1	0.7735	-0.00301
2008-2009	4	-1	0.7736	-0.00247
2009-2010	4	-1	0.7637	-0.0567
2010-2011	5	0	0.7714	-0.01452
2011-2012	4	-1	0.7791	0.027667
2012-2013	5	0	0.7812	0.039172
2013-2014	3	-2	0.7545	-0.10711
2014-2015	5	0	0.7798	0.031502
2015-2016	5	0	0.785	0.059991
2016-2017	5	0	0.748	-0.14272
2017-2018	4	-1	0.7838	0.053417
2018-2019	4	-1	0.7847	0.058348
2019-2020	5	0	0.7562	-0.09779
2020-2021	5	0	0.7754	0.007396

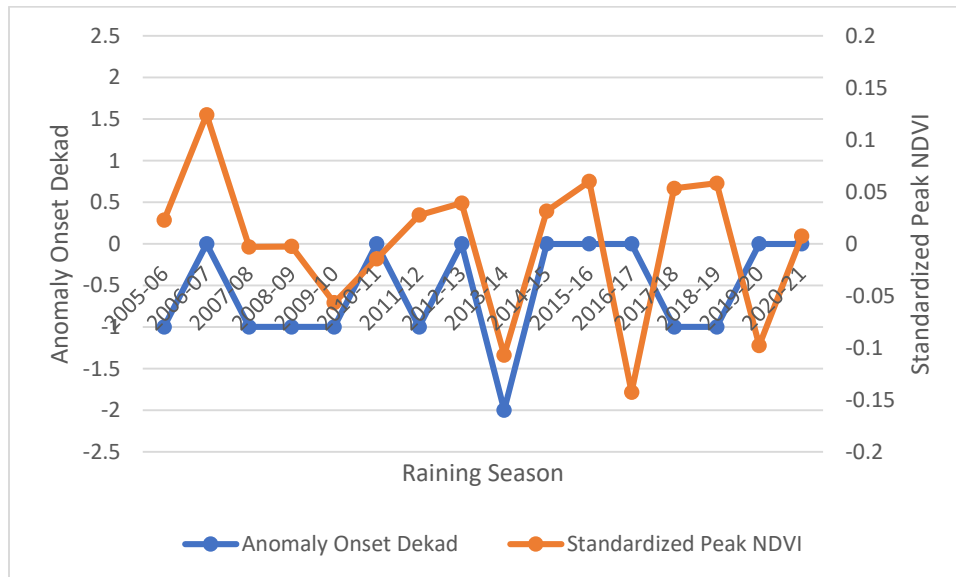


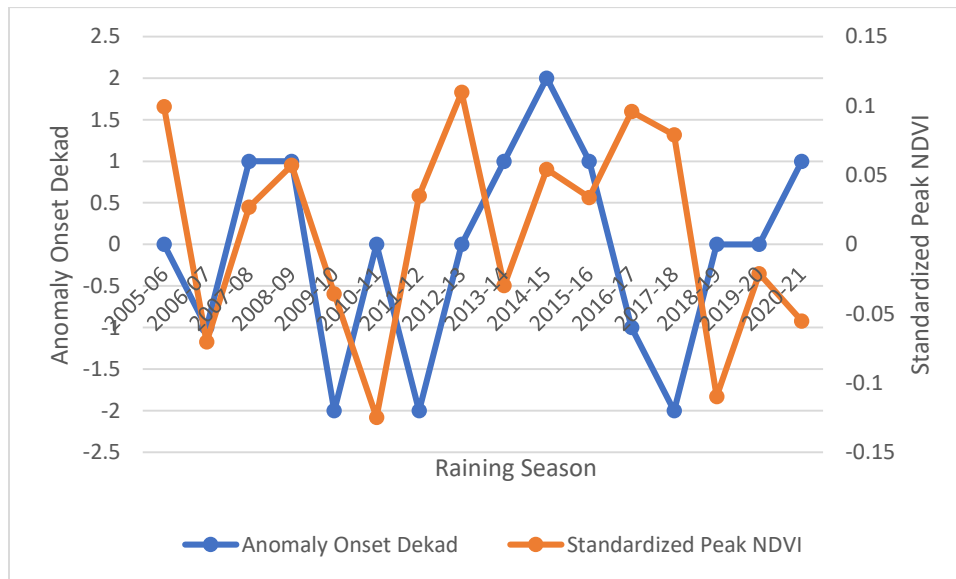
Figure 4.3.3.5: ODA and SP-NDVI for Mpongwe District

**Appendices 4.3.4: Onset Dekads and Peak NDVI for Districts of Eastern Province**

**Appendix 4.3.4.1: Onset Dekads and Peak NDVI for Chipata District**

*Table 4.3.4.1: Onset Dekad and Peak NDVI for Chipata District*

Year	Onset Dekad	Onset Anomaly	April Peak NDVI	Standardized Peak NDVI
2005-2006	6	0	0.769	0.099307
2006-2007	5	-1	0.7397	-0.07033
2007-2008	7	1	0.7565	0.026938
2008-2009	7	1	0.7617	0.057043
2009-2010	4	-2	0.7457	-0.03559
2010-2011	6	0	0.7303	-0.12475
2011-2012	4	-2	0.7579	0.035043
2012-2013	6	0	0.7708	0.109728
2013-2014	7	1	0.7467	-0.0298
2014-2015	8	2	0.7612	0.054149
2015-2016	7	1	0.7577	0.033886
2016-2017	5	-1	0.7684	0.095833
2017-2018	4	-2	0.7655	0.079043
2018-2019	6	0	0.7329	-0.10969
2019-2020	6	0	0.7482	-0.02111
2020-2021	7	1	0.7423	-0.05527



*Figure 4.3.4.1: ODA and SP-NDVI for Chipata District*

### Appendix 4.3.4.2: Onset Dekads and Peak NDVI for Nyimba District

Table 4.3.4.2: Onset Dekad and Peak NDVI for Nyimba District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7845	-0.01398
2006-2007	5	0	0.788	0.004886
2007-2008	4	-1	0.7776	-0.05118
2008-2009	5	0	0.7752	-0.06412
2009-2010	4	-1	0.7815	-0.03016
2010-2011	6	1	0.7921	0.02699
2011-2012	4	-1	0.7831	-0.02153
2012-2013	7	2	0.7974	0.055563
2013-2014	5	0	0.7962	0.049094
2014-2015	8	3	0.8041	0.091684
2015-2016	6	1	0.8068	0.106241
2016-2017	5	0	0.782	-0.02746
2017-2018	5	0	0.7887	0.00866
2018-2019	6	1	0.7744	-0.06843
2019-2020	5	0	0.7673	-0.10671
2020-2021	7	2	0.7946	0.040468

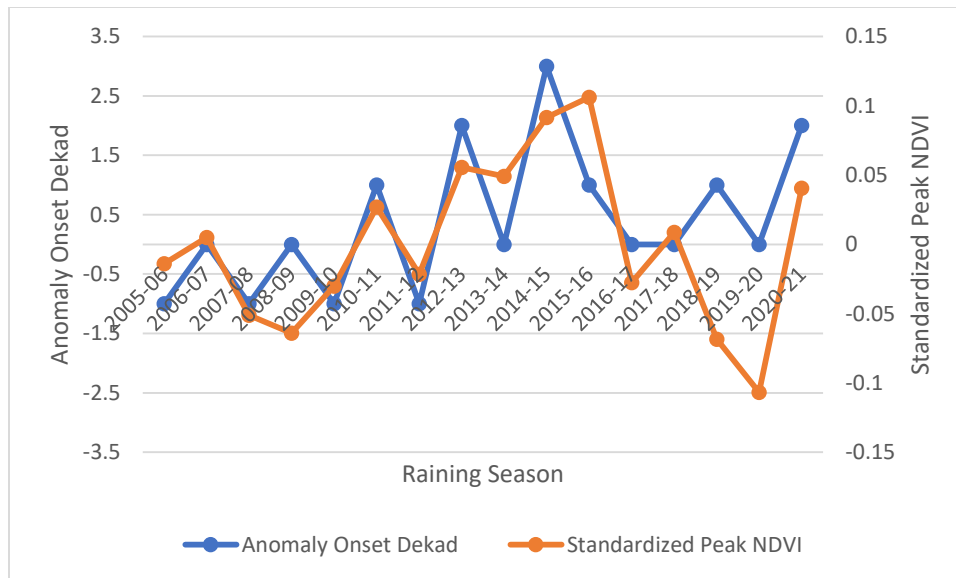


Figure 4.3.4.2: ODA and SP-NDVI for Nyimba District

### Appendix 4.3.4.3: Onset Dekads and Peak NDVI for Petauke District

Table 4.3.4.3: Onset Dekad and Peak NDVI for Petauke District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-2	0.7399	-0.03695
2006-2007	5	-1	0.7627	-0.13151
2007-2008	4	-2	0.7514	-0.19243
2008-2009	5	-1	0.7334	-0.28947
2009-2010	4	-2	0.7485	-0.20807
2010-2011	6	0	0.7665	-0.11103
2011-2012	6	0	0.7436	-0.23448
2012-2013	7	1	0.7534	-0.18165
2013-2014	7	1	0.7563	-0.16602
2014-2015	8	2	0.7525	-0.1865
2015-2016	8	2	0.7754	-0.06304
2016-2017	5	-1	0.7313	-0.3008
2017-2018	5	-1	0.7383	-0.26306
2018-2019	6	0	0.7295	-0.3105
2019-2020	6	0	0.6943	-0.50027
2020-2021	7	1	0.7658	-0.1148

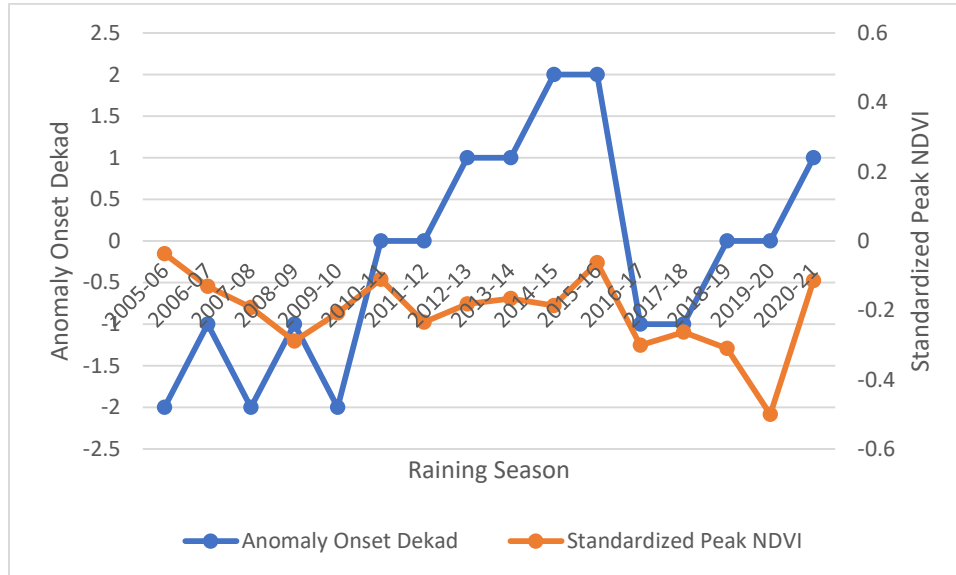


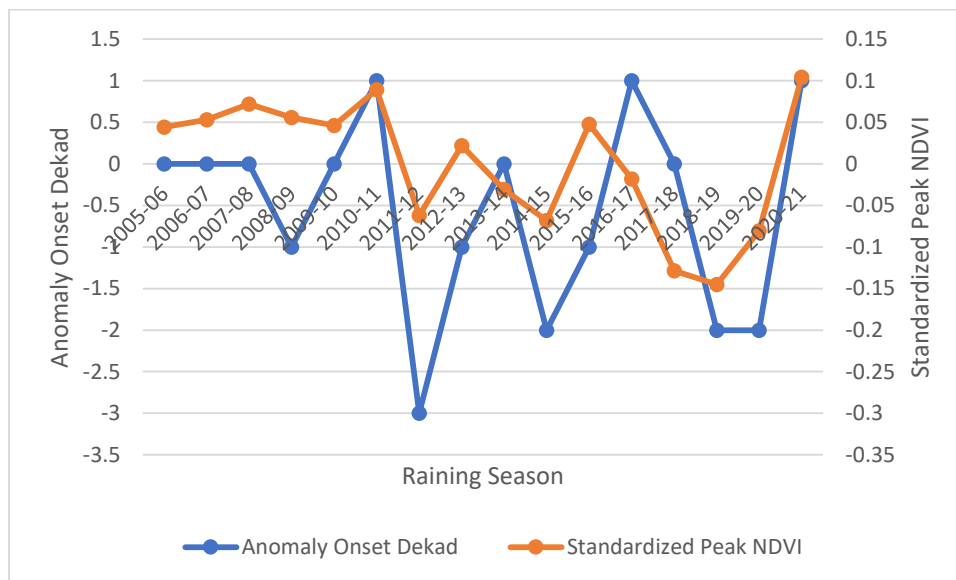
Figure 4.3.4.3: ODA and SP-NDVI for Petauke District

**Appendices 4.3.5: Onset Dekads and Peak NDVI for Districts of Luapula Province**

**Appendix 4.3.5.1: Onset Dekads and Peak NDVI for Chienge District**

*Table 4.3.5.1: Onset Dekad and Peak NDVI for Chienge District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.4949	0.044299
2006-2007	4	0	0.4959	0.052953
2007-2008	4	0	0.4981	0.071992
2008-2009	3	-1	0.4962	0.055549
2009-2010	4	0	0.4951	0.046029
2010-2011	5	1	0.5001	0.0893
2011-2012	1	-3	0.4826	-0.06215
2012-2013	3	-1	0.4923	0.021798
2013-2014	4	0	0.4862	-0.03099
2014-2015	2	-2	0.4819	-0.06821
2015-2016	3	-1	0.4953	0.04776
2016-2017	5	1	0.4877	-0.01801
2017-2018	4	0	0.4749	-0.12879
2018-2019	2	-2	0.473	-0.14523
2019-2020	2	-2	0.4805	-0.08032
2020-2021	5	1	0.5018	0.104012

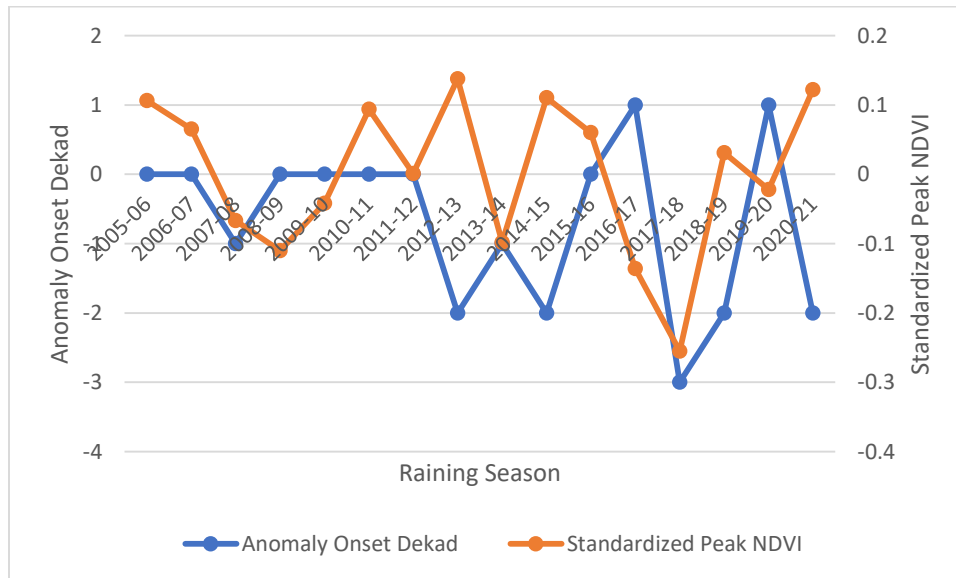


*Figure 4.3.5.1: ODA and SP-NDVI for Chienge District*

**Appendix 4.3.5.2: Onset Dekads and Peak NDVI for Kawambwa District**

*Table 4.3.5.2: Onset Dekad and Peak NDVI for Kawambwa District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7705	0.106498
2006-2007	4	0	0.7632	0.065445
2007-2008	3	-1	0.7397	-0.06671
2008-2009	4	0	0.732	-0.11001
2009-2010	4	0	0.7441	-0.04197
2010-2011	4	0	0.7683	0.094126
2011-2012	4	0	0.7518	0.001336
2012-2013	2	-2	0.7761	0.13799
2013-2014	3	-1	0.7341	-0.0982
2014-2015	2	-2	0.7712	0.110435
2015-2016	4	0	0.7623	0.060384
2016-2017	5	1	0.7274	-0.13588
2017-2018	1	-3	0.7062	-0.2551
2018-2019	2	-2	0.7571	0.031141
2019-2020	5	1	0.7477	-0.02172
2020-2021	2	-2	0.7733	0.122244



*Figure 4.3.5.2: ODA and SP-NDVI for Kawambwa District*

### Appendix 4.3.5.3: Onset Dekads and Peak NDVI for Lunga District

Table 4.3.5.3: Onset Dekad and Peak NDVI for Lunga District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.4467	0.126766
2006-2007	5	0	0.4323	-0.01372
2007-2008	4	-1	0.4418	0.078962
2008-2009	4	-1	0.4141	-0.19128
2009-2010	4	-1	0.4377	0.038963
2010-2011	5	0	0.435	0.012622
2011-2012	4	-1	0.4261	-0.07421
2012-2013	4	-1	0.4302	-0.03421
2013-2014	5	0	0.4404	0.065304
2014-2015	5	0	0.4433	0.093596
2015-2016	5	0	0.4447	0.107254
2016-2017	5	0	0.4379	0.040914
2017-2018	5	0	0.4401	0.062377
2018-2019	6	1	0.419	-0.14347
2019-2020	5	0	0.4154	-0.17859
2020-2021	5	0	0.4346	0.008719

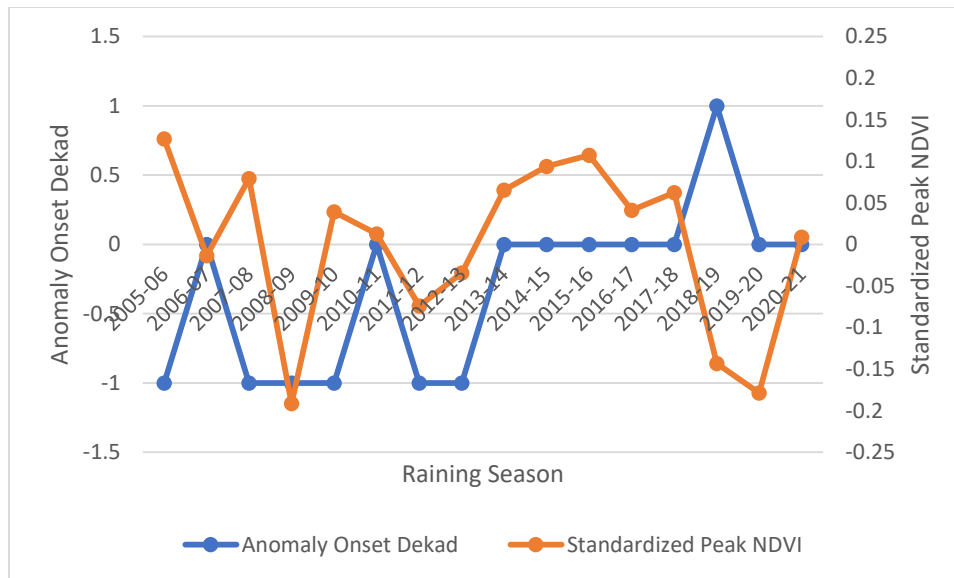


Figure 4.3.5.3: ODA and SP-NDVI for Lunga District

### Appendix 4.3.5.4: Onset Dekads and Peak NDVI for Mansa District

Table 4.3.5.4: Onset Dekad and Peak NDVI for Mansa District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7476	-0.04428
2006-2007	5	1	0.7865	0.173397
2007-2008	4	0	0.74	-0.0868
2008-2009	4	0	0.7387	-0.09408
2009-2010	4	0	0.7467	-0.04931
2010-2011	4	0	0.7566	0.006085
2011-2012	4	0	0.7541	-0.0079
2012-2013	4	0	0.7715	0.089461
2013-2014	5	1	0.7393	-0.09072
2014-2015	7	3	0.7765	0.11744
2015-2016	5	1	0.7767	0.118559
2016-2017	6	2	0.7322	-0.13045
2017-2018	5	1	0.719	-0.20431
2018-2019	4	0	0.7795	0.134227
2019-2020	5	1	0.7533	-0.01238
2020-2021	5	1	0.77	0.081068

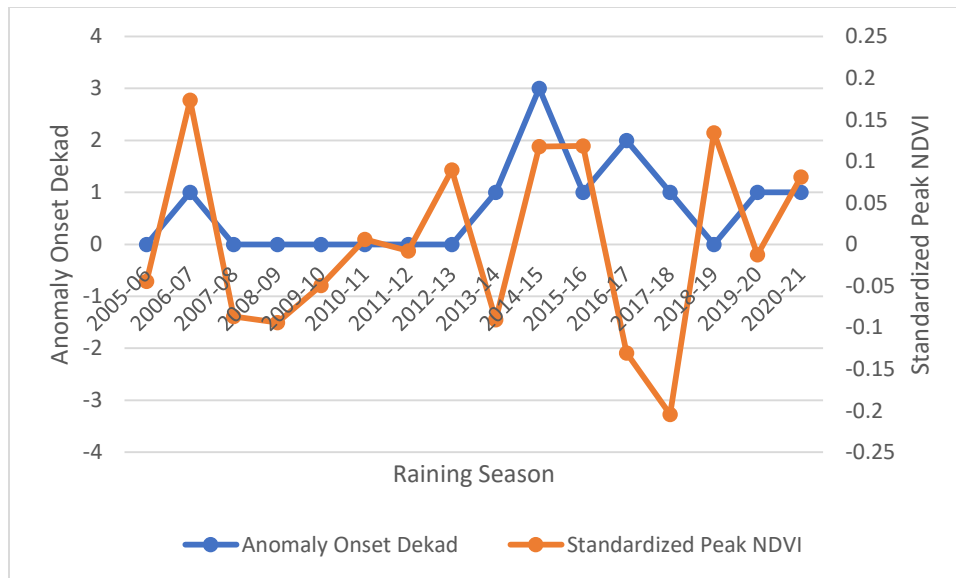
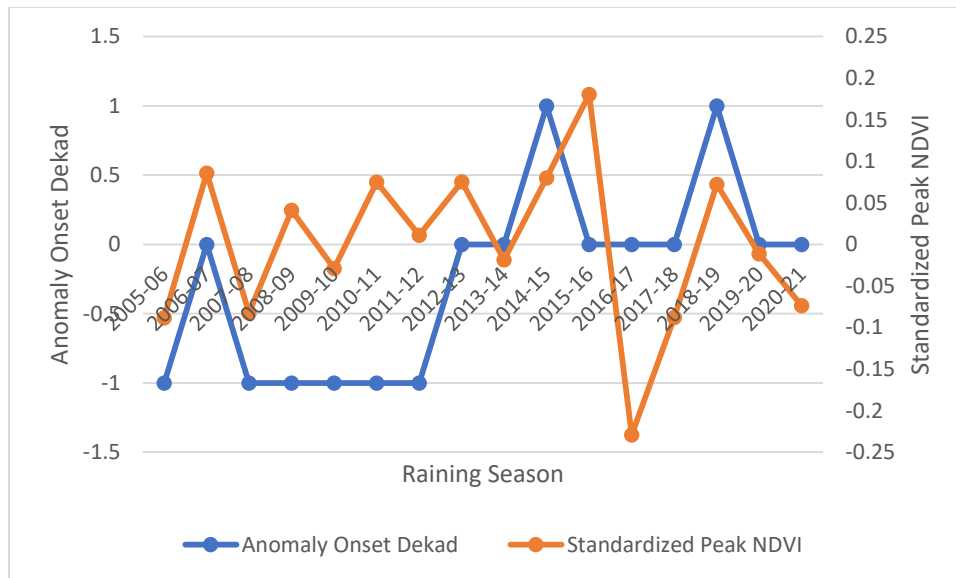


Figure 4.3.5.4: ODA and SP-NDVI for Mansa District

**Appendix 4.3.5.5: Onset Dekads and Peak NDVI for Milenge District**

*Table 4.3.5.5: Onset Dekad and Peak NDVI for Milenge District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7589	-0.08838
2006-2007	5	0	0.7908	0.085785
2007-2008	4	-1	0.76	-0.08237
2008-2009	4	-1	0.7826	0.041016
2009-2010	4	-1	0.7698	-0.02887
2010-2011	4	-1	0.7888	0.074865
2011-2012	4	-1	0.7771	0.010988
2012-2013	5	0	0.7889	0.075411
2013-2014	5	0	0.7717	-0.01849
2014-2015	6	1	0.7897	0.079779
2015-2016	5	0	0.8081	0.180236
2016-2017	5	0	0.7331	-0.22924
2017-2018	5	0	0.759	-0.08783
2018-2019	6	1	0.7883	0.072135
2019-2020	5	0	0.773	-0.0114
2020-2021	5	0	0.7616	-0.07364

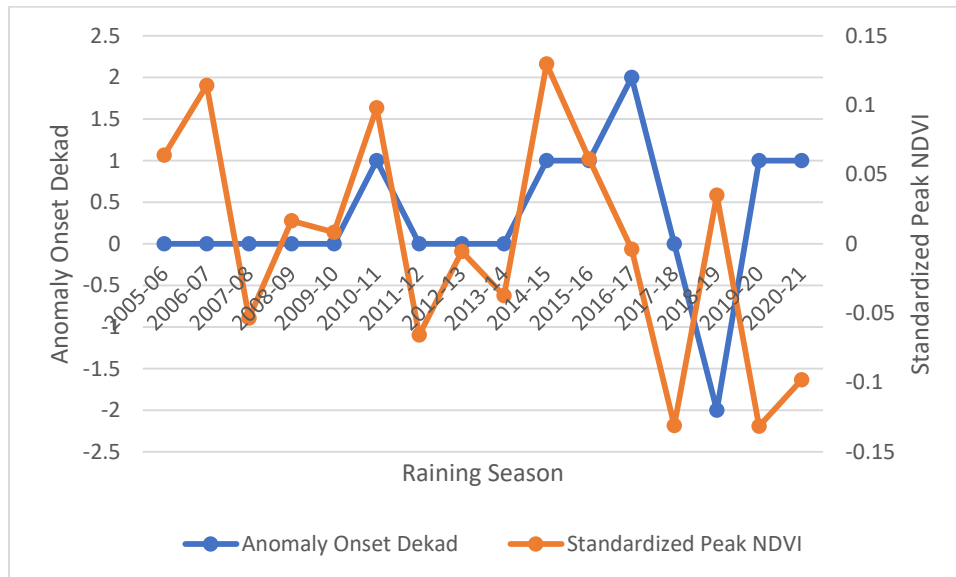


*Figure 4.3.5.5: ODA and SP-NDVI for Milenge District*

**Appendix 4.3.5.6: Onset Dekads and Peak NDVI for Mwense District**

*Table 4.3.5.6: Onset Dekad and Peak NDVI for Mwense District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7716	0.064037
2006-2007	4	0	0.7806	0.114208
2007-2008	4	0	0.7505	-0.05359
2008-2009	4	0	0.7631	0.016654
2009-2010	4	0	0.7616	0.008292
2010-2011	5	1	0.7777	0.098042
2011-2012	4	0	0.7483	-0.06585
2012-2013	4	0	0.7591	-0.00564
2013-2014	4	0	0.7534	-0.03742
2014-2015	5	1	0.7834	0.129817
2015-2016	5	1	0.7711	0.06125
2016-2017	6	2	0.7594	-0.00397
2017-2018	4	0	0.7366	-0.13107
2018-2019	2	-2	0.7664	0.03505
2019-2020	5	1	0.7365	-0.13163
2020-2021	5	1	0.7425	-0.09818



*Figure 4.3.5.6: ODA and SP-NDVI for Mwense District*

### Appendix 4.3.5.7: Onset Dekads and Peak NDVI for Nchelenge District

Table 4.3.5.7: Onset Dekad and Peak NDVI for Nchelenge District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.5126	0.025324
2006-2007	4	0	0.5116	0.017004
2007-2008	4	0	0.512	0.020332
2008-2009	4	0	0.5228	0.110188
2009-2010	4	0	0.5072	-0.0196
2010-2011	4	0	0.514	0.036972
2011-2012	1	-3	0.5111	0.012844
2012-2013	3	-1	0.5135	0.032812
2013-2014	3	-1	0.523	0.111852
2014-2015	2	-2	0.5172	0.063596
2015-2016	4	0	0.5144	0.0403
2016-2017	6	2	0.4996	-0.08284
2017-2018	1	-3	0.4903	-0.16021
2018-2019	2	-2	0.5007	-0.07368
2019-2020	2	-2	0.4975	-0.10031
2020-2021	2	-2	0.5054	-0.03458

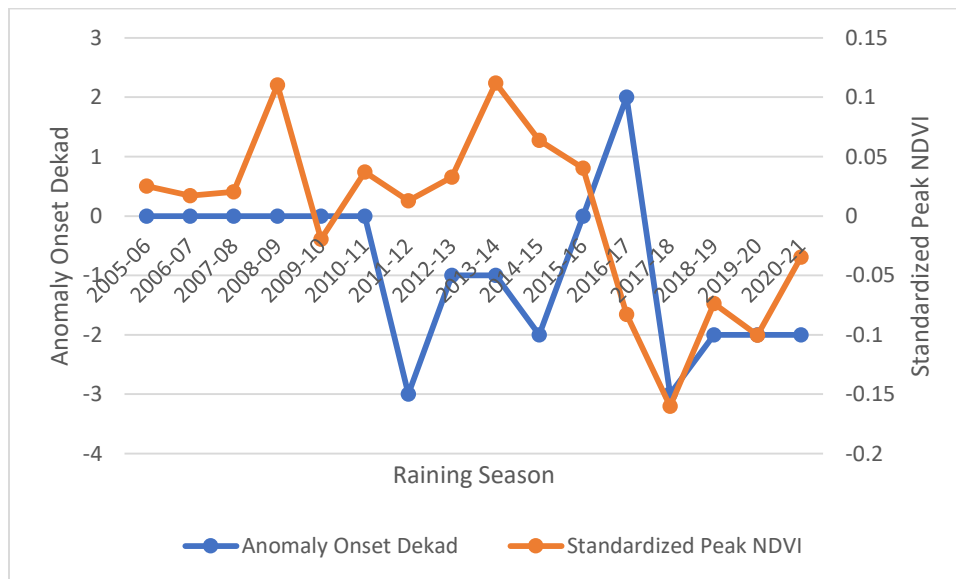
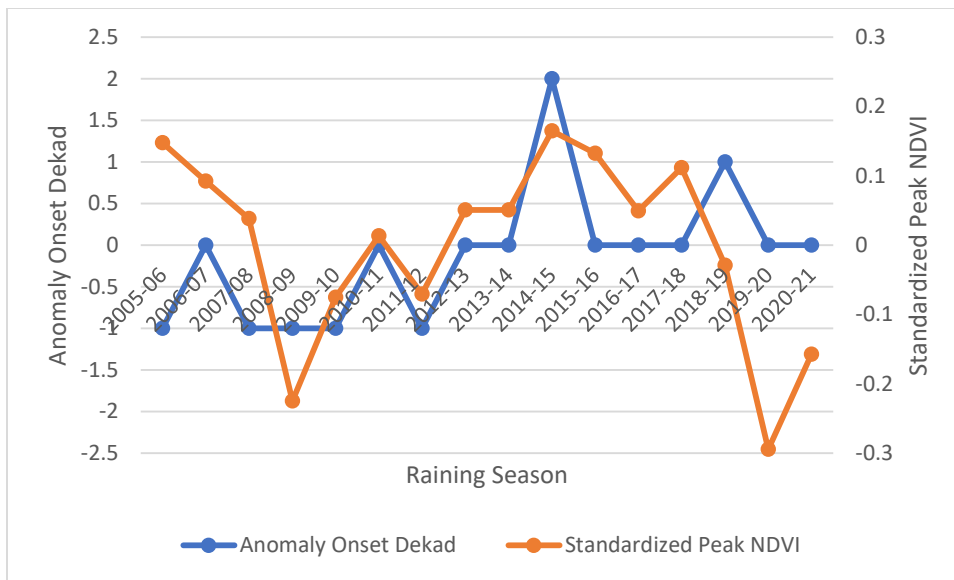


Figure 4.3.5.7: ODA and SP-NDVI for Nchelenge District

**Appendix 4.3.5.8: Onset Dekads and Peak NDVI for Samfya District**

*Table 4.3.5.8: Onset Dekad and Peak NDVI for Samfya District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.6794	0.147687
2006-2007	5	0	0.6708	0.09245
2007-2008	4	-1	0.6624	0.038497
2008-2009	4	-1	0.6214	-0.22484
2009-2010	4	-1	0.6447	-0.07519
2010-2011	5	0	0.6585	0.013448
2011-2012	4	-1	0.6454	-0.07069
2012-2013	5	0	0.6643	0.050701
2013-2014	5	0	0.6643	0.050701
2014-2015	7	2	0.6821	0.165029
2015-2016	5	0	0.677	0.132272
2016-2017	5	0	0.6641	0.049416
2017-2018	5	0	0.6738	0.111719
2018-2019	6	1	0.6519	-0.02894
2019-2020	5	0	0.6105	-0.29485
2020-2021	5	0	0.6319	-0.1574



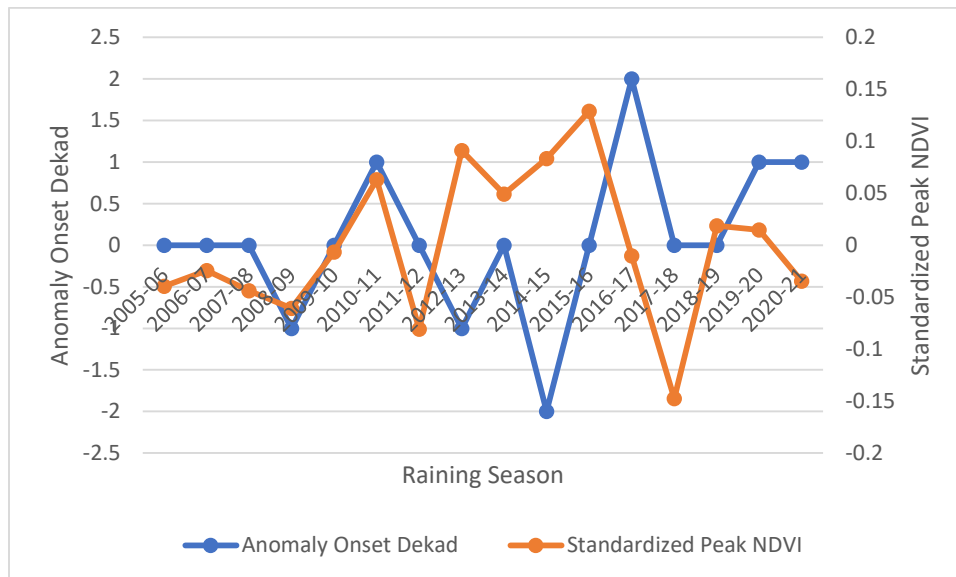
*Figure 4.3.5.8: ODA and SP-NDVI for Samfya District*

**Appendices 4.3.6.: Onset Dekads and Peak NDVI for Districts of Northern Province**

**Appendix 4.3.6.1: Onset Dekads and Peak NDVI for Kaputa District**

*Table 4.3.7.1: Onset Dekad and Peak NDVI for Kaputa District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.6916	-0.03952
2006-2007	4	0	0.6941	-0.02433
2007-2008	4	0	0.6909	-0.04377
2008-2009	3	-1	0.6881	-0.06078
2009-2010	4	0	0.697	-0.00672
2010-2011	5	1	0.7085	0.063134
2011-2012	4	0	0.6848	-0.08083
2012-2013	3	-1	0.7131	0.091076
2013-2014	4	0	0.7062	0.049163
2014-2015	2	-2	0.7118	0.083179
2015-2016	4	0	0.7193	0.128736
2016-2017	6	2	0.6964	-0.01036
2017-2018	4	0	0.6738	-0.14764
2018-2019	4	0	0.7012	0.018792
2019-2020	5	1	0.7005	0.01454
2020-2021	5	1	0.6924	-0.03466

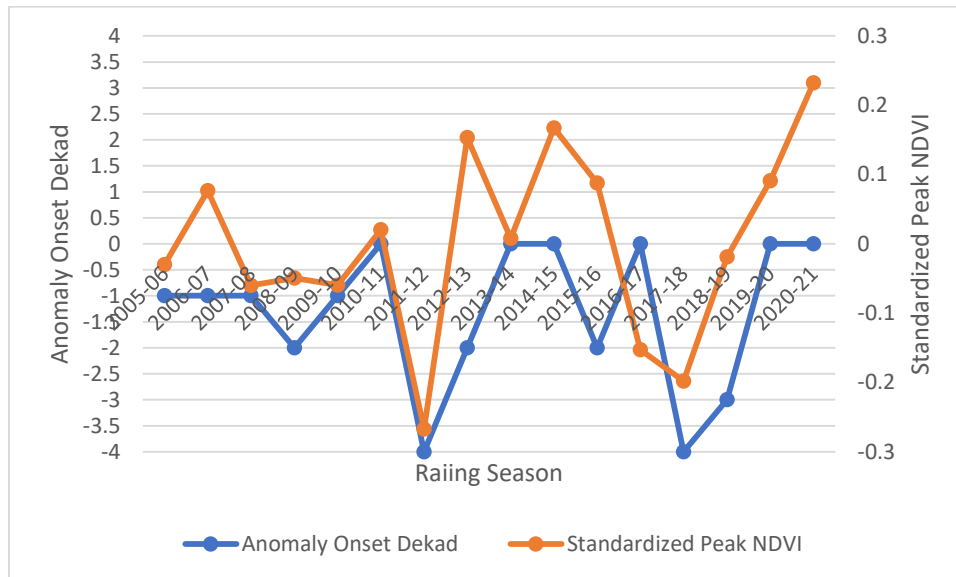


*Figure 4.3.7.1: ODA and SP-NDVI for Kaputa District*

**Appendix 4.3.6.2: Onset Dekads and Peak NDVI for Nsama District**

*Table 4.3.7.2: Onset Dekad and Peak NDVI for Nsama District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.74	-0.03012
2006-2007	4	-1	0.7589	0.076785
2007-2008	4	-1	0.7347	-0.0601
2008-2009	3	-2	0.7366	-0.04935
2009-2010	4	-1	0.7348	-0.05953
2010-2011	5	0	0.7489	0.020221
2011-2012	1	-4	0.6981	-0.26712
2012-2013	3	-2	0.7724	0.153145
2013-2014	5	0	0.7467	0.007777
2014-2015	5	0	0.7749	0.167286
2015-2016	3	-2	0.7608	0.087532
2016-2017	5	0	0.7183	-0.15286
2017-2018	1	-4	0.7103	-0.19811
2018-2019	2	-3	0.742	-0.01881
2019-2020	5	0	0.7614	0.090925
2020-2021	5	0	0.7864	0.232333

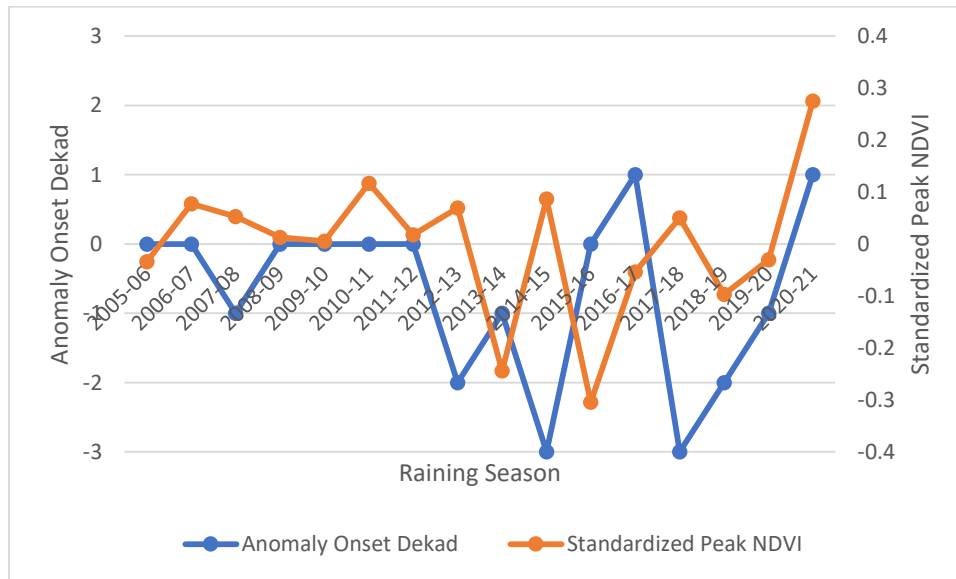


*Figure 4.3.7.2: ODA and SP-NDVI for Nsama District*

**Appendix 4.3.7: Onset Dekads and Peak NDVI for Districts of North Western Province**  
**Appendix 4.3.7.1: Onset Dekads and Peak NDVI for Chavuma District**

*Table 4.3.7.1: Onset Dekad and Peak NDVI for Chavuma District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.5861	-0.03388
2006-2007	4	0	0.6017	0.077399
2007-2008	3	-1	0.5982	0.052432
2008-2009	4	0	0.5926	0.012484
2009-2010	4	0	0.5916	0.00535
2010-2011	4	0	0.6072	0.116634
2011-2012	4	0	0.5933	0.017477
2012-2013	2	-2	0.6006	0.069552
2013-2014	3	-1	0.5566	-0.24432
2014-2015	1	-3	0.603	0.086673
2015-2016	4	0	0.5482	-0.30425
2016-2017	5	1	0.5833	-0.05386
2017-2018	1	-3	0.5979	0.050292
2018-2019	2	-2	0.5773	-0.09666
2019-2020	3	-1	0.5866	-0.03032
2020-2021	5	1	0.6294	0.274999

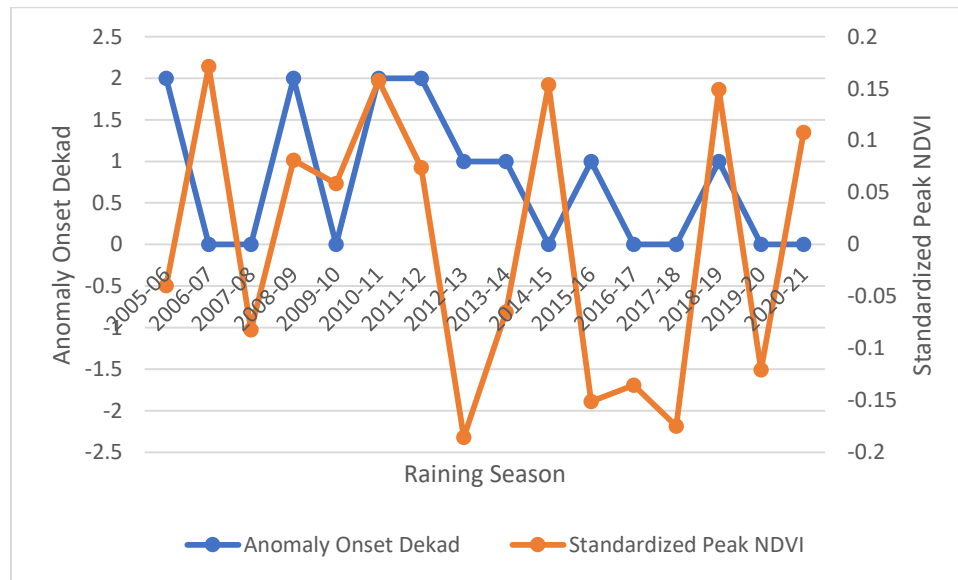


*Figure 4.3.7.1: ODA and SP-NDVI of rain Season for Chavuma District*

**Appendix 4.3.7.2: Onset Dekads and Peak NDVI for Ikelenge District**

*Table 4.3.7.2: Onset Dekad and Peak NDVI for Ikelenge District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	3	2	0.7374	-0.03945
2006-2007	1	0	0.7746	0.171316
2007-2008	1	0	0.7299	-0.08194
2008-2009	3	2	0.7587	0.081232
2009-2010	1	0	0.7547	0.058569
2010-2011	3	2	0.7722	0.157719
2011-2012	3	2	0.7574	0.073866
2012-2013	2	1	0.7116	-0.18562
2013-2014	2	1	0.7329	-0.06494
2014-2015	1	0	0.7715	0.153753
2015-2016	2	1	0.7177	-0.15106
2016-2017	1	0	0.7205	-0.1352
2017-2018	1	0	0.7135	-0.17486
2018-2019	2	1	0.7707	0.14922
2019-2020	1	0	0.7231	-0.12047
2020-2021	1	0	0.7634	0.107861



*Figure 4.3.7.2: ODA and SP-NDVI for Ikelenge District*

### Appendix 4.3.7.3: Onset Dekads and Peak NDVI for Kabompo District

Table 4.3.7.3: Onset Dekad and Peak NDVI for Kabompo District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7823	0.035192
2006-2007	4	0	0.7809	0.027532
2007-2008	1	-3	0.777	0.00619
2008-2009	4	0	0.7595	-0.08957
2009-2010	4	0	0.7797	0.020965
2010-2011	4	0	0.7782	0.012757
2011-2012	4	0	0.7803	0.024248
2012-2013	2	-2	0.7673	-0.04689
2013-2014	3	-1	0.7746	-0.00694
2014-2015	4	0	0.783	0.039023
2015-2016	4	0	0.7582	-0.09669
2016-2017	4	0	0.7767	0.004549
2017-2018	1	-3	0.7746	-0.00694
2018-2019	6	2	0.7733	-0.01406
2019-2020	3	-1	0.774	-0.01023
2020-2021	5	1	0.7943	0.100858

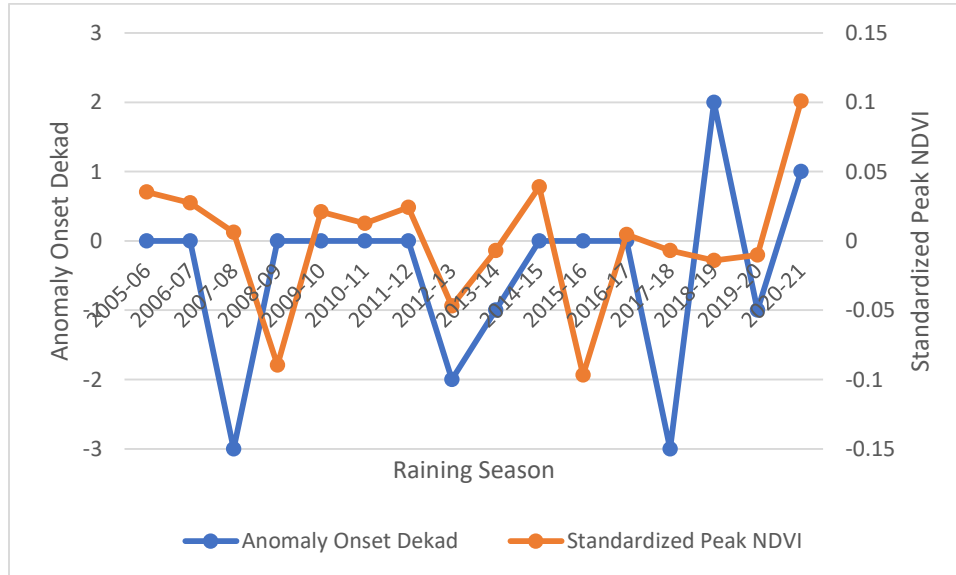
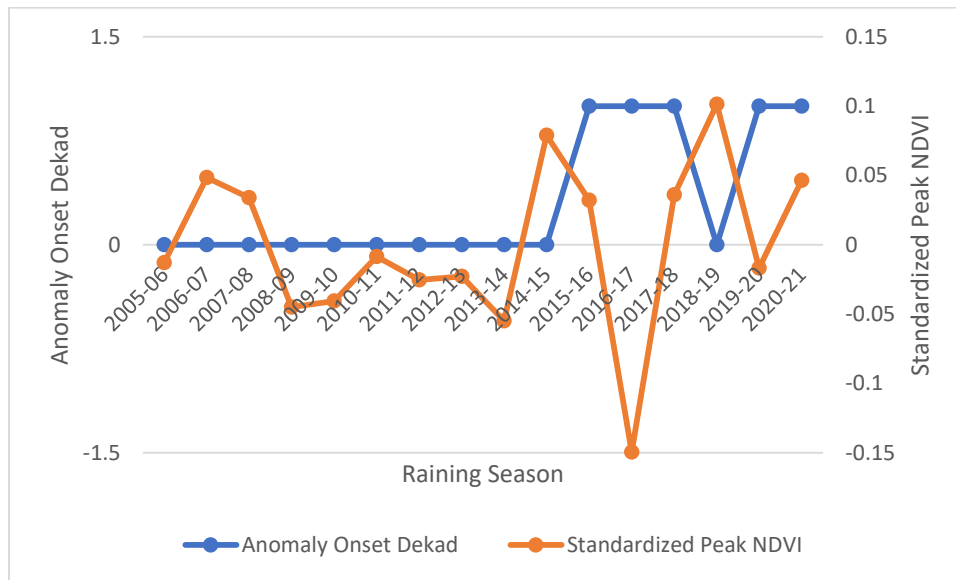


Figure 4.3.7.3: ODA and SP-NDVI for Kabompo District

**Appendix 4.3.7.4: Onset Dekads and Peak NDVI for Kasempa District**

**Table 4.3.7.4: Onset Dekad and Peak NDVI for Kasempa District**

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7774	-0.01299
2006-2007	4	0	0.7887	0.048496
2007-2008	4	0	0.786	0.033804
2008-2009	4	0	0.7715	-0.0451
2009-2010	4	0	0.7723	-0.04074
2010-2011	4	0	0.7782	-0.00864
2011-2012	4	0	0.7751	-0.02551
2012-2013	4	0	0.7756	-0.02279
2013-2014	4	0	0.7697	-0.05489
2014-2015	4	0	0.7943	0.078967
2015-2016	5	1	0.7857	0.032172
2016-2017	5	1	0.7523	-0.14957
2017-2018	5	1	0.7864	0.035981
2018-2019	4	0	0.7984	0.101277
2019-2020	5	1	0.7767	-0.0168
2020-2021	5	1	0.7883	0.046319

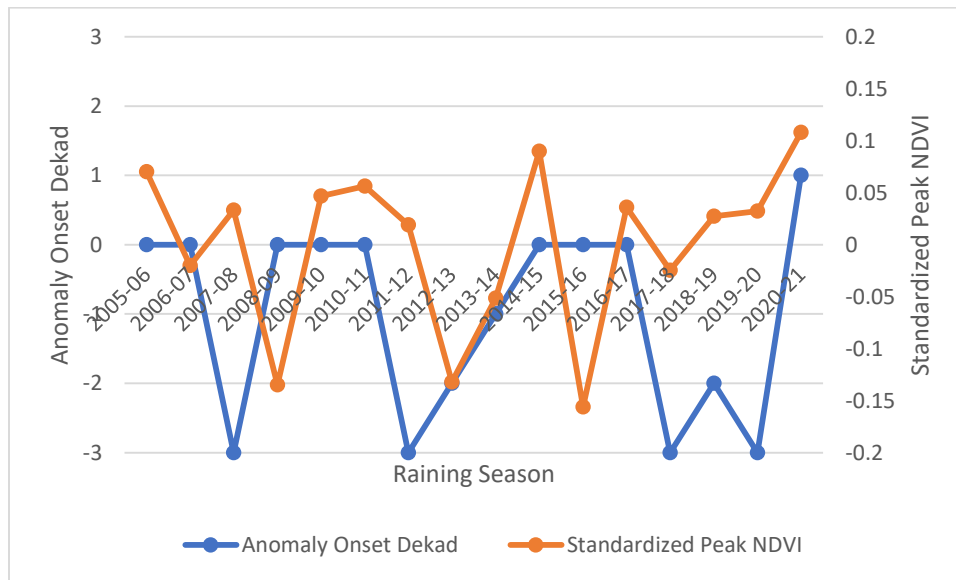


**Figure 4.3.7.4: ODA and SP-NDVI for Kasempa District**

**Appendix 4.3.7.5: Onset Dekads and Peak NDVI for Manyinga District**

*Table 4.3.8.5: Onset Dekad and Peak NDVI for Manyinga District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.8071	0.070188
2006-2007	4	0	0.7902	-0.02002
2007-2008	1	-3	0.8002	0.033359
2008-2009	4	0	0.7687	-0.13477
2009-2010	4	0	0.8027	0.046703
2010-2011	4	0	0.8045	0.05631
2011-2012	1	-3	0.7975	0.018948
2012-2013	2	-2	0.7692	-0.1321
2013-2014	3	-1	0.7843	-0.05151
2014-2015	4	0	0.8108	0.089937
2015-2016	4	0	0.7647	-0.15612
2016-2017	4	0	0.8007	0.036028
2017-2018	1	-3	0.7893	-0.02482
2018-2019	2	-2	0.7991	0.027488
2019-2020	1	-3	0.8	0.032292
2020-2021	5	1	0.8142	0.108084

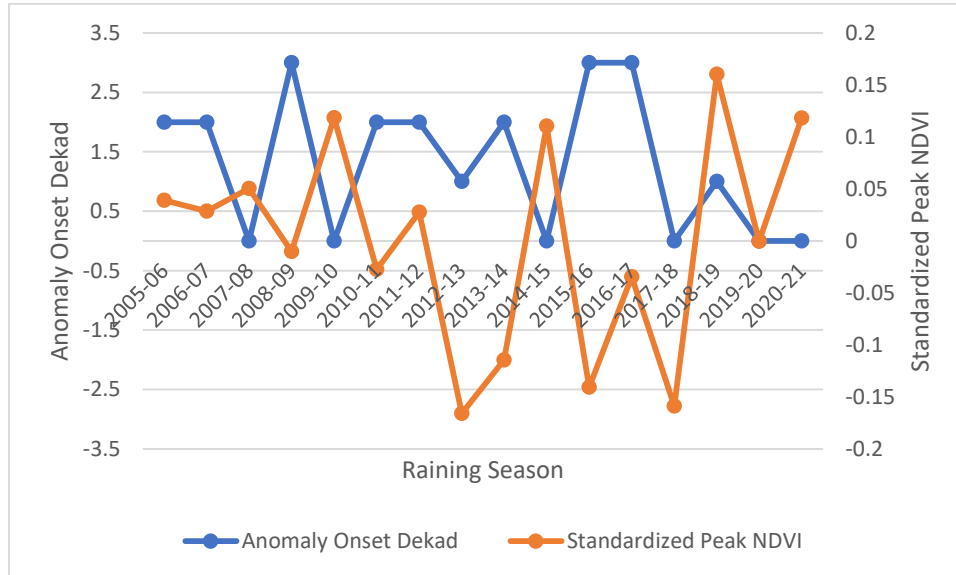


*Figure 4.3.8.5: ODA and SP-NDVI for Manyinga District*

**Appendix 4.3.7.6: Onset Dekads and Peak NDVI for Mwinilunga District**

*Table 4.3.7.6: Onset Dekad and Peak NDVI for Mwinilunga District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	3	2	0.7783	0.039047
2006-2007	3	2	0.7764	0.028626
2007-2008	1	0	0.7804	0.050566
2008-2009	4	3	0.7693	-0.01032
2009-2010	1	0	0.7928	0.118582
2010-2011	3	2	0.7662	-0.02732
2011-2012	3	2	0.7762	0.027529
2012-2013	2	1	0.7409	-0.1661
2013-2014	3	2	0.7503	-0.11454
2014-2015	1	0	0.7913	0.110354
2015-2016	4	3	0.7455	-0.14087
2016-2017	4	3	0.7649	-0.03445
2017-2018	1	0	0.7422	-0.15897
2018-2019	2	1	0.8004	0.160269
2019-2020	1	0	0.7711	-0.00045
2020-2021	1	0	0.7927	0.118033

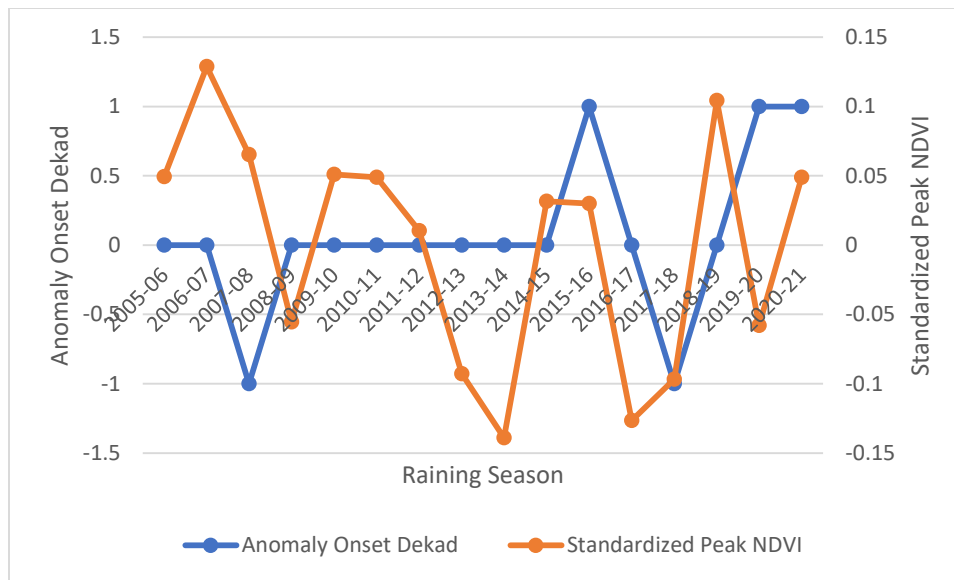


*Figure 4.3.7.6: ODA and SP-NDVI for Mwinilunga District*

**Appendix 4.3.7.7: Onset Dekads and Peak NDVI for Solwezi District**

*Table 4.3.8.7: Onset Dekad and Peak NDVI for Solwezi District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7891	0.049467
2006-2007	4	0	0.8037	0.128777
2007-2008	3	-1	0.792	0.06522
2008-2009	4	0	0.7698	-0.05537
2009-2010	4	0	0.7894	0.051096
2010-2011	4	0	0.789	0.048924
2011-2012	4	0	0.7819	0.010355
2012-2013	4	0	0.7629	-0.09286
2013-2014	4	0	0.7544	-0.13903
2014-2015	4	0	0.7858	0.031541
2015-2016	5	1	0.7855	0.029911
2016-2017	4	0	0.7567	-0.12654
2017-2018	3	-1	0.7622	-0.09666
2018-2019	4	0	0.7992	0.104332
2019-2020	5	1	0.7693	-0.05809
2020-2021	5	1	0.789	0.048924

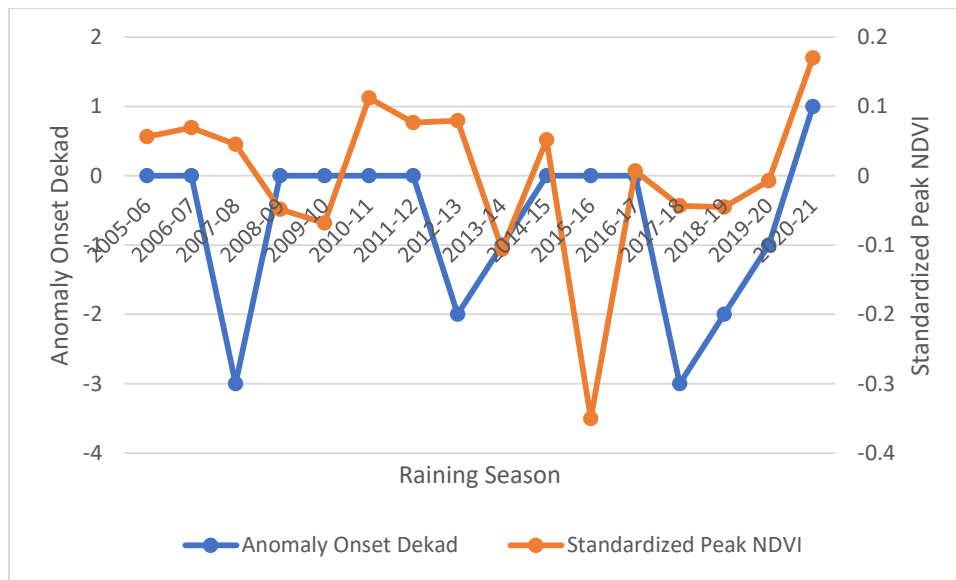


*Figure 4.3.8.7: ODA and SP-NDVI for Solwezi District*

**Appendix 4.3.7.8: Onset Dekads and Peak NDVI for Zambezi District**

*Table 4.3.8.8: Onset Dekad and Peak NDVI for Zambezi District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.6956	0.056297
2006-2007	4	0	0.6977	0.069217
2007-2008	1	-3	0.6938	0.045222
2008-2009	4	0	0.6786	-0.0483
2009-2010	4	0	0.6754	-0.06799
2010-2011	4	0	0.7047	0.112286
2011-2012	4	0	0.6989	0.0766
2012-2013	2	-2	0.6994	0.079677
2013-2014	3	-1	0.6692	-0.10613
2014-2015	4	0	0.6949	0.05199
2015-2016	4	0	0.6295	-0.35039
2016-2017	4	0	0.6876	0.007076
2017-2018	1	-3	0.6794	-0.04338
2018-2019	2	-2	0.6791	-0.04522
2019-2020	3	-1	0.6853	-0.00708
2020-2021	5	1	0.7141	0.170121



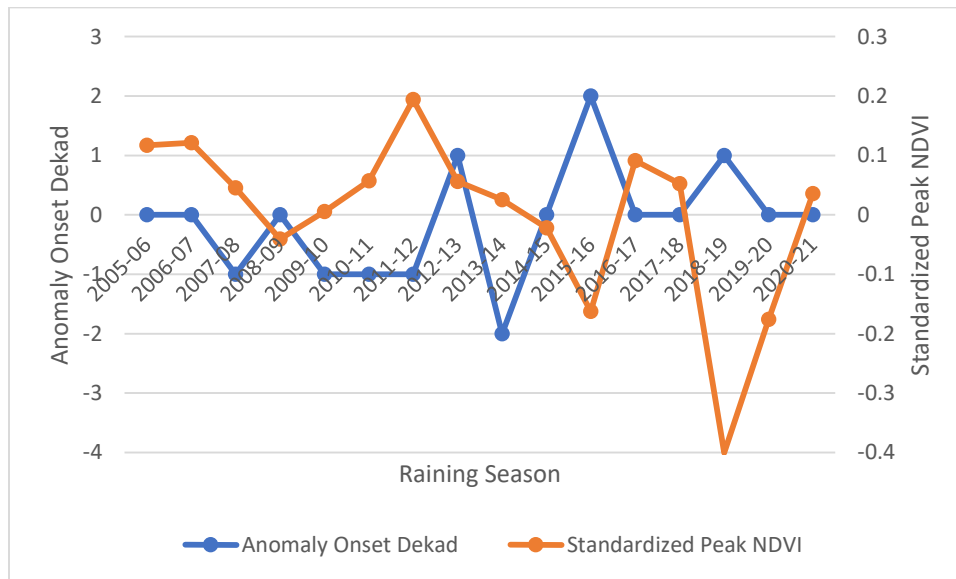
*Figure 4.3.7.8: ODA and SP-NDVI for Zambezi District*

**Appendices 4.3.8: Onset Dekads and Peak NDVI for Districts of Southern Province**

**Appendix 4.3.8.1: Onset Dekads and Peak NDVI for Choma District**

*Table 4.3.8.1: Onset Dekad and Peak NDVI for Choma District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	0	0.7199	0.116941
2006-2007	5	0	0.7206	0.12115
2007-2008	4	-1	0.708	0.045394
2008-2009	5	0	0.6937	-0.04058
2009-2010	4	-1	0.7014	0.005712
2010-2011	4	-1	0.71	0.057418
2011-2012	4	-1	0.7327	0.193899
2012-2013	6	1	0.7098	0.056216
2013-2014	3	-2	0.7047	0.025553
2014-2015	5	0	0.6968	-0.02195
2015-2016	7	2	0.6734	-0.16264
2016-2017	5	0	0.7156	0.091088
2017-2018	5	0	0.7092	0.052608
2018-2019	6	1	0.6338	-0.40073
2019-2020	5	0	0.6712	-0.17586
2020-2021	5	0	0.7064	0.035774

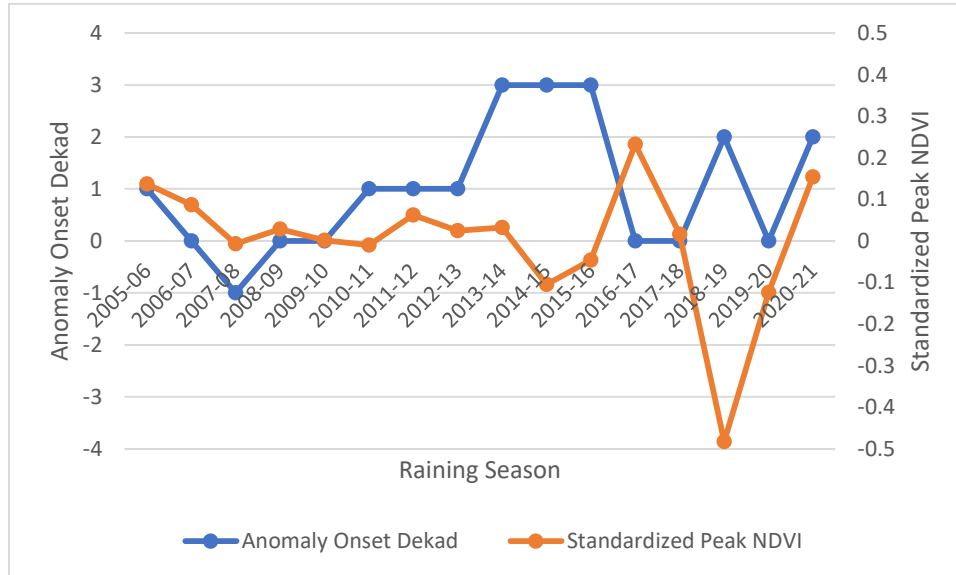


*Figure 4.3.8.1: ODA and SP-NDVI for Choma District*

**Appendix 4.3.8.2: Onset Dekads and Peak NDVI for Gwembe District**

*Table 4.3.8.2: Onset Dekad and Peak NDVI for Gwembe District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	1	0.6318	0.136607
2006-2007	5	0	0.6246	0.08715
2007-2008	4	-1	0.6109	-0.00695
2008-2009	5	0	0.6161	0.028764
2009-2010	5	0	0.6121	0.001288
2010-2011	6	1	0.6104	-0.01039
2011-2012	6	1	0.621	0.062422
2012-2013	6	1	0.6155	0.024643
2013-2014	8	3	0.6166	0.032198
2014-2015	8	3	0.5967	-0.10449
2015-2016	8	3	0.6052	-0.04611
2016-2017	5	0	0.6457	0.232086
2017-2018	5	0	0.6142	0.015713
2018-2019	7	2	0.5416	-0.48298
2019-2020	5	0	0.5939	-0.12373
2020-2021	7	2	0.6343	0.15378

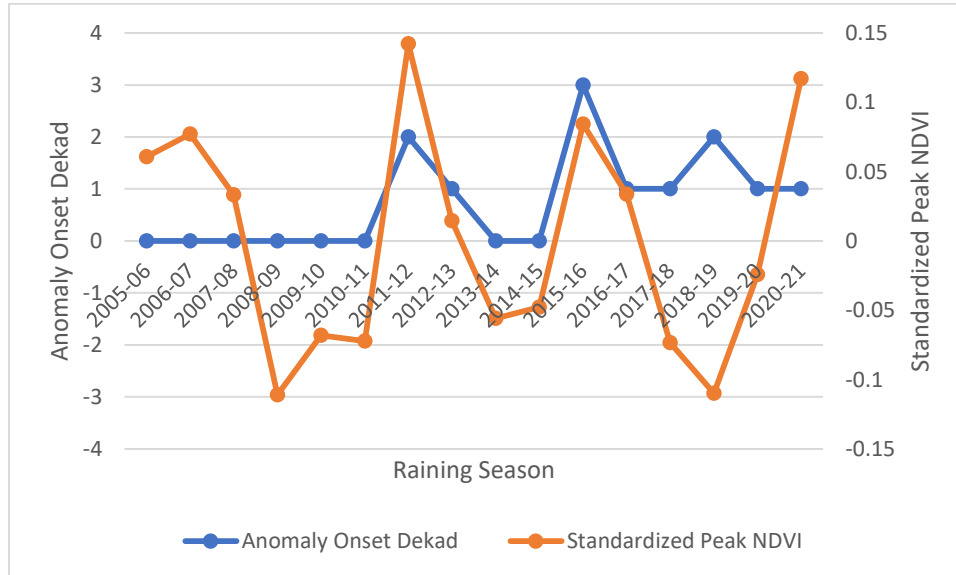


*Figure 4.3.8.2: ODA and SP-NDVI for Gwembe District*

**Appendix 4.3.8.: Onset Dekads and Peak NDVI for Itezhi-Tezhi District**

*Table 4.3.8.3: Onset Dekad and Peak NDVI for Itezhi-tezhi District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7329	0.060775
2006-2007	4	0	0.7357	0.077197
2007-2008	4	0	0.7282	0.03321
2008-2009	4	0	0.7036	-0.11107
2009-2010	4	0	0.7109	-0.06825
2010-2011	4	0	0.7102	-0.07236
2011-2012	6	2	0.7468	0.142298
2012-2013	5	1	0.725	0.014442
2013-2014	4	0	0.713	-0.05594
2014-2015	4	0	0.7144	-0.04773
2015-2016	7	3	0.7369	0.084235
2016-2017	5	1	0.7283	0.033797
2017-2018	5	1	0.71	-0.07353
2018-2019	6	2	0.7038	-0.10989
2019-2020	5	1	0.7184	-0.02427
2020-2021	5	1	0.7425	0.117078

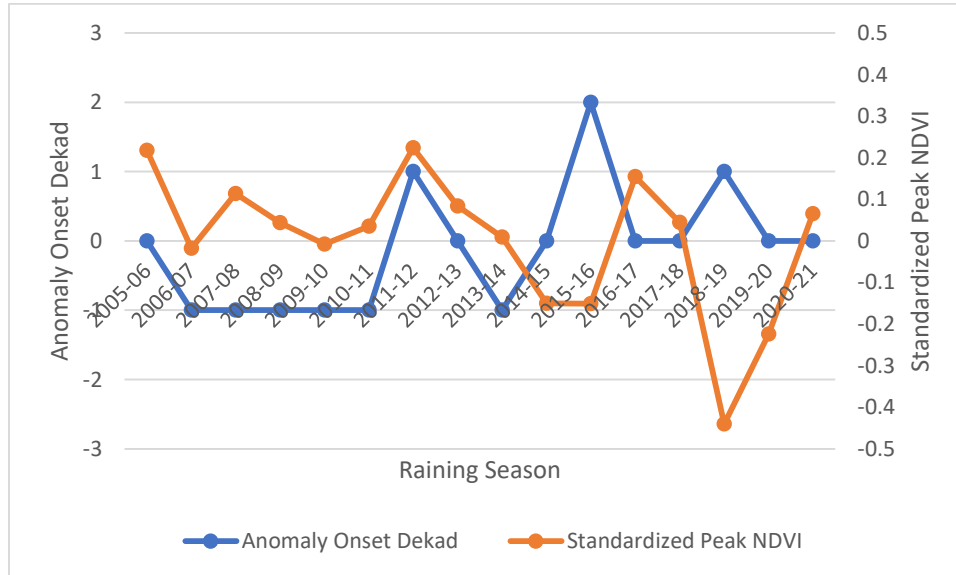


*Figure 4.3.8.3: ODA and SP-NDVI for Itezhi-tezhi District*

**Appendix 4.3.8.4: Onset Dekads and Peak NDVI for Kalomo District**

*Table 4.3.8.4: Onset Dekad and Peak NDVI for Kalomo District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	0	0.7039	0.217663
2006-2007	4	-1	0.6663	-0.01802
2007-2008	4	-1	0.6873	0.113611
2008-2009	4	-1	0.6762	0.044034
2009-2010	4	-1	0.6679	-0.00799
2010-2011	4	-1	0.6748	0.035259
2011-2012	6	1	0.7049	0.223931
2012-2013	5	0	0.6826	0.084151
2013-2014	4	-1	0.6706	0.008932
2014-2015	5	0	0.6452	-0.15028
2015-2016	7	2	0.6451	-0.15091
2016-2017	5	0	0.6938	0.154354
2017-2018	5	0	0.6763	0.044661
2018-2019	6	1	0.5989	-0.4405
2019-2020	5	0	0.6334	-0.22424
2020-2021	5	0	0.6796	0.065346

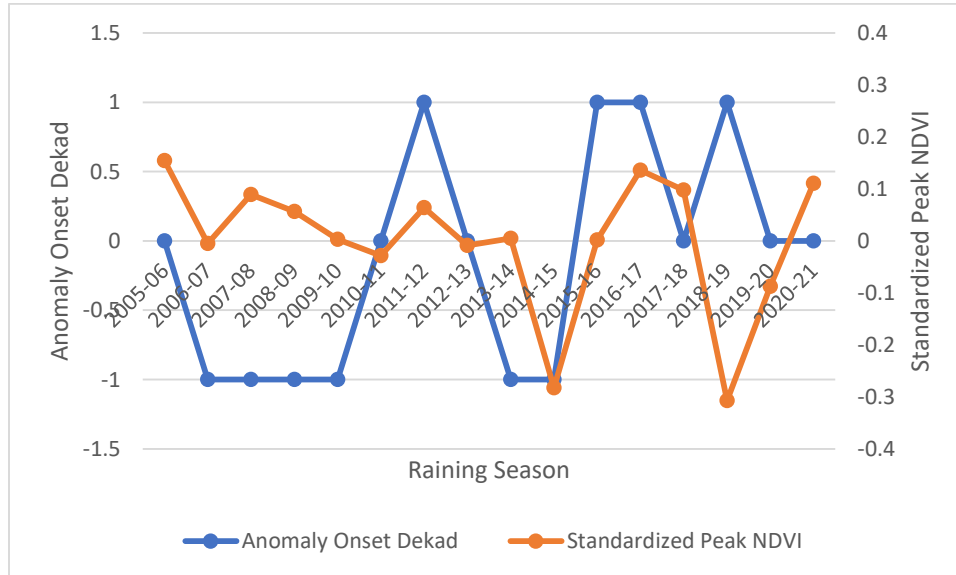


*Figure 4.3.8.4: ODA and SP-NDVI for Kalomo District*

**Appendix 4.3.8.5: Onset Dekads and Peak NDVI for Kazungula District**

*Table 4.3.9.5: Onset Dekad and Peak NDVI for Kazungula District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	0	0.7372	0.154667
2006-2007	4	-1	0.7103	-0.00486
2007-2008	4	-1	0.7262	0.089435
2008-2009	4	-1	0.7207	0.056819
2009-2010	4	-1	0.7116	0.002854
2010-2011	5	0	0.7063	-0.02858
2011-2012	6	1	0.7219	0.063935
2012-2013	5	0	0.7097	-0.00841
2013-2014	4	-1	0.7119	0.004633
2014-2015	4	-1	0.6635	-0.28239
2015-2016	6	1	0.7114	0.001668
2016-2017	6	1	0.7341	0.136283
2017-2018	5	0	0.7276	0.097737
2018-2019	6	1	0.6593	-0.3073
2019-2020	5	0	0.6964	-0.08729
2020-2021	5	0	0.7298	0.110784

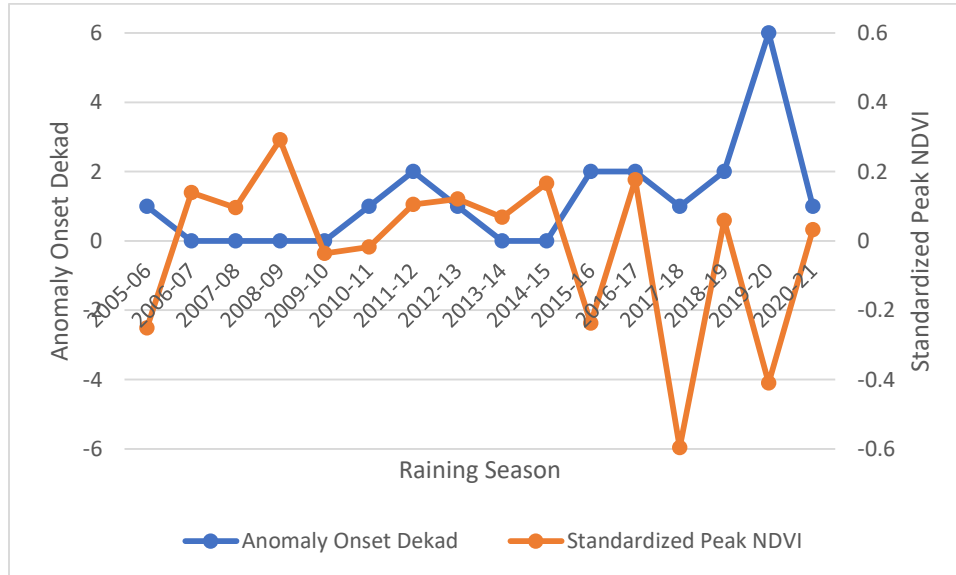


*Figure 4.3.9.5: ODA and SP-NDVI for Kazungula District*

**Appendix 4.3.8.6: Onset Dekads and Peak NDVI for Livingstone District**

*Table 4.3.8.6: Onset Dekad and Peak NDVI for Livingstone District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.6263	-0.25109
2006-2007	4	0	0.6874	0.139049
2007-2008	4	0	0.6806	0.095629
2008-2009	4	0	0.7113	0.291658
2009-2010	4	0	0.6599	-0.03655
2010-2011	5	1	0.6629	-0.01739
2011-2012	6	2	0.6821	0.105207
2012-2013	5	1	0.6846	0.12117
2013-2014	4	0	0.6763	0.068172
2014-2015	4	0	0.6917	0.166506
2015-2016	6	2	0.6285	-0.23704
2016-2017	6	2	0.6933	0.176723
2017-2018	5	1	0.5721	-0.59718
2018-2019	6	2	0.6749	0.059233
2019-2020	10	6	0.6014	-0.41009
2020-2021	5	1	0.6707	0.032415

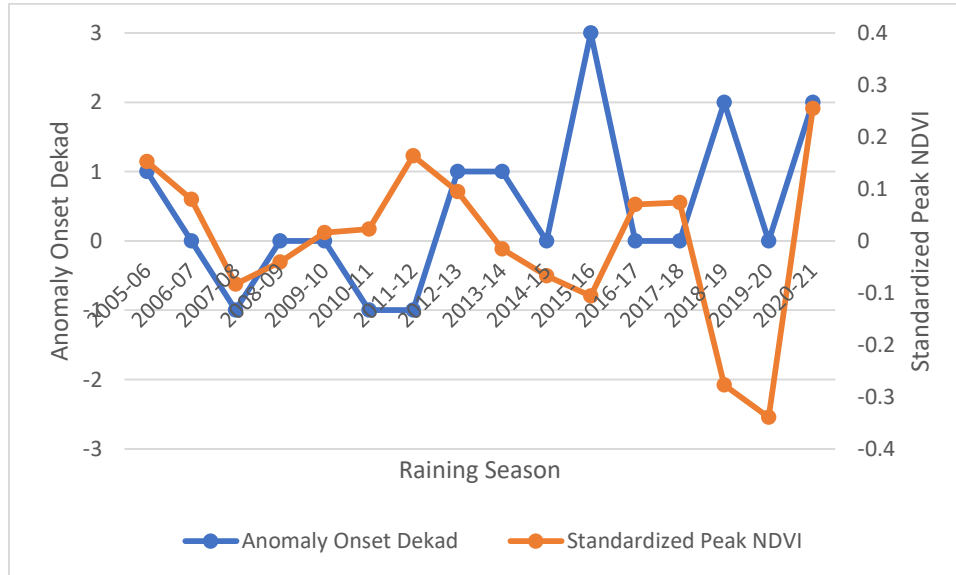


*Figure 4.3.8.6: ODA and SP-NDVI for Livingstone District*

**Appendix 4.3.8.7: Onset Dekads and Peak NDVI for Mazabuka District**

*Table 4.3.9.7: Onset Dekad and Peak NDVI for Mazabuka District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	1	0.7478	0.152563
2006-2007	5	0	0.7353	0.079723
2007-2008	4	-1	0.7073	-0.08344
2008-2009	5	0	0.7146	-0.0409
2009-2010	5	0	0.7244	0.016207
2010-2011	4	-1	0.7255	0.022617
2011-2012	4	-1	0.7497	0.163634
2012-2013	6	1	0.7379	0.094874
2013-2014	6	1	0.719	-0.01526
2014-2015	5	0	0.7101	-0.06712
2015-2016	8	3	0.7034	-0.10616
2016-2017	5	0	0.7337	0.0704
2017-2018	5	0	0.7343	0.073896
2018-2019	7	2	0.6741	-0.2769
2019-2020	5	0	0.6634	-0.33925
2020-2021	6	2	0.7654	0.255121

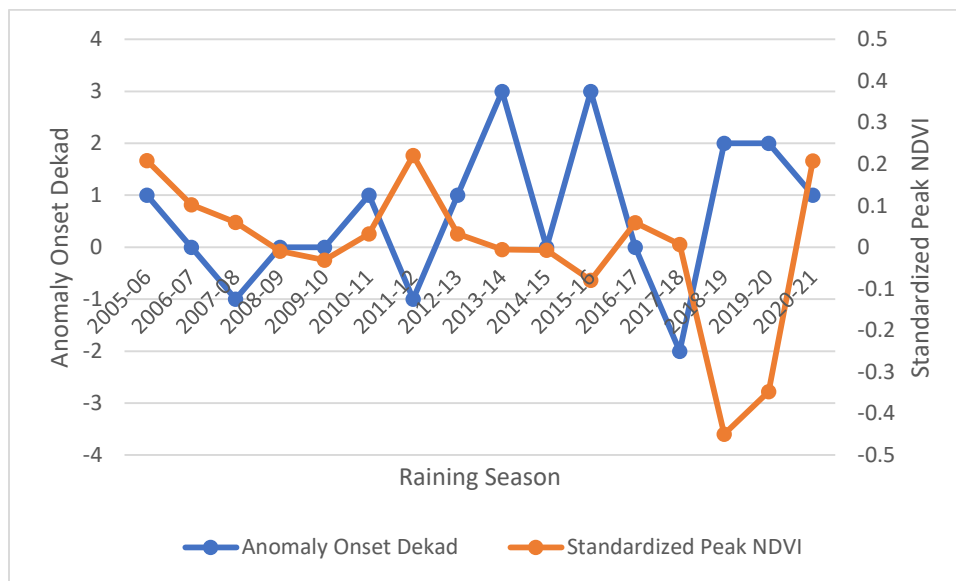


*Figure 4.3.8.7: ODA and SP-NDVI for Mazabuka District*

**Appendix 4.3.8.8: Onset Dekads and Peak NDVI for Monze District**

*Table 4.3.8.8: Onset Dekad and Peak NDVI for Monze District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	1	0.7472	0.208251
2006-2007	5	0	0.7292	0.102323
2007-2008	4	-1	0.722	0.059952
2008-2009	5	0	0.7102	-0.00949
2009-2010	5	0	0.7066	-0.03067
2010-2011	6	1	0.7173	0.032293
2011-2012	4	-1	0.7493	0.220609
2012-2013	6	1	0.7173	0.032293
2013-2014	8	3	0.7109	-0.00537
2014-2015	5	0	0.7106	-0.00714
2015-2016	8	3	0.6983	-0.07952
2016-2017	5	0	0.7218	0.058775
2017-2018	3	-2	0.713	0.006988
2018-2019	7	2	0.6354	-0.44968
2019-2020	7	2	0.6528	-0.34728
2020-2021	6	1	0.7471	0.207663



*Figure 4.3.8.8: ODA and SP-NDVI for Monze District*

**Appendix 4.3.8.9: Onset Dekads and Peak NDVI for Namwala District**

Table 4.3.8.9: Onset Dekad and Peak NDVI for Namwala District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	-1	0.7159	0.166949
2006-2007	5	0	0.7121	0.143657
2007-2008	4	-1	0.6805	-0.05003
2008-2009	4	-1	0.6979	0.05662
2009-2010	5	0	0.6655	-0.14197
2010-2011	5	0	0.6976	0.054781
2011-2012	4	-1	0.7266	0.232533
2012-2013	6	1	0.6842	-0.02735
2013-2014	6	1	0.7027	0.086041
2014-2015	5	0	0.6735	-0.09294
2015-2016	7	2	0.6812	-0.04574
2016-2017	5	0	0.6868	-0.01142
2017-2018	3	-2	0.6829	-0.03532
2018-2019	7	2	0.6442	-0.27253
2019-2020	5	0	0.6775	-0.06842
2020-2021	5	0	0.6895	0.005133

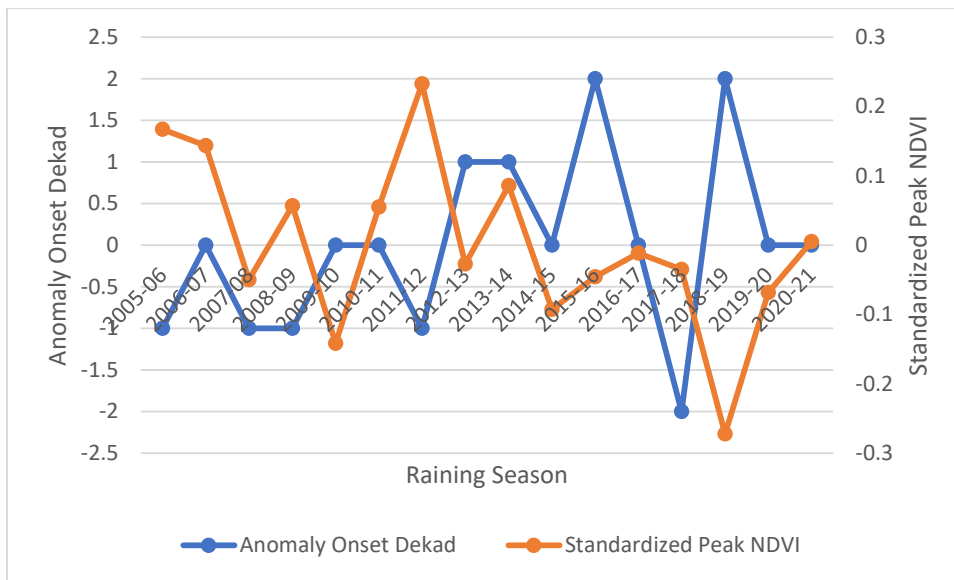


Figure 4.3.8.9: ODA and SP-NDVI for Namwala District

**Appendix 4.3.8.10: Onset Dekads and Peak NDVI for Siavonga District**

Table 4.3.8.10: Onset Dekad and Peak NDVI for Siavonga District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	0	0.7002	0.123514
2006-2007	5	-1	0.6817	0.009655
2007-2008	4	-2	0.6883	0.050275
2008-2009	5	-1	0.6973	0.105666
2009-2010	5	-1	0.6889	0.053968
2010-2011	6	0	0.6723	-0.0482
2011-2012	6	0	0.6689	-0.06912
2012-2013	6	0	0.6827	0.015809
2013-2014	8	2	0.6899	0.060122
2014-2015	8	2	0.6916	0.070585
2015-2016	8	2	0.6715	-0.05312
2016-2017	6	0	0.6977	0.108128
2017-2018	5	-1	0.6952	0.092741
2018-2019	7	1	0.5821	-0.60334
2019-2020	5	-1	0.6564	-0.14605
2020-2021	7	1	0.7174	0.229372

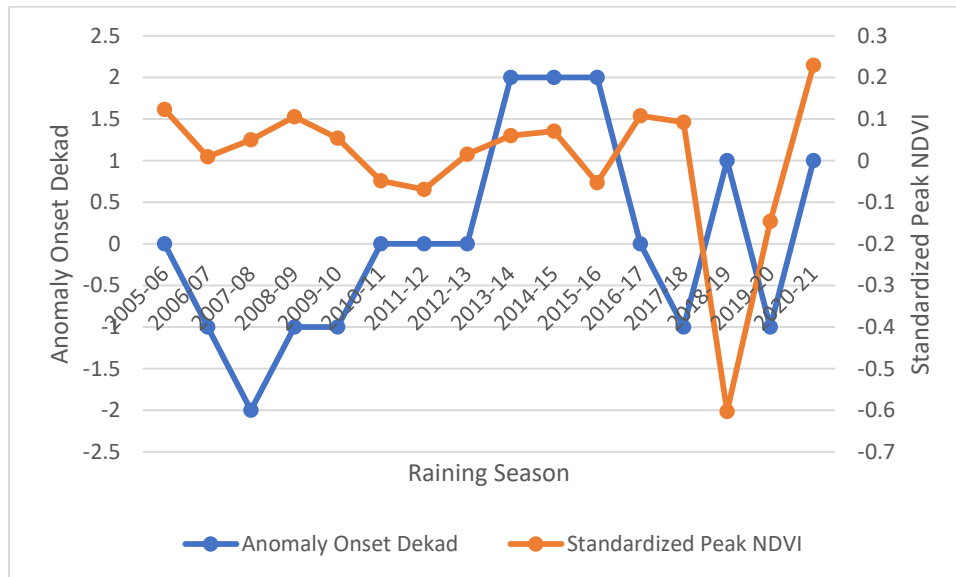
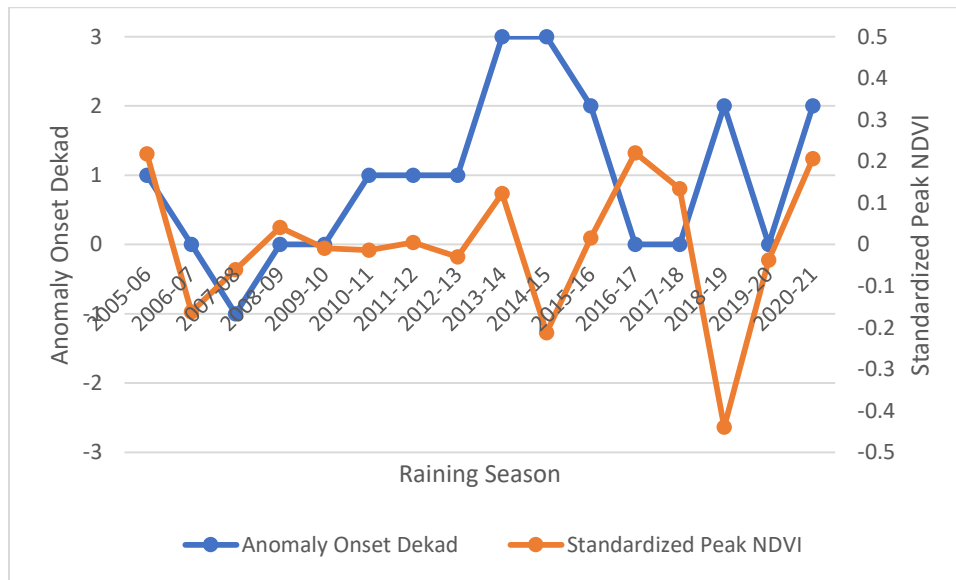


Figure 4.3.8.10: ODA and SP-NDVI for Siavonga District

**Appendix 4.3.8.11: Onset Dekads and Peak NDVI for Sinazongwe District**

*Table 4.3.8.11: Onset Dekad and Peak NDVI for Sinazongwe District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	1	0.6043	0.217743
2006-2007	5	0	0.5523	-0.16189
2007-2008	4	-1	0.5662	-0.06041
2008-2009	5	0	0.5801	0.041066
2009-2010	5	0	0.5733	-0.00858
2010-2011	6	1	0.5726	-0.01369
2011-2012	6	1	0.5751	0.004563
2012-2013	6	1	0.5704	-0.02975
2013-2014	8	3	0.5913	0.122834
2014-2015	8	3	0.5454	-0.21227
2015-2016	7	2	0.5766	0.015514
2016-2017	5	0	0.6047	0.220664
2017-2018	5	0	0.5929	0.134515
2018-2019	7	2	0.5143	-0.43932
2019-2020	5	0	0.5693	-0.03778
2020-2021	7	1	0.6028	0.206792



*Figure 4.3.8.11: ODA and SP-NDVI for Sinazongwe District*

### Appendix 4.3.8.12: Onset Dekads and Peak NDVI for Zimba District

Table 4.3.8.12: Onset Dekad and Peak NDVI for Zimba District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	6	1	0.7205	0.220684
2006-2007	5	0	0.6565	-0.16528
2007-2008	4	-1	0.6815	-0.01451
2008-2009	5	0	0.6986	0.088613
2009-2010	4	-1	0.5733	-0.66703
2010-2011	4	-1	0.6897	0.03494
2011-2012	6	1	0.7067	0.137461
2012-2013	5	0	0.71	0.157362
2013-2014	8	3	0.7223	0.231539
2014-2015	8	3	0.6514	-0.19603
2015-2016	7	2	0.699	0.091025
2016-2017	5	0	0.7285	0.26893
2017-2018	5	0	0.7264	0.256265
2018-2019	6	1	0.6222	-0.37213
2019-2020	5	0	0.6555	-0.17131
2020-2021	5	0	0.7004	0.099468

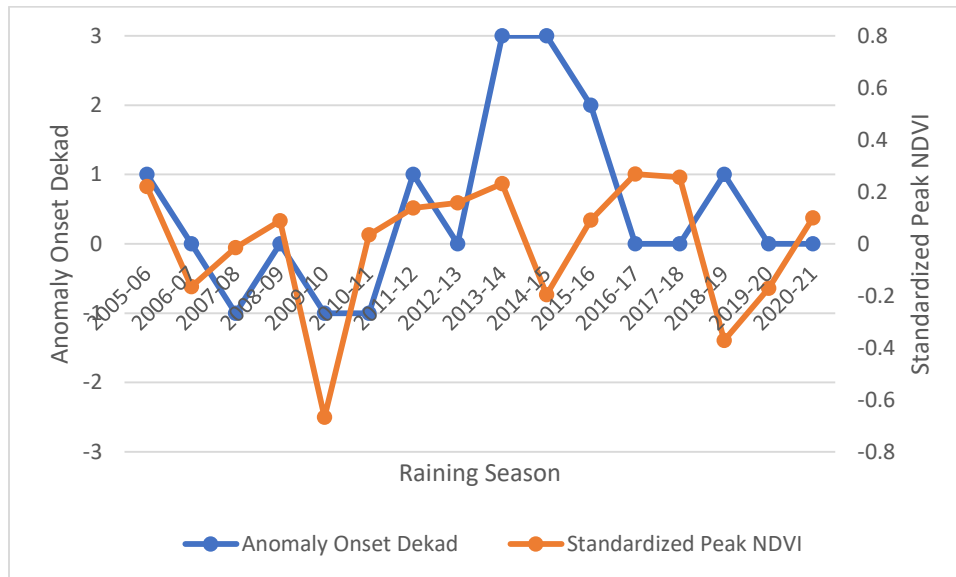
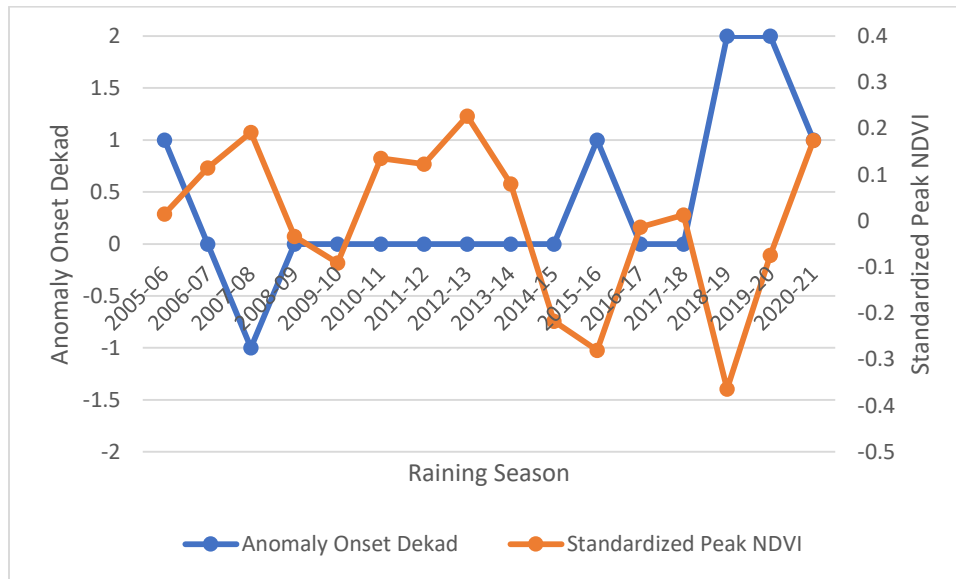


Figure 4.3.8.12: ODA and SP-NDVI for Zimba District

**Appendices 4.3.9: Onset Dekads and Peak NDVI for Districts of Western Province**  
**Appendix 4.3.9.1: Onset Dekads and Peak NDVI for Kalabo District**

*Table 4.3.9.1: Onset Dekad and Peak NDVI for Kalabo District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.5669	0.014709
2006-2007	4	0	0.5804	0.114933
2007-2008	3	-1	0.5907	0.191401
2008-2009	4	0	0.5604	-0.03355
2009-2010	4	0	0.5526	-0.09145
2010-2011	4	0	0.5832	0.135721
2011-2012	4	0	0.5815	0.1231
2012-2013	4	0	0.5955	0.227036
2013-2014	4	0	0.5757	0.08004
2014-2015	4	0	0.5357	-0.21692
2015-2016	5	1	0.5272	-0.28003
2016-2017	4	0	0.5631	-0.0135
2017-2018	4	0	0.5666	0.012482
2018-2019	6	2	0.5159	-0.36392
2019-2020	6	2	0.5549	-0.07438
2020-2021	5	1	0.5884	0.174326



*Figure 4.3.19.1: ODA and SP-NDVI for Kalabo District*

### Appendix 4.3.9.2: Onset Dekads and Peak NDVI for Kaoma District

Table 4.3.10.2: Onset Dekad and Peak NDVI for Kaoma District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.738	0.039248
2006-2007	4	0	0.746	0.085679
2007-2008	4	0	0.7354	0.024158
2008-2009	4	0	0.7203	-0.06348
2009-2010	4	0	0.7269	-0.02517
2010-2011	4	0	0.7204	-0.0629
2011-2012	4	0	0.7449	0.079294
2012-2013	4	0	0.7313	0.000363
2013-2014	4	0	0.7193	-0.06928
2014-2015	4	0	0.7225	-0.05071
2015-2016	5	1	0.7358	0.02648
2016-2017	4	0	0.7417	0.060722
2017-2018	4	0	0.7282	-0.01763
2018-2019	6	2	0.7266	-0.02692
2019-2020	6	2	0.7184	-0.07451
2020-2021	5	1	0.7441	0.074651

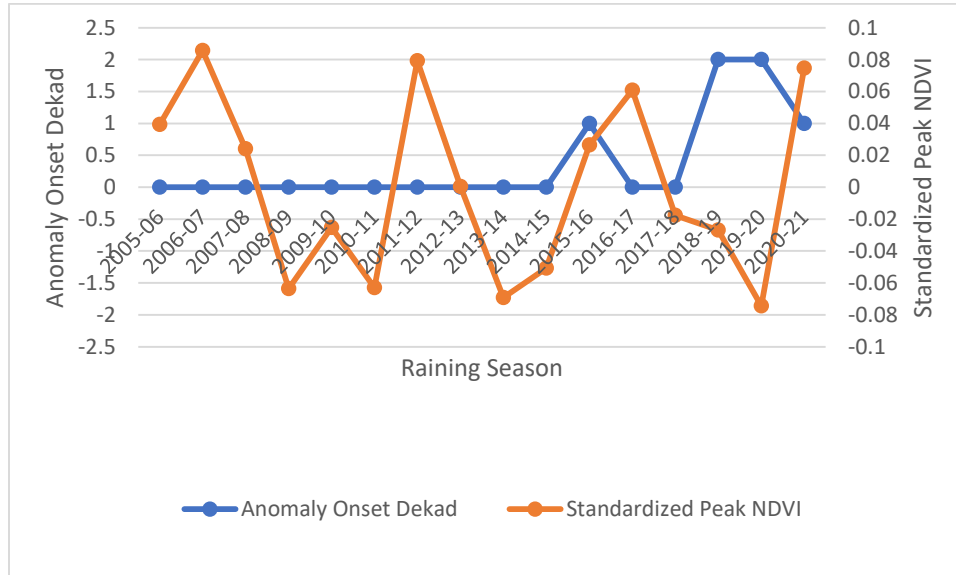
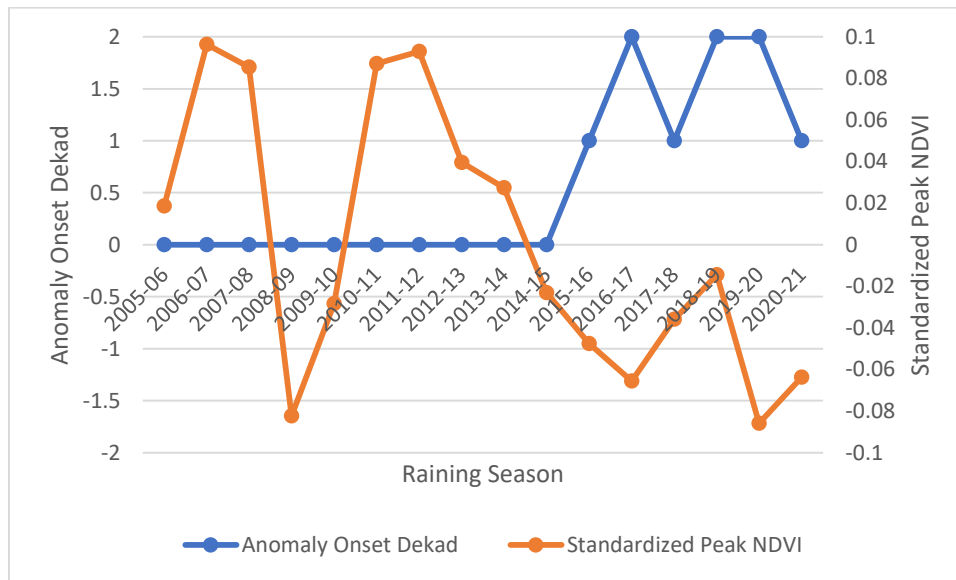


Figure 4.3.10.2: ODA and SP-NDVI for Kaoma District

**Appendix 4.3.9.3: Onset Dekads and Peak NDVI for Lukulu District**

*Table 4.3.9.3: Onset Dekad and Peak NDVI for Lukulu District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.7341	0.018609
2006-2007	4	0	0.7475	0.096383
2007-2008	4	0	0.7456	0.085355
2008-2009	4	0	0.7167	-0.08238
2009-2010	4	0	0.726	-0.0284
2010-2011	4	0	0.7459	0.087096
2011-2012	4	0	0.7469	0.0929
2012-2013	4	0	0.7377	0.039503
2013-2014	4	0	0.7356	0.027315
2014-2015	4	0	0.7269	-0.02318
2015-2016	5	1	0.7227	-0.04756
2016-2017	6	2	0.7196	-0.06555
2017-2018	5	1	0.7247	-0.03595
2018-2019	6	2	0.7284	-0.01447
2019-2020	6	2	0.7161	-0.08586
2020-2021	5	1	0.7199	-0.06381



*Figure 4.3.9.3: ODA and SP-NDVI for Lukulu District*

### Appendix 4.3.9.4: Onset Dekads and Peak NDVI for Mitete District

Table 4.3.9.4: Onset Dekad and Peak NDVI for Mitete District

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	4	0	0.5745	0.028951
2006-2007	4	0	0.5914	0.15341
2007-2008	1	-3	0.5998	0.215271
2008-2009	4	0	0.5545	-0.11834
2009-2010	4	0	0.5633	-0.05353
2010-2011	4	0	0.5934	0.168139
2011-2012	4	0	0.5792	0.063564
2012-2013	2	-2	0.5965	0.190969
2013-2014	3	-1	0.5797	0.067246
2014-2015	4	0	0.5594	-0.08225
2015-2016	5	1	0.5212	-0.36357
2016-2017	4	0	0.5634	-0.05279
2017-2018	4	0	0.5773	0.049572
2018-2019	6	2	0.5358	-0.25605
2019-2020	3	-1	0.5594	-0.08225
2020-2021	5	1	0.5803	0.071665

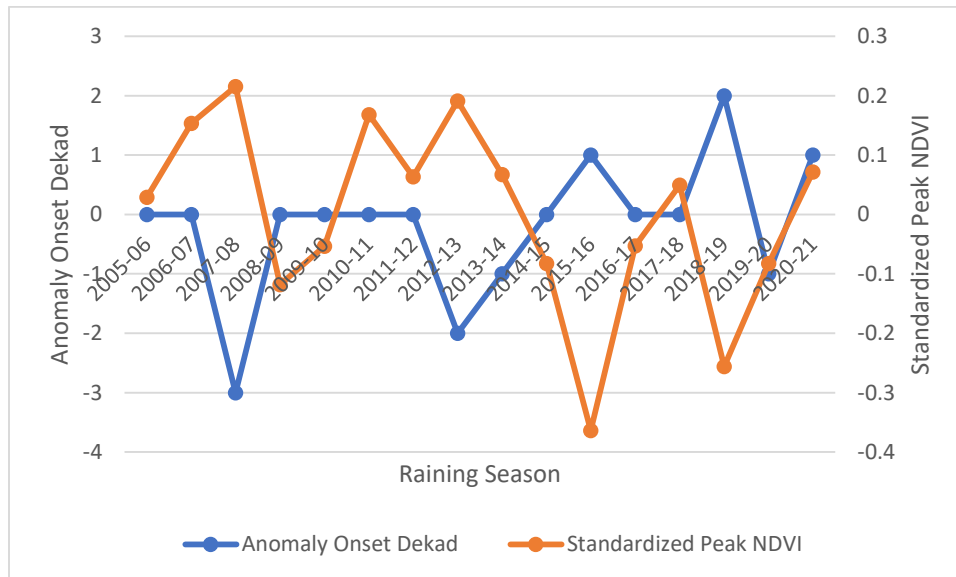
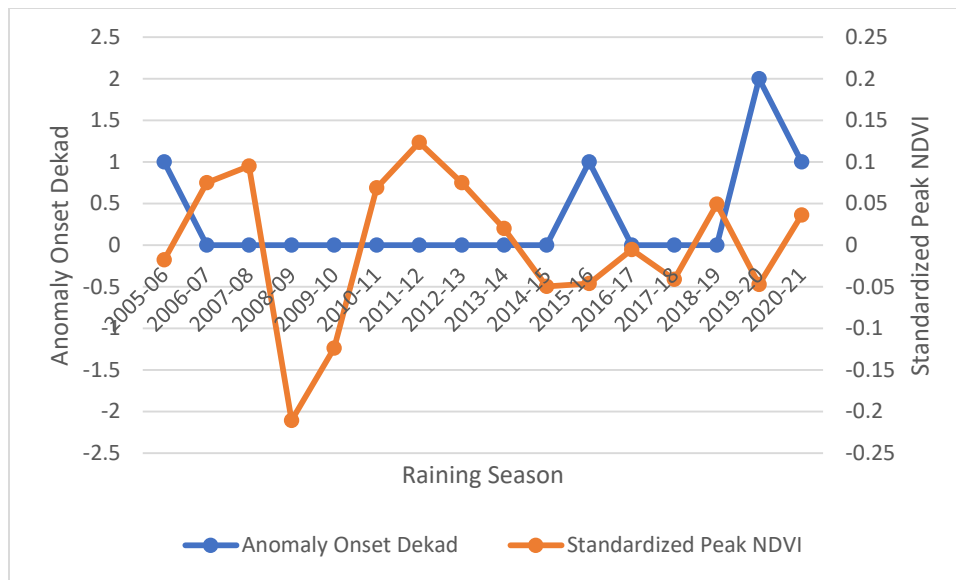


Figure 4.3.9.4: ODA and SP-NDVI for Mitete District

**Appendix 4.3.9.5: Onset Dekads and Peak NDVI for Mongu District**

*Table 4.3.9.5: Onset Dekad and Peak NDVI for Mongu District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.6243	-0.01774
2006-2007	4	0	0.638	0.074829
2007-2008	4	0	0.641	0.095098
2008-2009	4	0	0.5957	-0.21097
2009-2010	4	0	0.6086	-0.12381
2010-2011	4	0	0.6371	0.068748
2011-2012	4	0	0.6452	0.123476
2012-2013	4	0	0.638	0.074829
2013-2014	4	0	0.6299	0.020101
2014-2015	4	0	0.6196	-0.04949
2015-2016	5	1	0.6201	-0.04611
2016-2017	4	0	0.6261	-0.00557
2017-2018	4	0	0.6208	-0.04138
2018-2019	4	0	0.6342	0.049154
2019-2020	6	2	0.6199	-0.04746
2020-2021	5	1	0.6323	0.036316

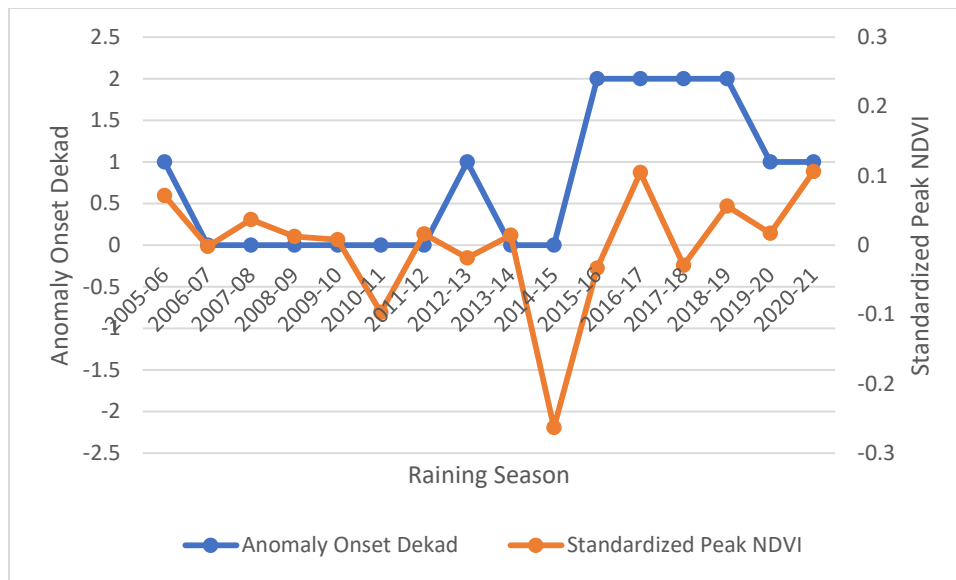


*Figure 4.3.9.5: ODA and SP-NDVI for Mongu District*

**Appendix 4.3.9.6: Onset Dekads and Peak NDVI for Mulobezi District**

*Table 4.3.9.6: Onset Dekad and Peak NDVI for Mulobezi District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.6982	0.071523
2006-2007	4	0	0.6863	-0.00189
2007-2008	4	0	0.6926	0.036976
2008-2009	4	0	0.6886	0.0123
2009-2010	4	0	0.6879	0.007981
2010-2011	4	0	0.6709	-0.09689
2011-2012	4	0	0.6892	0.016001
2012-2013	5	1	0.6836	-0.01855
2013-2014	4	0	0.6889	0.01415
2014-2015	4	0	0.6439	-0.26346
2015-2016	6	2	0.6812	-0.03335
2016-2017	6	2	0.7036	0.104836
2017-2018	6	2	0.6819	-0.02903
2018-2019	6	2	0.6957	0.0561
2019-2020	5	1	0.6894	0.017235
2020-2021	5	1	0.7038	0.10607

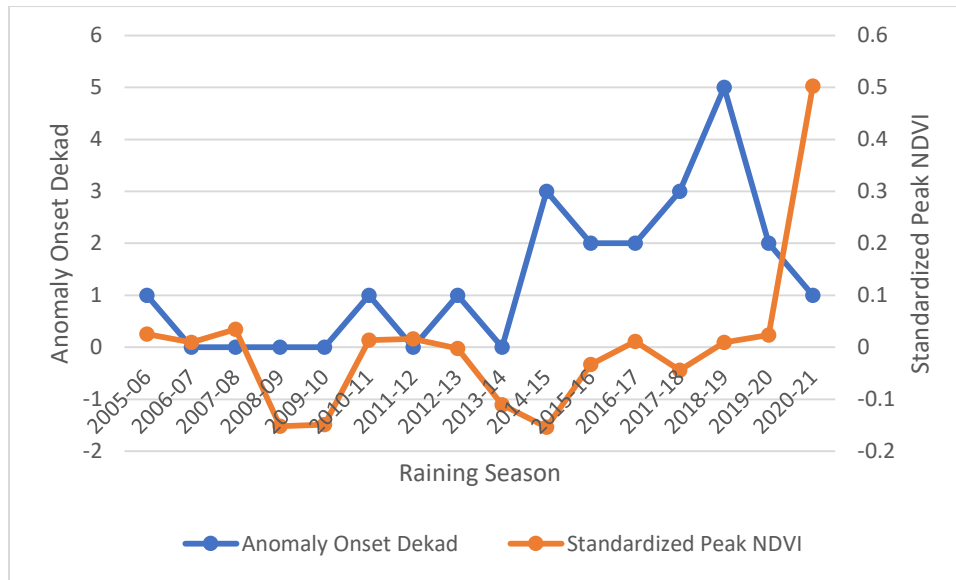


*Figure 4.3.6.6: ODA and SP-NDVI for Mulobezi District*

**Appendix 4.3.9.7: Onset Dekads and Peak NDVI for Senanga District**

*Table 4.3.9.7: Onset Dekad and Peak NDVI for Senanga District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.6298	0.025244
2006-2007	4	0	0.6274	0.009115
2007-2008	4	0	0.6312	0.034653
2008-2009	4	0	0.6034	-0.15218
2009-2010	4	0	0.6039	-0.14882
2010-2011	5	1	0.6281	0.013819
2011-2012	4	0	0.6284	0.015835
2012-2013	5	1	0.6257	-0.00231
2013-2014	4	0	0.6096	-0.11051
2014-2015	7	3	0.6032	-0.15352
2015-2016	6	2	0.6211	-0.03322
2016-2017	6	2	0.6277	0.011131
2017-2018	7	3	0.6195	-0.04398
2018-2019	9	5	0.6274	0.009115
2019-2020	6	2	0.6295	0.023228
2020-2021	5	1	0.7008	0.5024

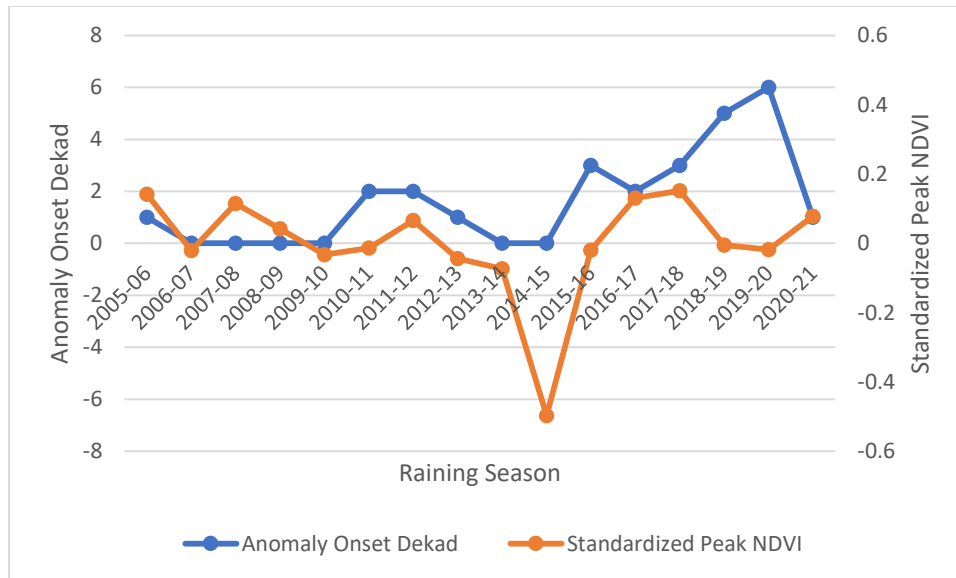


*Figure 4.3.9.7: ODA and SP-NDVI for Senanga District*

**Appendix 4.3.9.8: Onset Dekads and Peak NDVI for Sesheke District**

*Table 4.3.9.8: Onset Dekad and Peak NDVI for Sesheke District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	1	0.7091	0.141544
2006-2007	4	0	0.6826	-0.02097
2007-2008	4	0	0.7048	0.115175
2008-2009	4	0	0.6929	0.042199
2009-2010	4	0	0.6807	-0.03262
2010-2011	6	2	0.6838	-0.01361
2011-2012	6	2	0.6967	0.065502
2012-2013	5	1	0.6789	-0.04366
2013-2014	4	0	0.6741	-0.07309
2014-2015	4	0	0.6049	-0.49745
2015-2016	7	3	0.6828	-0.01974
2016-2017	6	2	0.7073	0.130506
2017-2018	7	3	0.7107	0.151356
2018-2019	9	5	0.6852	-0.00502
2019-2020	10	6	0.683	-0.01851
2020-2021	5	1	0.6988	0.07838

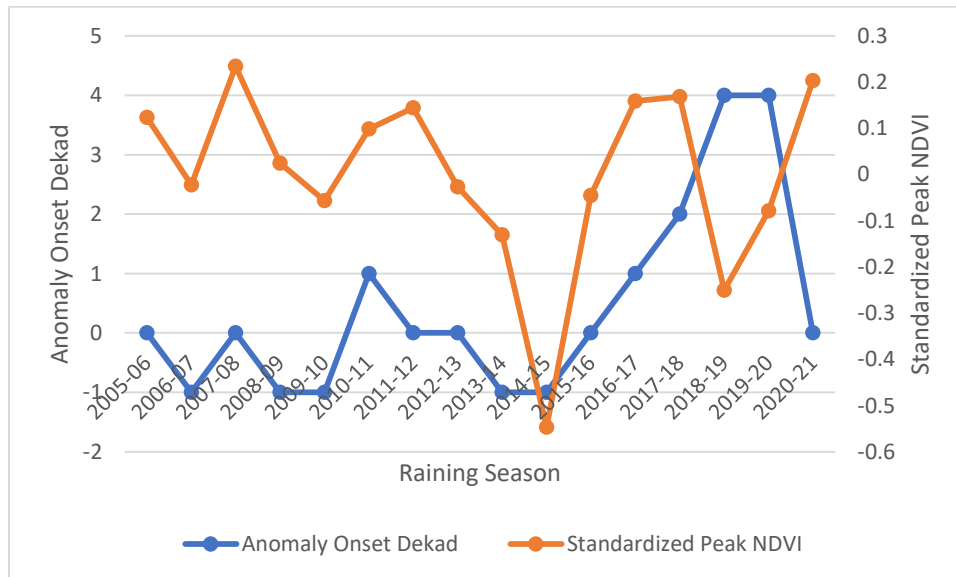


*Figure 4.3.9.8: ODA and SP-NDVI for Sesheke District*

**Appendix 4.3.9.9: Onset Dekads and Peak NDVI for Shangombo District**

*Table 4.3.9.9: Onset Dekad and Peak NDVI for Shangombo District*

Year	Onset Dekad	Onset Anomaly	Peak NDVI	Standardized Peak NDVI
2005-2006	5	0	0.6499	0.123331
2006-2007	4	-1	0.6279	-0.0222
2007-2008	5	0	0.6667	0.234465
2008-2009	4	-1	0.635	0.024765
2009-2010	4	-1	0.6227	-0.0566
2010-2011	6	1	0.6462	0.098855
2011-2012	5	0	0.6531	0.144499
2012-2013	5	0	0.6272	-0.02683
2013-2014	4	-1	0.6115	-0.13069
2014-2015	4	-1	0.5486	-0.54678
2015-2016	5	0	0.6244	-0.04536
2016-2017	6	1	0.6553	0.159053
2017-2018	7	2	0.6568	0.168975
2018-2019	9	4	0.5934	-0.25042
2019-2020	9	4	0.6194	-0.07843
2020-2021	5	0	0.662	0.203374



*Figure 4.3.10.9: ODA and SP-NDVI for Shangombo District*

### Appendix 4.5.1: DMMU AFI Analysis from 2018 to 2021

No.	District	May -Sep 2018	Oct 2018- Mar 2019	May- Sep 2019	Oct 2019- Mar 2020	Feb- Mar 2021	Jun- Sep 2022	No. of Times	Correlations	AFI Mode
1	Solwezi	1	1			2	2	4	0.073064	2
2	Luanshya						2	1	0.234355	2
3	Lufwanyama						2	1	0.166378	2
4	Masaiti						2	1	0.186589	2
5	Mpongwe						2	1	0.172371	2
6	Chipata						2	1	-0.02478	2
7	Chibombo	1	2	3	3		1	5	0.129774	3
8	Mkushi	1	2			2		3	0.454809	2
9	Mansa			2	2	2	2	4	0.109891	2
10	Lusaka						2	1	-0.50645	2
11	Mwense			2	2	2		3	-0.01738	2
12	Nchelenge			2	2		2	3	0.276426	2
13	Kasempa						2	1	-0.1191	2
14	Mwinilunga			2	2		2	3	-0.35493	2
15	Namwala	2	2	2	2		2	5	-0.44819	2
16	Itezhi-tezhi	2	2	2	3		2	5	0.339624	2
17	Kapiri mposhi			2	3		2	3	0.368203	2
18	Serenje			2	3	2	2	4	0.60387	2
19	Mumbwa	2	2	3	3		2	5	0.04869	2
20	Petauke	2	3	2	3	3	2	6	0.325193	3
21	Kawambwa			2	2	3	2	4	-0.01547	2
22	Chongwe	2	2	2	3		2	5	0.374055	2
23	Kafue	2	2	3	3		2	5	0.261473	2
24	Chavuma	2	2	3	3	3	2	6	0.033839	3
25	Zambezi	2	2	3	3	3	2	6	0.098099	3
26	Kalomo	2	2	3	3		2	5	-0.30499	2
27	Kazungula	2	2	3	3	3	2	6	0.017565	3
28	Monze	1	2	3	3		2	5	-0.43767	3
29	Ikelenge			2	3			2	0.173916	3
30	Manyinga			2	3			2	0.110352	3
31	Zimba	1	2	3	3		2	5	0.18899	3
32	Kalabo	2	2	3	3	3	2	6	-0.55626	3
33	Gwembe	2	2	4	4	3	3	6	-0.26546	4
34	Samfya	2	2	3	3	3	3	6	0.299008	3
35	Luangwa	2	3	3	3	3	3	6	0.101329	3
36	Kabompo			3	3		2	3	0.195416	3
37	Kaputa			3	3	3	2	4	-0.17561	3
38	Mazabuka	1	2	3	3	3	2	6	-0.08708	3
39	Siavonga	2	3	3	3	3	2	6	-0.1274	3
40	Sinazongwe	2	3	3	3	3	3	6	-0.15179	3
41	Kaoma	2	3	3	3		2	5	-0.16626	3
42	Lukulu	2	3	3	3	3	2	6	-0.60511	3
43	Mitete	2	3	3	3	3	2	6	-0.64974	3
44	Mongu			3	3	3	2	4	-0.15617	3
45	Mulobezi	2	3	3	3	3	2	6	0.333518	3
46	Senanga	2	3	3	3		2	5	-0.00168	3
47	Sesheke	2	3	3	3	3	2	6	0.189931	3
48	Lunga	3	3	4	4	3	3	6	-0.09794	3
49	Shangombo	2	2	3	4	3	3	6	0.002466	3

#### Appendix 4.5.2: Correlations and Assigned AFI-Phase of risk level

No.	Province	District	Correlation	AFI-Assigned
1	Central	Chibombo	0.129774	2
2	Central	Kapiri Mposhi	0.368203	2
3	Central	Mkushi	0.454809	2
4	Central	Mumbwa	0.04869	2
5	Central	Serenje	0.60387	2
6	Copperbelt	Luanshya	0.234355	2
7	Copperbelt	Lufwanyama	0.166378	2
8	Copperbelt	Masaiti	0.186589	2
9	Copperbelt	Mpongwe	0.172371	2
10	Copperbelt	Chingola	-0.00516	2
11	Eastern	Nyimba	0.605511	2
12	Eastern	Petauke	0.325193	2
13	Eastern	Chipata	-0.02478	2
14	Luapula	Chienge	0.584487	2
15	Luapula	Mansa	0.109891	2
16	Luapula	Milenge	0.222161	2
17	Luapula	Nchelenge	0.276426	2
18	Luapula	Samfya	0.299008	2
19	Luapula	Kawambwa	-0.01547	2
20	Luapula	Lunga	-0.09794	2
21	Luapula	Mwense	-0.01738	2
22	Lusaka	Chongwe	0.374055	2
23	Lusaka	Kafue	0.261473	2
24	Lusaka	Luangwa	0.101329	2
25	Lusaka	Rufunsa	0.522725	2
26	Lusaka	Lusaka	-0.50645	3
27	Northern	Nsama	0.567593	2
28	Northern	Kaputa	-0.17561	3
29	North-Western	Chavuma	0.033839	2
30	North-Western	Ikelenge	0.173916	2
31	North-Western	Kabompo	0.195416	2
32	North-Western	Manyinga	0.110352	2
33	North-Western	Solwezi	0.073064	2
34	North-Western	Zambezi	0.098099	2
35	North-Western	Kasempa	-0.1191	3
36	North-Western	Mwinilunga	-0.35493	3
37	Southern	Itezhi-Tezhi	0.339624	2
38	Southern	Zimba	0.18899	2
39	Southern	Choma_	-0.49759	3

40	Southern	Gwembe	-0.26546	<b>3</b>
41	Southern	Kalomo	-0.30499	<b>3</b>
42	Southern	Kazungula	0.017565	<b>2</b>
43	Southern	Livingstone	-0.2854	<b>3</b>
44	Southern	Mazabuka	-0.08708	<b>2</b>
45	Southern	Monze	-0.43767	<b>3</b>
46	Southern	Namwala	-0.44819	<b>3</b>
47	Southern	Siavonga	-0.1274	<b>3</b>
48	Southern	Sinazongwe	-0.15179	<b>3</b>
49	Western	Mulobezi	0.333518	<b>2</b>
50	Western	Sesheke	0.189931	<b>2</b>
51	Western	Kalabo	-0.55626	<b>3</b>
52	Western	Kaoma	-0.16626	<b>3</b>
53	Western	Lukulu	-0.60511	<b>3</b>
54	Western	Mitete	-0.64974	<b>3</b>
55	Western	Mongu	-0.15617	<b>3</b>
56	Western	Senanga	-0.00168	<b>2</b>
57	Western	Shangombo	0.002466	<b>2</b>