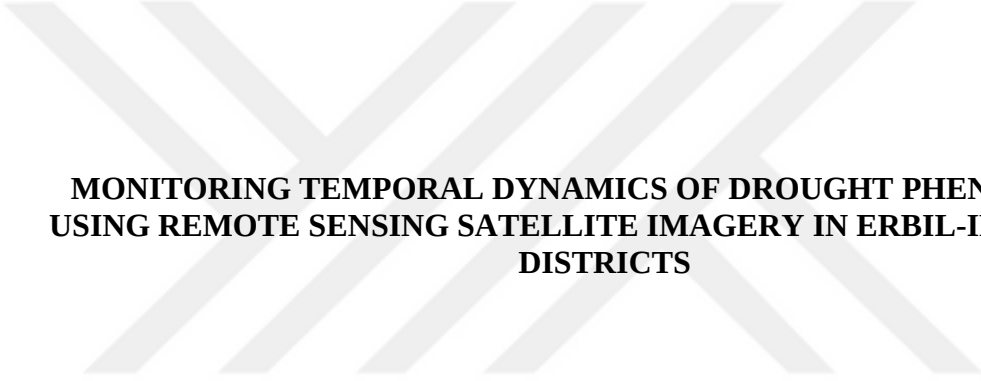


**REPUBLIC OF TURKEY
HARRAN UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES**

DOCTORATE THESIS



**MONITORING TEMPORAL DYNAMICS OF DROUGHT PHENOMENON
USING REMOTE SENSING SATELLITE IMAGERY IN ERBIL-IRAQ-PLAIN
DISTRICTS**

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DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

ŞANLIURFA

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**The Republic of Turkey
HARRAN UNIVERSITY
GRADUATE OFFICE**

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ÖZET

Doktora Tezi

ERBİL(İRAK) BÖLGESİNDE UZAKTAN ALGILAMA VE UYDU GÖRÜNTÜLERİNİ KULLANARAK KURAKLIĞIN ZAMANSAL DİMANİĞİNİN TAKİBİ

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Tüm çevre sorunlarının en karmaşık ve zararlı olan kuraklık, “yağışların kaydedilen seviyelerden daha az olması veya yanlış insan müdahalesi nedeniyle ortaya çıkan ve yeryüzünün kaynaklarının üretim sistemlerini olumsuz yönde etkileyen birçok hidrolojik soruna neden olan fenomen olarak tanımlanmaktadır. " Kuraklığın bilimsel tanımı, belirli bir alandaki kuraklığın başlangıcı, sonu, mekansal boyutu ve yoğunluğunu belirlemeye odaklanır. Son yıllarda, GIS ve RS, ister doğal olarak meydana gelen isterse insan yapımı olsun, farklı türlerdeki çevre sorunlarının incelenmesinde önemli roller oynadılar. Bu çalışma, tarımsal kuraklık risk değerlendirmesi alanında RS ve GIS kullanımına odaklanmaktadır. Mevcut çalışmada, kuraklık riskine maruz kalan alanlar, standardize edilmiş katılım endeksini (SPI) belirlemek için çalışma alanının 2009–2019 yıllarına ait yağış verileri ile Landsat TM ve OLI'den alınan uydu görüntüleri kullanılarak tespit edilmiştir. bitki örtüsü, su ve sıcaklık yüzdeleri tahmin etmek ve izlemek için NDVI, GNDVI, NDWI, DSWI ve LST dahil olmak üzere çeşitli spektral endeksleri üretmek. Ayrıca, endeksler ile YSI sonuçları arasındaki ilişkiyi ortaya çıkarmak için doğrusal regresyon yöntemi kullanılmıştır. Çalışma, kuraklık şiddetinin farklı alanlarda nasıl değiştiğini gösterdiğinden, sonuçlar hem LST hem de NDWI göstergeleri arasında SPI 3 arasında güçlü bir korelasyon olduğunu ortaya koymuştur. 2009 yılında, çalışma alanının merkezi orta dereceli bir kuraklığa maruz kalırken, 2011 ve 2017 yıllarında şiddetli ve aşırı kuraklığın etkileri çalışma alanının orta ve güney kısımlarına yansımıştır. Genel olarak, çalışma alanı şiddetli kuraklıklardan muzdarip değildir ve toplam çalışma alanının yaklaşık% 50-65'i normal kuraklık aralığına düşmektedir. Dahası, GNDVI ve NDVI doğrudan pozitif bir ilişki içindedir: Mevsimsel değişikliklere göre birinin değeri ne kadar yüksekse, diğerinin karşılık gelen değeri o kadar yüksek olur. Bu çalışmanın önemi, kuraklık olgusunu, şiddetini ve mekansal değişimlerini izlemesinde yatmaktadır. Çalışmanın sonuçları, kuraklıkların şiddetini azaltmak ve bunları doğru bir şekilde yönetmek için gerekli önlemleri ve planları uygulamak için bir araç olarak kullanılabilir.

ANAHTAR KELİMELER: Landsat görüntüler, Kuraklık, Standart katılım endeksi, Bitki indeksi, Kara Yüzey Sıcaklığı

ABSTRACT

Doctorate Thesis

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Drought, the most complex and harmful of all environmental problems, is defined as “the phenomenon that occurs when rainfall is less than the recorded levels or due to incorrect human interference, which causes several hydrological problems that negatively affect the production systems of the earth’s resources.” The scientific definition of drought focuses on determining the onset, end, spatial extent and intensity of drought in a given area. In recent years, GIS and RS have played major roles in studying different types of environmental problems, whether these are naturally occurring or man-made. This study focuses on the use of RS and GIS in the field of agriculture drought risk assessment. In the current work, the areas exposed to drought risks were identified using the rainfall data of the study area for the years 2009–2019 to determine standardized participation index (SPI), as well as satellite images from Landsat TM and OLI, which were utilized to derive several spectral indices, including NDVI, GNDVI, NDWI, DSWI and Land Surface Temperature (LST), to estimate and monitor the percentages of vegetation, water, and temperatures. Furthermore, the linear regression method was used to reveal the relationship between the indices and SPI results. The results revealed that there is a strong correlation between both LST and NDWI indicators with SPI 3. As the study illustrated the way in which drought severity varies in different areas. In 2009, the center of the study area was exposed to a moderate drought, while in 2011 and 2017 the effects of severe and extreme drought were reflected in the central and southern parts of the study area. Generally, the study area does not suffer from severe droughts, with some 50–65% of the total study area falling within the normal drought range. Moreover, GNDVI and the NDVI are in a direct positive relationship: the higher the value of one, the higher the corresponding value of the other, according to seasonal changes. The importance of this study lies in the fact that it monitors the drought phenomenon, its severity, and its spatial variations. The results of the study can be used as a means to implement the necessary measures and plans to mitigate the severity of droughts and to manage them properly.

KEY WORDS: Landsat imagery, Drought, Standardized participation index, Vegetation index, Land Surface Temperature

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LIST OF SYMBOL AND ABBRIVATIONS

AVHRR	Advanced Very High-Resolution Radiometer
CI	Chlorophyll Index
CMI	Crop Moisture Index
CSDI	Crop Specific Drought Index
CWSI	Crop Water Stress Index
DN	Digital Number
DSWI	Disease Water Stress Index
DVs	Digital Values
ECMWF	European Centre for Medium-range Weather Forecasts
ETM+	Enhanced Thematic Mapper Plus
EWSI	European Web Site on Integration
GIMMS	Global Agricultural Monitoring System
GIS	Geographical Information Systems
GNDVI	Green Normalized Difference Vegetation Index
GVMi	Global Vegetation Moisture Index
IMD	India Meteorological Department
IR	Infrared
IRS	Internal Revenue Service
LAI	Leaf Area Index
LSE	Land Surface Emissivity
LST	Land Surface Temperature
MCSA	Monte Carlo Sampling Approach
MNDWI	Modified Normalized Difference Water Index
MPDI	Modified Perpendicular Drought Index
MSI	Moisture Stress Index
MSI	Media Sustainability Index
NCEP	National Centers for Environmental Predictions
NCRC	National Climate Research Centre
NDTI	Normalized Difference Temperature Index
NDVI	Normalized Vegetation Index
NDWI	Normalized Difference Water Index
NIR	Near-Infrared
NMDI	Normalized Multiband Drought Index
OLI	Operational Land Imager
PDI	Power-Distance Index
PDSI	Palmer Drought Severity Index
PRI	Photochemical Reflectance Index
RGB	Red, Green, And Blue
SAVI	Soil Adjust Vegetation Index
SIWSI	Shortwave Infrared Water Stress Index
SPEI	Standardized Precipitation-Evapotranspiration Index
SPI	Standardized Precipitation Index
SRWI	Simple Ratio Water Index
SWIR	Short-Wave Infrared
TCI	Temperature Condition Index
TIFF	Tagged Image File Format
TM	Thematic Mapper
TMI	Trmm Microwave Imager
TVX	Temperature Vegetation Index
USA	United States

USGS	United States Geological Survey
UTM	Universal Transform Mercator
VCi	Vegetation Condition Index
VIRS	Visible and Infrared Scanner
VIS	Visible
VSDI	Visible and Shortwave Drought Index
WGS	World Geodetic System
WMO	World Meteorological Organization



1. INTRODUCTION

Drought as a phenomenon can take place on multiple places on the planet and this phenomenon is what distinguishes the Great Plains weather conditions (Wilhite and Rosenberg, 1986). In terms of its definition, it is that time of the year when rainfall decreases less than the anticipated yearly average which could lead to significant alterations in the availability of plans (Wilhite and Glantz, 1985). However, this phenomenon has undesirable effects on different areas of life such as plantation and whether or not the area becomes a touristy place which is one of the social aspects of drought (Wilhite, 2000). Hence, it is quite important to study drought and prepared the appropriate equipment to observe it so that people in power get precise information on how to deal with it (Western Governors' Association, 2004).

The Middle East and in particular Iraq has, for many years, been inflected by drought in addition to having a decrease in the amount of water coming from rivers; moreover, the area is also suffering from having drought being spread more in one area in comparison to another. When it comes to Erbil plain districts, this city has been through many drought occurrences which were the result of different causes such as a decreased precipitation average, hot weathers, a decreased water gain and not utilizing water efficiently. These causes engendered an impact of different dimensions on the region manifested in having a reduction in water resources, how much water is present under the surface, having people migrating to other areas and deterioration in plantation.

Rainfall, in particular in the city of Erbil the largest in the north of Iraq, is not allocated in an equal fashion and this is when talking about the geography of the distribution and during the year. That is to say, the largest amounts of rain fall only between October and May, and the occurrence of drought usually takes place in the hot season and in the fall, which has a drastic effect on the yields of the region (Qader,

Therefore, it is quite important to observe and study drought in Erbil to lessen its multidimensional impacts whether on agriculture or on society.

There exist two techniques of drought observation: ground observation and remote sensing. Ground observation, which makes use of ground monitoring to observe possible drought occurrences, has its own desirable and undesirable sides. Its desirable effects lie in that the method is immediate and provides precise outcomes. However, the desirable effect is that it is not fast in giving a sufficient and complete amount of data for the area under investigation. What is more, this technique needs a lot of effort which makes it very not cheap. Consequently, the second method is regarded the best for drought observation. Space remote sensing is a quick and cheap solution for observing drought occurrences; nonetheless, it needs the advancement of a complicated scheme to investigate an area under investigation. Remote sensing and geographical information system (GIS) have had a major positive effect regarding the study of earth and in particular drought observation and this is from the time such technologies were first developed.

The procedures of remote sensing revolve around having a couple of satellites in space and some aircrafts that assess different characteristics of the surface of the earth through the employment of electromagnetic radiation, and it is right now employed for a lot of objectives related to the environment or some other issues like monitoring global change, plantation, metrology, some army-related uses, and for the investigation of resources which can/cannot be renewed (Schowengerdt, 2006). Remote sensing can be defined as the procedure of gaining data regarding the surface of earth and that of the water by means of images gained from a space observational mechanism while employing electromagnetic radiation in a single or different region(s) (Campbell, 2002). Because of the new advancement which were given to remote sensing, it is now not difficult at all to view images from satellites regarding the planning of cities or soil in addition to having other tasks. Moreover, the various settings of a complex ecological system can be mapped quite effectively by using the technology. For instance, different

indicators have been advanced to investigate the characteristics of plantation and the changeability of plantation, and a large set of remotely sensed information are not possible to be collected in plantation research. In the final place, remote sensing has been shown to be quite beneficial for studying drought in various places on earth. That's said, GIS are regarded to be efficient to map and analyze images in software programs. GIS is defined as a program to capture, store, manipulate, analyze and display information about the surface of earth (Maguire, 1991). In this research, to make a land cover map of the area of the study, the Arc Map 10.7 GIS software was employed.

One kind of drought which is commonly referred to as agricultural drought, engenders agricultural damage of high amount; moreover, it can also lead to damage in vegetation cover. This issue creates a major problem to how much food is secure and in particulate for regions where there are countries that rely on agriculture as a principle source of commerce and survivability. There exist two ways for observing agricultural drought when using remote sensing. The first way writes down alterations in the moisture of soil by making images of the spectral reflectance of the surface in the images of the satellite. What is being studied in this study is agro-drought because the place of the study is an area of agriculture, and between the years 2009-2019 there was the danger of having drought. Because of a rise in soil humidity, the reflective properties of soil got less as it was found in a study by Bowers and Hanks (1965). The second way of remote sensing is concerned with alterations in the physiological operations of plantation by writing down the spectral properties of leaves through the employment of remote sensing. This technique was used by Idso et al. (1975) and Jackson et al. (1981) in their study on drought observation employing the indicator of water stress. Therefore, the context of the study is commonly viewed as an area of agriculture; consequently, it is important to spot drought in the area of the study to be informed about how much has drought impacted production in agriculture.

The moderate resolution imaging spectrometer (Landsat imagery) is one of the important elements of remote sensing for drought observation. This component can

images of the surface every two weeks. For the time being, the Landsat imaging system is put into use in a lot of countries or places that are in danger of encountering drought. Along the Landsat imaging system, it is also employed as an efficient way to measure rainfall in order to obtain an outlook of any decrease or rise in the yearly precipitation. Because remote sensing has been attested to be an efficient way for drought catastrophes observation in a lot of countries on the planet, it has been used in this research along the employment of a Landsat imaging system. Few studies have been conducted in Iraq that has used technologies of geographical data to investigate droughts and their effects. Hence, there is this urgent necessity to conduct such drought research to reduce this catastrophe and provide answers for the effects of this phenomenon.

As it was noted above, remote sensing has the possibility to observe and pinpoint drought of agriculture in huge areas in very short times. The main principle of using remotely sensed data to pinpoint drought is that distinguishable indicators are clear when they are observed from different positions of the electromagnetic spectrum that can be gotten from the remote sensing posts. A lot of research has used spectral vegetation indicators to observe and pinpoint drought of agriculture. The SVIs were developed to enhance explanations of vegetation indices when employing remote-sensing data and could be employed to assess the state of vegetation while decreasing the radiance of the sun and the background impacts of the soil (Jackson and Huete 1991; Moulin 1999; Darvishzadeh et al. 2009). Furthermore, the merging of various spectral bands is so associated with the biophysical and biochemical characteristics of vegetation vigor is related to how healthy the plant is and can be employed to pinpoint morphological and physiological alterations engendered by the stress which drought causes (RullanSilva et al. 2013). Consequently, the indices of spectral plantation have been attested to be more practical for indicating stress caused by drought.

1.1. The Aim and Objective of the Study

The main of this study is to investigate the importance of remote sensing data in monitoring and detecting agriculture drought phenomenon. To do this, we utilized time series satellite imagery from Landsat platform along with metrological station data. To fulfill the study aim; four sub-objectives has been designed as follow:

1. Monitor and detect temporal variation of drought phenomenon over the study area 2009 till 2019.
2. Evaluating the importance and feasibility of difference spectral indices like (NDVI, GNDVI, NDWI, DSWI), (LST) and (SPI) in monitoring and detecting drought phenomenon.
3. Exploring exhibiting correlation between different spectral indices and SPI.
4. Mapping temporal changes of drought phenomenon over the study area by means of remote sensing data.

1.2. Research Questions

1. What are the associations between the remote sensing indices and rainfall in the area of the research?
2. And in what way they can point to drought? In what ways did the changeability of seasons and their spreading affect the number of times of having agro-drought between 2009-2019?

2. LITERATURE REVIEW

2.1. Literature Review Introduction

One of the dangers which can inflect nature is drought. We all know that drought happens when there is little or no rain. That is, when the level of raining and water dramatically decreases (Morella et al, 2007). As a result of drought lack of sufficient water happens in environment and some other groups and sectors. Moreover, when temperature goes up and remains high for a long time, evaporation happens and, consequently, raining decreases (Peck and Adams, 2010). Further, when raining doesn't happen in the right time, crops and plans delay their growth, consequently, droughts occur. These circumstance's desperately affects the wind. Once the high winds are badly affected, the level of humidity drops down. It is common that drought happens in all places. Droughts vary from one place to another depending on the climate of the places. In some place's droughts remain for a long time, whereas in some place's droughts do not last long. However, droughts are still regarded as a "temporary condition". Lots of people think that drought is something relevant to natural catastrophe. However, the real cause of drought is due to the fact that people use water abundantly and this leads to drought (Booker et al, 2005). Thus, when there is drought, natural water cannot meet people's needs. Further, developed and developing countries deal with this problem differently. Drought affects all people and economy is severely affected (Omar, 2014).

It is obvious that droughts terribly influence those things that highly depend on water, such as agriculture, food, and agro-food. Also, it also severely impacts employment as many people lose their jobs as a result of droughts, especially in agricultural sectors. Droughts impacts those lands the most which solely depend on rain. This is because when there is no rain, production will significantly decrease (Berrittella et al, 2007). Some societies depend too much on the lands that are either irrigated or rain-fed. These lands provide food for these societies. Hence, both types of lands are severely impacted because low precipitation leads to low production and low production leads to few agro-foods.

Iglesias et al (2007) and Wilhite et al. (2007) maintain that it is complex to show and measure the influence that droughts have on economy. It is really important to have some methodologies to assess the effects droughts have and these methodologies should be able to distinguish drought from other factors that impact economy.

It is important to precisely assesses factors relating to socioeconomic and environment because this helps to mitigate droughts and its influences. Due to the fact that climate is changing rapidly, forms of accurate assessments should be upgraded, so that natural threats, such as droughts, are to be prevented from occurring. As a result, Xerochore and ConHaz Logar and van den Bergh, 2013 has been proposed. This project is funded by EU. The aim of this project is to ameliorate and reduce the impacts of droughts. In this project several alternatives have been investigated so as to gauge their competence in reducing influences. Looking at the literature, it appears that so many studies have been conducted on how to handle a special drought occurrence and how it happens (Ding et al, 2011). On the contrary, we do need to have accurate assessments on how droughts severely impact society, economy, and environment.

2.2. Definitions of Drought

Generally speaking, drought occurs when it does not rain for a long time. This results in lacking sufficient water, which harshly affects vegetation, animals and human beings (Heathcote, 2013). Drought is a common event that happens everywhere. That is, occurs in dry zones as well as wet zones. However, we should know that there is a disparity between drought and aridity (dryness). Aridity is permanent which happens as result of lack of rain. If a land is impacted by aridity, this land will change into desert (Hartmann et al, 2013). According to (Wipfler et al, 2009), definitions of droughts are of two kinds: conceptual drought and operational drought. Conceptual drought talks about the impact's droughts and it as meanings. For example, conceptual drought tells us that droughts happen as a result of low precipitation, which harshly devastates plants, crops, etc. However, the operational type of drought sheds light on the beginning of the its harshness, and how dry it is (Estrela and Vargas, 2012). To know when a drought

begins, we should investigate when rain stops. To gain this, the present amount of rain is compared to the average precipitation in the history of the place.

If we want to know how much moisture in soil decreases, operational definition tells us that we should compare and contrast daily rain with evaporation rates occurring in a day. Operational definition throws light on how many times droughts occurred, how harsh they are and how long they last. These are all in a given historical period. For this reason, one should gather data monthly, daily and hourly. Plus, crop profit should be gathered for this type of definition. Because there are few accurate definitions, many experts encounter difficulty in implementing their policies to prevent droughts from happening. Consequently, information for this kind of delineation are gathered into different time periods (every month, day or hour), and information with regard to the effect of time are also gathered which includes the time of gathering the crops or other time points. Therefore, during droughts, people try to utilize mathematical indices to know when to preserve, control and manage those fresh water that has been saved. These mathematical indices allows the planners to have a “climatology” of lands which assists them to know when the next droughts happen and how harsh the current drought is.

2.3. Drought Kinds

Four ways are found to assess drought. These approaches include Water-related (Hydrological) drought, Climate-related (Meteorological) Drought, Social-economic drought, and agriculture methods look at the physical manifestation of drought. However, socioeconomic method tells us how drought impacts the community and its economy. That showed in figure 2.1.

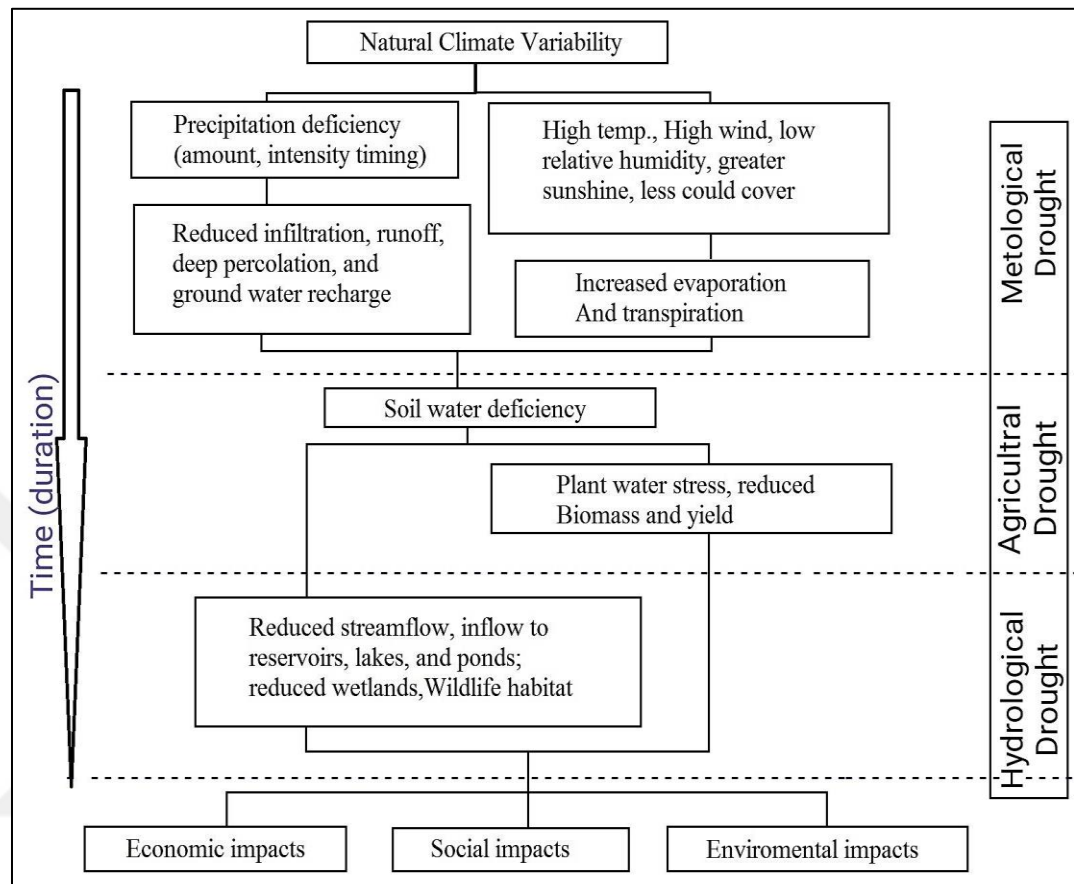


Figure 2.1. Relationship between these types of drought

2.3.1. Water-related drought

Water-related drought is a kind of method that assesses drought and water on surface and subsurface of the earth. It shows how deficient this water is. For this reason, achieve the result, this approach assesses water reservoirs, streams, rivers, lakes, ponds and underground water. This approach is not precise in telling us the recurrence of drought as there is a period of time between water deficiency and rainfall. This method practical only when rainfall is very low for a while and water shortage underground can seen and noticed. Further, though nature is responsible for this kind of drought, people make it worse. Furthermore, there is a relationship between hydrological and meteorological droughts. This relationship is relevant to their “recurrence interval accordingly”. Moreover, this type of drought influences the lands to change and

deteriorate, which, consequently, impacts the size and frequency of hydrological droughts.

2.3.2. Climate-related (meteorological) drought

Climate-related (Meteorological) Drought is explained as a water-shortfall in an area over a period of time. That is, the size of annual rain shortfall is compared to the normal rain in a year. This type only focuses on a specific location. This kind of drought is this drought type is the initial sign that drought occurs in an area. For this reason, we should call these type region-specific definitions as only focuses on the rainfall of a specific area. This type of drought has its own data to assesses drought such as “evaporation, wind velocity, temperature, humidity”, and daily precipitation.

2.3.3. Social-economic drought

This type of drought happens when lack of sufficient water severely impacts people’s life. It also affects society and its economy. This definition regards water as an economic thing. When rain shortfall occurs, people’s demand raises and this increase in demand impacts the economy of a society. It is obvious that some goods rely heavily on natural water. A once there is suitable weather and rainfall, these particular goods increase. Water varies from one year to another because sometimes the rates of precipitation are high, whereas other times rainfall is low. So, in this case, socioeconomic drought occurs as people’s demand for a particular good gets higher than the supply of this good. That is, the number of goods is less than the number people who demand these goods. Also, rain shortfall leads to shortage in hydroelectricity production. In this case, the government should use another means to provide electricity for people, such as petroleum, which is very expensive.

The main source of the high demand is because the population is increasing and economy is ameliorating. This makes the government build lots of reservoir, production, and technology. To analyze the impacts of this type pf the drought we

focus on people and animal, crops and plants, water, industry and commercial. We know how they are impacted and how to get rid of this drought.

2.3.4. Agricultural drought

Lack of moisture impedes some crops and plant to grow. Consequently, agricultural drought occurs. There is a link between this kind of drought and meteorological droughts as well as their influences. It is clear that agricultural droughts deal with the disparity existent between real and possible evaporation, rain shortfall, lack of ground water and “reservoir levels” and groundwater shortages, etc. Plant’s demand for water relies on certain things, such as the plant’s biological features, how it grows, what kind of weather it needs, and how what sort of soil this plant needs. Therefore, in order to have an accurate definition of agricultural droughts, we need to consider how a crop or plant is susceptible to drought and its different phases of growth. Further, once a land lacks sufficient moisture, this prevents the seeds from growth, resulting in restricting crops. In order to assesses agricultural droughts, we need to take into consideration fertility and soil moisture, land and its characteristics, weather conditions, the type of water for the soil, and the types of insects that attack a crop.

In this following section, we look at and wrote down in words these three points (i) causes of drought (ii) drought effects (iii) importance of Remote Sensing and GIS for drought managements (iv) drought present in-use techniques for observing drought and their limits, which includes techniques such as -situ-based, remote sensing-based, and synergic-based, with an increased focus on distant sensing part. These reviewed issues give a complete understanding regarding the advancement in these areas which prompts researchers to carry out more research in this context.

2.4. Causes of Drought

The most common definition of drought is lack of rainfall. There are many factors leading to droughts. It is obvious that vapor in the air leads to rain. Precipitation, hail

sleet result from having lots of moisture in the air and low pressure. This is due to the that when high moisture and low pressure interact, rainfall occurs. On the other hand, when dry air and high pressure interact, moisture will be too low in the air. If there is or no moisture in the air, there will be little or no rain. Consequently, this leads to In this case, the winds will carry continental air instead of the winds that come from oceans. These winds are warm and sufficient moisture (Waugh, 2000). As mentioned above, due to insufficient moisture in this air, rainfall doesn't happen and drought

It is clear that droughts happen on the dry are of leeward side of a mountainous area. This draught occurs when the air, which is moist and warm, encounters the barrier of a mountain. Later, the air climbs up to the section of the mountain that is colder than the other parts of the mountain. Later, under the influence of low temperature and pressure, the moisture becomes dense, which, consequently, then it becomes rainfall. Once it becomes rainfall, it falls on the windward of the mountain. At the same time, the dry and cold air goes to the side of the mountain which is leeward. These dry airs down have any moisture and they are not able to form any rainfall. Consequently, drought happens on the downwind of the mountain (Wipfler et al, 2009).

El Niño is also another cause of drought. El Nino happens when the part of the warm water of sea goes to another part of the water, usually the final sea part (Ritcher and Semenov, 2005). Later, the air gathers over the warm water leading to El Nino rise. The El Nino leads to heavy rain. On the contrary, on the other part of the sea, the water which is not hot makes the air cooler and this coolness does not allow the air to be dense and this obstruction deters the formation of rainfall (Davis, 2001). Once, the formation of rainfall does not happen, the region faces drought.

2.5. Drought Effects

The impact of droughts is so deep that it does affect everything in society. This is due to the fact that water is of central importance in our life by which we can produce many things (Magrama, 2014). Therefore, economy would be the first part of the society

that drought will negatively impact. Usually drought affect every sector of life either directly or indirectly. Direct impact is when drought reduces water, food production, forest productivity and rangeland productivity. Also, it destroys fish and other animals and raises wild animals collective (Quiroga, 2011). However, indirect impact happens the result of the direct impact. Income would be less and farmers would not produce crops and agriculture would be ineffective. Taxes would be reduced for the government depend on. Plus, the number of unemployment will increase and migration starts. Also, farmers and businessman will start borrowing money from bank. The effects could be divided into:

2.5.1. Economy-related effects

It is obvious that drought mainly affects agriculture as this sector depends on water, especially surface water. Moreover, drought usually leads to many diseases, such as the diseases related to plants as well as insects. It also leads to the damage to land owing to wind. Also, when drought occurs, usually the possibility of happening fire to forests and ranges will increase, which we all know that this will be dangerous for both humans and animals. When drought happens, agriculture production decreases and this decrease leads to economic crisis. This crisis gets worse for those countries which their main income is agriculture.

Also, one of the economic impacts caused by drought is income. Income is decreases as a result of drought. This decrease severely affects many sectors in Once the economy is severely affected, the factories that produce tools and goods for agricultures will also decline (Jenkins et al, 2003). Further, owing to the reduction of farm production, farmers can only sell few things to people. Plus, failure in animal as as crop productions makes farmers lose lots of things. Also, in this case people should choose expensive alternatives to buy. This is because farming becomes too expensive the food produced by the farmers will be too costly because they have to choose something else instead of water. The government and the federal state will get less tax

because the incomes are decreased. This fall in incomes causes financial crisis in government and country.

Food will be less and demand for food will be high with no supply to meet this demand. Thus, the price of food will significantly increase. The increase in price happens because the government ought to import supplies from other countries (Berrittella et al, 2009). Further, Drought leads to water decrease in the channels and this makes it difficult for the ships to maneuver in the channels. As a result, this makes the cost of the transport increase and people in this case search for other means of transportations that are less expensive. Drought also impacts hydroelectricity production. In this case, the officials in the government should seek for other alternatives, such as petroleum, to compensate for the lack of water (Carroll, 2009). This method is so expensive that makes electricity bills be so costly (Schoengold, 2006).

2.5.2. Ecological effects

Drought causes forests to set on fire and affects animals and plants severely. Everything in the environment is affected by drought, such as soil, wildlife, water and air (Frey, Luechinger, and Stutzer 2009). A couple of the impacts do not last long and can be cured not for too long, such as losing the natural homes of animals. If the droughts are seasonal, the effects and the species can be recovered. But, when the droughts affect soil and land, the impacts are permanent, which in turn, leads to permanent loss of production (Dono and Mazzapicchio, 2010).

2.5.3. Societal effect

Drought also impacts our social life. It affects health system, life quality, etc. Also, environmental and economic droughts impact our social life. They are all interconnected (Pérez y Pérez and Barreiro-Hurlé, 2009). One of the main effects of droughts is migration. Once an area is stricken by droughts, people in this area make an attempt to leave the place to other areas that are free from droughts. In these areas they search for

resources to depend on. People usually leave villages and towns and go to big cities in search of new life. When the disaster ends, no one returns to their previous places. This leaves negative impacts on the urban and rural populations. For example, the population in rural areas decreases while it increases in the urban areas. This increase in the population leads to poverty, high rate in crime, lack of resources, and instability (Martin-Ortega et al. 2012).

2.6. Importance of Remote Sensing and GIS for Drought Managements

Remote Sensing and GIS rely on the factors that lead to droughts. For this reason, they play an important role in identifying and managing droughts. For mitigating the impacts of droughts, three phases are available and each phase has some other steps.

2.6.1. Getting ready for the drought stage

Prior to having drought, it is important to pinpoint not only the place which is likely to develop drought but also the degree of the drought. This issue can be implemented by into the following steps:

2.6.1.1. Risk zone/drought prone identification

Pinpointing a threaten area, or a place which is likely to develop drought, relies on the assessment of diachronic information with regard to rain amounts or evaporation of the zone under investigation. Nonetheless, traditional techniques of knowing which area is under the threat of drought do not contain space-related alterations or the effect of the human being. However, employing GIS allows to identify zones which are likely to develop drought and it employs satellite, fed-in information of vegetation to give space-related data on those zones, not forgetting how often low growth occurs, standard deviations and the likeliness of vegetation growth (Gil-Sevilla, 2010).

2.6.1.2. Drought prediction

Anticipation of the changeability found in the climate is positive regarding the employment of distant sensing data concerning the anticipation of drought by means of inspections of the spikes of snow, the atmospheric systems of air and ocean cycles, first soil dampness, combined oceanic/atmospheric models, and the water under disposal for watering (Xiao-Jun, 2012). Through merging systems of experimental satellite in a successful manner, precise anticipations of worldwide abnormalities can be attained without effort. By means of the employment of enhanced, combined models, a lot of states anticipate beforehand the periods in which drought happens, and it is by means of these anticipations that they erect their decision-making regarding agricultural decisions, the spreading of products and finishing farms.

Moreover, the effective state of the information interpreted on initial areas is a condition regarding the efficiency of the temperature of the seasons and the anticipation of abnormality by various observational posts like the European Centre for Medium-Range Weather Forecasts (ECMWF), the National Climate Research Centre (NCRC), and the India Meteorological Department (IMD) (Earsel and Maktav, 2009). Recent interpretation means additionally give forward an improved efficiency state of the climate of the seasons and and weather fore casting. Nonetheless, the possible assistance of the current observational satellites is not thoroughly made use of, as the interaction attained by merging the sensors is not employed altogether or it is not spreader worldwide. Therefore, those liaising employers like World Meteorological Organization (WMO) and the National Centers for Environmental Predictions (NCEP) requires an enhanced information flow from decision makers. What is more, the anticipation services by El Niño should get enhanced to distribute data to those extensive consumers.

2.6.2. Drought staving-off stage

2.6.2.1. Initial cautioning and drought observing

The techniques of observing drought in many states depend on the data present on the aspects relating to drought like the state of crops, the weather, the amount of rain falling and the accessibility of water. Brief, and extensive coverage in addition to data needed for observing the states of drought are provided by Satellites. Nowadays, data sensing for premature threats and observing drought is reliant on temperatures, the dampness of ground outer-layers, the amount of rain fallen, and the observation of the plant cover (Singh et al, 2014). In addition to that, information attained from various sensors and several-channel information providers and from information providers stationing for geographical observations are employed to assess rainfall, the degree, and coverage surface impacts such as dampness of the ground.

2.6.2.2. Rainfall monitoring

One of the main reasons of drought is not having a rainfall or that which is restrained. Therefore, better precise space-related assessments are provided by remote sensing techniques in comparison to traditional ones that depend on point data and possess restrained monitoring systems. The techniques of the methods of rain amount observation could be categorized into being visible (VIS) and infrared (IR), or, when talking about microwave, they can be active or passive (Magraba, 2014).

The first techniques introduced were VIS and IR; therefore, they exhibited a decreased precision point (Gebremichael and Hossain, 2010). These modules dissect the assessment processes of rainfall into cloud-indexing, bi-spectra, life history, and cloud models. One specific feature of the physics of clouds is highlighted by every technique just mentioned when employing visual representation from satellites. For example, the degree of rain levels of every cloud pinpointed by the visual representation technique is assigned by using the cloud indexing module. In a similar fashion, bi-spectral techniques form a link between luminous and cold clouds and their likelihood of rainfall (less

of rainfall likelihoods are linked with clouds whose stratus is not thick or dark.) Passive microwave methods employ water-assessment systems on particular spaces (Ahrens, 2011). And finally, the other type of microwave (the active one) makes use of equipment found in a spacecraft to follow and study rainfall. This equipment gives an outlook of three dimensions of the anti-horizontal spreading of precipitation; hence, allowing the investigation of its building-up. Additionally, the can decide about numerical oceanic land assessments and enhance the general assessment precision by merging the practicality of radars, TMI, and VIRS instruments (Liang Li and Wang, 2012).

2.6.2.3. Valuation of ground temperatures

The decreased degree of evapotranspiration or the decreased state of the stress of water in plant areas are additional indexes of drought. Transportation of vapor due to canopy resistance is cause by high water stress; consequently, increased canopy temperatures are caused (Vachani and Usmani, 2014). The high temperatures in surface temperatures which are satellite-based can be made use of as an index for drought observation, as it links power equilibrium between vegetation and soil on the one hand and the power and atmospheric equilibrium on the other, while evapotranspiration providing an essential part in the process. The stress of water is found in the high luminosity of the temperatures of surfaces and its impact on the canopies of the surface observed by alterations in vision-related characteristics (Gómez, 2004).

2.6.2.4. Assessment of the moisture of the soil

Soil dampness is an important aspect in informing of the drought in agriculture. It assists in partitioning the power on the surface into dormant (evapotranspiration) and susceptible, atmospheric heat conversion and also divides rainfall into excess and infiltration. Assessments of soil dampness stem from point estimations, soil dampness techniques, and remote sensing. Conventional soil dampness assessment methods engender point bias, as they do not interpret space-related dissemination. The other hydrological techniques also yield commonly not very good assessments, as soils

big chronological and space-related changes because of rainfall, not having homogenous traits in the soil, and plant areas. Because it has the ability to gather information over an extensive space-related scattering, remote sensing can provide a holistic assessment of solid dampness near the surface. Nonetheless, the technique might render not efficient because of the restricted depths on which the assessments of solid are acceptable and the time repetition of the satellite. Consequently, for the assessment of soil dampness to be practical in research regarding water, agriculture and climate; the dampness of the has to be linked to the profiles of the dampness of the solid in areas their saturation is absent.

The issues with regard to the link between surface dampness to the profile of the solid and the related research have engendered findings that point to the direction of four ways: inversion, regression, knowledge-based, and merging distant-sensed information to soil water equilibrium systems.

2.6.2.5. Observation of plant covers

The overall impacts of rainfall, weather, soil dampness and the agricultural operations are reflected in vegetation. Therefore, observation of plant areas by means of satellites offers an initial cautionary for drought indicators. Research have illustrated that there is a relationship between red energy and energy of near-infrared properties (NIR) on the plants found on the surface. The reflection of red power becomes less with vegetation growth because of the absorption of plant (Nielsen, 2010). Conversely, because of the spreading (either when transmitted or reflected) by enact, turgid leaves; the reflected NIR power will become more with vegetation growth (Goodman, 2000). Determination of plant scattering or possible drought systems are decided by means of the levels of red and NIR which are collected by the satellite. Nonetheless, the quantity of red and NIR that is collected by the satellite is affected by the sun's radiation, hence rendering the technique into unreliability when employed alone.

2.6.3. Reaction/modification stage

2.6.3.1. Valuation of drought effect

The employment of remote sensing for the effect of drought revolves around the measurement of substructure, distribution of people, the use of land, illnesses, crops or harvest of agriculture, and the accessibility of mobile water in the surrounding of the regions which got impacted. SPOT, LANDSAT, MODIS, GIMMS and IRS are those seasons of increased resolution which investigate these aspects. In this context, in order to determine drought, the sensor LANDSAT was used in this research.

2.6.3.2. Help regarding decision making for relief management

The employment of remote sensing in drought reaction revolves around aiding in making decisions for the management of yields, water, reduction and other different tactics. The aforementioned elements are also estimated by means of SPOT, LANDSAT, MODIS, GIMMS and IRS. In countries like India, maps for action plans are produced at the watershed degree of application. Absence of the insufficiency of rainfall primely produces drought; a condition which happens because of cold, waterless wafts resting on land surfaces in addition to having it in surfaces of an increased pressure or lands with normally decreased dampness levels. Therefore, dampness represents such an influential aspect in the building-up or rainfall. Moreover, in some parts of the world, drought engenders extreme impacts which are categorized into those that affect the environment, the economy or the society.

The impacts on the environment are the actual representations of drought cases. They can either remain for a long time or not. When talking about the actual occurrences which do not last for a long time, vegetation and animals can regain their place of living when the drought is over. Nonetheless, drought occurrences which last for a long time revolve around alterations in places where animals usually live and also in the physical forms of land. When it comes to the social effects of drought, then we will be talking

how the lives of people will be affected by the drought. The economic effects include effect of drought economically speaking. The sector of agriculture is the one that is affected the worse although drought impacts a lot of aspects of the economy. Hence, an account of the effects of drought on the sector of agriculture should specify appropriate tactics. The advancement of method which are not complicated lives for its reputation when it comes to dealing with these effects, as it is likely to do them again over other impacted lands. Decision planners generated various techniques of lessening the effects of drought because of the extreme aftermaths which drought causes. Different methods are used in gathering information that has the ability of enabling predicting the future of drought since effective decisions need appropriate data. These models consist techniques of satellite observation revolving our planet or fixed on airplanes. The assist in charting the weather systems, hence, allowing forecasting of drought which in the future.

2.7. Present Methods for Monitoring Drought

Relying on the source of the information of the techniques and ways which are employed to monitor drought, three categories can be identified; as an illustration of that there are the techniques and methods known as “in-situ” such as metrological data, methods which are based on sensing, and finally there are the synergic-based ones (Niemeyer, 2008).

2.7.1. In-situ agricultural-related techniques and ways to monitor drought

The methods under discussion are regarded to be the best indicators in terms of accuracy and the time of use in comparison with the other ones (Maes and Steppe 2012). Such methods rely on the statistical assessments of hydro-climatic factors (this includes rainfall, degree of the weather, changeable moisture, and soil-and-water-related content) which are attainable from the climate, agriculture practices, and the cycle and movement of water positions; moreover, these factors can give data whether qualitatively or quantitatively related to an area under study (Kanellou et al. 2008).

As an illustration of what has been mentioned, there are few illustrations about that such as: (i) an indicator which uses rainfall and the degree of the weather is the Palmer drought severity index (PDSI) (Palmer, 1965); (ii) another one which not only uses rainfall and weather degree but also the humidity of the soil is known as the crop moisture index (CMI) (Palmer, 1968); (iii) a third example which is reliant on the perceived and implied vaporization of liquids is the crop water stress index (CWSI); (iv) a fourth indicator which makes use of data taken from weather degree, rainfall, and the cycle of land-to-atmosphere-water transformation is crop specific drought index (CSDI) (Meyer et al. 1993), and (v) the standardized precipitation index (SPI) which employs rainfall systems (Meyer et al. 1993).

The aforementioned indicators were used to monitor drought of agriculture in an effective way in various researchers since agricultural areas are the ones which initially affected in the beginning of drought because of the lack of rainfall even though the indicators were first made for the purpose of meteorological drought (Quiring and Papakryiakou 2003, Paulo and Pereira 2006, Pashiardis and Michaelides 2008). Because it is easy and flexible to use when monitoring drought on every week, every 10 days, or during an interval of 1,3,6,9,12 and 24 months while having four levels of drought (semi-normal, average, intense and highly intense drought scenarios) (McKee et al. 1993), the World Meteorological Organization (WMO) advises that all nationally local services of meteorology, agricultural, and hydrology ought to employ SPI to monitor drought (WMO, 2012).

2.7.2. Remote sensing and geographical information system based agricultural drought monitoring methods.

Those who use GIS depend on those reports about droughts in order to make appropriate decisions. Those people are high ranking people on the international levels. Also, local people also utilize GIS to get benefits from, such as farmers, traders, businessman, and managers. These people know that using GIS and detecting droughts are of significant importance so that they can be ready of anything dangerous happens. If

they know about droughts in advance, they could work to lessen its impact (Singh and Zommers, 2014). One of the techniques used to predict droughts is remote sensing techniques. This technique is so clear and precise. These techniques can swiftly share all the information about droughts in different areas through satellites or aircrafts indicators installed (Choudhury et al, 2009).

Those satellites will move around the globe clearly evaluate the surface of the earth after a few days. Plus, airplanes collect other details of those areas that are small. Remote sensing process is easy nowadays because many powerful and advanced computer programs and GIS have been invented. These programs gather the data and present them in a map-like way (Longley, 2001). The information presented by these technologies is helpful in terms of identifying and monitoring droughts.

Employing distant sensory-based techniques is one of the options available to tackled the indicators of space-related milieu in the drought occurring in agricultural. Such techniques rely on interpreting alterations in the spectral and thermal characteristics of plants and of ground surfaces because of the impacts pertaining the drought of agriculture (Anjum et al. 2011); this in turn, according to Anderson et al. 2011, had a major impact when it comes to controlling and observing agricultural drought in vegetation growth in their concomitant seasons What is clear is that it is important to comprehend vegetation and ground surfaces spectral reactions in water contexts prior to tackling those techniques which are employed for distant monitoring concerning the drought of agriculture in case distant measured information was employed to assess agricultural drought.

From a general perspective, the main principle for developing distant sensory means was to make use of one or several of the following principles:

1. Vegetation spectral behavior to differences in the composition of water content: Many research papers have studied the reaction of the spectral characteristics of

vegetation in relation to changes in the condition of water. For example, it was found, by Jensen 2007, Wang and Qu, 2009; Tang et. al. 2010 that such characteristics increase when there are greater degrees of stress in water. The following figure (Fig.2.2) depicts illustration of a reflecting-response assessed in the lab of Magnolia leaf (*Magnolia grandiflora*) when subjected to various kinds of water composition.

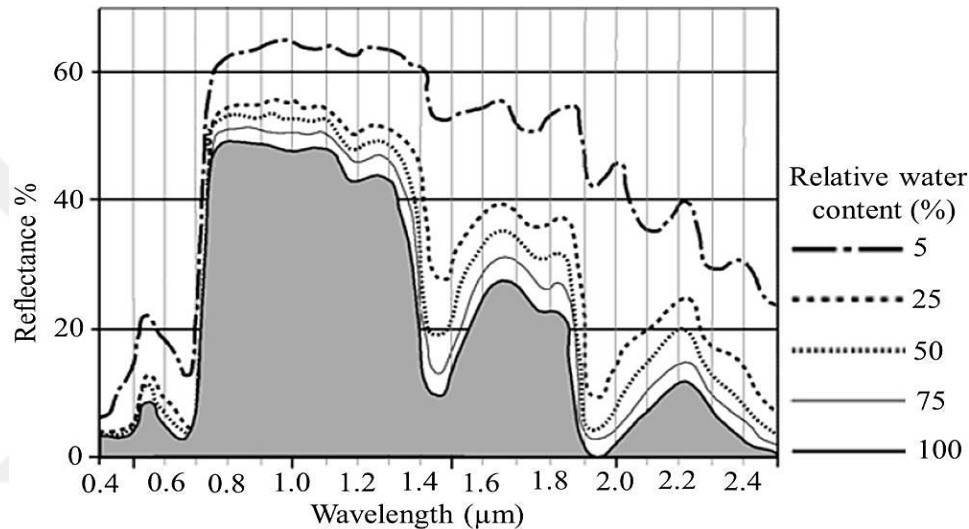


Figure 2.2. An illustration of a reflecting-response, within the spectral range 0.4 μ m to 2.6 μ m assessed in the lab of Magnolia leaf (*Magnolia grandiflora*) when subjected to various kinds of water composition by Jensen (2007).

Based on the information in the above figure, it can be seen that there is a clear general raise in the reproduction in the spectral variety 0.4 μ m to 2.6 μ m when talking about water composition of not a high level. What is more, the figure presents various constellations of reflections as it is the case with the observable spectral groups of the colors blue (i.e., 0.4-0.5 μ m) and green (0.5-0.6 μ m) since there are minor alterations because of variations in water composition. Nonetheless, there was more sensitivity of red spectral band (0.6-0.7 μ m) to water stress (Jensen 2007). It was generally apparent there were little differences of the composition of water levels as the NIR (i.e., 0.7-1.3 μ m) illustrated since this part of the range was primarily subtle to alterations in the inner making of the leaf. The NIR reflection might exhibit a clear increase, only when the stress in water reach enough levels that drastically engender lack of water in leaf (Jensen 2007).

Moreover, Ceccato et al. (2001) mentioned that there are other things to keep in mind and which could impact the NIR reaction of vegetation like leaf area index (LAI), the kinds of plant and thickness. Consequently, it can be said that water stress in an indirect manner impacted the NIR reaction of vegetation. According to Hunt and Rock 1989, Ceccato et al. 2001, Ghulam et al. 2008, The SWIR spectral groups (i.e., 1.3-2.5 μ m) displayed solid association with the variation of water in leaves and it was labelled as that band with most sensitivity to variation of water in leaves.

Furthermore, a merging between SAILH and PROSPECT model to observe the stress of crop drought in the crops of maize and wheat was employed by Huber et al (2006). In that study extreme space-related remote sensing data gotten from ASD Field indicated having varied development of the stages of crop in Vienna, Austria. The research indicated that drastic variations in the reflectance of the canopy when it comes to experience stressed crop. The most pinpointed alterations where attained over near (NIR) and mid (MIR) infrared wavelength region. That was the result of alterations of the interior composition of leaf, differences in the tendencies of the leaf, because of wilting, and the zone index of the leaf. According to the aforementioned literature, the reflection spectrum in specific at the near infrared region (NIR) possesses an increased likelihood to observe and locate the stress of drought over the canopies of plants.

2. Variables which are related to the green trait of plants (such as the Vegetation Condition Index (VCI), the Modified Perpendicular Drought Index (MPDI), NDVI, and other ones) which are attained relying on the functionality of seen and near infrared spectral bands and which are largely employed to monitor the states of drought in ecological systems worldwide (e.g., Tucker and Choudhury 1987, Kogan 2002, Samanta and Ganguly 2011, Shahabfar et al. 2012). In such variables the color blue and NIR spectral bands were made use of as being the reduced band in terms of sensitivity to the differences in the content of water while making use of the red spectral band as higher in terms of sensitivity to the differences in the content of water. Using these techniques to monitor agricultural drought was applied relying on the idea that the factor of stress in

water is the sole variable which controls the process of the plant growth. A noticeable delay in terms time when reacting to water stress was observed in the variables with the green traits of plants even though such methods are largely employed to agricultural drought (Gao 1996; Jackson et al. 2004; Chakraborty and Sehgal 2010); is more, they also failed to register in an accurate manner the real states of water in since there are different variables which could have an effect on the condition of plants like insects, chlorophyll, temperature, enology, and the type of vegetation (Anjum et al. 2011).

On the other hand, that's said, the drought found in areas where citrus is planted, in the plain of Seferihisar Kavakdere, was studied in a study by Yildirim and Asik (2017) by employing the index of NDVI and SAVI. The findings of the study pointed at the direction that a negative correlation was found with the temperature of the surface during watering periods where intensely high temperature and reduced rainfall decreased dampness accessibility for vegetation. In a similar fashion, drought occurrence over Salt Lake in Turkey was studied by Orhan et al., (2014) by merging the data of optical and thermal infrared together. In this research, Landsat-5 made it possible to get many temporary LST.

Furthermore, between 1984 and 2011, the evaluation of the effect of drought during that period was analyzed using NDVI, vegetation condition index (VCI), and temperature vegetation index (TVX). The findings indicated that significant alterations in the LST happened (about 2°C) in the Salt Lake Basin zone between 1984 and 2011. In a similar fashion, the significance of MODIS information in observing drought in Karnataka (India) was investigated in as study by Sruthi and Aslam (2015).

Severe weather occurrences such as drought which significantly impacts the production in agriculture are caused by rising temperature and changes in the of rain. Drought of agriculture is merely the result of a decrease in the production crops because of non-systematic patterns in perspiration in addition to a reduction in the

dampness of the soil; this leads to having an effect in the economy of the country. A minor alteration in the Monsoon, and since the Indian agriculture is hugely reliant on it, can affect the productivity in addition to how much crops is produced significantly. The finalized by saying that the merging between LST and NDVI gives such practical data the observation of drought in agriculture and precautions alerting system for peasants.

In addition, the occurrences of drought in America between the years 1989-2000 was studied by Peters et al., (2002) by using NDVI and employing images from Advanced Very High-Resolution Radiometer (AVHRR). The results show that the SVI, in addition to additional drought observation equipment, is practical for evaluating the degree and intensity of drought at a space-related concentration of 1 km. SVI can provide a very realistic gauge of the state of plants within drought zones, and more particularly zones of differing drought states.

3. The variables which are related to the wet nature of plants such as the normalized multiband drought index (NMDI), the shortwave infrared water stress index (SIWSI), the moisture stress index (MSI), NDWI and some other ones attained from the spectral bands of NIR and SWIR and employed to contain drought occurrences via the condition of plants vegetation (Hunt and Rock 1989, Gao et al. 1996, Fensholt and Sandholt 2003, Wang and Qu 2007). The spectral band of NIR, in such variables, plays the role of wetness index whereas the SWIR one is employed to measure the moisture (Zhang et al. 2013). The application of plants moisture references in the analysis of agricultural drought was observed to be a much developed and straightforward wetness gauge of plants when compared with the variables related to the green traits of plants. Nonetheless, these variables were found to be influenced by the types of land covers, how intense the vegetation is, the multiplicity of the surface of the land which indicated significant ambiguities in the attained statistical readings (Gao 1996; Ghulam et al., 2008).

What is more, Al-Bakri et al (2018) employed other spectral vegetation indices (NDVI, MSI, EWSI, PDI and MPDI) gathered from MODIS for estimating the states of

drought in Mafraq in Jordan. They showed that PDI index attained from MODIS is the most precise assessor that obtain a high degree of correlation ($R^2 = 0.73$) with soil dampness assessments, however, the indices of the stress of soil water (EWSI and MSI) revealed a somewhat lesser correlations with soil dampness and modeled processes of water returning to the atmosphere. Consequently, the employment of MODIS-PDI in place of MODIS-NDVI could be advised for charting drought intensity without looking diachronically information.

Picoli (2017) carried out a study on the same footing by contrasting a lot of spectral indicators, attained from the images of (Modis), in pinpointing drought occurrences in sugarcane (*Saccharum officinarum*) yields. These indicators were NDVI, EVI2, GVMI, NDI6, NDI7, NDWI, SRWI, and MSI. What is more, these indicators were afterwards matched against the standardized precipitation-evapotranspiration index (SPEI), calculated for 1, 3, and 6 months. The findings indicated there were significant correlations of four of them with SPEI: GVMI, MSI, NDI7, and NDWI. Spectral indicators from Modis indicator found on the Aqua satellite (MYD) were more appropriate for the uncovering of drought, and March gave forth the most related indicators for that aim.

The latent possibility of EnMAP and Sentinel-2 Information for pinpointing Drought Stress Phenomena in Deciduous Forest Communities utilizing Photochemical Reflectance Index (PRI) Moisture Stress Index (MSI), NDWI, and Chlorophyll Index (CI) were measured in 2015 by Dotzler et al. The study showed significant differences between CI, MSI and NDWI in the overall chlorophyll and concentration of water at the canopy level and an increased sensor for the observation of drought.

Hazaymeh and Hassan (2017) probed the likelihood of remote sensing data to observe drought over semiarid area in Jordan. Like the aforementioned research, there an employment and attainment from not only Landsat but also MODIS satellites for the NDWI, NDVI, visible and shortwave drought index (VSDI), normalized multiband

drought index (NMDI), moisture stress index (MSI), and LST. In addition, they assessed drought sensors attained from remote sensing models with a set of 8-day ground-based standardized precipitation index values (i.e., SPI-1, SPI-2, ..., SPI-8). The findings showed that the technique could be essential for observing the states of drought found in agriculture in places with a somewhat little rain not at a practically elevated resolution (i.e. 30-m) but also in time period which is not long (i.e. 8-day).

4. Variables which are related to meteorology and which are worked out by means of the thermal spectral band attained from the temperature of the surface (knowns as LST) and which is employed to assess the stress of water plants and also to monitor drought. The aforementioned factors are calculated to indicate the assessment of plants water stress, soil moisture and evapotranspiration; and this is done by using the readings and calculations of the temperature of the surface which includes things such as the apparent thermal inertia and the approaches which are related to single LST (Tang and Li 2014) like the normalized difference temperature index (NDTI; McVicar and Jupp 1998) and the temperature condition index (TCI; Kogan 2002). Applying the thermal infrared measurements from space was reliant on the present link between the temperature of the surface and the soil and the condition of the water of vegetation. Generally speaking, assessing agricultural drought employing distant methodologies which are based on sensing variables was observed to be influenced by the particular states of the thermal spectral band's sensor, the derivation algorithm of LST, method-related cases, and landscape variety (Moran 2004, Rahimzadeh -Bajgiran et al. 2012).

In these days, there are a number of platforms which are employed for the study of LST and determining the kinetic temperature of the surface of the earth; these platforms are like NOAA, AVHRP, MODIS (Terra and Aqua) and Terra ASTER with thermal bands. Nonetheless Landsat-5 TM and 7 ETM+ are employed, from the now-existing satellites which contain thermal infrared band, in researching LST with special consideration to cities. Many researchers such as Zhang and Wang (2008), Qin et al.

(2001), Cristobal et al. (2009), Ifatimehin and Segun (2008), Liu and Zhang (2011), Li et al. (2004) stressed that the reasons for using Landsat imagery were:

- I. Free available and easy to access data.
- II. Being the oldest and longest indicator employed to observe and pinpoint alterations in the environment.
- III. The footage of the Landsat is made up from various bands that are found on various wavelengths. Out of those bands, six are situated inside the seen, proximate and not long infrared regions, while having one band inside a thermal band. The diversity of various bands has an important significance for a lot of environment-related practices and in particular when doing research of LST, which engendered different traits being pinpointed at the same time.
- IV. When it comes to LST, Landsat information has important prospects for a lot of practices in that regard. However, it is quite understood that the various traits of the surface of the earth produce different radiation types on various wavelengths. Consequently, it is vital to employ satellite information like Landsat with different types of bands.

It is clear that platforms such as NOAA/AVHRR are only appropriate to be used at the macro-level when compared with other platforms. Therefore, they might not be able to permit identifying various characteristics which are inside digital pixels in digital images (Gallo et al., 1993). Conversely, Landsat data has the capability of pinpointing various types of land surface. Consequently, using data of Landsat, it is possible to investigate the link between the earth's temperature and the various kinds of land cover and this done for the evaluation of every land surface when it comes to its effect on LST (Walawnder and Hajto, 2010). In the Landsat, there exists one band found in the thermal region which has a spectral range of (10.4-12.5 μm) with a 120 resolution of thermal Band 6; such a resolution is good enough to analyze the specific space-related patterns of thermal differences on the surface of the earth (Qin et al., 2001).

Currently, various methods and techniques which have been advanced and made and this relying on the various satellite data; these methods or techniques are like: the single-channel method proposed by Jimenez-Munoz and Sobrino (2003), the mono-window algorithm proposed by Qin et al. (2001), the temperature/emissivity separation method proposed by Gillespie et al., (1998), and the split-window method proposed by Sobrino et al., (1996). The data of this study had only a single band situated in the thermal region as the data was gathered using a Landsat-5 TM Landsat-8 platform. Therefore, the sole drawback of Landsat information was related to the procedure of atmospheric improvement that continued to be a difficult assignment in comparison to other indicators like ASTER which has multiple bands situated in the thermal region (Alsultan et al., 2005; Cristobal et al., 2009). Formerly, the atmospheric correction process was the engenderer of the derivation of the surface temperature measurement when employing Landsat-5 TM thermal band; this issue was quite complicated theoretically speaking and needed more parameters (Zhang et al., 2007). In contrast, various scholars did a lot of efforts to study the ready appropriate algorithms, relying on the process radiometric and atmospheric improvement to obtain LST by employing Landsat data of TM (Chavez, 1996; Qin et al., 2001). While doing the literature review, we came across a couple of studies which were conducted employing a different Landsat data like radioactive transfer, mono-window algorithm, and the single-channel method. Due to the fact that it only possesses one thermal band, it is not possible to use the split-window algorithm with Landsat-5 TM Landsat-8 even though it can be regarded as an alternative method (Sobrino et al., 2004).

The mono-window algorithm was presented in the study done by Qin et al. (2001). This was further assisted after taking into consideration the variability in terms of space atmospheric parameters in the place of merely employing the brightness temperature. Moreover, according to Zhang et al (2007), the importance of such algorithm lies in the fact that it is available to specialist who did have the data of situ atmospheric profile. To put it differently, the mono-window can merge the normal atmospheric profile with local in-situ ground meteorological information in order to give emissivity, effective mean

atmospheric temperature and atmospheric transference which are regarded as parameter needs. As a matter of fact, the employment of this algorithm, relying on three various parameters, is quite necessary during the operation of LST retrieval and in getting a precise result. The parameters are: near surface temperature (Air Temperature), mean atmospheric transference, land surface emissivity.

Conversely, it is vital to indicate that important studies were conducted without resorting to the aforementioned parameters. As an illustration about that, Adinna et al. (2009), Kumar et al. (2012) and Zhang et al. (2006) only employed the emissivity of land surface by transforming the assessment of brightness to the temperature of the reflectance of the satellite and after that to the actual temperature of the ground. Moreover, Ahmed et al. (2005), Al-Rashidi et al. (2007), Habib (2007), Kwartan and Small (2005) and Saleh (2011) conducted a numerous amount of studies where they employed only the temperature of the brightness of the satellite. Consequently, by means of a Landsat thermal band, many studies employed different algorithms and techniques to obtain LST.

In the last decades many studies have been used LST calculated from different remote sensing platforms to monitor and detect drought phenomenon in a different part of the world. For example, in Iraq (Al-Quraishi 2018) studied Drought Monitoring using Spectral and Meteorological based Indices in the city of Sulaimanya-Iraq. In this study, spectral vegetation indices such as NDVI, LST, and NDWI were calculated from Landsat imagery. Beside remote sensing data rainfall data were used. The results show a positive correlation between NDVI and rainfall data for the years 1990, 2000 and 2008. In addition, the vegetation cover decreased dramatically in 2008. Similar study by Fadhil (2011) has used five vegetation, soil, water, and LST indices obtained from Landsat 7 ETM_ imageries of June 2007 and June 2008 to study drought over Erbil governorate in Iraq. The statistics showed a significant lessening in the vegetation cover by 56.7% and a decreased in the moisture of soil/vegetation by 29.9% of the overall study area.

In Turkey, (Orhan et al., 2014), utilized multi LST obtained from Landsat-5 to study drought event over Salt Lake, Turkey. Moreover, NDVI, vegetation condition index (VCI), and temperature vegetation index (TVX) were employed to evaluate the effect of drought over the region between 1984 and 2011. The statistical findings revealed having significant alterations in the surface temperature (about 2°C) in the Salt Lake Basin area during the 28-year period (1984–2011).



3. MATERIAL and METHODS

3.1. Study Area

The Erbil plain district, situated in the governorate of Erbil in the north of Iraq see figure (3.1), was selected as the place of the study. Erbil plain district is located between the latitude degrees of $35^{\circ} 43' 00''$, $36^{\circ} 20' 00''$ and the longitude degrees of $43^{\circ} 53' 00''$, $44^{\circ} 16' 00''$. In relation to recent survey results carried out by the authorities in Erbil, the area of the study is regarded to be one of the most areas inhabited in Erbil (221,294 people). Erbil plain is situated in the center of the province of Erbil, and it overlooks the spacious field at the joining juncture of different main routes in the north, middle and south of Iraq. Four sub-areas make up Erbil plain district: Qushtapa, Bnaslaw, Daratw, and Kasnazan. The area's space is nearly (1307) squared kilometer and its climate, in accordance to the Koppen classification, is known to be under a somewhat-arid, continental and Mediterranean climate of a BSh kind (Koppen et al., 2011). The reason why the area of the study is said to have a continental climate is that it is the vicinity of the dry climate located in the south and west. The climate is, in other words, dry and hot during summer but cold and wet in winter. The yearly temperature and precipitation mean of Erbil plain district is (21.4) °C and (390) mm, one after another (Meteorological and Seismological Department of Erbil Governorate, 2014). It is the hottest during July and August; it rains the most between the months March and December. As for its surface, it is somehow even and full with hills; the area is raised at (228 m) and it can reach (1076 m) in areas and in particular in the far most north part of the study figure (3.2). Land use is associated with the amount of rain during seasons; consequently, wheat and barley are two well-known winter yields. However, the land is mostly used for habitation purposes within the city in the forms of concrete blocks. Soil with the color of brown, which is found primarily in the study area under the surface, is appropriate for the yields of arid land. Such surfaces have a brown soil layer of nearly 25-35 cm and renders to a mixture of brown and gray and sometimes white. The soil of the top layer is chalk-like and has 1 or 2% of organic substance.

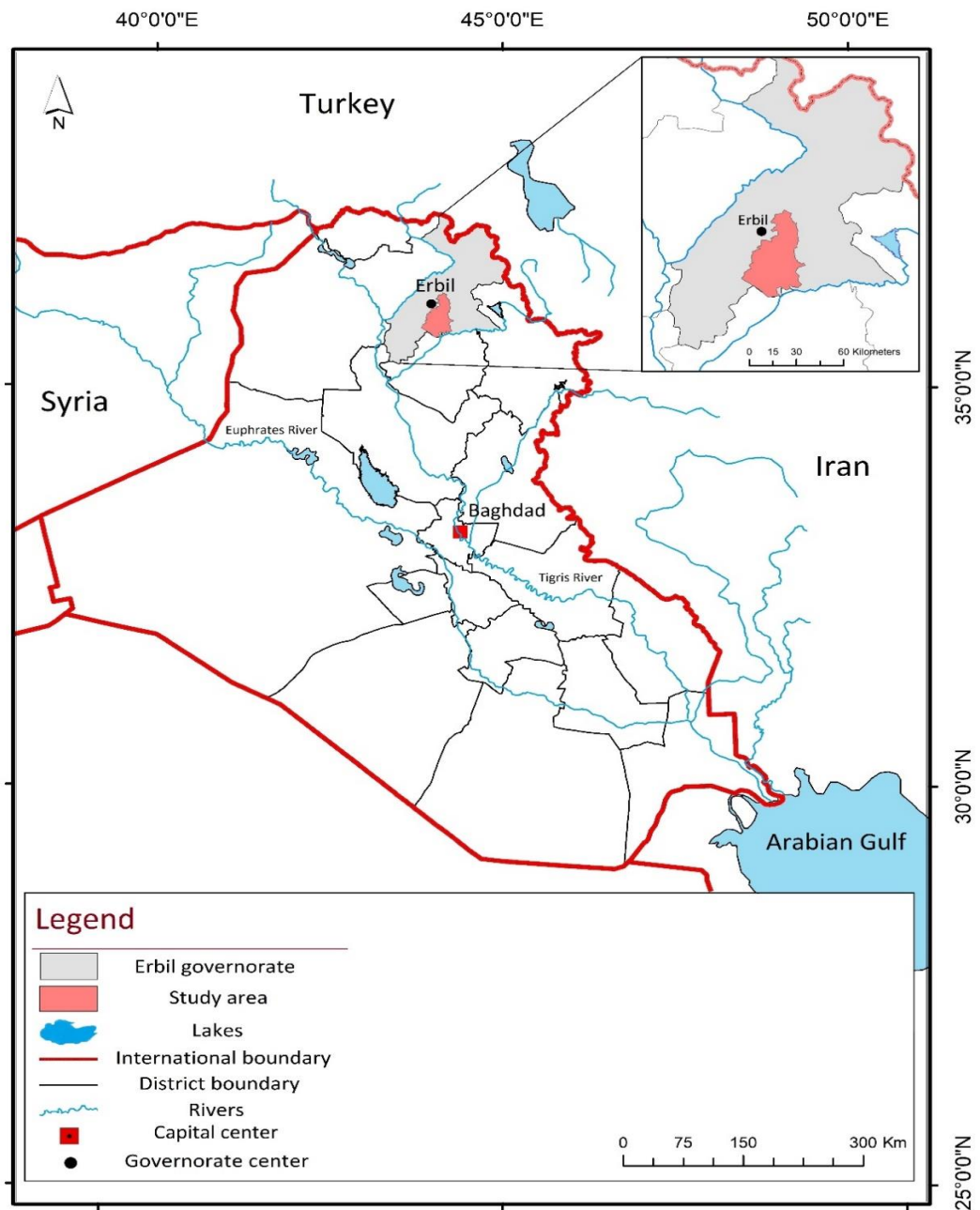


Figure 3.1. Location map of the study area

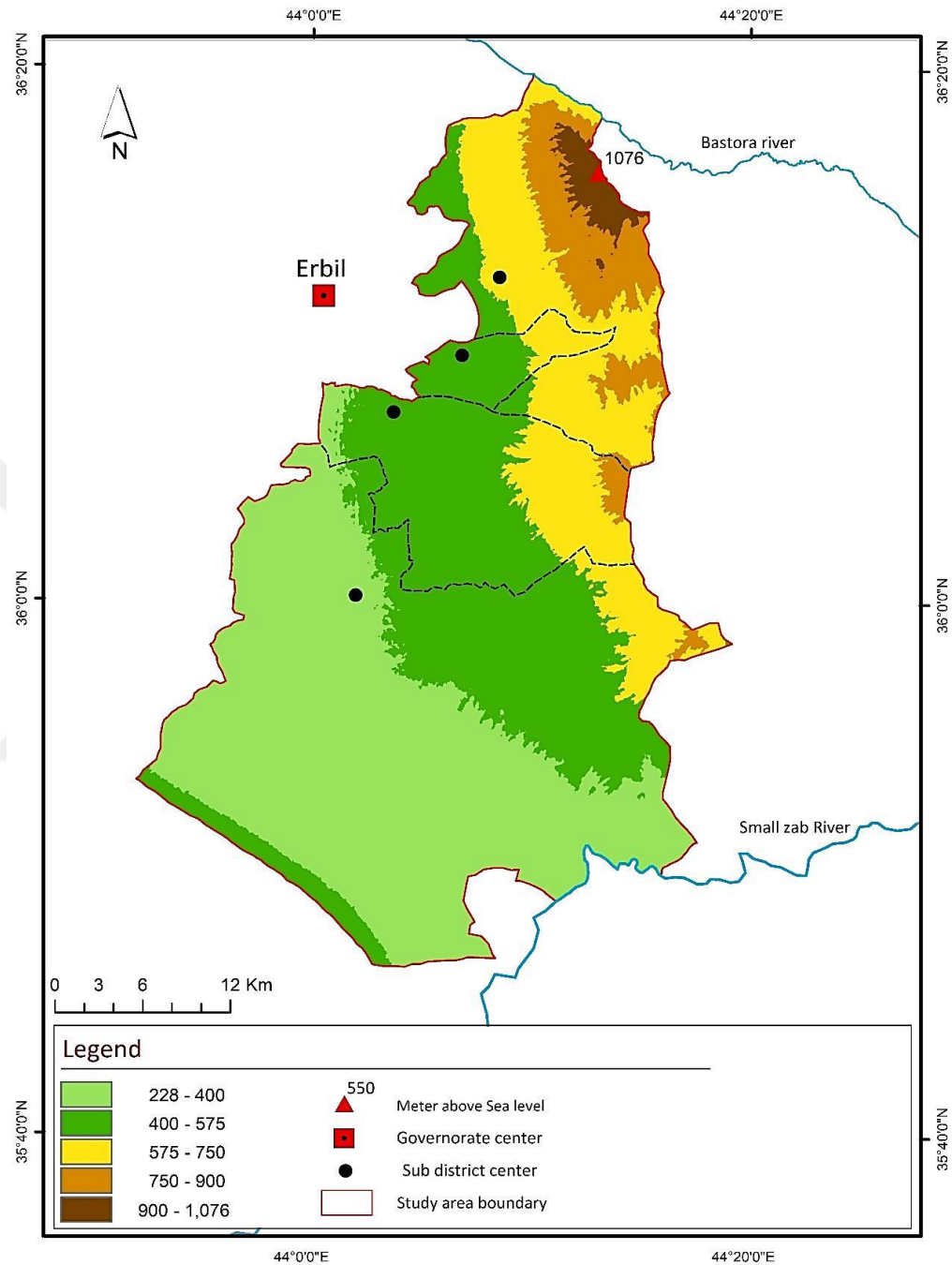


Figure 3.2. Topographic map of the study area

3.2. Satellite Data Preparation

In order to fulfil and achieve the objectives of this research, imagery from satellite available most of the times was chosen for this research. Information gathered during

clear skies monthly from 2009-2019, and the images were acquired from USGS Global Visualization Viewer (<http://glovis.usgs.gov/>). By means of the Universal Transform Mercator (UTM) in the system zone of 38, WGS84, the images altogether were adjusted using geometry and they were afterwards correlated with one another with a precision below the pixel level (Table 3.1).

It is important to note that, we have selected images to represent the different seasons in the region. For example, we for the winter season we focused to get clear image from January and February, for spring we selected April and May, Summer we selected June, July and August and for Autumn the September and October images has been used.

Table 3.1. Metadata specification of Landsat-5 TM and Landsat-8 OLI used in this study

Data	year	Image ID	Path/Raw	Projection/ Ellipsoid
Landsat 5	2009	LT051690352009021201T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2009	LT051690352009050301T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2009	LT051690352009080701T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2009	LT051690352009090801T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2009	LT051690352009101001T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2010	LT051690352010052201T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2010	LT051690352010081001T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2010	LT051690352010091101T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2010	LT051690352010101301T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2011	LT051690352011011701T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2011	LT051690352011052501T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2011	LT051690352011081301T1	169/35	UTM Zone 38/ WGS 84
Landsat 5	2011	LT051690352011091401T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2013	LC081690352013042801T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2013	LC081690352013081801T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2013	LC081690352013091901T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2013	LC081690352013102101T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2014	LC081690352014010901T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2014	LC081690352014051701T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2014	LC081690352014082101T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2014	LC081690352014092201T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2014	LC081690352014102401T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2015	LC081690352015021301T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2015	LC081690352015052001T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2015	LC081690352015082401T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2015	LC081690352015092501T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2015	LC081690352015101101T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2016	LC081690352016021601T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2016	LC081690352016052201T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2016	LC081690352016082601T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2016	LC081690352016091101T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2016	LC081690352016101301T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2017	LC081690352017011701T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2017	LC081690352017052501T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2017	LC081690352017082901T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2017	LC081690352017091401T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2017	LC081690352017101601T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2018	LC081690352018081601T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2018	LC081690352018091701T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2019	LC081690352019051501RT	169/35	UTM Zone 38/ WGS 84
Landsat 8	2019	LC081690352019081901T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2019	LC081690352019090401T1	169/35	UTM Zone 38/ WGS 84
Landsat 8	2019	LC081690352019102201RT	169/35	UTM Zone 38/ WGS 84

Furthermore, official government institutions were resorted to in order to have non-primary information like space-related information which stands to the outer edges of the city and the most recent statistics of the gathering of the population (table3.2).

Table 3.2. Administrative and other secondary data utilized in this study

Information	Properties
Map of major cities in Iraq	This is a file in the form of ArcGIS. It has data on the Iraq borders, the most important cities and governorates.
Map of the plain district of Erbil	This is a file in the form of ArcGIS that has the data of the main district names and the formation of the borders of the city.
DEM	A precision of (30 m) has been used in the research as its digital assessment framework in addition to the (USGS) Earth Explorer. And also, Web and Geo-referenced to UTM zone 38, WGS 84.
Weather station data of the Erbil plain district	This is a file in the Excel format which contains the registered climate-related measurements – humidity, temperature and rainfall - from 2009 until 2019.

Some prior-processing procedures were carried out when making ready the satellite images for additional analysis. These procedures included first cropping the study area from the overall image, after that a couple of spectral vegetation indicators in the literature were used to observe drought. In the current research, the spectral reflectance data gathered from the Landsat TM and OLI indicators were used to measure spectral vegetation indicators which are related to drought occurring in agriculture and the stress of plants. The equation for calculating these vegetation indicators can be seen in (table3.3).

Table 3.3. List of spectral indices calculated from Landsat5 and 8 optical bands

Index	Abbrev.	Equation	Reference
Normalized Difference Vegetation Index	NDVI	$\frac{NIR - Red}{NIR + Red}$	(Tucker, 1979)
Green Normalized Difference Vegetation Index	GNDVI	$\frac{NIR - Green}{NIR + Green}$	(Fu et al., 2008)
Disease Stress water index	DSWI	$\frac{NIR + Green}{SWIR + Red}$	Galvao et al., 2005)
Normalized Difference Water Index	NDWI	$\frac{NIR - SWIR}{NIR + SWIR}$	(Hardinsky and Lemas, 1983)

3.2.1. Image Pre-processing

Data of various spectral bands are extracted from the Landsat satellite, with each one being saved in a Geo TIFF file format. A layer stack technique was used to get images with full color and to merge the spectral bands. All of the bands (1-7) were added together from Landsat-5 with the exception of the thermal band (B6). When it comes to Landsat-8, six spectral bands were employed and put on each other; that is to say, the second, third, fourth, fifth, sixth and seventh bands, and each one has a space-related resolution of 30 m. Lastly, to get the image in colors, the second, third and fourth bands were employed for landsat-5 and landsat-8 which stands for the colors red, green and blue.(Fig.3.3) contains the image as it is fully colored form in RGB format.

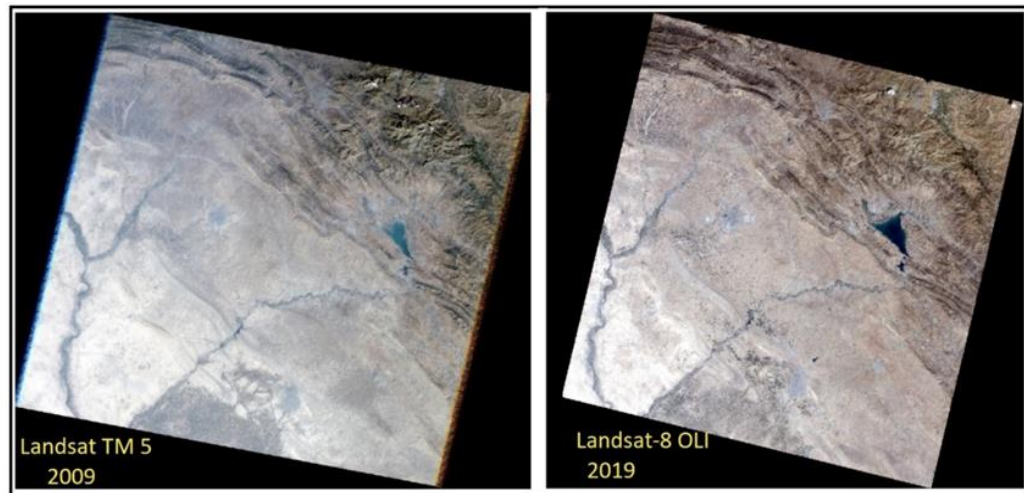


Figure 3.3. An example of false color composite of Landsat TM and OLI of the Erbil plain districts

3.2.2. Subset of the study area

A subcategory means in the format of ERDAS IMAGINE was employed to cut the area of the study which the plain district of Erbil. In order to achieve that, the most recent map was made use of to know the space-related borders of the city. The appropriate choosing of the site of the study is of great importance regarding the setting forth of the circumstances required for particular interpretation and to accomplish the goals of the research even though the preparation of the study site is not an arduous undertaking when talking about remote sensing research. Consequently, the area which was cut from the main source image from Landsat-5 TM and Landsat-8 OLI was of 1307 Km² hectares in total (see Figure 3.4 for additional information).

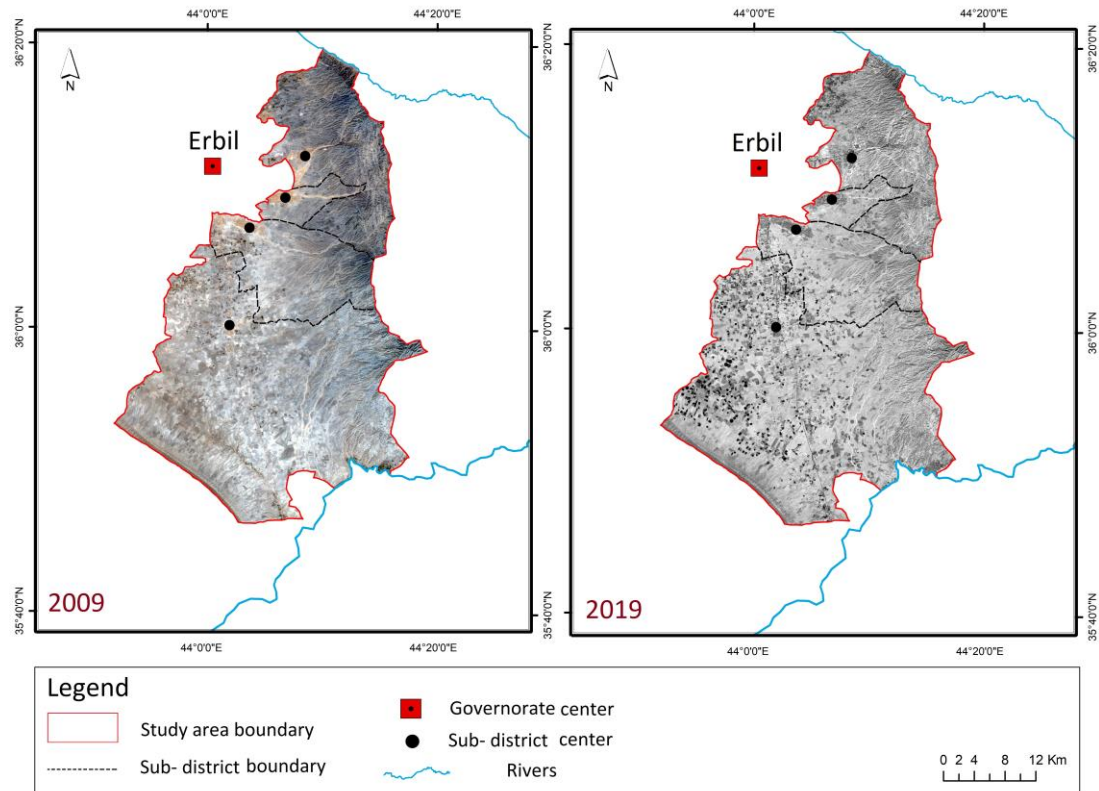


Figure 3.4. An example of Landsat-5 TM and Landsat-8 OLI images covering the area under consideration

3.2.3. Calculating spectral index

Data obtained through remote sensing technologies form the bulk of the data used in environmental process analyzes regardless of their scale. Such data is quite useful in studies which try to determine the change in a given location over the last few decades. Remote-sensing data like the Landsat, Sentinel-2, and Spot-5 imagery data also help with the classification of areas for a variety of studies which then can perform a wide range of analysis on the targeted locations. Such classifications may involve image resolution, electromagnetic spectrums, energy sources, media imaging, and a number of bands as classification criteria. The resolution of the available data – whether on spatial positioning, spectral positioning, radiometry, or temporal positioning- is an important factor in terms of accuracy.

Amongst these data sources, Landsat represents the great majority of the data used in classification studies, as it offers several bands with regards the wavelength (blue, green, red, infrared, thermal and panchromatic bands). The panchromatic band is a meta-band that is used in increasing the data resolution. Landsat TM5 has a total of 7 bands, whereas Landsat-8 OLI has 11. Four of these bands are used in NDVI, GNDVI, NDWI, DSWI and LST calculations, which are the green, red, NIR, and SWIR bands. band, wavelength, and resolution information for Landsat TM 5 and Landsat-8 OLI data are given in the table (3.4) below:

Table 3.4. Specifications of Landsat TM 5 and Landsat-8 OLI data

Landsat TM 5				Landsat-8 OLI		
Resolution (meter)	Wavelength (micrometers)	Band name	Band	Band Name	Wavelength (micrometers)	Resolution (meter)
30	0.45- 0.52	Blue	Band 1	Ultra-blue	0.435- 0.451	30
30	0.52 - 0.60	Green	Band 2	Blue	0.452 – 0.512	30
30	0.63 - 0.69	Red	Band 3	Green	0.533 -0.590	30
30	0.76 - 0.90	NIR	Band 4	Red	0.636 – 0.673	30
30	1.55 - 1.75	SWIR	Band 5	NIR	0.851 – 0.879	30
120	10.4 - 12.5	Thermal	Band 6	SWIR 1	1.566 -1.651	30
30	2.08 - 2.35	SWIR	Band 7	SWIR 2	2.107 – 2.294	30
			Band 8	Panchromatic	0.503- 0.676	15
			Band 9	Cirrus	1.363 – 1.384	30
			Band 10	TIRS 1	10.60 – 11.19	100 *30
			Band 11	TIRS 2	11.50 – 12.51	100 * 30

3.2.3.1. The normalized difference vegetation index (NDVI)

Many studies investigating the temperature of the land have shown that NDVI to an increasingly used method for monitoring and tracing the conditions of vegetation as this method is regarded as a fitting coefficient due to the fact that it possesses a reduced degree of sensitiveness when it is compared to different methods when assessing variations in the states of the air (Tso and Mather, 2009). This is the reason why NDVI was used to assess the relationship between NDVI and LST .The central course of action of the aforementioned method is centered on measuring two substantial bands retrieved

from considered satellites which is (called “NIR” which means ‘near infrared’) in to red band (Liu and Zhang, 2011; Gao, 2009). In fact, both red and near infrared spectral regions can be used to indicate whether the vegetation is in good condition or not. Furthermore, the near infrared band has a reflection indication of 60% and this is found between the wavelengths of (0.7-1.3 μm). Nonetheless, band number 3 has the reflection potential of only 20% in the wavelength oscillating between (0.5- 0.7 μm). According to Kidwell (1990), retrieving the exact formula of the measurements of NDVI while using the bands of Landsat -5 and Landsat-8 is carried out in this fashion:

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red}) \quad (3.1)$$

3.2.3.2. Calculation of green normalized difference vegetation index (GNDVI)

This index is in truth a modified version of NDVI that has higher sensitivity for chlorophyll content change in the targeted area. Chlorophyll is more commonly found in leaves of the plants and is somewhat related to the nitrogen content. Besides these, the DM values can also be obtained by the GNDVI index data (Gitelson et al ,1996). This index uses the visible green and near-infrared information to increase the sensitivity towards the chlorophyll presence, and the obtained data is quite useful in photosynthesis rate measurements and plant stress surveys. The below formula represents how the GNDVI is calculated:

$$\text{GNDVI} = (\text{NIR} - \text{GREEN}) / (\text{NIR} + \text{GREEN}) \quad (3.2)$$

In this formula, NIR and green values are directly the digital numbers from obtained from the NIR and green bands, respectively. As part of our study, average NIR wavelengths are between 749.85 and 750.18 nm, and average green wavelengths are between 549.82 and 550.18 nm.

3.2.3.3. Normalized difference water index (NDWI)

This index is specifically used in water related analysis studies and is based on green and NIR bands of the remote imaging data. It was developed by McFeeters in 1996 to enhance the detection of water-based properties of the landscapes. NDWI is also sensitive to plant water content and therefore can be used to monitor plant water status.

The idea of this index is based on the fact the water content have low reflectance compared to other types of biochemical properties of plant. Water content only reflect the visible part of the em spectrum, which is mostly concentrated towards the blue spectrum (0.4 - 0.5 μm) instead of green (0.5 -0.6 μm) and red (0.6 – 0.7 μm). The water content inside plant will observe most light in the shortwave reflectance region in particular from 1.1 nm to 2400 nm. NDWI was calculated using the below equation:

$$\text{NDWI} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR}) \quad (3.3)$$

NDWI values are usually somewhere between -1 and 1, and in most cases are above 0.5. Buildup features, on the other hand, usually have values between 0 and 0.2. Since vegetation has relatively lower values with significant margins, distinguishing between the two becomes easy in calculations.

3.2.3.4. Disease water stress index (DSWI)

Which describes planation stress because of the lack of water and due to destruction, the below formula represents how the DSWI is calculated:

$$\text{DSWI} = (\text{NIR} + \text{GREEN}) / (\text{SWIR} + \text{RED}) \quad (3.4)$$

3.2.4. Land surface temperature calculation and retrieval

In this research, the basic calculation process employed is the mono-window calculation process for obtaining LST; an algorithm set forth by Qin et al. (2001). To

Markham and Barker (1986), the basic assumption of this algorithm is the mathematical formula for the transformation of thermal radiance that normally focuses on changing statistical readings of the digital satellite to radiometric ones by means of the low-and-high-gain satellite values. To put it differently, according to Qin et al. (2001), developing the mono-window algorithm for the retrieval of LST in relation to the data of the thermal band obtained by “is with the idea that how hot or cold the brightness of the thermal band is at the level of the satellite has the ability to be figured out when to the data.” Nonetheless, there are a couple of extra parameters needed when employing the mono-window mathematical process, and these are: the area’s effectiveness in emitting energy, the transmittance of the air and the operative average of the temperature of the atmosphere which are the two factors which can be estimated by employing two extra parameters i.e. surface air and near-surface temperature and the composition of vapor of water (Liu and Zhang, 2011). Moreover, both of the proportional value of atmospheric moisture and air ground temperature are needed to assess and calculate the composition of the vapor of water. The procedures below exemplify all the formula that are needed when employing the mono-window algorithm for the obtaining LST:

I. In the first place, a conversion of the DVs (the digital values) of the image of the satellite to obtained spectral radiance is implemented employing this NASA’s mathematical formula as it can be seen below (Markham and Barker, 1986):

$$L_y = L_{MIN} + (L_{MAX} - L_{MIN}) \times QCAL / QCAL_{MAX} \quad (3.5)$$

Where: L_y = the measurement of the spectral radiance obtained by the indicator in $mW \text{ cm}^{-2} \text{ sr}^{-1} \mu\text{m}^{-1}$. L_{MIN} = the average spectral radiance for digital value (1) for Landsat-5 TM band equal 1.238. and for Landsat-8 is equal (1). L_{MAX} =the average spectral radiance for digital value (255) for Landsat-5 TM B6 equal 15.303, and for Landsat-8 is equal (65535). $QCAL$ =Landsat data grey scale being a digital number (DN) oscillating from 0 to 255 or 1 to 255; that is, Band 6 of the Landsat TM 5 and B10 & B11 of the Landsat-8 OLI in this research. $QCAL_{MAX}$: the outmost quantified calibrated pixel

value (normally equals to 255). All data was retrieved from satellite header files from Chapter 11 of the Landsat Handbook Guide.

II. Here, Planck's function is normally used to transform the spectral reflection data to satellite blackbody temperature as the DV's were being transformed into spectral radiation. That being said, an alternative mathematical equation provided by Markham and Barker (1986) was used to the same end, which is given below:

$$B_t = [K_2 / \text{LOG} (1 + K_1 / L_{(y)})] - 273.15 \quad (3.6)$$

In this formula B_t represents the reading of satellite blackbody temperatures in Celsius degrees. K_1 and K_2 specify Landsat-5TM calibration constants representing at-sensor spectral radiances of Landsat TM Band6, which are 607.76 and 1260.56 and Landsat-8 OLI Band10&11 which are 774.89 and 1321.08 one after another. $L_{(y)}$ indicates the satellite spectral radiance from the first formula.

These equations provide what is called the "outermost atmospheric temperature" (Zhang et al., 2006). It seems obvious that the radiance from the atmosphere is influencing the satellite in a way that may lead to sponging. Use of the mono-window formula, therefore, provides the means for an accurate evaluation of LST as it allows for consideration of an additional factor. Each of the used factors is significantly influential due to the parts they take in emendation atmospheric processes explained below.

3.2.4.1. Land surface emissivity

The radiance emitted from surface objects is assessed to retrieve their temperature assessment using the wavelengths of thermal infrared. Hence, these assessments provide the temperature of surface object radius and consequently there is an important reliance what the goal object sends out (Prakash, 2000). Therefore, to get accurate readings regarding the retrieval of LST, it is quite important to obtain the emissivity values. In emissivity as a concept is pivotal in studying LST since it is (abbreviated as ϵ) a relative

notion that measures how vivid the surface objects are (which is known as Planck's law) to predict the radiation that is emitted and it also indicates how effecting the emission of thermal energy is along on the surface into the atmosphere. In this regard, (ϵ) should be made known to assess the surface temperature precisely from radiance measurements. (Sobrino et al., 2008). Moreover, Earth surface is not made up from black bodies 100%. Consequently, it is essential to measure or assess the thermal emission of the surface studied (Gartland, 2008). However, it is a difficult thing to get an accurate assessment of the ground being assessed. There are various methods that were given by numerous researchers regarding retrieving acceptable assessments of ground emissivity (Qin et al., 2001). For example, a good measurement of calculation for how emissive the surface is using three different techniques which are contain in a paper by Zhang et al. (2006).

These techniques are the values of NDVI, the categorizing of pictures and the relative nature of plantation of the bare ground. However, using NDVI is the fitting technique as it was noted by Ifatimehin (2007) when they mentioned that the emissive nature of the surface is highly relative when looking at increasingly dense planation surfaces and high varied surfaces. Furthermore, the techniques developed by Zhang which depend on categorizing the picture might be very not easy to be used with Landsat information because this technique needs data of an increased resolution. Therefore, in this study, the statistical readings of emissions were gotten using NDVI values. The following (table3.5) presents some information of the mathematical equations developed by Zhang et al (2006) for the assessment of surface emission based on NDVI readings.

Table 3.5. Measurement of Ground Surface Emissivity employing values of NDVI

NDVI values	Estimation of land surface emissivity
$NDVI < 0.185$	0.995
$0.185 \leq NDVI < 0.157$	0.970
$0.157 \leq NDVI \leq 0.727$	$1.0094 + 0.047 \times \text{LOG} (NDVI)$
$NDVI > 0.727$	0.990

ERDAS IMAGINE software was used to make calculations using the relative functions, to which the assessments were used as inputs and the emission values for targeted surfaces were obtained as assessment outputs.

3.2.4.2. Estimation of atmospheric transmittance

Atmospheric transmission was evaluated by Qin et al. (2001) employing the composition of the vapor of water by means of the following equation:

$$W_c = 0.0981 \times \{10 \times 0.6108 \times \exp [(17.27 \times (T_0)) / (237.3 + (T_0))] \times RH\} + 0.1697 \quad (3.7)$$

In this formula Where: W_c : represents the water vapor composition in g/cm^2 , T_0 : denotes the temperature of the air or the near surface in Celsius degrees. RH: stands for the relative humidity. The near surface temperature and relative humidity information for this study were obtained from the Erbil plain districts forecast station. Using the water vapor evaluations and the obtained data in the equation by Qin et al, the below atmospheric transmission assessments were obtained (Table 3.6).

Table 3.6. The proposed equations to calculate Atmospheric transmission by (Qin et al)

Profile	Water vapour (WC)(g/cm ²)	Transmittance estimation equation (T)	Squared correlation	Standard error
High air temperature	0.4 – 1.6	$0.974290 - 0.08007 \times (W_c)$	0.9961	0.002368
	1.6 – 3.0	$1.031412 - 0.11536 \times (W_c)$	0.99827	0.002539
Low air temperature	1.4 – 1.6	$0.982007 - 0.09611 \times (W_c)$	0.99463	0.003340
	1.6 – 3.0	$1.053710 - 0.14142 \times (W_c)$	0.99899	0.002375

These equations are expected to deliver accurate results (Table 3.5) due to using high-squared correlation values and having low standard errors. That being said, it is still important to use certain discretion to ensure accuracy, like using information from clear sky data or data with no abrupt air condition changes in its recent history. It is also worth noting that the water vapor structure was found to be between 1.6 and 3.0 (Table 3.7), which is expected considering the ground temperatures and relative humidity values or Erbil plain districts. When all the values are in place the equations turn out as the following:

$$T = 1.031412 - 0.11536 \times W_c \quad (3.8)$$

In this equation: T = stands for the Atmospheric transmission. W_c = represents the assessed composition of water vapor attained from the later formula.

Table 3.7. The Parameters employed for obtaining LST for Erbil plain districts city by means of mono-window formulae

Values per year	Air temperature Celsius		Humidity (RH) %	
	Binaslawwa	Qushtapa	Binaslawwa	Qushtapa
12-Feb-09	7.6	8.5	69.7	54.7
3-may-09	16.7	17.2	72.3	70.6
7-Ayg-09	37.2	36.5	16.2	13.3
8-Sep-09	30.1	31.4	24.1	16.4
10-Oct-09	21.3	24.2	53.1	28.6
22-May-10	23.1	25.6	10.2	0.2
10-Aug-10	35.9	36.1	25.4	11.7
11-Sep-10	33.6	32.8	21.3	16.7
13-Oct-10	18.9	20.7	59.7	45.2
17-Jan-11	7.8	6.68	45.3	64.9
25-May-11	26.9	27.5	29.3	20.2
13-Aug-11	32.2	31.5	17.8	16
14-Sep-11	30.1	29.8	18.3	13.6
28-Apr-13	22.8	25.9	24.5	20.7
18-Aug-13	36.6	33.1	12.5	15.5
19-Sep-13	27.6	28.4	25.5	25
21-Oct-13	19.4	20.5	41.3	22.4
9-Jan-14	8.7	10.1	35.0	29.4
17-May-14	27.8	29.6	22.4	17.2
21-Aug-14	33.4	32.7	15.4	10.6
22-Sep-14	26.6	25.7	22.7	24.0
24-Oct-14	18.0	18.5	67.0	61.3
13-Feb-15	7.0	8.7	76.0	67.3
20-May-15	31.2	31.1	16.3	17.8
24-Aug-15	34.7	33.2	15.9	22.2
25-Sep-15	29.1	28.6	13.9	19.6
11-Oct-15	22.4	23.2	45.9	31.0
16-Feb-16	15.5	16.6	42.0	36.8
22-May-16	29.2	28.7	16.1	16.5
26-Aug-16	38.3	37.7	9.6	11
11-Sep-16	32.5	31.9	13.8	14.2
13-Oct-16	25.6	24.6	22.8	24.8
17-Jan-17	9.3	8.4	61.4	67.3
25-5-17	25.2	24.7	17.3	18.1
29-Aug-17	35.6	35.0	10.8	12.4
14-Sep-17	34.6	32.9	7.9	10.1
16-Oct-17	21.5	22.4	19.0	24.2
16-Aug-18	36.4	36.2	12.9	16.7
17-Sep-18	30.7	29.6	19.4	21.0
15-May-19	28.5	28.1	24.9	25.5
19-Aug-19	35.2	34.1	19	19.3
4-Sep-19	32.7	31.6	19.6	18.2
22-Oct-19	25	22.8	17.9	38.9

Emissivity (LSE) Extracted based on NDVI values

3.2.4.3. Mean atmospheric temperature

The mean values for the atmospheric temperature which is the final parameter needed for the assessments can be found using the formula proposed by Qin et al. (2001) and Sun et al. (2010)., which reveals the below results (Table 3.8):

Table 3.8. Estimation of mean atmospheric temperature.

Area	Average of the temperature of the air
For USA 1976	$25.9396 + 0.88045 \times (T_0)$
For tropical	$17.9769 + 0.91715 \times (T_0)$
Sor mid- latitude summer	$16.0110 + 0.92621 \times (T_0)$
For mid-latitude winter	$19.2704 + 0.91118 \times (T_0)$

Taking the two images analyzed in this research was done in the 9th month of the year. Consequently, the ground was still affected by the summer season; hence, the equation to follow was selected to assess the average of the temperature of the air:

$$T_a = [16.0110 + 0.92621 \times (T_0)] - 273.15 \quad (3.9)$$

In this formula Where: T_a = represents the average atmospheric temperature in Celsius degrees. T_0 = denote the surface air temperature in the Kelvin unit. Information of the temperature of the ground was attained from Erbil plain districts city weather agency.

I. Using all of the available information and data to determine the final parameters, the below mono-window formula was ready to be used to determine the LST in the following manner:

$$LST = \{A \times (1 - C - D) + [B \times (1 - C - D) + C + D] \times B_t - D \times T_a\} / C \quad (3.10)$$

In this equation: LST = Represents the land surface temperature in Celsius degrees. B_t = Denotes the brightness temperature in Celsius degrees. T_a = the average of the temperature of the atmosphere in Celsius. What is more, both of the parameters A and B possess normal values (i.e. -67.355351 & 0.458606 one after another) as it was stated by (Qin et al., 2001). And when it comes to the parameters C & D, they can be attained by means of the following equation:

$$C = \varepsilon \times T \quad (3.11)$$

here: ε = represents the emissivity attained from the values of NDVI. T = denotes the atmosphere transmission.

$$D = (1 - T) \times [1 + (1 - \varepsilon) \times T] \quad (3.12)$$

ERDAS IMAGINE software has a “special modeler”, which was used to place all the equations in order to work on a large set of processing tasks. Appendix 2 provides in-depth information regarding the specimen used in the ERDAS IMAGINE software.

3.2.5. Preparing reference data

As the study's main goal is to monitor and detect agricultural drought, the first step is to identify the study sites' agricultural areas (reference point). To do this we have taken a novel approach by selecting threshold values obtained from the NDVI index as (Sparse vegetation area = $0.20 > \text{NDVI} < 0.4$), (Moderate vegetation area = $0.4 > \text{NDVI} < 0.6$) and (Dense vegetation area = $\text{NDVI} > 0.6$) (see Figure 3.5). Below is an example of the ArcGIS formula used in our study:

$$\text{Con} (("NDVI" > 0.2) \& ("NDVI" < 0.4), 1, 2) \quad (3.13)$$

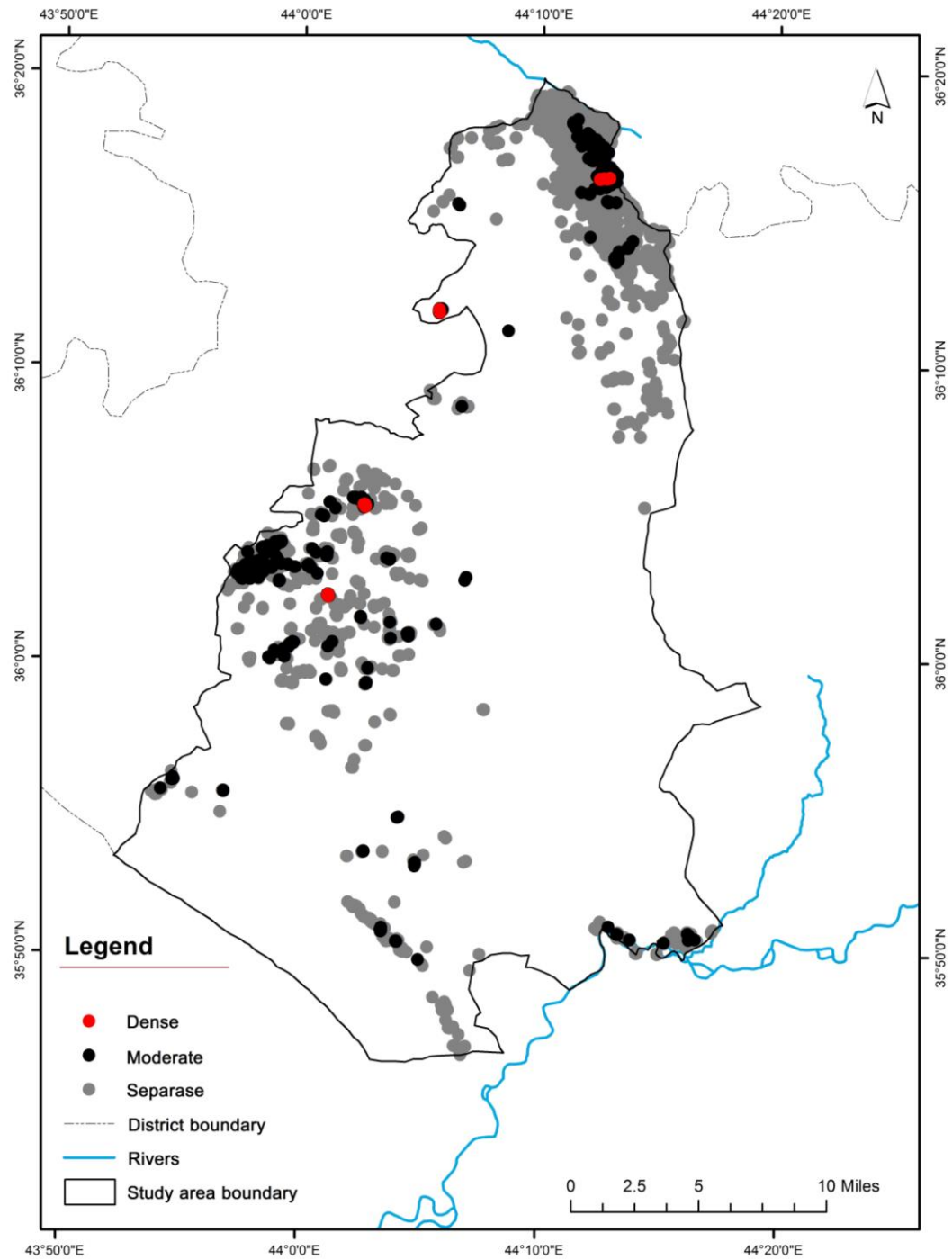


Figure 3.5. Preparing reference data

These threshold values are identified based on the literature review. Previous have used Landsat imagery for semi-arid areas. For this analysis, we used the NDVI data

for the date 10-10-2009. The reason for selecting 10-10-2009 as a start point is that this period, the region has its lowest precipitation rates, and therefore the vegetation present at this time is from agricultural fields and not from the seasonal vegetation cover that is watered by rain. As we know from the literature review, NDVI values between and 0.4 are typical for agricultural land. Therefore, we may not use these data for further analysis.

3.3. Statistical Analysis

In this research the following workflow (Figure 3.6) has been used to gain the study's objectives and answer the research question.

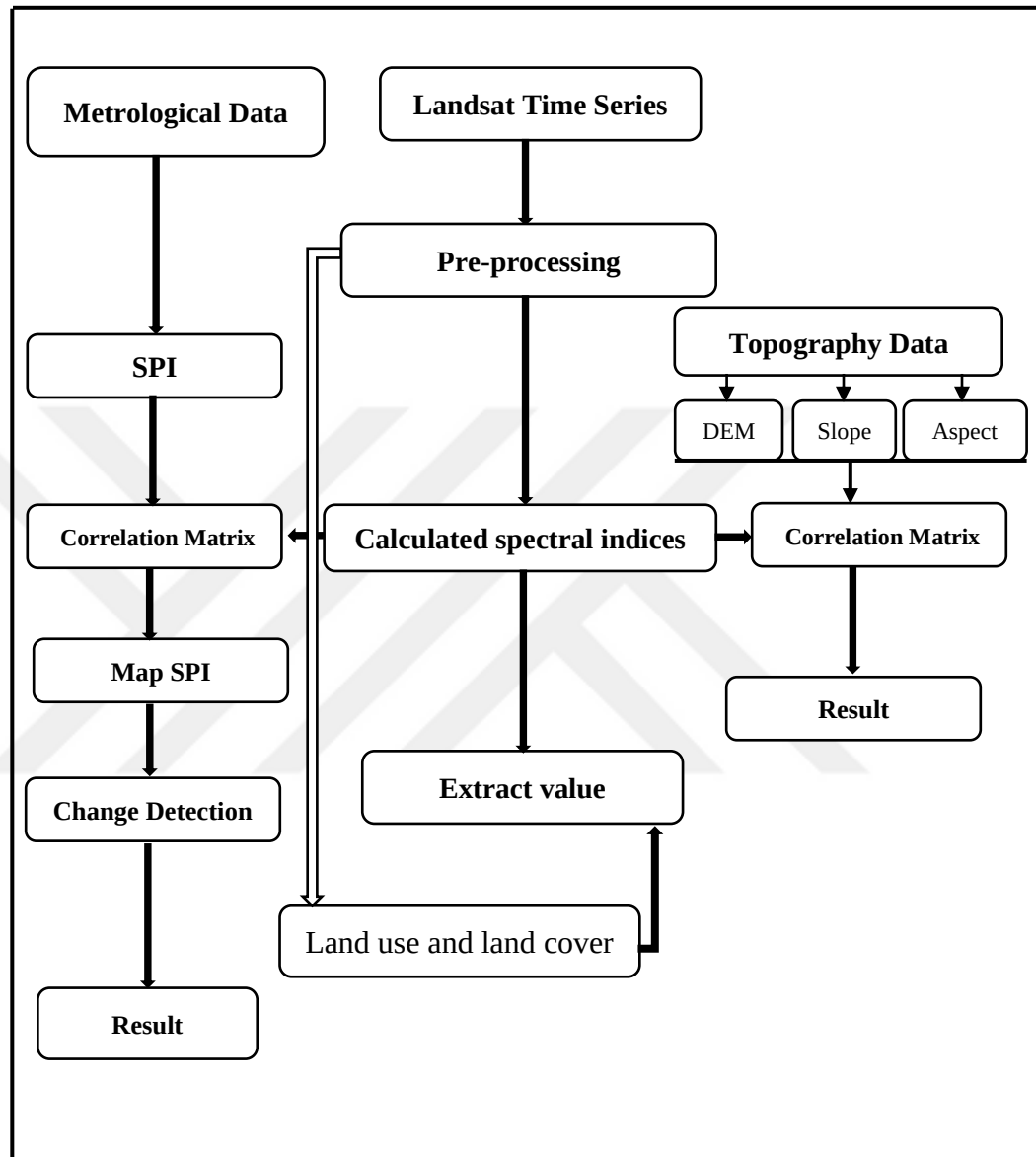


Figure 3.6. A general workflow of methodology used in this study.

In this study supervised classification techniques has been used to classify land use and land cover in (2009-2017). Full detail about the process of supervised classification can be found in (Dabbagh, 2015).

3.3.1. Outlier detection:

The first step of the statistical analysis is to remove outliers from the dataset. The definition of outliers is “in statistics, an outlier is an observation point that is distant from other observations”. This step is of significant importance in doing any statistical analysis. In this research, calculated vegetation indices, which include NDVI, GNDVI, DSWI, NDWI and LST, were removed from the most effectual outlier values. The approach used to steer clear of the outlier is the Monte Carlo sampling approach (MCSA) and Z-score. The Z-score is quantifying an observation when the data (spectral indices) follow the normal distribution. Z-scores are the number of standard deviations above and below the mean that each value falls. For example, a Z-score of 2 indicates that an observation is two standard deviations above the average value of the given index (e.g. NDVI) while a Z-score of -2 signifies it is two standard deviations below the mean. A Z-score of zero represents a value that equals the mean. To calculate the Z-score for an observation, take the raw measurement, subtract the mean, and divide by the standard deviation. Mathematically, the formula for that process is the following:

$$Z = (X - \mu) / \sigma \quad (3.14)$$

The further away an observation's Z-score is from zero, the more unusual it is. A standard cut-off value for finding outliers are Z-scores of +/-3 or further from zero.

3.3.2 Re-scale calculated vegetation index values

This research utilizes the box plot technique. This technique is employed to show distribution and variation among the index known as calculated vegetation. Furthermore, this aforesaid technique is also used to investigate the variation that is temporal among separate vegetation classes. These classes include sparse, moderate, and dense. On the contrary, making comparison between the vegetation indexes is quite hard as each one of them is in possession of separate unit and scale. NDVI, GNDVI, NDWI, DSWI and LST which are the values of measured vegetation were used to solve the issue. The solution was that the scale was rearranged based on a zero to one scale, employing the

Min max normalization method. In general, the word “normalization” is used informally in statistics, and so the term normalized data can have multiple meanings. However, in our case, we did normalize our data from different spectral indices to eliminate the units of measurement and enabling us to more easily compare data from indices. The following formula has been used to re-scale the indices values:

$$\text{R-NDVI} = (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (3.15)$$

Where X is the original index value, and $X_{\max}$, $X_{\min}$ are the min and max for the original index value.

3.3.3. Standardized precipitation index (SPI)

The characterization of drought over longer periods of times can be done most effectively employing SPI. In case there was a drought monitoring entity which is working along a short period of time regarding the monitoring process, it can associate SPI to the soil moisture over longer periods of times and it can associate that to the underground water and the additional capacities of water storages. These characteristics render the instrument very efficient for carrying out drought monitoring studies along different chronological benchmarks taking into account that the procedure is not restricted to a specific time measurement and the fact that there are many justifications for conducting observation operations (Wu et al, 2001). The attained rain-amount can be made into numbers as an official standard from specific pinpointed function related to the dispersing of probability which can be then employed as a standard for the representation of rainfall data. The investigator can start with creating a spreading of frequency of rainfall data of the region under investigation at a particular point in time while calculating the SPI (Iglesias, 2009), (Singh et al, 2014). The increasing spreading of the rainfall can consequently be specified without effort by installing a function related to the probable nature of the immensity of gamma. This allows the observing team to select the time measurement standard that best fits the designated procedure.

Therefore, the SPI could be calculated for a couple of months. For example, the monitored droughts of agriculture can be filled in for shorter time phases from 3 to 6 months (Beighley and Killgore, 2011). On the other side of the spectrum, those perks of the underground water of an area in association to the situation of the drought can be filled in with readings exceeding the specified ones. The variability of SPI is hence an additional positive point in the efficiency of the practical adaptation in the monitoring of drought. To Wardlow et al (2012), SPI is efficient attributed to its simple and flexible use. One of the most alluring perks of the tool is that when faced with the condition of having rainfall in reality, the drought data can be given in a specific fashion. As it was illustrated above, an important perk of the efficient monitoring of drought is the capability to give actual or real data which could be attained by the investigators with ease. As a matter of fact, SPI has the ability to give appropriate space-related and time-related precipitation spreading in contrast to using rain measurement tools, which makes it an appropriate instrument for giving information attained from satellites regarding rainfall that are practical to monitor drought and to analyze it (Omar, 2014).

Consequently, the SPI has been used in this research to obtain an idea about the link between rainfall and the growth of agricultural yield in Erbil plain district with precipitation amounts. Measuring the SPI is needed to access the rain information for 30 years for the operation of the software. It was measured employing the underneath method and the categorization plan (see Table 3.9) as suggested by Mcgee et al. (1993), so the precipitation information between 2009 and 2019 has been inserted and its outputs 5 SPI pieces of information which are (SPI1, SPI3, SPI6, SPI9, and SPI12) when:

SPI1 stands for the rain fall for 30 days.

SPI3 stands for the rain fall for 90 days.

SPI6 stands for the rain fall for 180 days.

SPI9 stands for the rain fall for 270 days.

SPI12 stands for the rain fall for 360 days.

Since the main aim of this research is to pinpoint drought of agriculture, only the SPI3 has been adopted for analysis in addition to only analyzing the length of the investigation period which is from 2009 till 2019. The mathematical formula of SPI is shown in equation 3.16

$$\text{SPI} = \frac{X_{ij} - X_{im}}{\sigma} \quad (3.16)$$

Where X_{ij} represents the seasonal precipitation and observation at the rain gauge station, X_{im} denotes the long-term seasonal mean, and σ is its standard deviation. Thom (1958) observed that the gamma distribution matches the time - series data of climatological precipitation well. Its probability density function determines the gamma distribution:

$$g(x) = \frac{1}{\beta \alpha \Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}} \quad \text{for } x > 0 \quad (3.17)$$

Where: α, β are the parameters of the scale and shape, x is the quantity of precipitation and $\Gamma(\alpha)$ signifies the gamma function. SPI calculation involves fitting distribution of gamma likelihood to a specified occurrence distribution of a station's precipitation wholes. For each class, the α and β variables of the gamma prospect density function are calculated for several intervals according to the interest of different time scales (1, 3, 6, 12 months, etc.) and according to the months. To appropriately predict α and β , maximum probability solutions are utilized:

$$\alpha = \frac{1}{4A} \left(1 + \sqrt{1 + \frac{4A}{3}} \right) \quad (3.18)$$

$$\beta = \frac{\bar{x}}{\alpha}, \text{ Where } A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \text{ and } n = \text{number of observations.} \quad (3.19)$$

The cumulative likelihood is then calculated through considering resulting parameters. for the given month of a detected precipitation occurrence and the time scale for the unknown $x = 0$ and the station concerned since there may be zeros in the gamma function precipitation distribution, the cumulative likelihood (Hayes et al., 2007). $H(x)$ is premeditated by the equation:

$$H(x) = iq + i1(1 - iq)iG(x) \quad (3.20)$$

The cumulative probability of the defective gamma function is hence q is the chance of $G(x)$ and zero. Then the total possibility, which is the value of the SPI, is converted to the regular natural accidental inconstant z with mean zero and alteration one. Once the intensity of the phenomenon is normalized, it is defined as stated in Table 3.9) this table also includes the related possibilities of occurrence of every gravity that normally emerge from the normal function of the probability density (Tigkas et al., 2015).

Table 3.9. SPI readings and the related drought classifications (McKee et al., 1993).

SPI values	Drought Category
$0 >$	Normal-No drought
0 to -0.99	Mild drought
-1.00 to -1.49	Moderately drought
-1.50 to -1.99	Severely drought
≤ -2.00	Extremely drought

3.3.4. Correlation between calculated SPI and vegetation index

Correlation coefficients are used to measure how strong a relationship is between two variables (SPI and spectral indices). There are several types of correlation coefficient, but the most popular is Pearson's. Therefore, in our study we utilized

Pearson's correlation (also called Pearson's R) which is a correlation coefficient commonly used in linear regression. In short, the Pearson's correlation is looking for a linear correlation between two variables or two datasets (x and y). In our case, the results of SPI (x) obtained from all the locations that have weather station have been used against the calculated vegetation index (y) and all the years mentioned in the study. The outcome of Pearson's correlation analysis is a value range from (-1 to 1). A value closer to -1 indicates stronger negative correlation and a value closer to 1 indicates strong positive correlation. The next step was using the highest negative or positive correlation (r) value of the vegetation index for the purpose of SPI. In doing so, Landsat imagery was employed. There are certain criteria available for choosing the highest correlation value. The criteria include:

1. The index possesses highest correlation with SPI results for all the imagery collected for this study and with both weather station data.
2. The correlation value for the selected index has to be higher and consistent with all imagery taken in this study.

3.3.5. Mapping SPI utilizing Landsat imagery

The SVI with the highest correlation value that was gained from the aforesaid section was used to produce the map of SPI. To generate this map, Landsat imagery was employed. Later, the highest (r) value of the index was chosen to produce the SPI maps because this value is very significant. The next step, Linear regression was utilized to produce the maps. This was done in order to roughly calculate and judge the value from Landsat imagery.

The study employs multiple regressions. The definition of this regression is that this is a technique utilized to "predict a variable of interest from several other variables". The predicted variable is called the criterion and the variables that tell us about the criterion are called predictor. One of the key requirements of the regression is metric

variables. However, other techniques and/or approaches are also obtainable to do the same job. The criterion variable in this study is SPI3 and the variables that are predicted are LST and NDWI, these show the highest correlation with SPI3. The range of the SPI classes was employed to divide the produced maps. The SPI classes are by (Table3.9). The last map comprises five classes and each of them is related to the drought intensity. As it can be seen in the following (Figure 3.7).

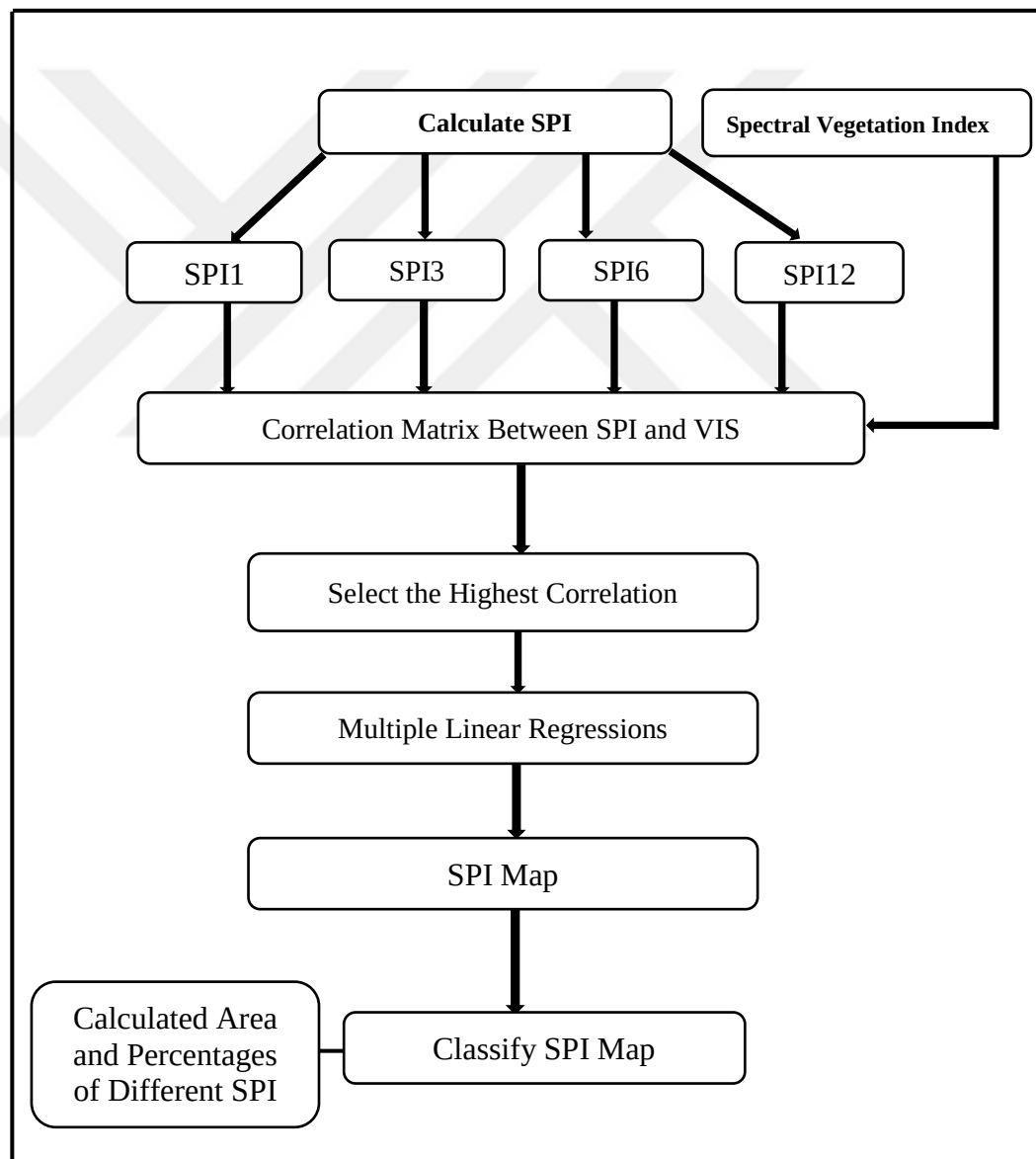


Figure 3.7. Workflow showing the steps to generate SPI maps from Landsat imagery

3.4. Evaluating the importance of Land surface temperature in detecting crop water stress during day and night time

In the previous steps, the spectral indices and Land surface temperatures (LST), were compared to determine the drought at the level of the total area of the study area, and for the purpose of demonstrating the applicability of both spectral indices and LST on the small area, we compared the results of The NDVI, NDWI and Land surface temperature (LST) at night and day on the wheat crop field. The results of the field surveys were used together with the information of the satellite images (Table 3.10) such as the percentage of moisture in the soil and the temperatures of the soil and the air, during the time of the satellite image capture. Then, the results of the day and night temperatures were compared with NDVI and NDWI.

Table 3.10. Satellite data used for calculating LST during day and night time

Satellite	Date
Aster	8-May-2017 (19:05pm)
Landsat-8	8-May-2017 (7:36am)

Full detail about the calculation of LST from ASTER data can be found in (Abdullah et al ., 2020)

3.5. Software Used

The Erdas Imagine 2014v (Geosystems, 2004) was resorted to while analyzing and classifying the image. Moreover, the information gained from stations that sense remotely is saved in the values of pixels which stand for X, Y data for the object which is monitored on the surface. This gave us the opportunity to transform the gotten data and outcomes of the information which is obtained remotely by sensing it into a GIS milieu. Hence, to accomplish the objective of the study, GIS parameters were made use of to assess space-related data and for the preparation of the final maps by means of ArcGIS 10.7v.

4. RESULTS and DISCUSSION

4.1. Results

4.1.1. Temporal and seasonal variation between rescaled spectral indices and LST.

The scale of all indices has been converted to (0-1) as the first step in comparing the vegetation index used in this study and the land surface temperature during the level of all years taken in this study between the years 2009-2019.

The comparison process was performed on three different vegetation cover levels (dense, moderate and sparse vegetation) and for all months considered in this study, as shown in Figure (4.1) and Appendix (1) through (10), where it was found that there are clear and noticeable changes in the relationship between all vegetation indices with the land surface temperature (LST) in particular within the dense vegetation cover. On the other hand, the value of the units of the rescaled Vegetation Index and the LST are clearly close to each other, especially in the winter or in February and at the level of all years except 2014 through 2016 see appendix (5 through 7).

It was also found that during the comparison process the rescaled spectral Index indicates such as the Normalized Difference Water Index (NDWI) and the Land Surface Temperature (LST) are more affected by the seasonal variations and variations in the vegetation cover. For example, it turns out that the NDWI and the LST are inversely related, which means that the higher the value of the NDWI the lower the land surface temperature and vice versa. These changes are evident in May and August, especially in the dense and sparse vegetation cover areas in see Appendix (1 through 10). Furthermore, most of the indices unlisted in this study have shown a noticeable change during the hot season in August. For example, in August 2009 a high degree of difference was observed between the unlisted spectral indices over the dense vegetation cover, whereas for the same in May small changes were observed.

Moreover, GNDVI and NDVI indices are highly correlated with each other, i.e., the higher the value of one, the higher the value of the other index, and this is according to the seasonal changes. However, it should be noted that NDVI is more affected by the dense vegetation during the levels of the study years where the value NDVI changes clearly between the areas of moderate and sparse vegetation.

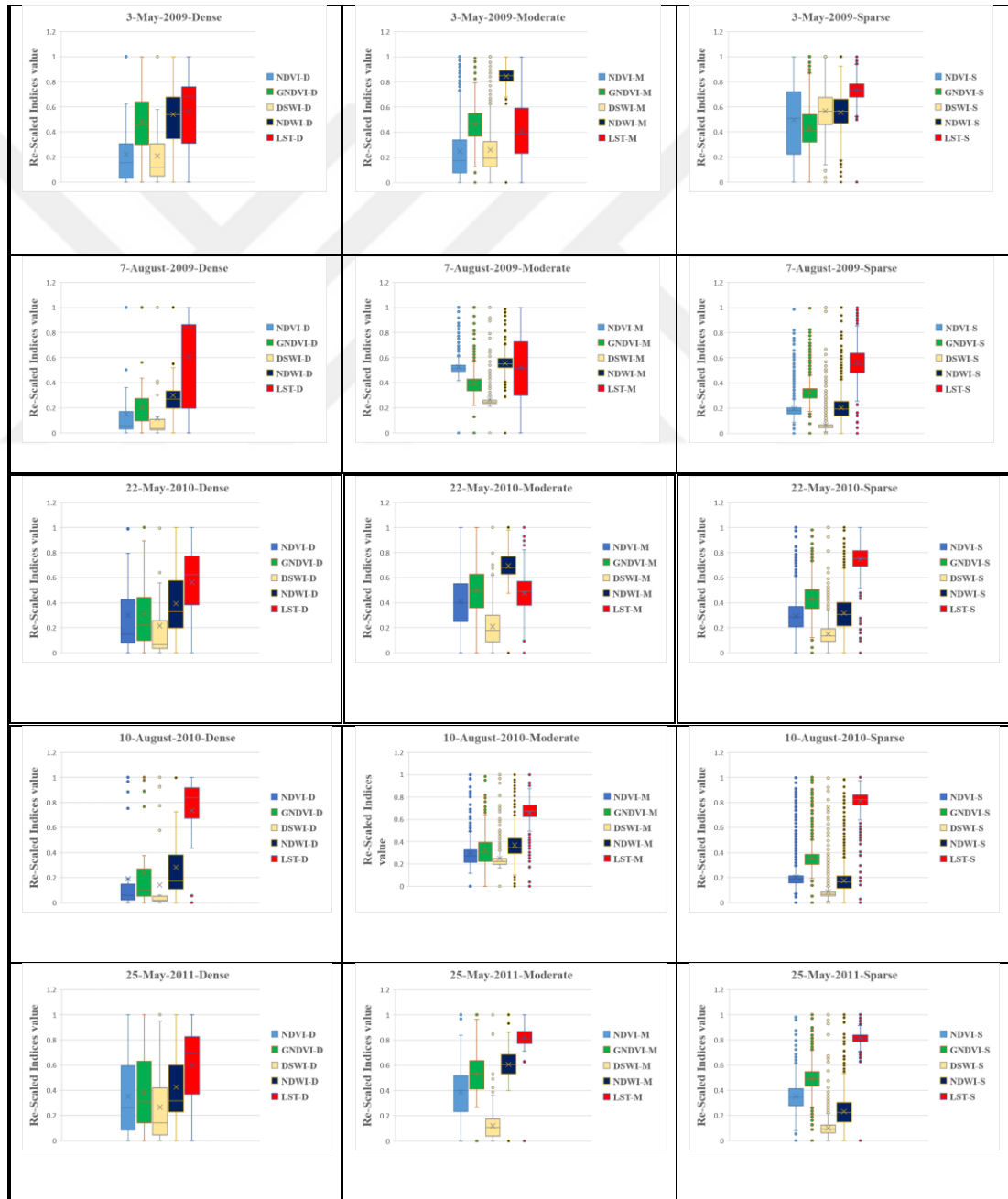
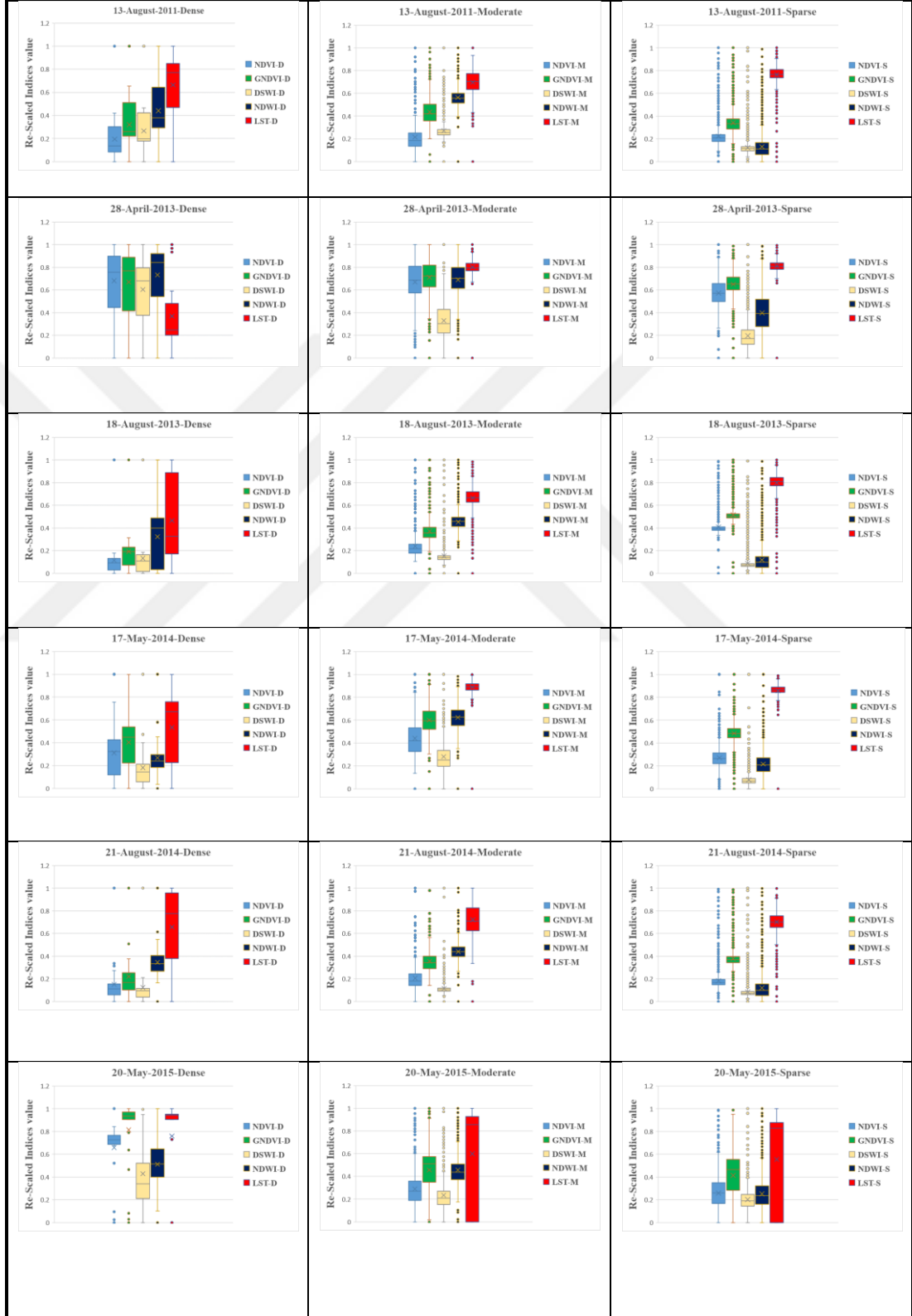


Figure 4.1. Continuous



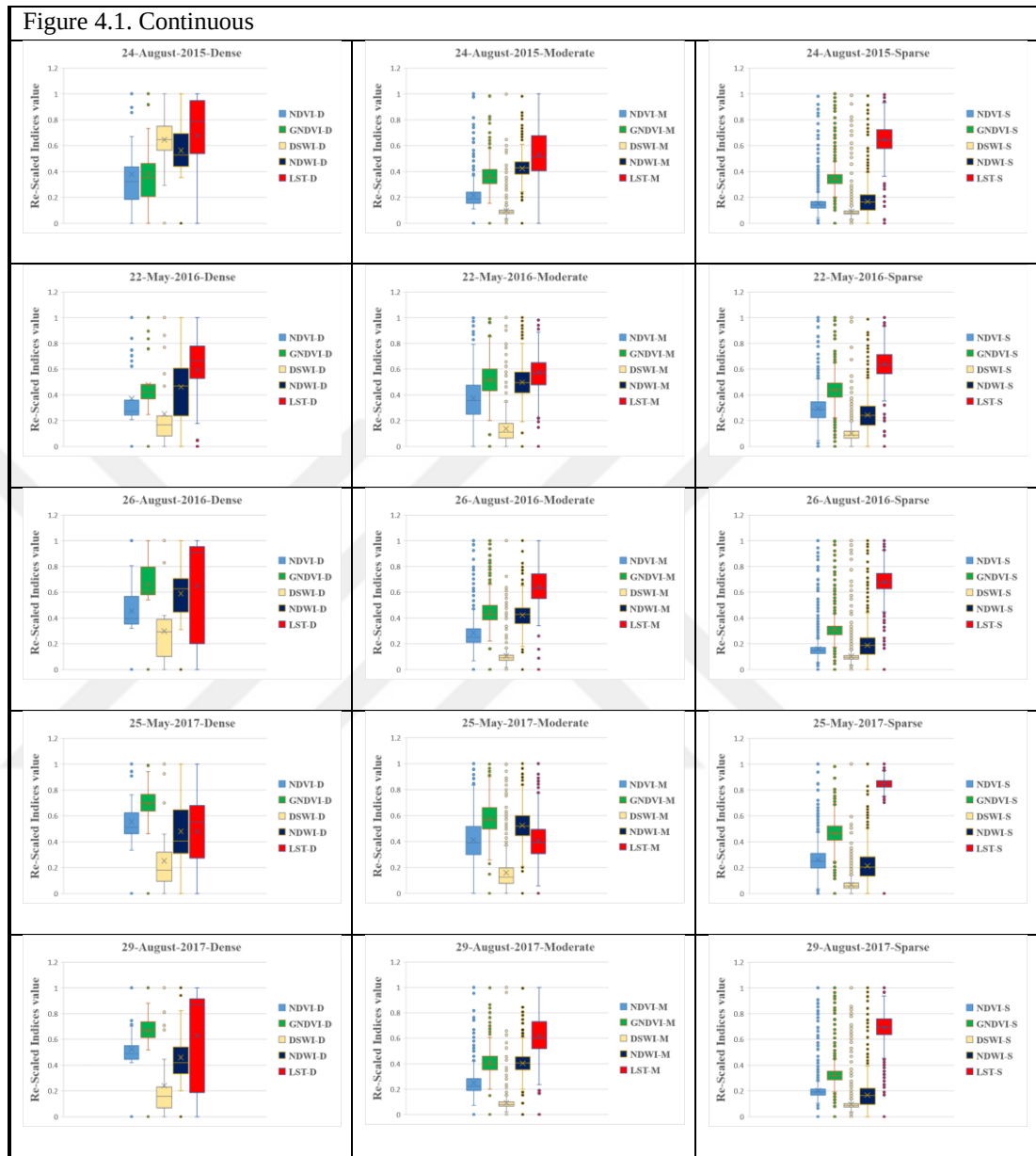


Figure 4.1. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST for the months May and August in 2009-2017

4.1.2. Temporal and seasonal variation between spectral indices and LST and their correlations.

Upon comparing the raw value of all vegetation indices, it was found that all those used in this study were affected by a specific season of the year. For example, Land Surface Temperature (LST) exhibited clear changes from the beginning of winter until the end of autumn, as shown in Figure (4.2) and appendix (4.11) through (4.19), where the lowest surface temperature was recorded in February for all types of vegetation characterized as dense, moderate, or sparse.

On the other hand, the Highest LST was recorded in the month of August for all years considered in this study, but we must pay attention to one important point that is the land surface temperature changed in the year 2010, but there were no significant changes in the value of the LST in the months of August and September, and its value remains high in the month of September.

On the other hand, the results of this study revealed that the seasonal changes are not affected equally by the indices taken in the study. For example, each of the two indices, the normalized difference water index (NDWI) and disease water stress index (DSWI), are two indices related to water content in plant and soil, which shows that the first index is more variable and its changes are clear so that the value of this index comes in the foreground, where the highest value was recorded in February in the wet season of winter (the month of precipitation). However, the value of the index decreases in September and October, which are two months in which the amount of precipitation falls in the study area, this indicates that there is a good reflection of the increase and decrease of the amount of water content in soil and plant.

Regarding the correlation between spectral indices and LST, the results shows that there is a strong negative correlation between LST and water related indices DSWI and NDWI (Table 4.1) This correlation ranges from (-0.24) to (-0.94). On the other hand, the

LST has recorded un consistent very weak positive to moderate negative correlation with the Normalized Difference Vegetation Index (NDVI) and the Green Normalized Difference Vegetation Index (GNDVI).

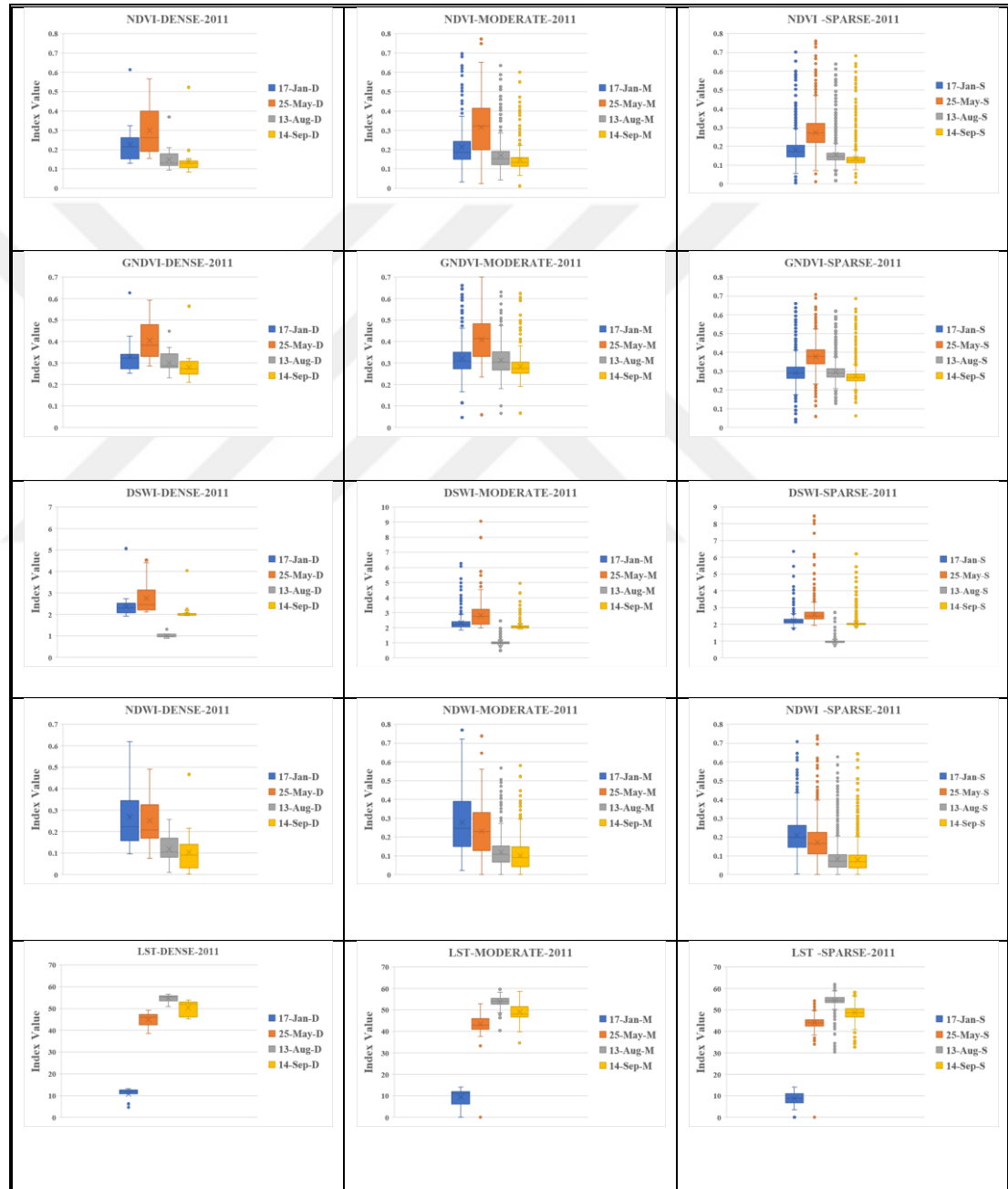


Figure 4.2. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse).

Table 4.1. Correlation matrix between calculated spectral indices

2009						2010					
	NDVI	GNDVI	DSWI	NDWI	LST		NDVI	GNDVI	DSWI	NDWI	LST
NDVI	1					NDVI	1				
GNDVI	0.80	1				GNDVI	0.98	1			
DSWI	0.99	0.73	1			DSWI	0.99	0.96	1		
NDWI	0.78	0.28	0.82	1		NDWI	0.29	0.42	0.18	1	
LST	0.11	0.68	0.00	-0.47	1	LST	-0.42	-0.59	-0.35	-0.83	1
2011						2013					
	NDVI	GNDVI	DSWI	NDWI	LST		NDVI	GNDVI	DSWI	NDWI	LST
NDVI	1					NDVI	1				
GNDVI	0.99	1				GNDVI	1.00	1			
DSWI	0.62	0.55	1			DSWI	1.00	0.99	1		
NDWI	0.67	0.56	0.40	1		NDWI	0.99	0.99	1.00	1	
LST	-0.65	-0.53	-0.47	-0.99	1	LST	-0.26	-0.25	-0.32	-0.28	1
2014						2015					
	NDVI	GNDVI	DSWI	NDWI	LST		NDVI	GNDVI	DSWI	NDWI	LST
NDVI	1					NDVI	1				
GNDVI	0.49	1				GNDVI	0.84	1			
DSWI	0.64	-0.33	1			DSWI	0.12	0.39	1		
NDWI	0.87	0.44	0.64	1		NDWI	-0.12	0.33	0.89	1	
LST	-0.56	0.36	-0.82	-0.30	1	LST	-0.53	0.00	0.45	0.80	1
2016						2017					
	NDVI	GNDVI	DSWI	NDWI	LST		NDVI	GNDVI	DSWI	NDWI	LST
NDVI	1					NDVI	1				
GNDVI	1.00	1				GNDVI	0.83	1			
DSWI	0.20	0.22	1			DSWI	0.25	-0.33	1		
NDWI	0.48	0.51	0.91	1		NDWI	0.75	0.30	0.74	1	
LST	0.23	0.29	0.74	0.88	1	LST	-0.19	0.34	-0.94	-0.59	1
2018						2019					
	NDVI	GNDVI	DSWI	NDWI	LST		NDVI	GNDVI	DSWI	NDWI	LST
NDVI	1					NDVI	1				
GNDVI	0.99	1				GNDVI	0.98	1			
DSWI	0.54	0.57	1			DSWI	0.90	0.79	1		
NDWI	0.87	0.89	0.87	1		NDWI	0.98	0.91	0.97	1	
LST	-0.02	-0.07	-0.85	-0.51	1	LST	-0.06	0.15	-0.46	-0.22	1

4.1.3. Results of generates maps of vegetation index and land surface temperature

In the index used, there is a different spatially and temporally results, as the figures (4.3) through (4.10) and Appendix (20 and 21), illustrate, and as it appears the months of February and May have recorded the highest percentage of vegetation cover, especially in the northern parts of the study area. Because the northern areas are considered as high areas where the height of the surface is more than 800 meters, while the elevation in the study area decreases towards the central and southern parts, and the average height of the surface of the study area is 480 meters above sea level

On the other hand, in the two months of August and September, the percentage of vegetation cover in the western and southern parts, such as the northern parts, is high, and the reason for this is that these parts are agricultural fields.

It was also found that there is a strong relationship between the Normalized difference vegetation index (NDVI) and disease water stress index (DSWI). For example, from Figures (4.3) and (4.5), the rise in the value of DSWI coincided with an increase in the value of vegetation, and in contrast, an inverse relationship is observed between Land Surface Temperature (LST) and normalized difference water index (NDWI) where the value of LST decreases with an increase in the value of NDWI, especially in the northern parts of the study area. It should also be noted that in 2018 and 2019, appendix (20,21), the lowest percentage of vegetation was recorded in the study area, with temperatures at their highest levels.

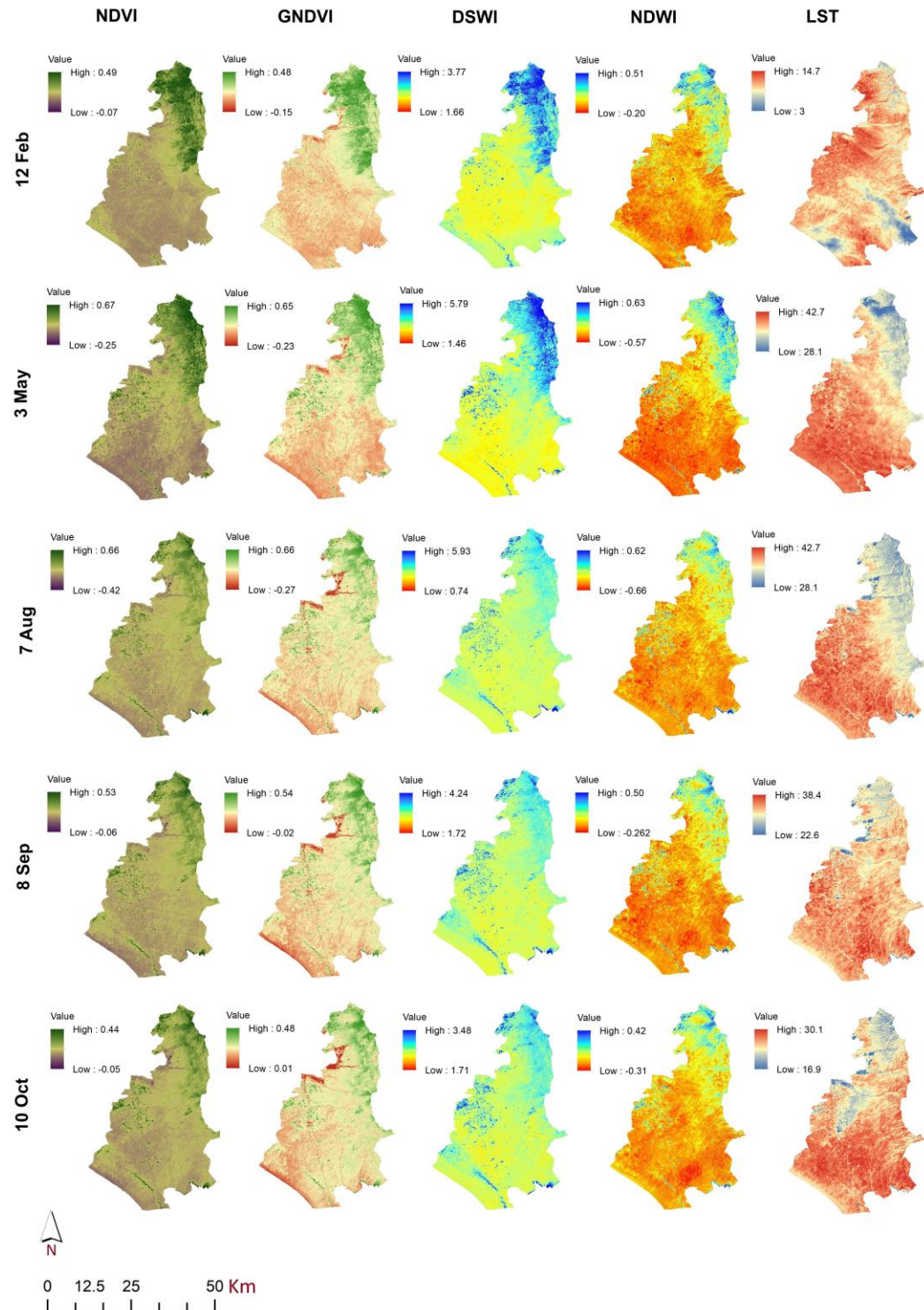


Figure 4.3. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2009

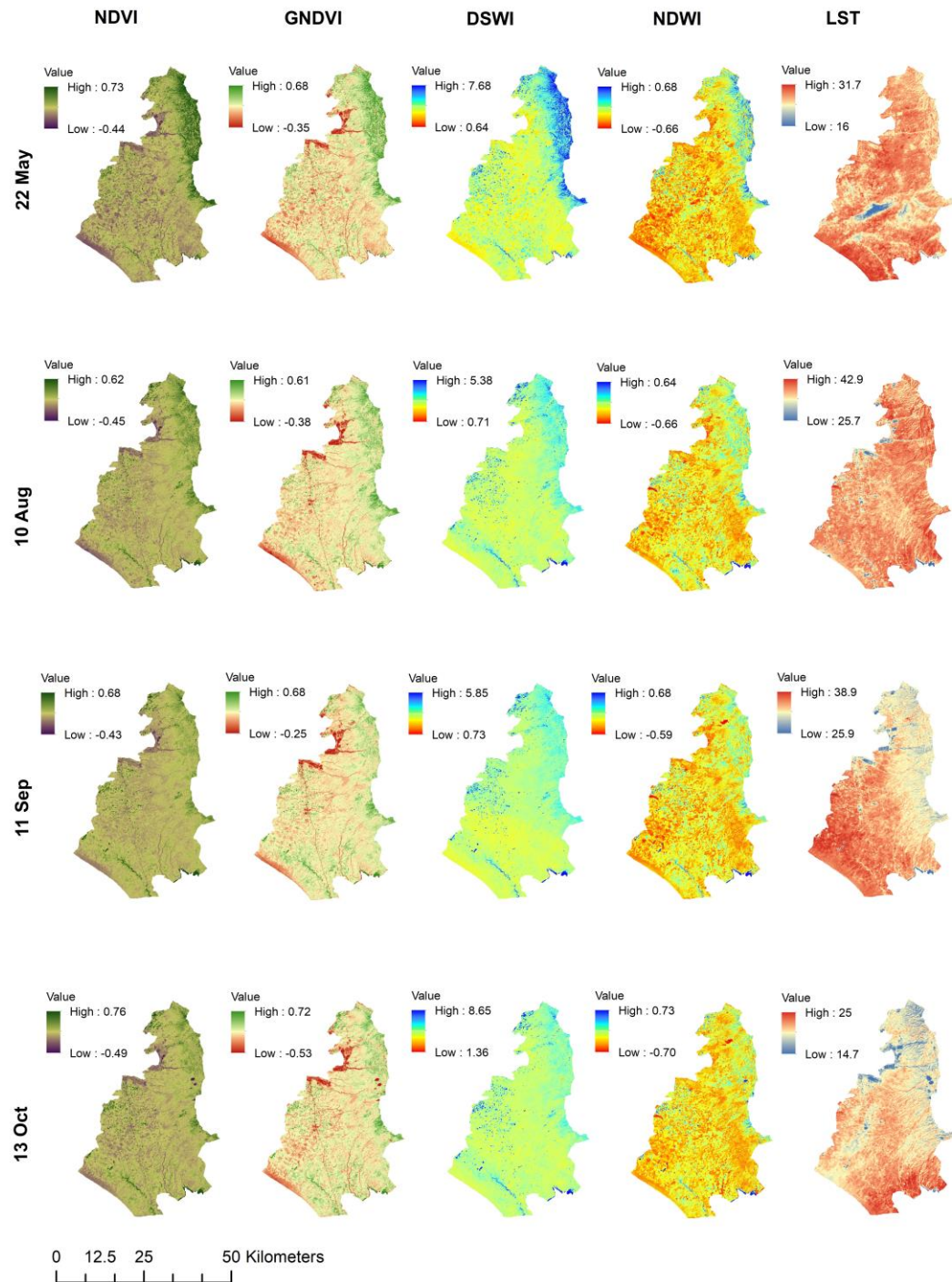


Figure 4.4. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2010

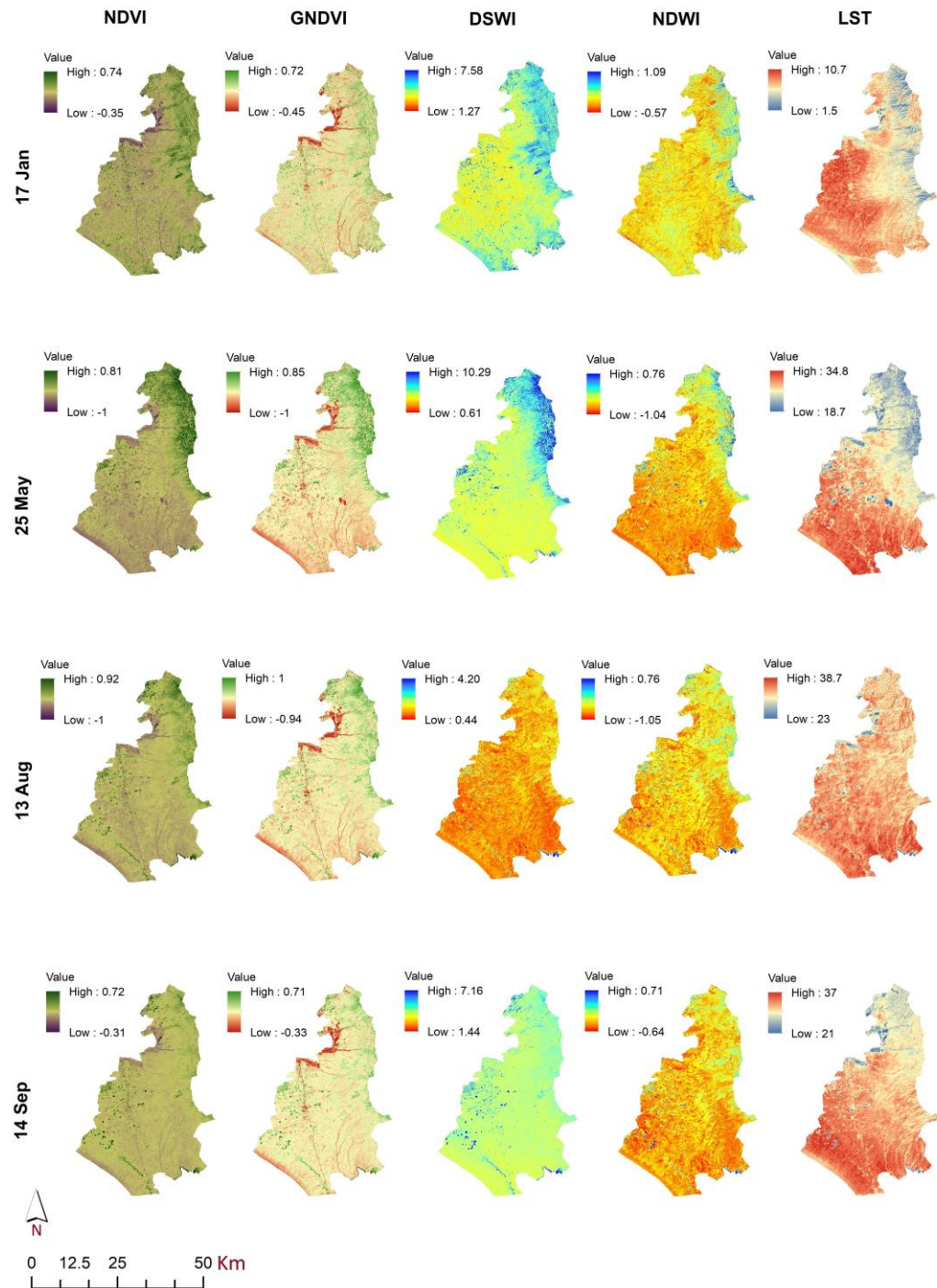


Figure 4.5. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2011

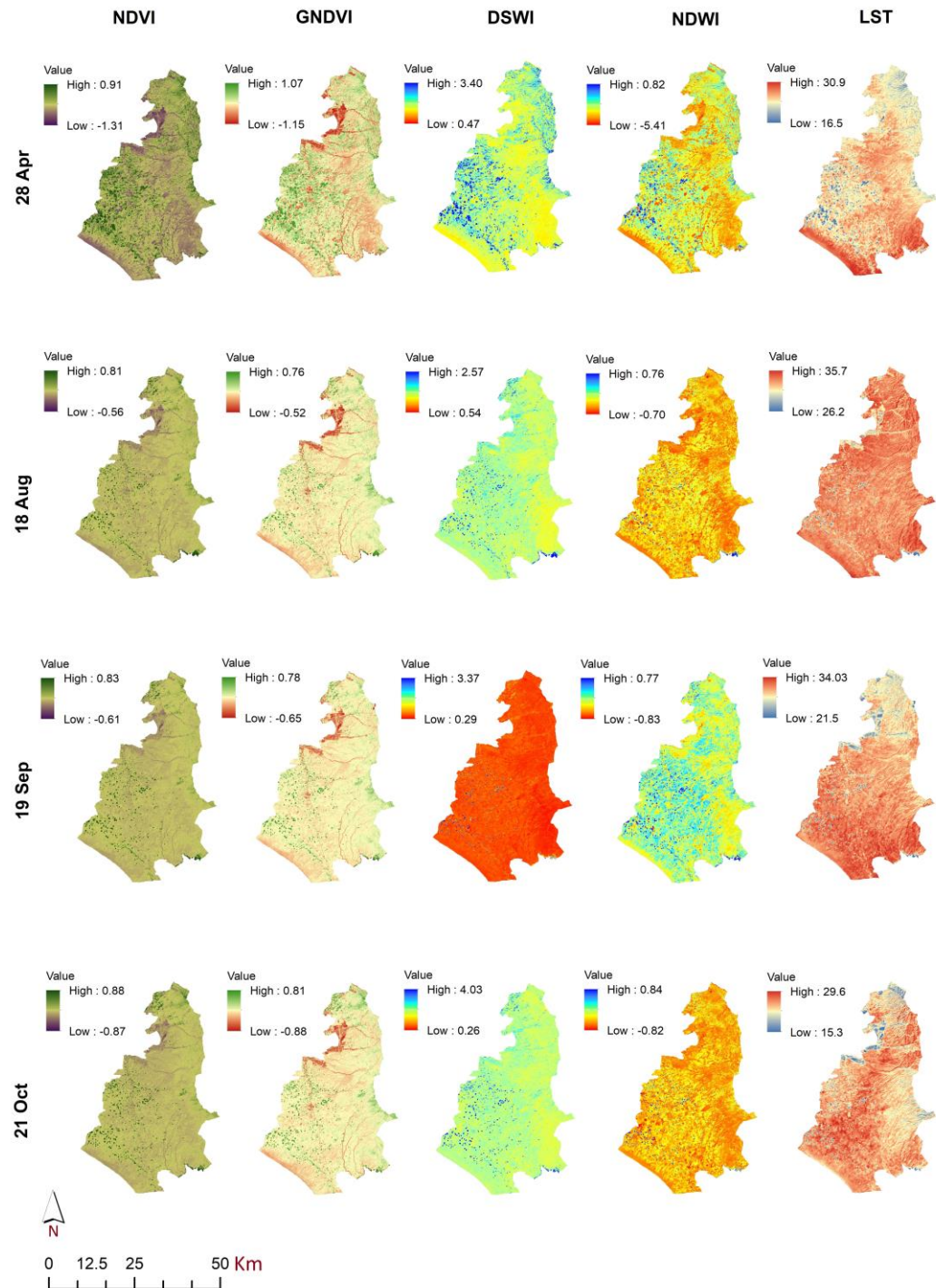


Figure 4.6. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2013

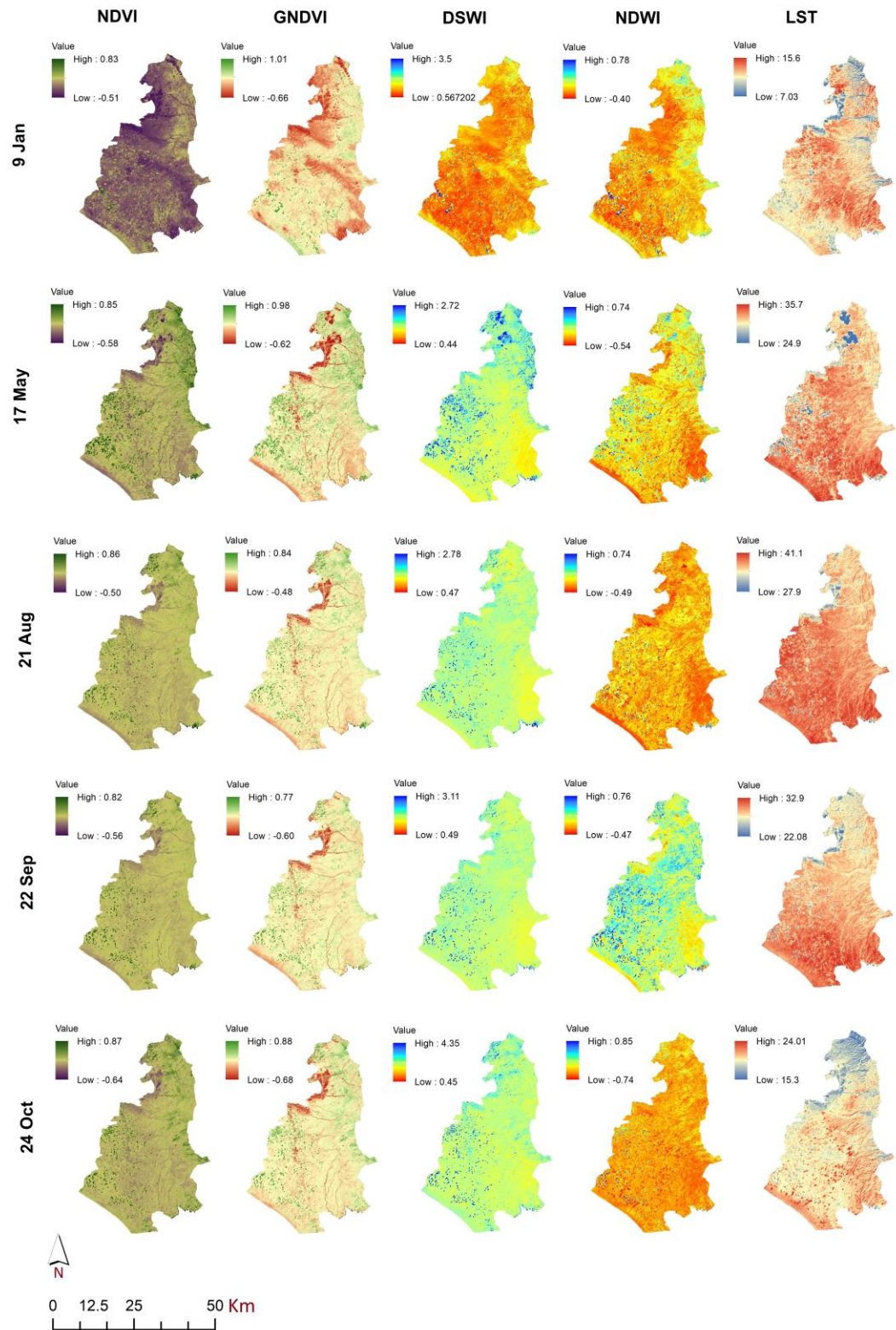


Figure 4.7. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2014

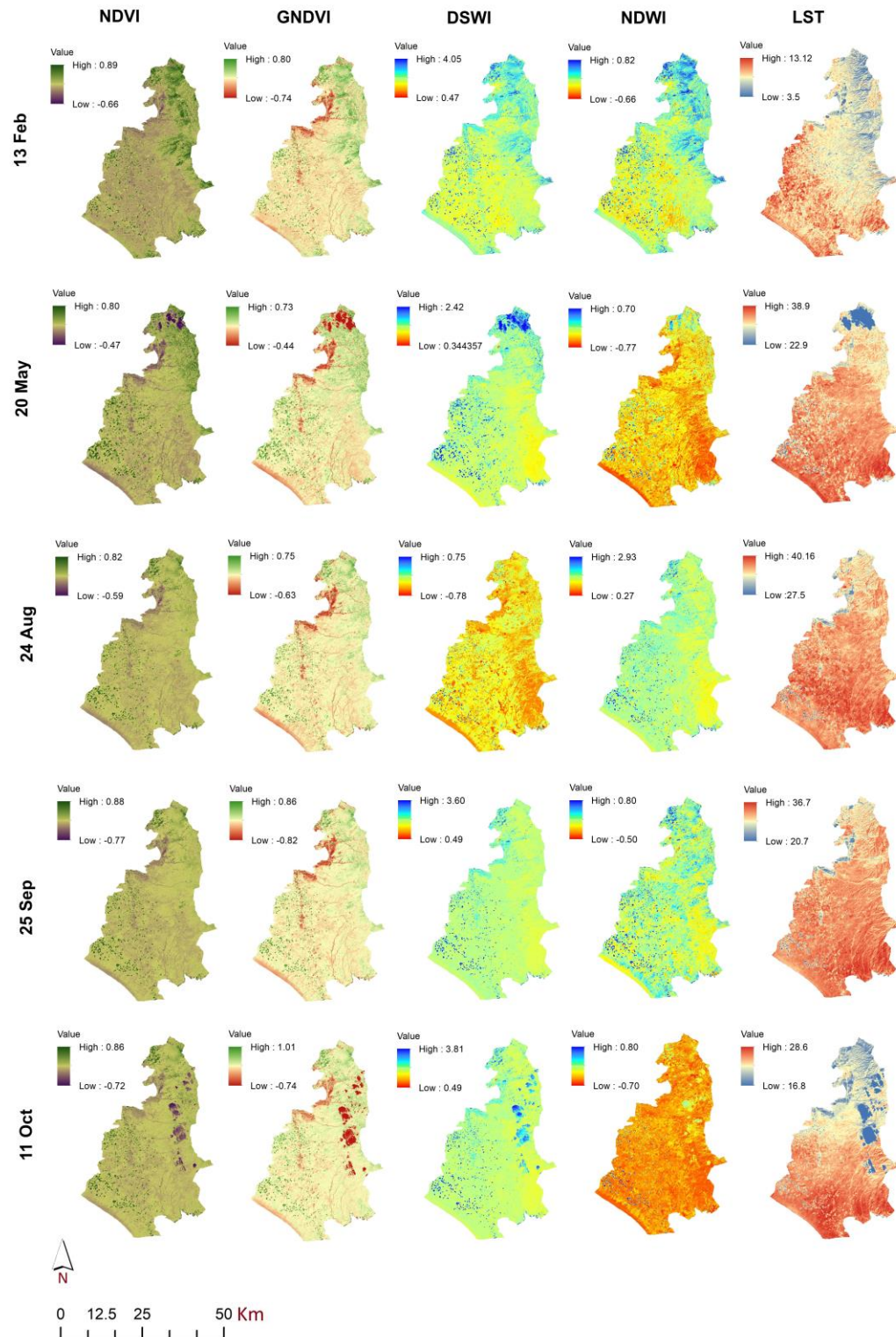


Figure 4.8. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2015

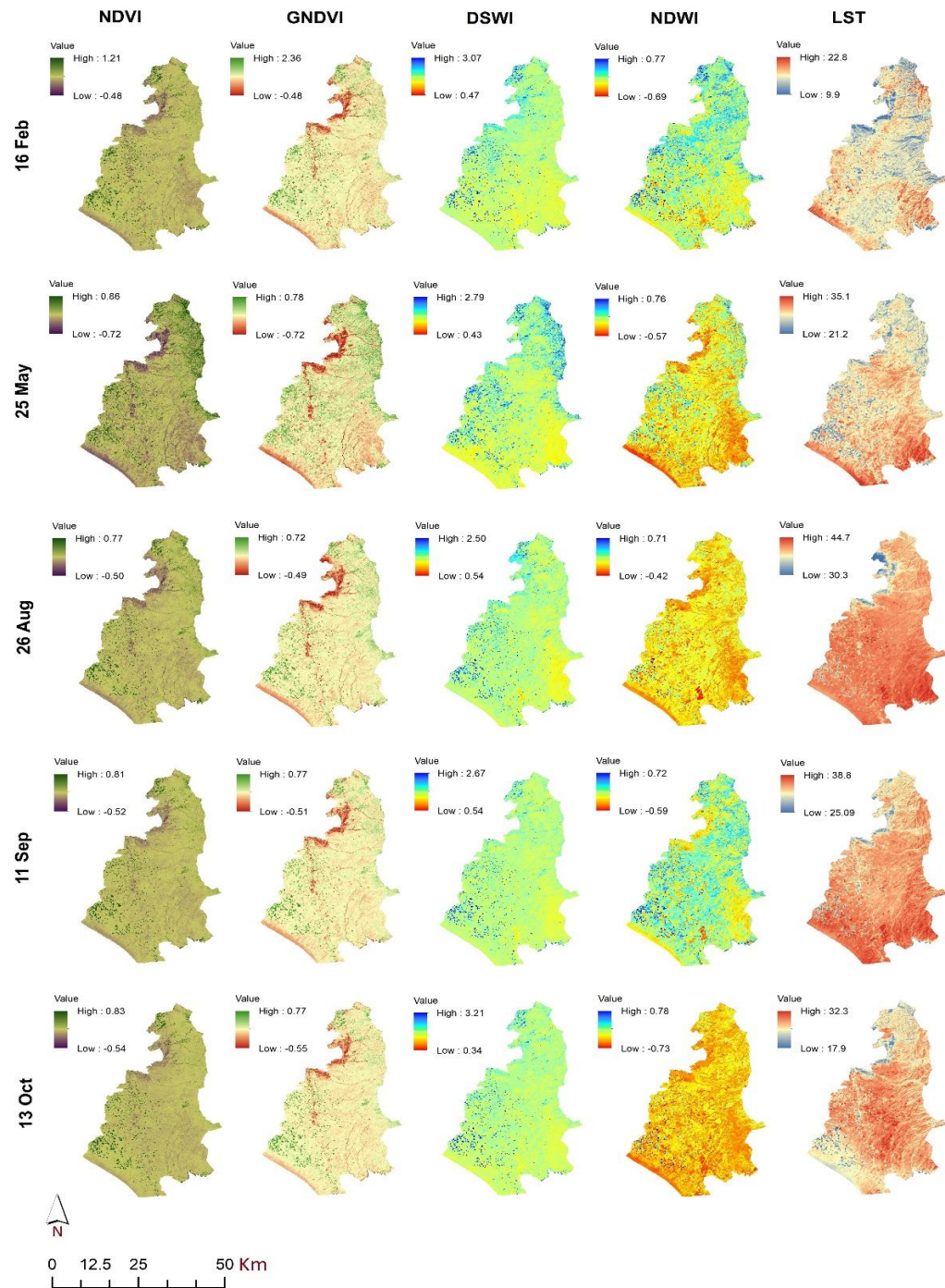


Figure 4.9. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2016

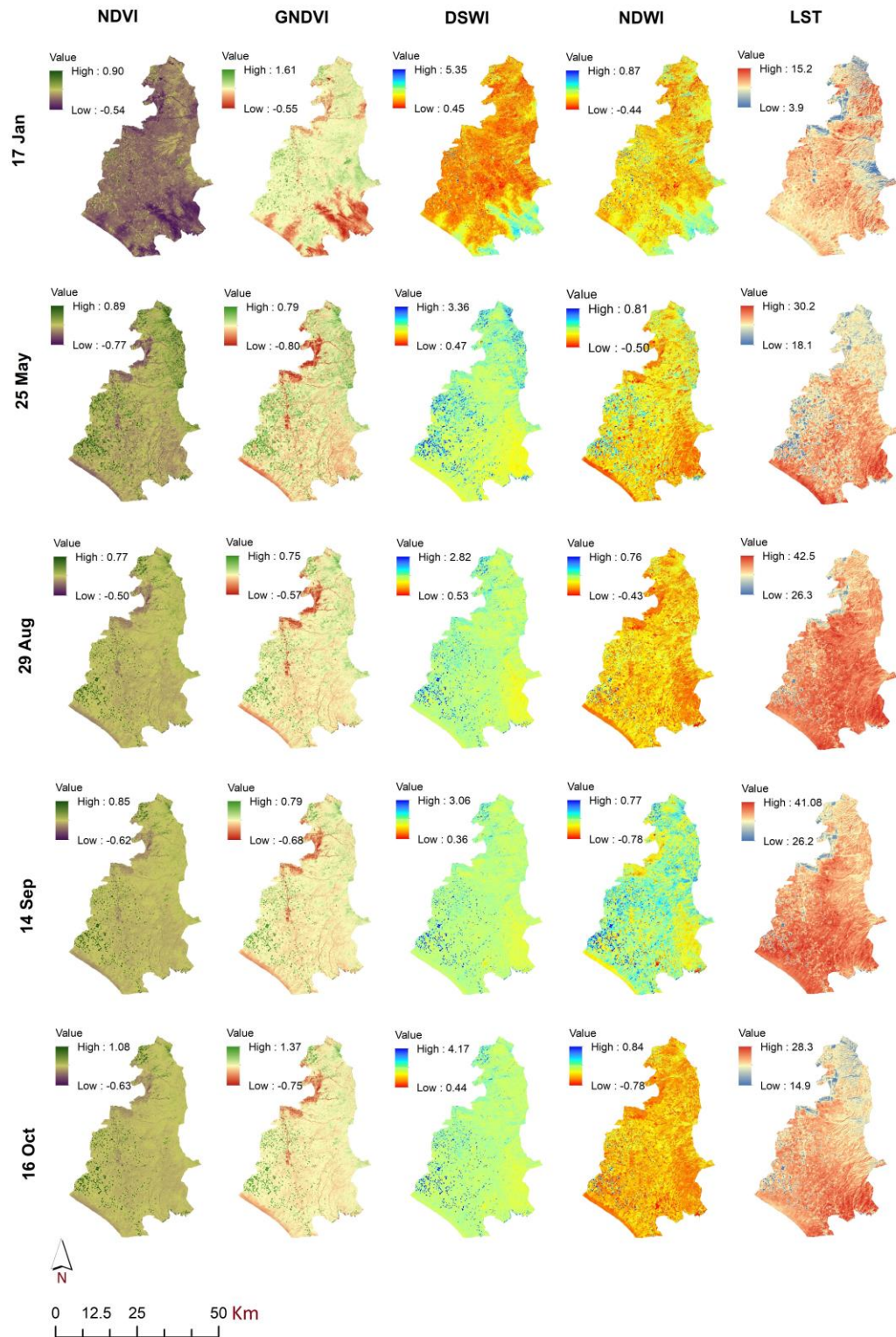


Figure 4.10. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2017

4.1.4. Results of LST Variation during day and night time over agriculture filed

This chapter of our study showed that land surface temperature (LST) results were affected by water stress more than the normalized difference vegetation index (NDVI) and Normalized difference water index (NDWI) in wheat fields, and this result was clearly observed at night figure (4.11), (4.12). On the other hand, both the normalized difference vegetation index (NDVI) and Normalized difference water index (NDWI) have a negative and weak relationship with daytime Land surface temperatures (LST), but this result changed to a positive result at night especially with Normalized difference water index (NDWI). Apart from that, the Land surface temperatures (LST) themselves have a lot of difference ($p < 0.05$) at night and during the day figure (4.12), and this difference has different implications for both the surface temperatures and the moisture content of the soil during the day and night figure (4.13).

LST-ASTER (7:05 PM)

20.45	20.45	20.24	20.03	19.82	19.52	19.22	18.92	18.92
20.45	20.45	20.24	20.03	19.82	19.52	19.22	18.92	18.92
20.27	20.27	19.98	19.69	19.4	19.14	18.88	18.62	18.62
20.09	20.09	19.72	19.36	18.99	18.77	18.55	18.32	18.32
19.91	19.91	19.47	19.02	18.58	18.39	18.21	18.02	18.02
19.64	19.64	19.32	19	18.68	18.48	18.29	18.09	18.09
19.37	19.37	19.17	18.98	18.78	18.57	18.37	18.16	18.16
19.1	19.1	19.02	18.95	18.88	18.66	18.45	18.23	18.23
18.54	18.54	18.67	18.8	18.94	18.69	18.45	18.2	18.2
17.98	17.98	18.32	18.66	19	18.72	18.45	18.17	18.17
17.42	17.42	17.96	18.51	19.05	18.75	18.45	18.14	18.14
17.42	17.42	17.96	18.51	19.05	18.75	18.45	18.14	18.14

LST-Landsat-8 (7:38 AM)

34.05	33.88	33.78	33.84	33.98	33.97	34.16	34.77	35.54
33.68	33.31	33.02	32.97	32.97	33.04	33.38	33.96	34.73
33.26	32.73	32.35	32.23	32.22	32.37	32.85	33.6	34.46
32.94	32.33	31.91	31.74	31.72	31.96	32.53	33.29	34.2
32.78	32.22	31.83	31.62	31.58	31.81	32.39	33.16	34.07
32.65	32.23	31.95	31.76	31.7	31.92	32.47	33.23	34.11
32.5	32.23	32.06	31.92	31.9	32.12	32.66	33.42	34.28
32.37	32.22	32.1	31.99	32	32.25	32.83	33.61	34.46
32.29	32.22	32.15	32.07	32.07	32.32	32.93	33.72	34.56
32.24	32.22	32.18	32.14	32.11	32.37	33	33.79	34.6
32.13	32.17	32.13	32.1	32.17	32.51	33.12	33.84	34.6
32.03	32.07	32.04	32.06	32.25	32.68	33.27	33.92	34.63

Figure 4.11. The maps of LST based on Landsat-8 and ASTER TIR data over a winter wheat crop field.

NDVI-Landsat-8

0.18	0.45	0.46	0.41	0.37	0.35	0.32	0.28	0.24
0.2	0.47	0.52	0.51	0.5	0.5	0.46	0.45	0.42
0.24	0.46	0.51	0.49	0.49	0.5	0.5	0.49	0.46
0.24	0.43	0.45	0.45	0.45	0.45	0.45	0.45	0.44
0.26	0.43	0.43	0.42	0.41	0.41	0.41	0.41	0.42
0.24	0.41	0.39	0.4	0.41	0.4	0.39	0.4	0.39
0.26	0.39	0.39	0.4	0.4	0.41	0.4	0.38	0.34
0.29	0.41	0.41	0.4	0.39	0.4	0.4	0.39	0.33
0.31	0.43	0.43	0.42	0.39	0.39	0.39	0.38	0.31
0.3	0.44	0.44	0.43	0.4	0.39	0.38	0.37	0.29
0.32	0.45	0.45	0.43	0.39	0.38	0.37	0.37	0.25
0.36	0.43	0.42	0.4	0.39	0.38	0.38	0.38	0.21

NDWI-Landsat-8

0.07	0.32	0.35	0.29	0.25	0.23	0.18	0.15	0.11
0.12	0.34	0.41	0.4	0.4	0.4	0.36	0.34	0.31
0.13	0.34	0.39	0.39	0.39	0.39	0.39	0.38	0.35
0.12	0.32	0.35	0.35	0.35	0.35	0.35	0.34	0.33
0.12	0.31	0.32	0.31	0.31	0.3	0.3	0.31	0.3
0.13	0.3	0.29	0.29	0.29	0.28	0.28	0.28	0.26
0.15	0.28	0.28	0.28	0.28	0.29	0.28	0.26	0.23
0.17	0.29	0.29	0.28	0.27	0.29	0.28	0.26	0.22
0.16	0.3	0.31	0.3	0.28	0.27	0.27	0.26	0.21
0.16	0.31	0.31	0.31	0.28	0.27	0.26	0.25	0.17
0.19	0.32	0.33	0.31	0.28	0.26	0.26	0.26	0.11
0.24	0.31	0.3	0.28	0.27	0.27	0.27	0.27	0.08

Figure 4.12. Results of calculated spectral indices over winter wheat crop field from the Landsat-8 imagery

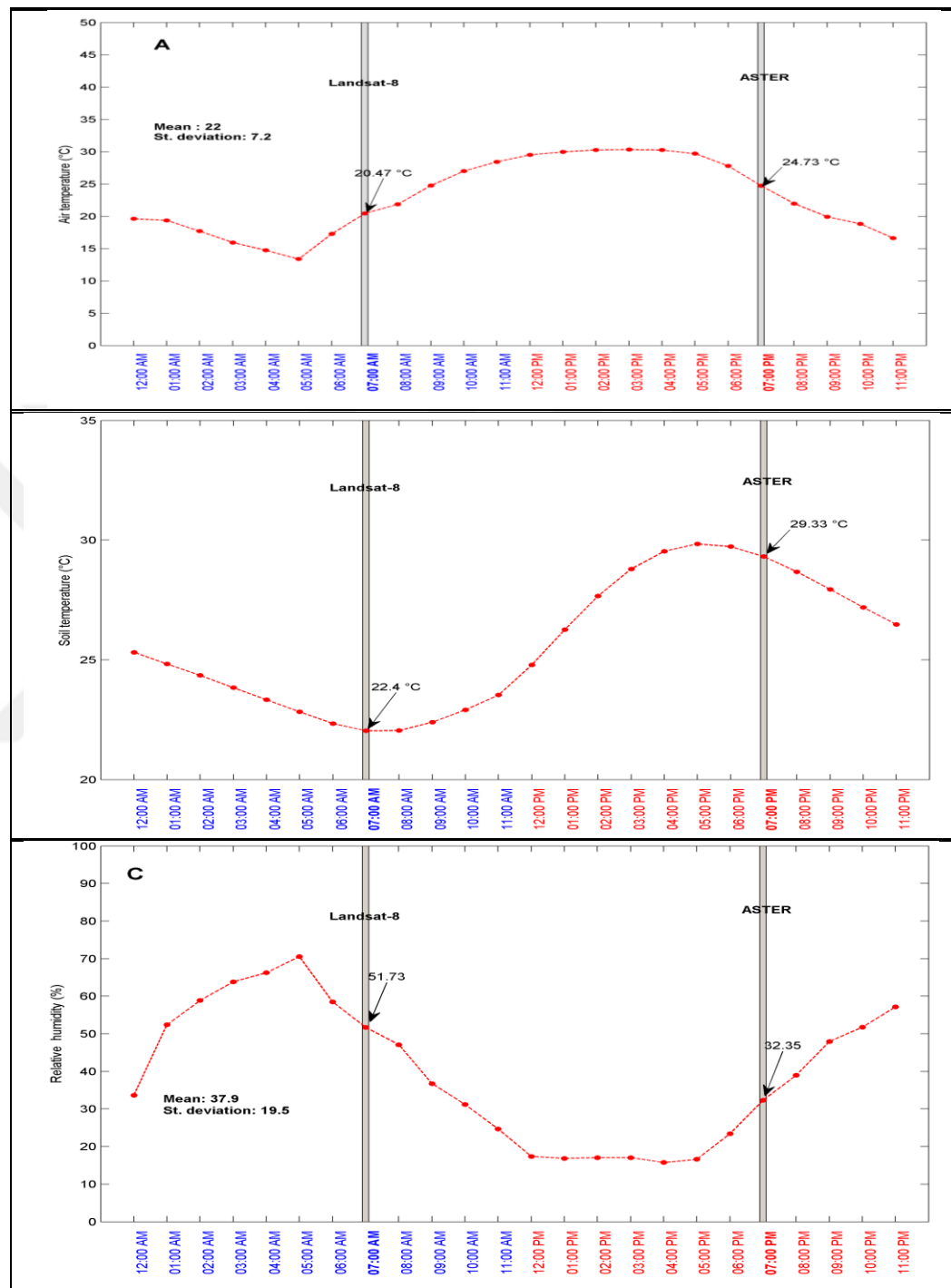


Figure 4.13. The trend of hourly based, air temperature (A), soil temperature (B) and relative humidity (C) on May 8, 2017. The two gray vertical lines indicate the acquisition time of both Landsat-8 and ASTER data.

4.1.5. Results of standardized precipitation index (SPI)

In order to measure the Standardized Precipitation Index (SPI) of the study area, precipitation data were used for each of the two climatic data stations Bnaslawwa and Qushtaba as shown by the results in Table 4.2.

Table 4.2. Average monthly rainfall at Bnaslawwa and Qushtaba weather stations (millimeters)

Bnaslawwa													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
2008-2009	16.0	15.5	18.5	1.0	22.0	71.0	34.5	0.0	4.0	37.0	0.0	0.0	219.5
2009-2010	21.0	20.0	71.0	16.0	54.5	61.5	29.0	19.0	0.0	7.0	0.0	0.0	299.0
2010-2011	3.0	0.0	27.0	101.5	31.0	23.0	71.0	16.0	0.0	0.0	0.0	0.0	272.5
2011-2012	12.0	8.0	18.5	50.5	27.0	81.0	26.0	8.0	0.0	0.0	0.0	0.0	231.0
2012-2013	10.8	53.4	100.6	183.5	65.3	15.5	20.7	22.2	0.0	0.0	0.0	0.0	472.0
2013-2014	0.0	16.5	103.5	74.5	8.3	90.8	17.9	1.8	0.0	0.0	0.0	0.0	313.3
2014-2015	82.5	107.0	56.6	46.1	42.5	46.0	13.5	0.0	0.0	0.0	0.0	0.0	394.2
2015-2016	40.5	126.0	83.5	40.0	35.5	59.0	38.5	1.5	0.0	11.0	0.0	0.0	435.5
2016-2017	0.0	20.5	114.0	22.5	14.5	60.8	30.5	0.5	0.0	0.0	0.0	0.0	263.3
2017-2018	0.0	25.0	19.5	43.0	163.0	10.0	96.0	34.0	0.0	0.0	0.0	0.0	390.5
2018-2019	34.0	119.5	184.0	115.5	80.0	192.5	0.0	0.0	0.0	0.0	0.0	0.0	725.5
Qushtaba													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
2008-2009	44.5	15.0	31.0	0.0	18.0	59.5	49.8	0.0	0.0	0.0	0.0	0.0	217.8
2009-2010	28.5	2.8	62.4	21.0	93.0	64.5	29.3	13.6	0.0	5.5	0.0	0.0	320.6
2010-2011	5.2	0.0	38.3	56.1	13.2	18.2	40.2	2.7	0.0	0.0	0.0	0.0	173.9
2011-2012	4.7	4.6	18.5	22.0	4.8	58.2	13.0	7.2	0.0	0.5	0.0	0.0	133.5
2012-2013	4.2	55.3	85.0	134.9	50.2	12.0	14.4	22.6	0.0	0.0	0.0	0.0	378.6
2013-2014	0.0	24.5	71.7	53.8	6.0	116.5	14.3	3.2	0.0	0.0	0.0	0.0	290.0
2014-2015	62.9	90.5	46.4	36.3	36.5	44.0	7.4	0.0	0.0	0.0	0.0	0.0	324.0
2015-2016	34.1	111.7	85.0	40.4	29.6	71.9	50.1	1.5	0.0	8.6	0.0	0.0	432.9
2016-2017	0.0	27.7	104.3	18.7	19.7	81.1	27.3	3.2	0.0	0.0	0.0	0.0	282.0
2017-2018	0.0	10.3	19.9	46.7	141.5	7.0	83.4	25.8	0.0	0.0	0.0	0.0	334.6
2018-2019	39.6	211.0	188.9	83.8	55.2	210.0	0.0	0.0	0.0	0.0	0.0	0.0	788.5

it is clear from the results that there is a big difference between the values of Standardized Precipitation Index (SPI1, SPI3, SPI6, SPI12.) For example, the SPI1 results, which is an index based on precipitation information flatulated dramatically when it compared to the other three types (see Figures 4.14 and 4.15). On the other

hand, the results obtained from the analysis of the SPI3 index were found to be affected by seasonal changes more than other indices. In other words, the SPI3 found to be more realistic when to detect season precipitation changes over the study area. For example, the value of SPI3 decreased during those months when the participation is close to zero such as; May, June and July in the climatic stations and at the level of the years taken in the study except for 2011 and 2017.

Another point worth mentioning in this regard is that the results of the SPI6 index, which is an index in which it uses precipitation data for six months, changed in the months of August and September, which means that the index is good and appropriate for identifying and diagnosing drought in those months of the year.



Figure 4.14. Monthly temporal variation of calculated standardized participation index (SPI1, 3, 6 and 12) for Bnaslaw weather station



Figure 4.15. Monthly temporal variation of calculated standardized participation index (SPI1, 3, 6 and 12) for Qushtapa weather station

4.1.6. Correlation between SPI and measured spectral indices and LST

In order to prepare and draw a map of the Standardized Precipitation Index (SPI), a correlation coefficient was calculated between the spectral indices and the Standardized Precipitation Index (SPI). For this purpose, it was used for all types of (SPI), which are SPI1, SPI3, SPI6, and SPI12. Furthermore, in order to determine the sensitive indices that can be used to map the (SPI), the principle that is mainly used in this field in our study is only the use of these spectral indices that have a strong relationship with Standardized Precipitation Index (SPI). Nonetheless, this could be done provided that the relationship between them is to be continuous which means it should last throughout the years (2009-2017).

As shown in Table (4.3), each of the LST and the Normalized Difference Water Index (NDWI) has a strong and stable relationship with SPI3. For example, there is a very strong relationship between LST and SPI3 in the year 2009 and 2017, which is equal to ($R = 0.63$ and 0.79) respectively, and the same result for NDWI as it is in a very strong relationship with SPI3 in the year 2017 which is equal to ($R = -0.92$).

With regard to the other indices, it can be said that they do not have a stable and clear relationship, and it is in a volatile relationship, as many changes occur up and down, from year to year and in SPI1 to SPI12. These indices are very suitable for drawing and preparing the Standardized Precipitation Index (SPI) map.

Table 4.3. Correlation matrix between spectral index and standardized participation index (SPI)

2009						2010					
Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST	Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.37	-0.05	-0.36	-0.16	0.12	SPI1	0.05	0.15	0.24	0.14	0.35
SPI3	-0.22	0.22	-0.34	-0.53	0.62	SPI3	-0.17	-0.40	-0.46	-0.68	0.70
SPI6	0.04	0.04	0.32	-0.06	0.57	SPI6	-0.51	-0.57	-0.56	0.17	0.38
SPI12	-0.32	-0.27	-0.29	-0.19	0.09	SPI12	0.15	-0.05	0.22	-0.65	0.82
Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST	Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.28	0.04	-0.27	-0.11	0.59	SPI1	0.02	0.27	0.21	0.16	0.40
SPI3	0.08	0.06	-0.05	-0.59	0.83	SPI3	-0.26	-0.18	-0.43	-0.56	0.90
SPI6	-0.37	0.25	-0.45	-0.15	0.84	SPI6	-0.27	-0.72	-0.71	0.05	0.06
SPI12	0.30	0.03	0.12	0.19	-0.52	SPI12	0.24	0.41	0.14	0.45	-0.94

2011						2013					
Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST	Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	Nan	Nan	Nan	Nan	Nan	SPI1	-1.00	-1.00	-1.00	-1.00	-1.00
SPI3	-0.46	-0.72	-0.50	-0.84	0.81	SPI3	-0.36	-0.26	-0.51	-0.83	-0.88
SPI6	-0.96	-0.98	-0.26	-0.46	0.44	SPI6	-0.24	-0.21	-0.26	-0.33	-0.34
SPI12	-0.72	-0.61	-0.46	-0.20	0.19	SPI12	-0.16	-0.16	-0.12	-0.18	-0.24
Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST	Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	Nan	Nan	Nan	Nan	Nan	SPI1	1.00	1.00	1.00	1.00	1.00
SPI3	-0.31	-0.54	-0.87	-0.99	0.97	SPI3	-0.68	-0.48	-0.35	-0.87	-0.82
SPI6	-0.31	-0.45	-0.37	-0.70	0.72	SPI6	-0.17	-0.15	-0.16	-0.23	-0.64
SPI12	0.65	0.53	0.41	0.60	-0.20	SPI12	-0.16	-0.15	-0.11	-0.17	-0.24

2014						2015					
Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST	Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.94	-0.41	-0.27	-0.97	-0.40	SPI1	-0.35	-0.45	-0.39	-0.35	-0.15
SPI3	-0.61	-0.58	0.32	-0.74	-0.91	SPI3	-0.54	-0.12	-0.61	0.77	0.66
SPI6	0.42	-0.20	0.53	0.28	-0.37	SPI6	0.27	0.18	-0.15	-0.08	-0.02
SPI12	0.50	-0.40	0.96	0.65	-0.64	SPI12	-0.73	-0.33	0.28	0.52	0.72
Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST	Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.90	-0.51	-0.16	-0.94	-0.50	SPI1	-0.96	-0.93	-0.34	-0.30	-0.10
SPI3	-0.47	-0.60	0.71	-0.69	-0.99	SPI3	-0.51	-0.31	-0.30	0.86	0.59
SPI6	0.57	-0.17	0.17	0.36	-0.58	SPI6	0.41	0.09	-0.43	-0.49	-0.46
SPI12	0.26	-0.28	0.68	0.63	-0.17	SPI12	-0.72	-0.24	0.24	0.63	0.96

2016						2017					
Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST	Qushtapa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.65	-0.67	-0.93	-1.00	-0.40	SPI1	0.26	0.72	-0.98	-0.52	0.99
SPI3	0.51	0.17	-0.54	0.87	0.64	SPI3	-0.26	0.09	-0.33	-0.92	0.79
SPI6	0.32	0.32	-0.22	0.15	0.35	SPI6	-0.34	0.17	-0.87	-0.88	0.70
SPI12	-0.02	-0.10	-0.65	-0.75	-0.96	SPI12	-0.30	0.22	-0.88	-0.79	0.65
Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST	Bnaslawwa	NDVI	GNDVI	DSWI	NDWI	LST
SPI1	-0.32	-0.25	-0.06	0.11	0.57	SPI1	-0.25	0.29	-0.95	-0.88	0.80
SPI3	0.11	-0.32	0.30	0.68	0.70	SPI3	-0.47	0.55	-0.26	-0.62	0.86
SPI6	0.34	0.36	-0.42	-0.03	0.21	SPI6	-0.32	0.24	-0.47	-0.34	0.57
SPI12	0.29	0.23	-0.77	-0.60	-0.67	SPI12	-0.25	0.31	-0.95	-0.77	0.78

4.1.7. Results of correlation between topographical variables and spectral indices

In this study, besides assessing the relationships between spectral indices and Standardized Precipitation Index (SPI), we attempted to study the subject in more detail as we used topographical data such as slope, aspect and terrain. For this purpose, the values of the indices used in the study were compared with the values of the three topographical data. As it was found from the table (4.4) that in general, the indices of the green ratio such as NDVI and the green normalized difference vegetation index (GNDVI) are in a weak positive relationship with the terrain, meaning that the green percentage increases with the increase in the terrain, but by a small percentage, all the special indicators are With the aqueous components such as NDWI,DSWI and SPI3 are in a weak to moderate negative relationship with the aspect and terrain data. For example, if we look at the relationship between the disease water stress index (DSWI) and the surface temperatures, we find that the value of the two indicators is (- 0.58) and (- 0.01) each, respectively. Likewise, a weak negative correlation was observed between LST and topographical variables in particular for aspect and terrain variables.

Table 4.4. correlation between spectral indices, SPI3 with topographical variables in 2009 -2017

2009	DEM	SLOPE	ASPECT
NDVI	0.05	0.01	0.00
GNDVI	0.10	0.00	0.00
DSWI	-0.21	0.01	-0.01
NDWI	-0.40	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.22	0.00	-0.20
2010	DEM	SLOPE	ASPECT
NDVI	0.04	0.02	0.02
GNDVI	0.08	0.01	0.02
DSWI	-0.09	0.01	0.00
NDWI	-0.30	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.12	0.00	-0.10
2011	DEM	SLOPE	ASPECT
NDVI	0.11	0.02	0.03
GNDVI	0.03	0.00	0.00
DSWI	-0.30	0.00	0.00
NDWI	-0.03	0.00	0.00
LST	-0.11	0.00	0.00
SPI3	-0.22	0.00	-0.20
2013	DEM	SLOPE	ASPECT
NDVI	0.08	0.01	-0.01
GNDVI	0.10	0.01	-0.01
DSWI	-0.04	0.00	-0.03
NDWI	-0.03	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.32	0.00	-0.20
2014	DEM	SLOPE	ASPECT
NDVI	0.14	0.02	-0.01
GNDVI	0.16	0.01	-0.01
DSWI	-0.58	0.00	-0.06
NDWI	-0.30	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.21	0.00	-0.30
2015	DEM	SLOPE	ASPECT
NDVI	0.09	-0.02	-0.01
GNDVI	0.14	-0.02	0.00
DSWI	-0.05	-0.01	-0.03
NDWI	-0.03	0.00	0.00
LST	-0.11	0.00	0.00
SPI3	-0.32	0.00	0.00
2016	DEM	SLOPE	ASPECT
NDVI	0.04	-0.03	-0.02
GNDVI	0.08	-0.02	-0.02
DSWI	-0.37	-0.03	-0.05
NDWI	-0.13	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.12	0.00	-0.10
2017	DEM	SLOPE	ASPECT
NDVI	0.14	0.00	0.03
GNDVI	0.16	0.00	0.03
DSWI	0.00	0.00	-0.01
NDWI	-0.03	0.00	0.00
LST	-0.01	0.00	0.00
SPI3	-0.02	0.00	0.00
2018	DEM	SLOPE	ASPECT
NDVI	0.09	0.00	0.00
GNDVI	0.14	0.01	0.01
DSWI	-0.34	0.00	-0.02
NDWI	-0.33	0.00	0.00
LST	-0.01	0.00	0.00
2019	DEM	SLOPE	ASPECT
NDVI	-0.03	0.00	0.00
GNDVI	-0.03	0.00	0.00
DSWI	-0.03	0.00	0.00
NDWI	-0.03	0.00	0.00
LST	-0.21	0.00	0.00

4.1.8. Results of land use and land cover classification

In this study, land uses were classified within the study area for the years 2009-2017, and then the comparison process was made between the type of uses with the indicators used in the study, and by looking at the area of uses and their change between 2009 and 2017, it was found that the area of uses has undergone changes. It is clear, and these changes followed the results of drought values and degrees, as the area of vegetation cover and agricultural crops decreased from (307.5 Km²) to (154.4 Km²), and on the other hand, the area of urbanization may increase clearly, as its area increases during the years 2009-2017 by about three times. Its area in 2017 reached more than (100 Km²), knowing that its area was (32.6 km²) in the year 2009, and these results and changes demonstrated the fact that the study area exposed to the danger of the phenomenon of drought with varying degrees within its different parts. On the other hand, the sites of uses may correspond to the degrees of Drought is consistent, as the phenomenon of drought occurs in the western and southwestern regions, and these areas are densely populated and have excellent housing units. Table (4.5) and figure (4.16).

Table 4.5. Summary results of LU/LC change between 2009 and 2017 (area in Km²)

Class name	Area (Km ²) in 2009	Area (Km ²) in 2017	Remark
Vegetation	307.5	154.6	Decrease
Open Land	967.5	1051.5	Increase
Urban	32.66	101.1	Increase

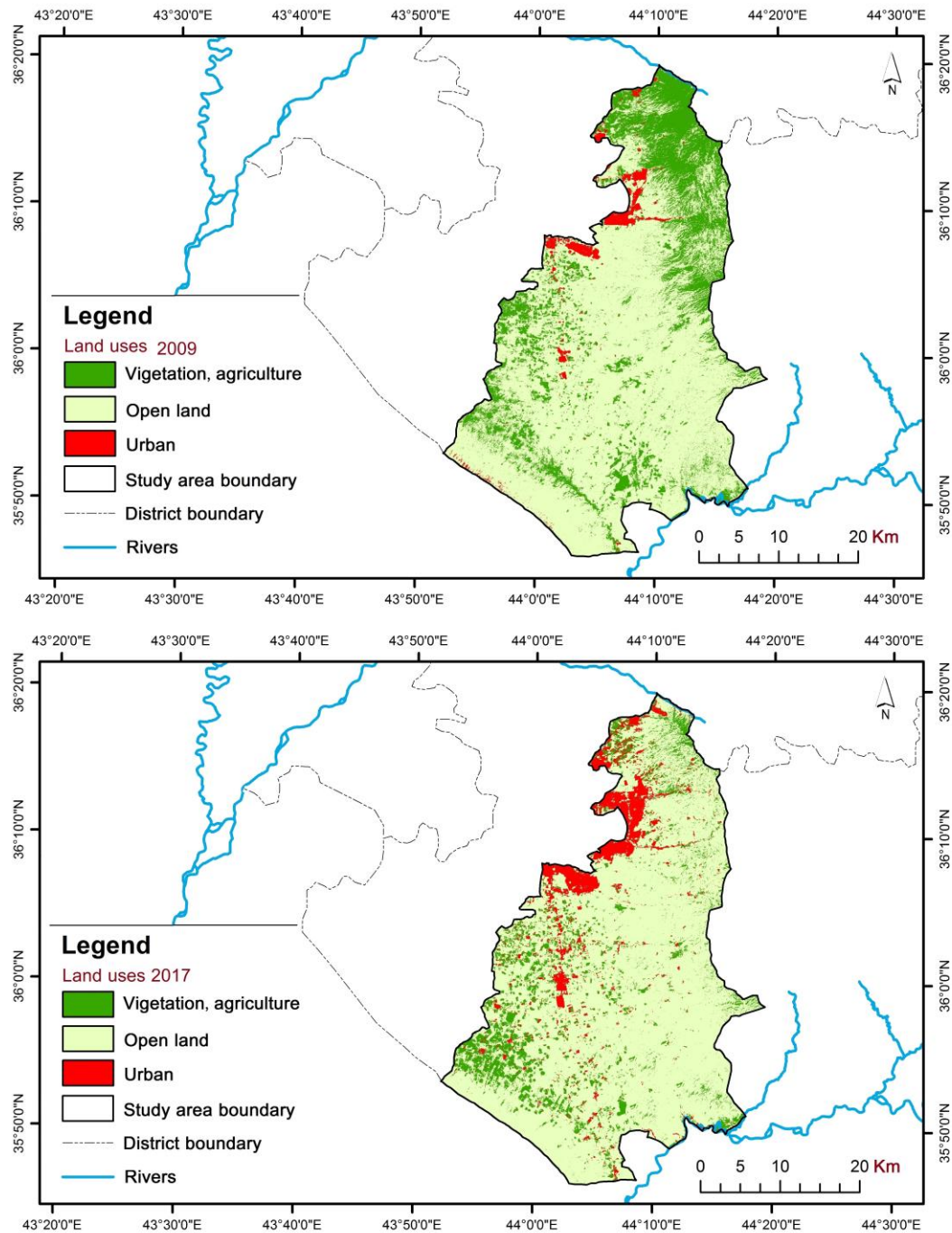


Figure 4.16. Classified images of Erbil plain districts for 2009 and 2007

Moreover, to understand the spectral behavior of each land use and land cover classes we extracted the mean value of the calculated indices and SPI3 value. as you can see from table (4.6) there is a good agreement between mean NDVI, LST and Standardized Precipitation Index (SPI) value, for example in both year's the highest NDVI was recorded over a vegetated area with lowest LST and SPI3. likewise, for the urban area the highest LST corresponded with the highest Standardized Precipitation Index (SPI3). this is indicating the sensitivity of the utilized spectral indices to detect different spectral behavior over different land use classes.

Table 4.6. Mean value of spectral indices and SPI3 for different on land use and land cover classes

2009	vegetation	open land	urban
NDVI	0.487	0.280	0.090
GNDVI	0.424	0.227	0.190
DSWI	1.289	1.578	2.009
NDWI	0.312	-0.005	0.010
LST	39.344	46.993	47.168
SPI3	0.457	0.298	-0.005

2017	vegetation	open land	urban
NDVI	0.138	0.127	0.090
GNDVI	0.293	0.225	0.192
DSWI	0.865	0.825	1.857
NDWI	0.085	0.059	0.015
LST	44.306	46.978	49.064
SPI3	0.464	0.324	-1.467

4.1.9. Result of temporal analysis of standardized precipitation index (SPI) mapping

In order to prepare a Standardized Precipitation Index (SPI) map for the study years, the relationships between all types Standardized Precipitation Index (SPI) and spectral indices were determined as discussed in the previous chapter (Table 4.3). It was found that SPI3 had a strong and continuous relationship with both the Land Surface Temperature (LST) and Normalized Difference Water Index (NDWI) spectral indices,

and therefore a multiple linear regression method was chosen to measure SPI3 (Table 4.7).

Table 4.7. Regression equations between spectral indices NDWI and LST with measured SPI value

Year	R Square (R^2)	Ccalculate
2009	0.320926	$-0.71151 + (-1.16228 * NDWI) + (0.029705 * LST)$
2010	0.123126	$-4.65562 + (48.06132 * NDWI) + (0.062255 * LST)$
2011	0.680497	$4.41648 + (-36.2663 * NDWI) + (-0.06545 * LST)$
2013	0.951799	$4.422729 + (-14.9405 * NDWI) + (-0.05792 * LST)$
2014	0.817381	$5.327475 + (-61.7885 * NDWI) + (-0.0384 * LST)$
2015	0.434207	$-1.27975 + (-22.888 * NDWI) + (0.068155 * LST)$
2016	0.850712	$-0.77855 + (-43.4852 * NDWI) + (0.088327 * LST)$
2017	0.740668	$1.211271 + (-21.9844 * NDWI) + (0.023869 * LST)$

Results obtained were then classified according to McKee et al.'s (1993) classification, which uses five levels (extremely drought, severely drought, moderately drought, mild drought, and normal-no drought) as shown in Table 3.9.

As it can be seen from figure (4.17), the study area, generally speaking, falls under the influence of normal drought conditions i.e. it is not affected by severe drought. For example, in 2009, the study area includes most of its parts on a wide area of (Moderately drought) and (near-normal) types. However, in 2010, the southern and southwestern parts of the study area are under the influence of severely drought conditions.

On the other hand, it is important to take into consideration that the central and southwestern parts are considered to be regions more affected by drought, at the level of all years taken in the study; however, the northeastern parts of the region are considered to be affected at the level of all years except for 2017 as it is characterized as moderately

drought. This can be attributed to the presence of dense vegetation in these parts of the study area, where there are many fields of shrubs and grasses.

According to figure (4.18), as for changes between the classes of Standardized Precipitation Index (SPI) for all years, the large parts of the study area were under the conditions of no drought, that is to say, there is no drought. Nevertheless, we should pay attention to one point which is the changes that occurred in the amount of drought classes. After the year 2011, the severe drought type increases its amount in comparison to the previous years. For example, in 2011 it was about 17.56% of the study area and it falls only under the influence of severely drought, but this situation changes in the coming years as in the years 2016 and 2017 since it increases to 23 and 20%, respectively.

As for the extremely drought class, it was in contrast to the severely drought class, which means that its changes were descending in the sense that its percentage decreases with the passage of the years. For example, in 2009 and 2010, the affected parts of the study area were in this category 14 and 12 % for each of them respectively. However, this percentage will decrease in the coming years until it reaches only 1% in 2017 figure (4.18).

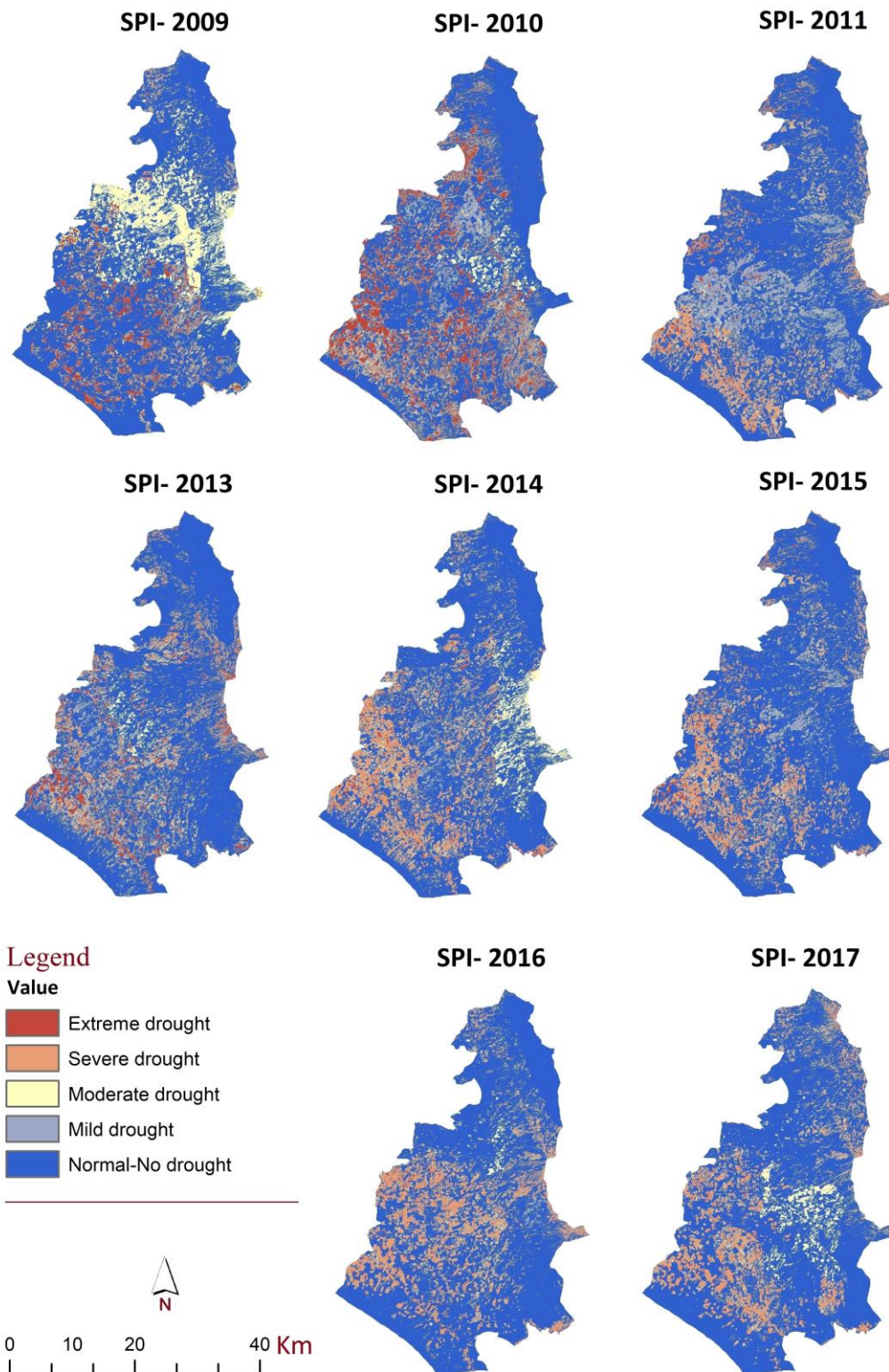


Figure 4.17. Results of generated SPI maps for the study area.

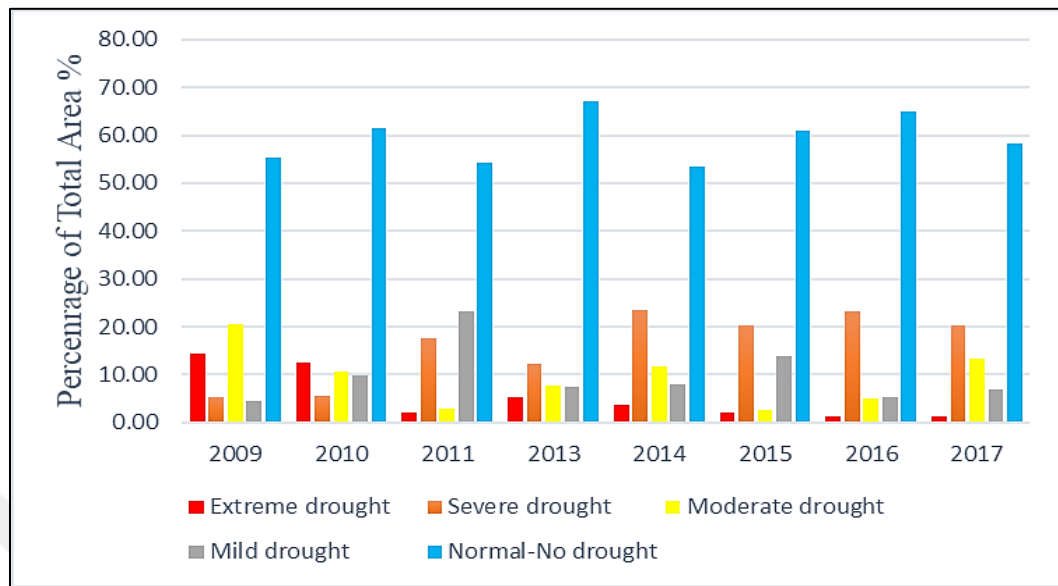


Figure 4.18. Temporal changes between SPI classes during 10 years considered in this study

Moreover, we further analyzed the results of Standardized Precipitation Index (SPI) maps to detect the transition between drought zones. We identified a region within the study area that has not changed during the study period from 2009-2017, or those regions which it has changed toward drought condition. To do this pixels-based change detection approach has been applied using SPI results from 2009 until 2017, and the study area divided into three different classes following the changes of Standardized Precipitation Index (SPI) value (no major changes, drought decreased and increased). As can be seen from Figure (4.19) the majority of the northern and eastern part of the study area has recorded no major changes. In other words, the drought value has remained almost the same during 2009 until 2017. On the other hand, the southern and western part has recorded major changes in particular toward increasing drought value.

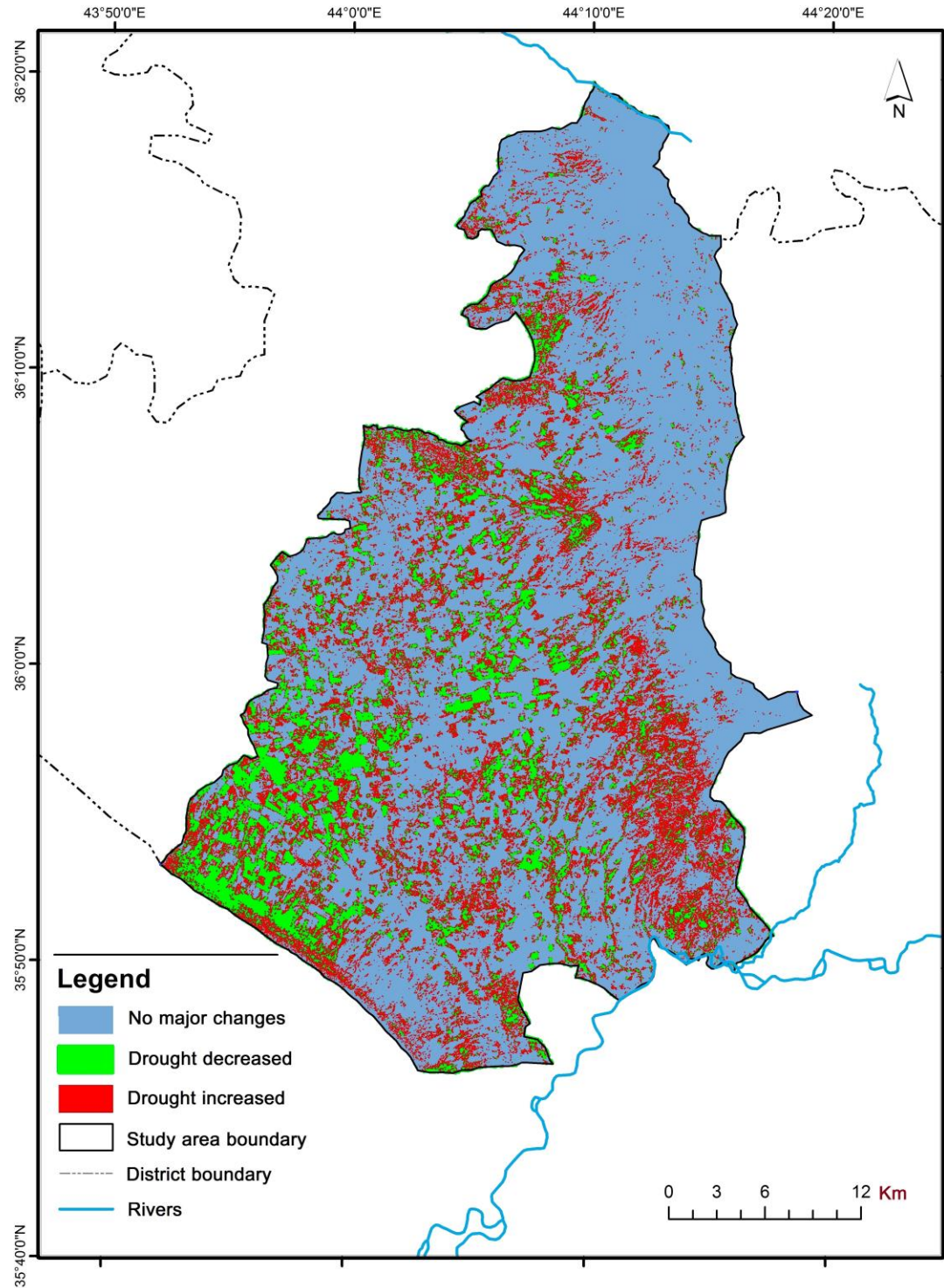


Figure 4.19. Change detection map of SPI during 2009- 2017

4.2. Discussion

Drought phenomenon monitoring is one of the basic requirements and current needs of many countries, especially those of the Middle East. One of the most effective means of determining the drought phenomenon over a broad area is remote sensing and the use of radar data and aerial images. In the twentieth century, drought spectral indicators emerged as a leading technical method of investigating plant stress, as well as for decision-making and implementation of measures to mitigate drought. In this study, both the Standardized Precipitation Index (SPI) technique and remote sensing data were used to determine the drought phenomenon in the Erbil Plain for the years 2009-2019.

The results obtained demonstrate that seasonal and annual changes in vegetation cover in the study area have an effect on both the Land Surface Temperature (LST) and the Normalized Difference Water Index (NDWI) (Figure 4.1) and appendix(1through 10).For example, LST is strongly affected by seasonal changes and variations in the type of vegetation cover. These effects can be traced back to the sensitivity of the temperature return to the vegetation surface, especially when the vegetation is of varying density. As an illustration, it is evident from the data that LST is inversely related to the Normalized Difference Vegetation Index (NDVI): as LST increases, the vegetation covers density decreases and vice versa. This relationship also indicates the sensitivity of LST to changes in vegetation cover, and it is more appropriate for determining agricultural drought. These results are consistent with the results of both studies (Abdullah, 2012; Rasul et al., 2015), which showed that there is an inverse relationship between LST and NDVI.

It is also important to note that indicators related to determining the value and percentage of moisture in soil and vegetation surfaces, such as the NDWI and Disease Water Stress Index (DSWI), were found in this study to be affected by seasonal and temporal changes, and that LST was affected by them (Figure 4.2) and appendix(11 through 19). It is clear that the use of short-wave infrared (SWIR) indicators is more affected by the changes that occur in the amount of water and their ratio (Zhang et al.,

2013; Zhao et al., 2013), and in this regard this result confirms the findings of Chakraborty and Sehgal (2010), as it showed that the NDWI is a good indicator for drought phenomenon monitoring. It was found that the SWIR index is affected by changes in the water index for vegetation as well as the component spongy mesophyll. On the other hand, the near infrared (NIR) index is affected only by those indoor plant materials. Therefore, when both SWIR and NIR are used together as in the NDWI, they are appropriate indicators to identify and monitor plant stress resulting from drought.

Moreover, in terms of variation in the distribution of vegetation cover for the study years (2009-2019), it appeared that the indicators using red, infrared and blue spectral bands are more sensitive at identifying time differences in vegetation. For example, the NDVI and the Green Normalized Difference Vegetation Index (GNDVI) indicators show variation in vegetation cover clearly and effectively during the seasons and in different parts of the study area Figures (4.3 through 4.10) and appendix (20,21). Generally, the highest percentage of vegetation cover was recorded from February through April as both NDVI and GNDVI increased, especially in the northeastern parts of the study area. This high percentage is due to seasonal precipitation, and for this reason both LST and NDWI was also affected in the aforementioned period. In August and September, a high percentage of vegetation cover was recorded in the central and western parts of the study area; this was due to agricultural activities in those areas. It has also been previously indicated that both LST and NDWI have a close relationship with the Standardized Precipitation Index (SPI3) (Table 4.3), and this result shows that remote sensing data, especially thermal and SWIR data, have an important role in monitoring the drought phenomenon.

The use of thermal data has been shown in many similar studies to be more efficient and more appropriate to determine drought levels (Ghaleb et al., 2015; Arekhi et al., 2020; Abdullah et al., 2020). It is clear that water in the soil and plants evaporates towards the atmosphere, and this implies that monitoring the temperature of the earth's surface through the use of thermal data is an important part of drought phenomenon

monitoring. Several studies have shown that the soil temperature rises when humidity is low; on the other hand, when the amount of water in the soil decreases, it affects the vegetation percentage due to the dryness of plant roots and the lack of water transport through the plant's tissues, and as a result, the stomata close and the plant's temperature rises because the evaporation rate in the plant decreases (Omar, 2014; Abdullah et al., 2018). For these reasons, thermal data has become widely used to determine the phenomenon of soil drought and vegetation. Our study also showed that a comparison of the results of Land surface temperature (LST) in the day and at night shows that the land surface temperatures (LST) increase with the decrease in the moisture content in the soil, especially at night time Figure (4.13), and this result indicates that the surface temperatures, especially at night, are a good tool to determine the water stress that causes agricultural drought.

In this study, the continuous and semi-stable relationship between LST and NDWI with the SPI3 appeared, and the reason for this is the existence of other types of SPI such as SPI 1, SPI 6 and SPI 12 (differentiated by the inclusion of more or less data), and therefore not have a response to drought phenomenon determine, For example, in the SPI1, climate data for one month are used, and this is often not appropriate for determining drought. This case may apply to SPI6 and SPI12, for which climatic data for six and twelve months respectively are used. In the end, there are differences in the results which lead to lower accuracy, but the matter is somewhat improved in the SPI3, as climate data covering a three-month period are used in this type, so it can be said that it is the most appropriate, and these results confirm the findings observed in previous work (Almedeij, 2014) which asserted that SPI3 is the most accurate and appropriate for determining the dehydration phenomenon. On the other hand, by looking closely at Figures (4.14) and (4.15) it was found that SPI3 is more stable in terms of the changes that occurred in all SPI species and their difference according to the rainfall periods. It is also found that the value of SPI3 increases during the rainfall period and vice versa - it decreases after the rainy season ends. This may be considered a good indication of the response of SPI3 to identify and monitor the drought phenomenon, as well as the

relationship of this type of SPI with vegetation cover and surface temperatures. This result further confirmed by the result of correlation analysis between spectral indices, SPI3 with topographical variables. For example, our results revealed that there is a moderate to strong negative correlation between terrain and aspect with SPI3 and water related spectral indices (NDWI and DSWI and LST). This might be due to the impact of terrain and aspect on soil moisture, as the higher elevation with higher slope degree has lower soil moisture compared to the lower elevation and flat surface. Previous studies have used LST–NDVI and slope in numerous applications associated with water and energy balance. The slope was found to be related to moisture availability and canopy resistance, indicating vegetation stress and/or soil water stress (Nemani and Running 1989; Carlson et al. 1994; Gillies and Carlson 1995; Gillies et al. 1997; Goetz 1997) Nemani et al. (1993) found that the slope is inversely correlated to a crop moisture index. Other studies showed that the slope is related to the rate of evapotranspiration from the surface (Prihodko and Goward 1997; Boegh et al. 1999).

I also denied reference to it because there is a continuous and stable relationship between SPI3, LST, and NDWI. Therefore, we used this type of SPI index to draw the drought map for the years recorded in this study. It appears from Figure (4.17) that, generally, the study area is not within the drought circumstance, but this result does not apply to all years; rather it differs from one year to the next. In 2009, for example, most of the central parts were under the influence of a drought of the medium type, while in 2011 and 2017, most of the central and southern parts of the study area lay under the influence of severe and extreme drought, and the reason for this increase in those three years was the amount of precipitation received. To ensure that this was correct, the total annual rainfall in the years 2009-2019 (table 4.2) was used, and it was found that the total annual rainfall in the years 2009, 2011 and 2017 was higher than in other years.

It is important to mention that the northeastern parts fell within normal drought conditions for all the years studied. This can be attributed to the local topology and its height above sea level, wherein the northeastern parts are characterized as highlands,

with an average elevation about 1000 meters above sea level. For this reason, precipitation may be higher there than in other parts and as a result trees and weeds grow in the area and appear in the form of green land cover. We further investigated this by utilizing change detection technique to identify the changes during the study period in 2009-2017. The results further revealed that the northeastern part of the study area has shown no major changes in regard to drought phenomenon (Figure 4.19). The major changes observed over the middle and western part of the study area in which the drought phenomena were increased. The possible reason for these findings is may be due to the decrease in the agriculture land and increase in buildup land cover (table 4.5) and figure (4.16). For example, the agriculture and vegetation land cover were decreased for about 150 Km² during the study period, whereas the built-up land increased from 20 Km² to 100 Km². These results indicate; a) the area has faced vast expansion of urban area over the agriculture land and; b) also due to climate change and decreases in precipitation rates the vegetation cover decreased dramatically.

Regarding the amount and percentage of drought, it can be seen from Figure (4.18) that in general, about 50 to 65 percent of the total study area lies under normal drought conditions, but the percentage of extreme drought increased in the year 2009 from 15 to 20 percent in all parts of the study area. This result indicates that although the area in general does not exist within a state of drought, the degree and severity of drought in the area is increasing, and this situation may continue in the future. This result is completely consistent with the results of one recent study (Gaznayee and Al-Quraishi, 2019), which showed that it is possible that the Erbil Plain district will suffer from severe drought in the future. Other studies on drought (Mekuria, 2012; Gu et al., 2008) showed that the use of indicators is a positive sign and a successful part of the process of drought mapping over a large area of land, as our study showed.

5. CONCLUSION and RECOMMENDATIONS

5.1. Conclusion

In summary, droughts are natural hazards that have many negative consequences. They occur because of a decline in annual precipitation in a specific area. They are similar to other types of natural hazards that occur anywhere: droughts can damage the environment, cause economic issues and lead to social problems. They produce significant challenges for regions or countries that engage in agriculture, and they can become a serious threat to food security and water supplies.

In this study, remote sensing data were used to determine the agricultural drought and its monitoring levels in the Erbil Plain area in northern Iraq. In the study, Landsat satellite data from 2009-2019 were used, and climate station data were obtained to calculate the SPI for all years. By comparing the indicators, it was found that LST and NDWI are more sensitive to changes in vegetation cover and drought, and this confirms the relevance of both thermal and NIR data for determining and monitoring of drought. Our study also demonstrated that satellite data can be used distinctly to draw a drought map. Furthermore, we showed that the study area experienced a significant increase in the severity of drought over the years; nevertheless, not all parts of the study area are exposed to drought, as the study illustrated the way in which drought severity varies in different areas. In 2009, the center of the study area was exposed to a moderate drought, while in 2011 and 2017 the effects of severe and extreme drought were reflected in the central and southern parts of the study area. Generally, the study area is characterized by the fact that it does not suffer from severe droughts, as about 50-65% of the total study area falls within the normal drought range. Moreover, the Green Natural Difference Index (GNDVI) and the NDVI are in direct relationship: the higher the value of one, the higher the corresponding value of the other, according to seasonal changes.

To conclude, it should be noted that satellite data are a vital tool that can be used permanently to monitor drought over a broad area. Through this monitoring it is possible to identify areas that have been exposed to drought and determine the severity of the impacts they face, and in that case, managing the drought hazard and mitigating its effects are challenges that can be more easily overcome.

5.2. Recommendation

In order to properly manage the drought problem and preserve soil and vegetation cover from its risks, the study presented a set of recommendations:

1. Preparing an advanced information database containing previous studies, field surveys, and reports related to the drought problem.
2. Establishing automated climate stations to accurately monitor and record the different climate elements.
3. Employing ideal techniques for irrigation projects to prevent the emergence of problems related to soil and plants.
4. Expanding green areas and intensively planting trees.
5. Carrying out and practicing agricultural activities properly so as to meet the needs of human settlements without reducing soil fertility and agricultural vitality.

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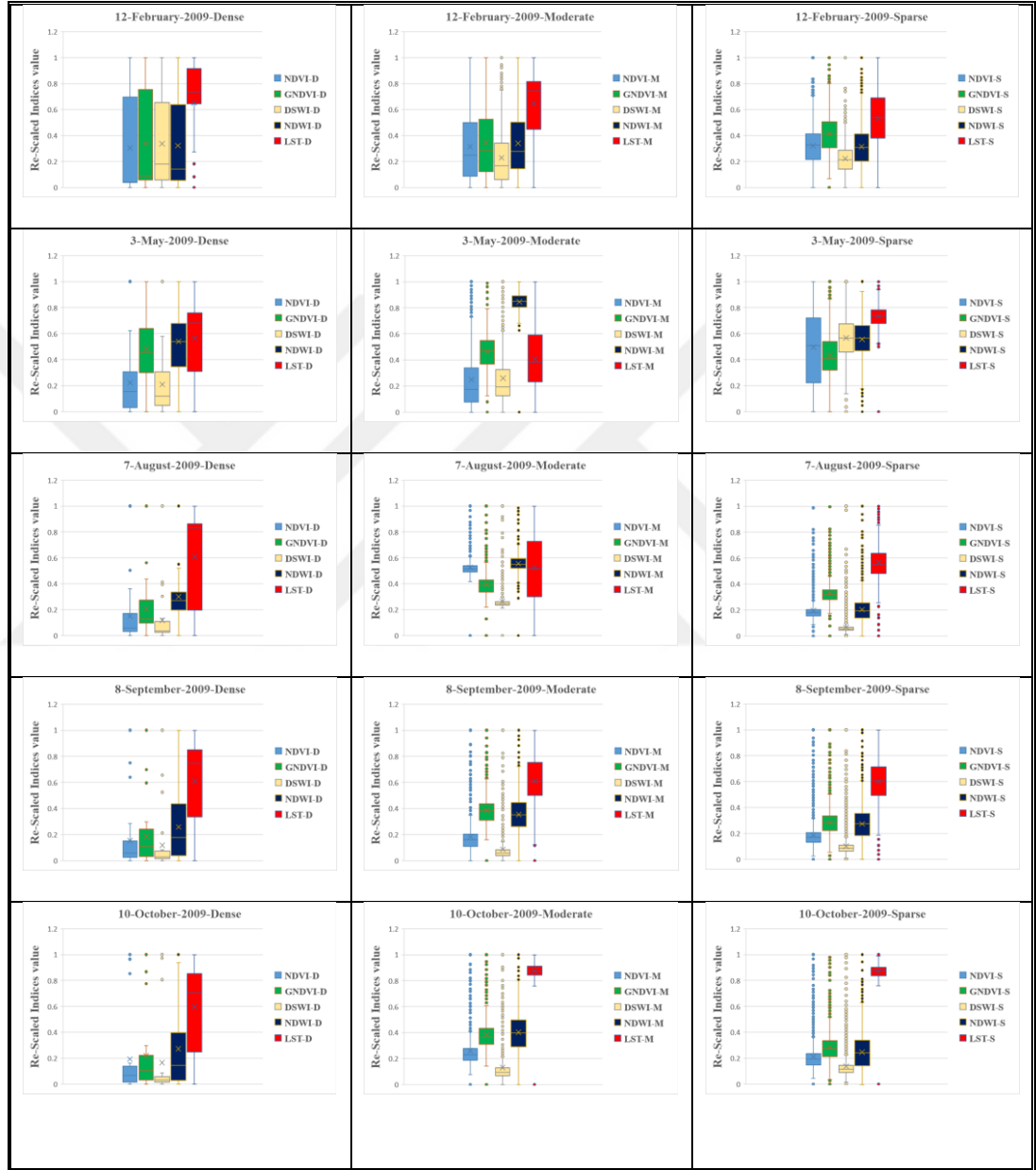
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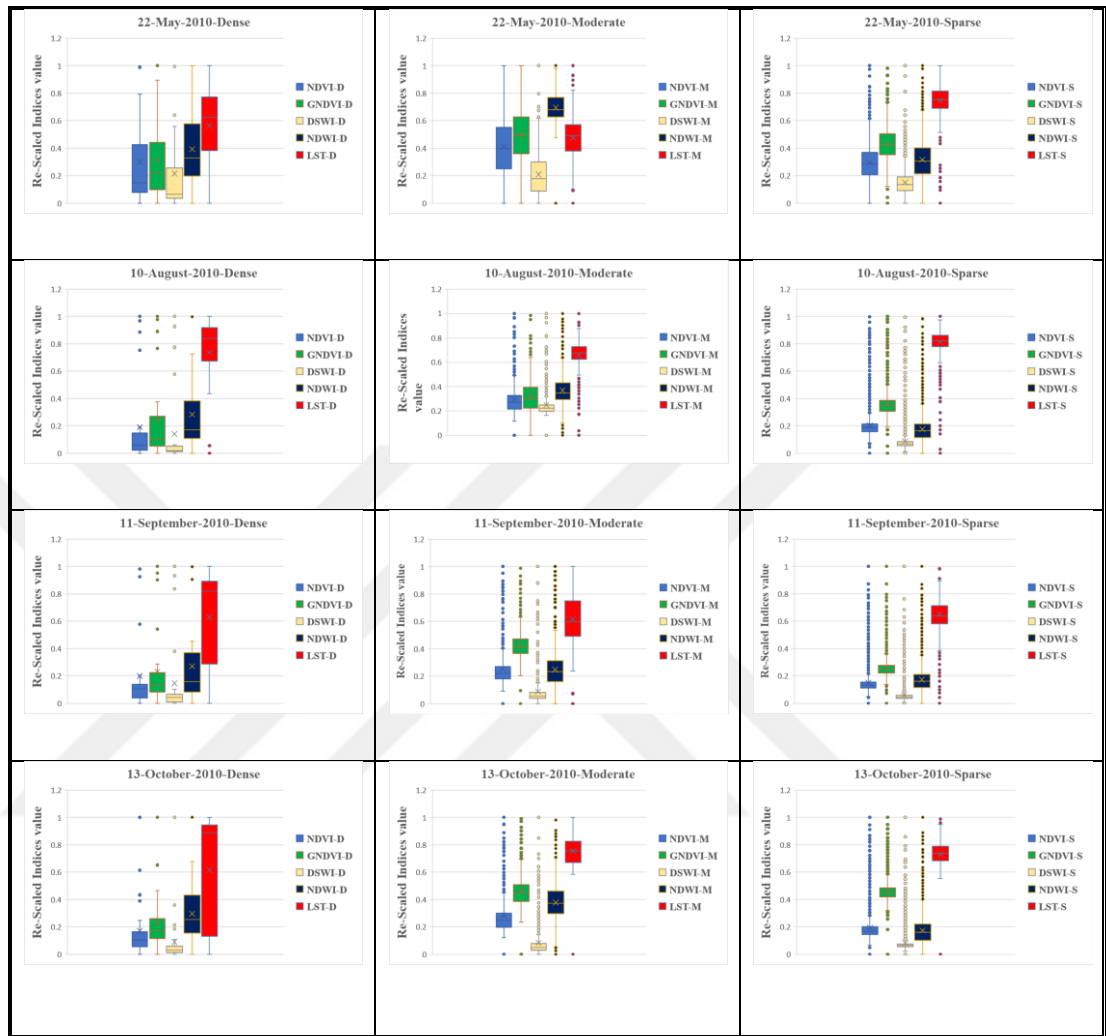
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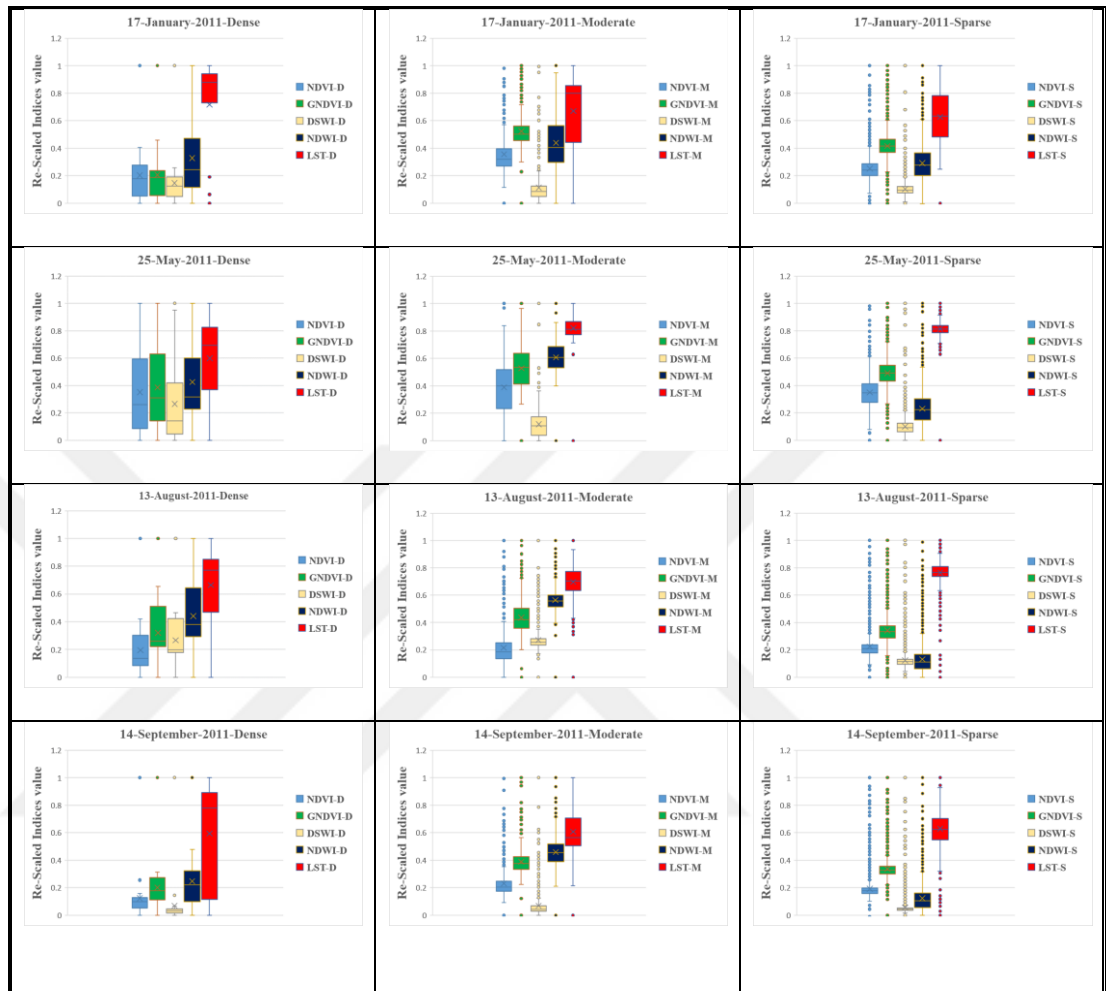
APPENDICES



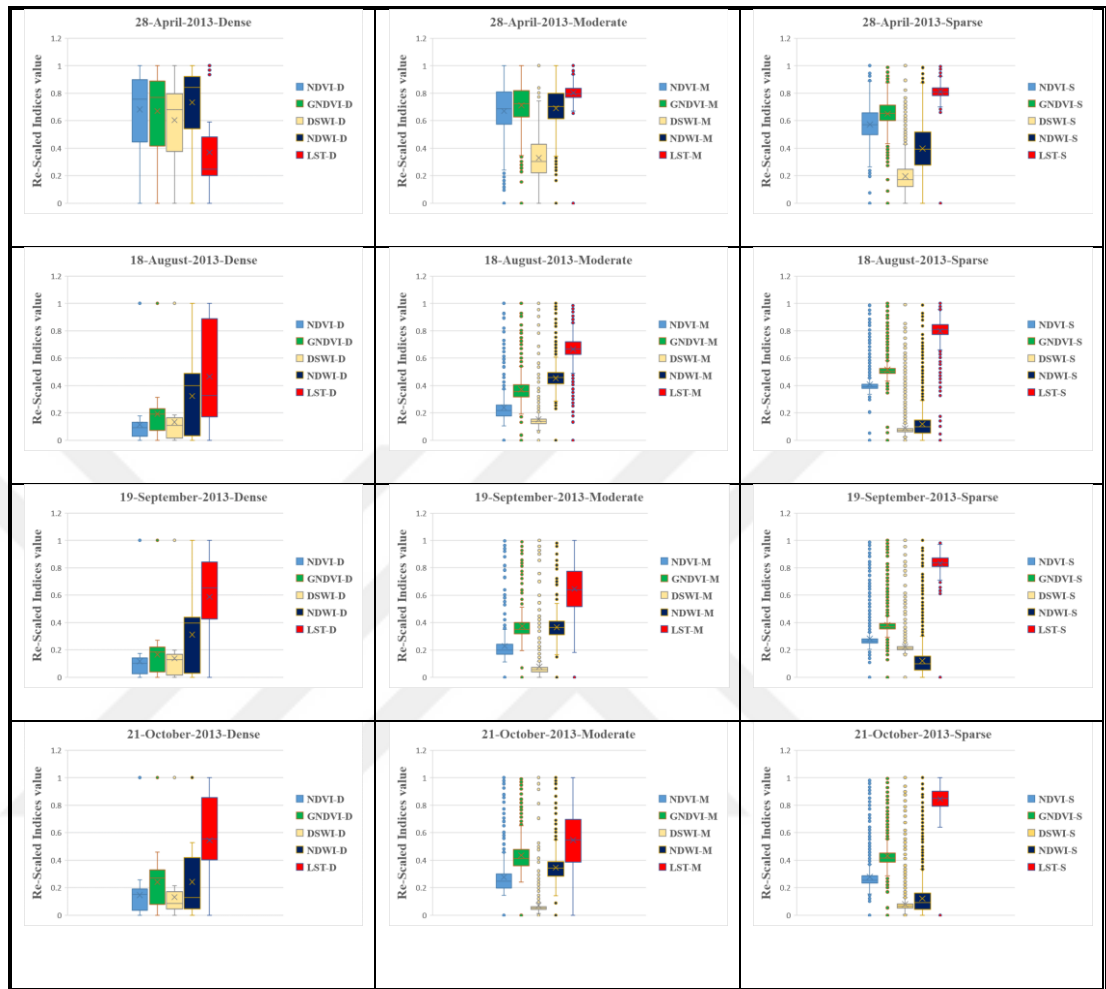
Appendix 1. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



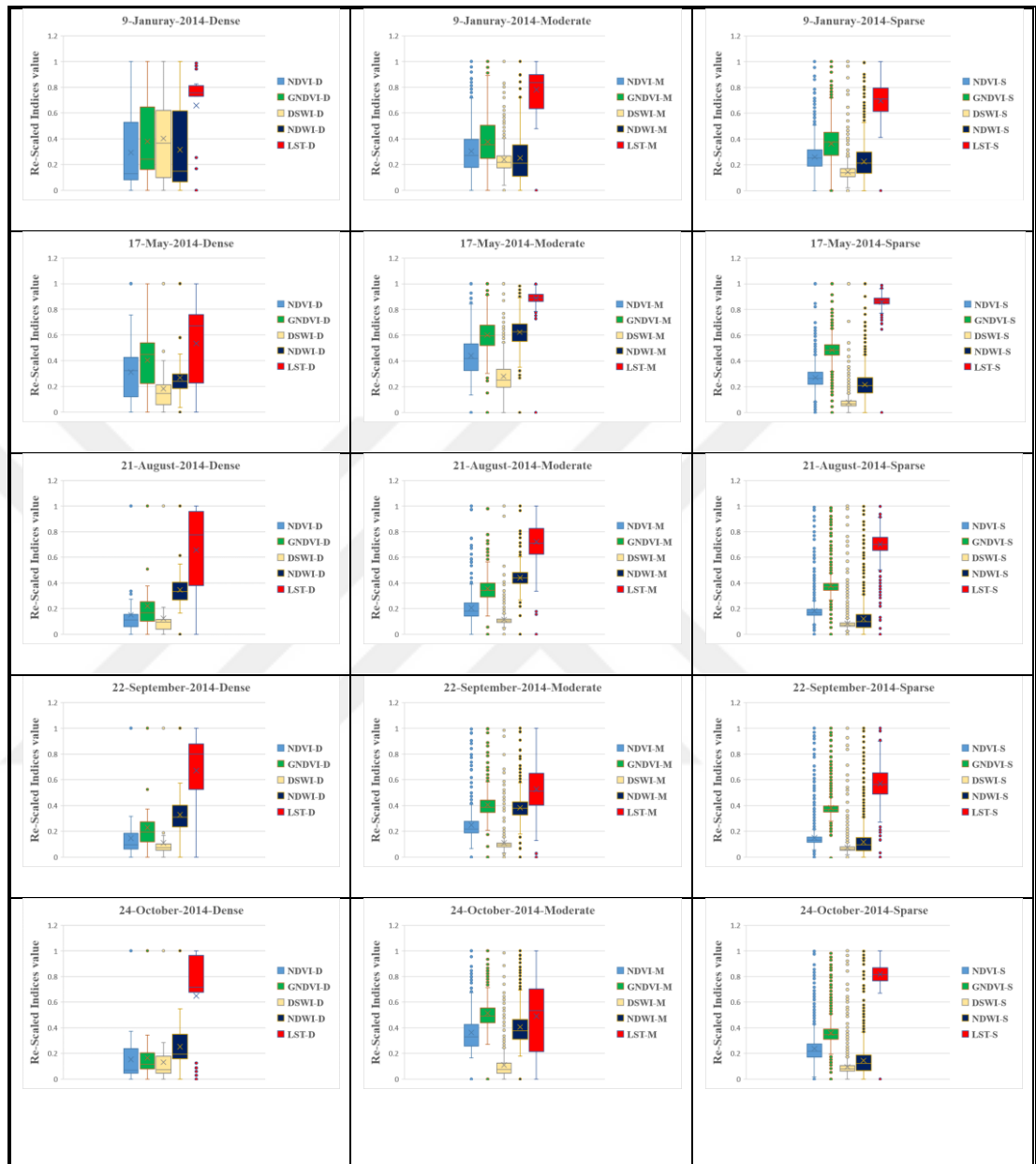
Appendix 2. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



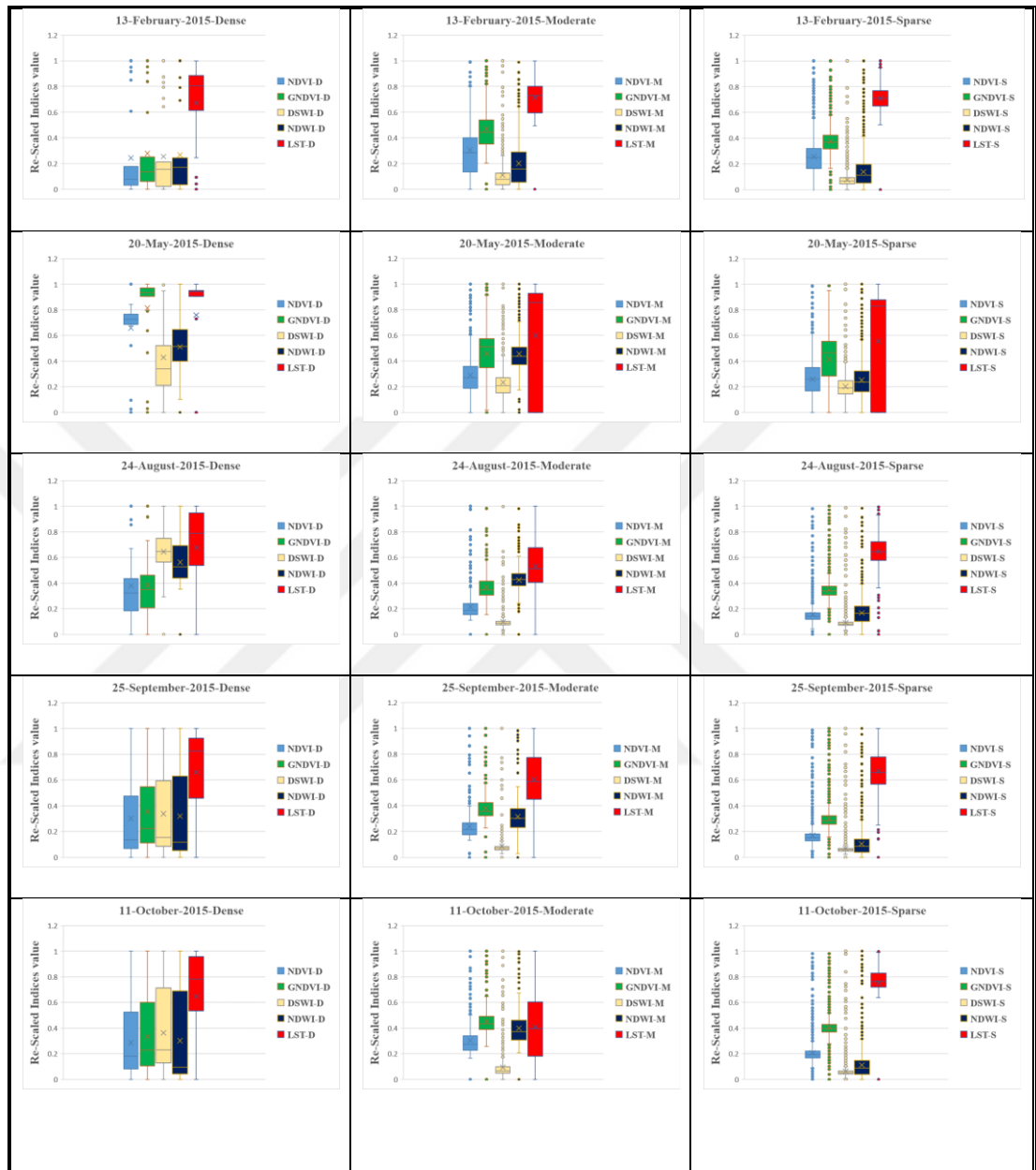
Appendix 3. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



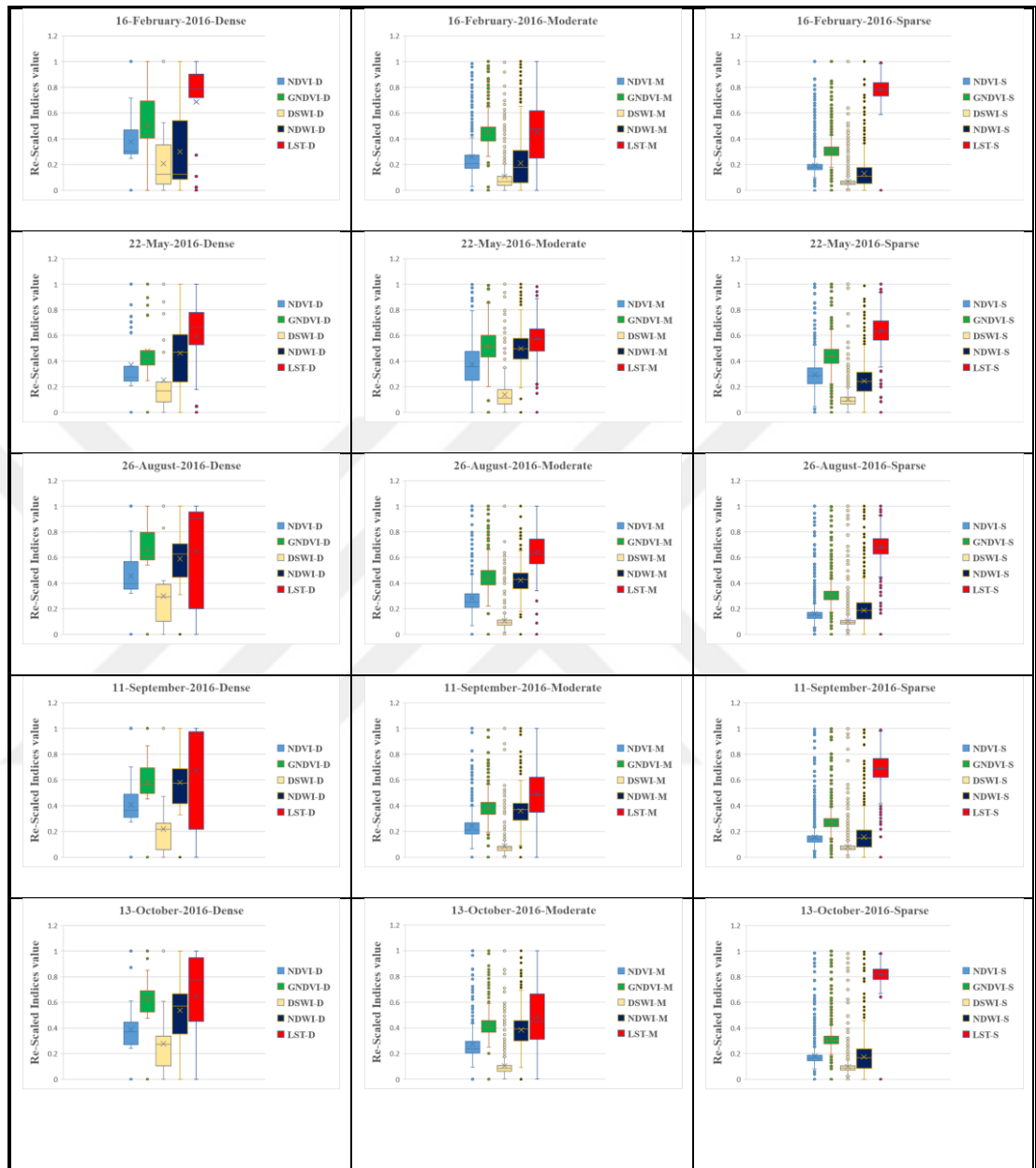
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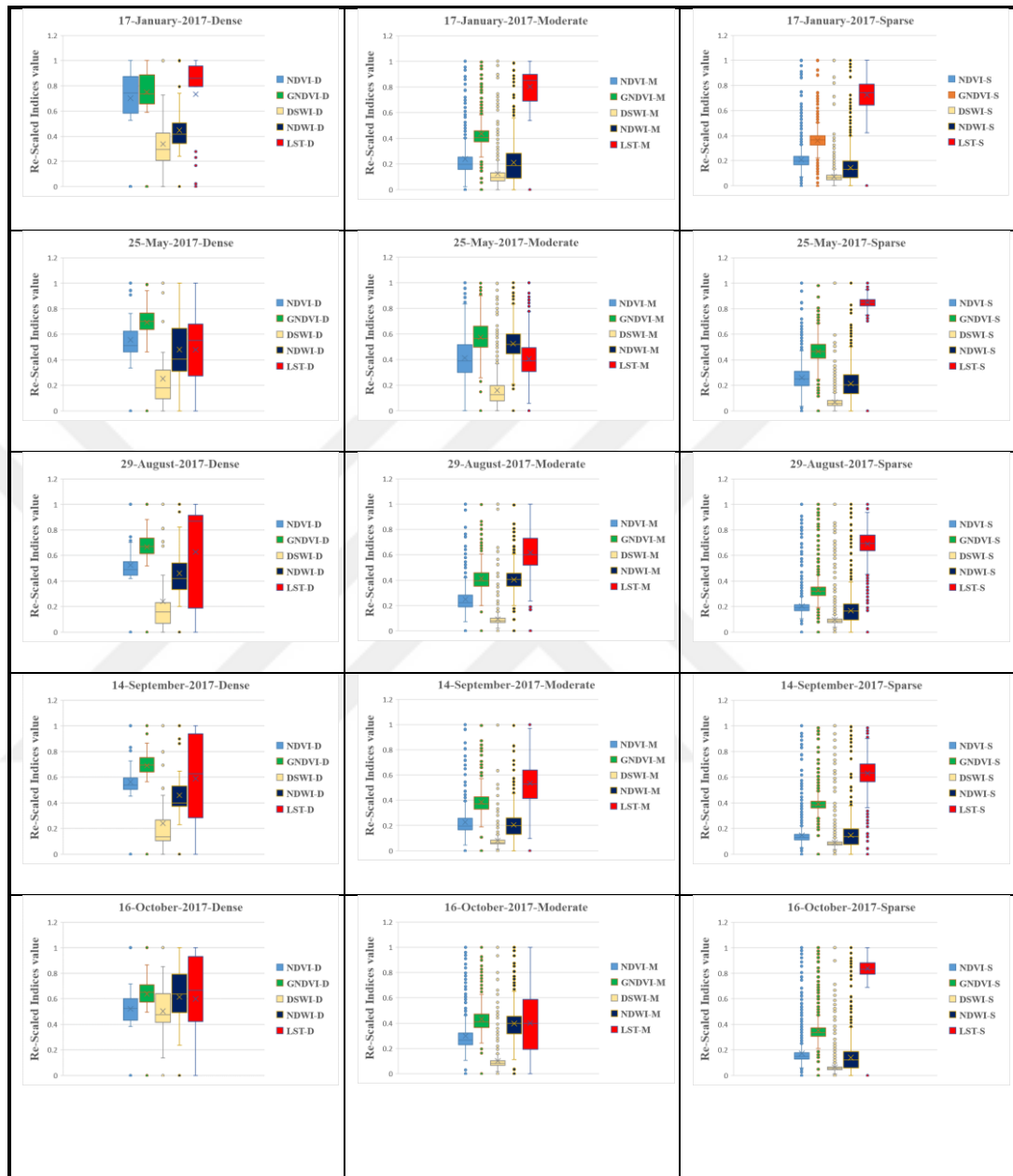
Appendix 5. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



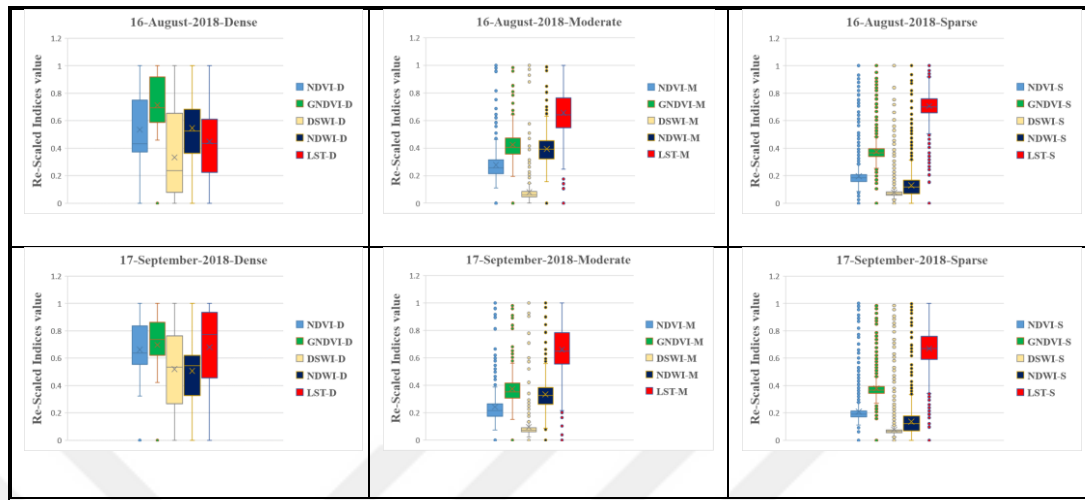
Appendix 6. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



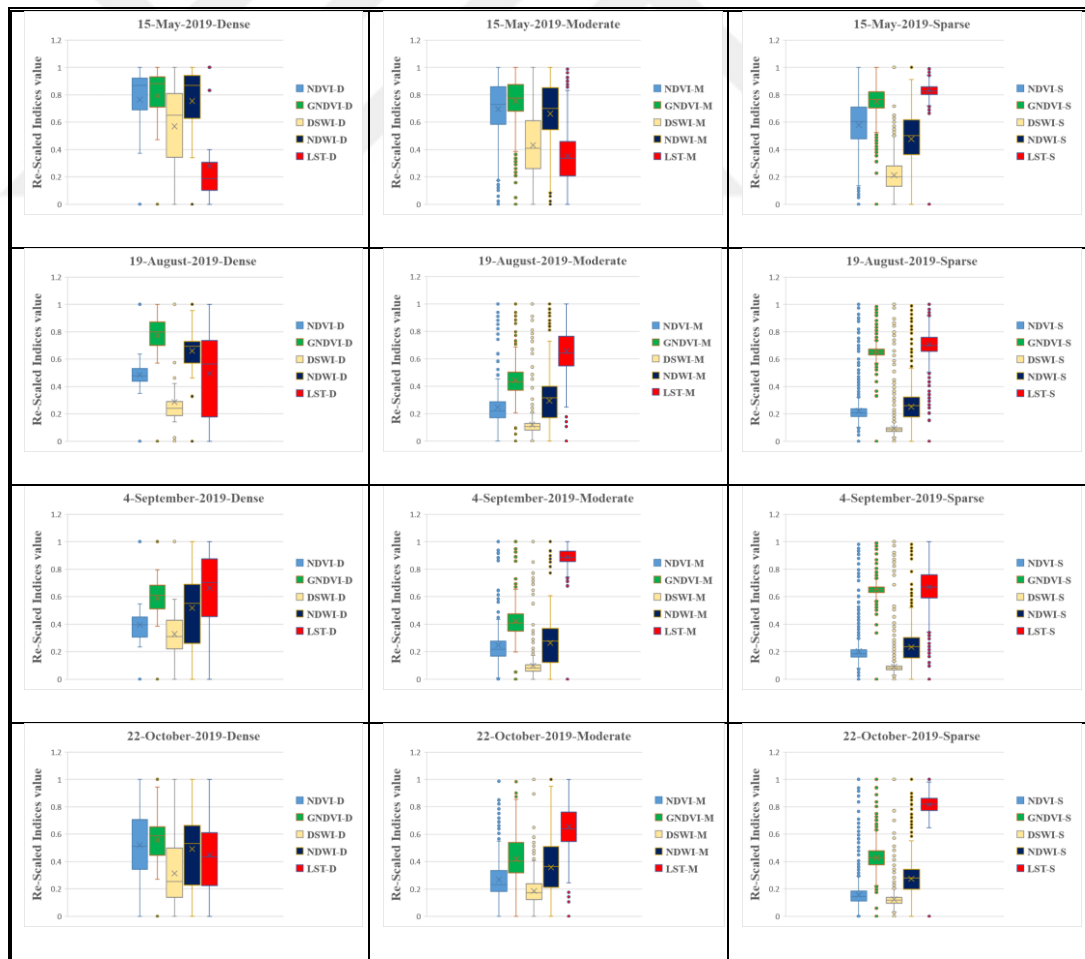
Appendix 7. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



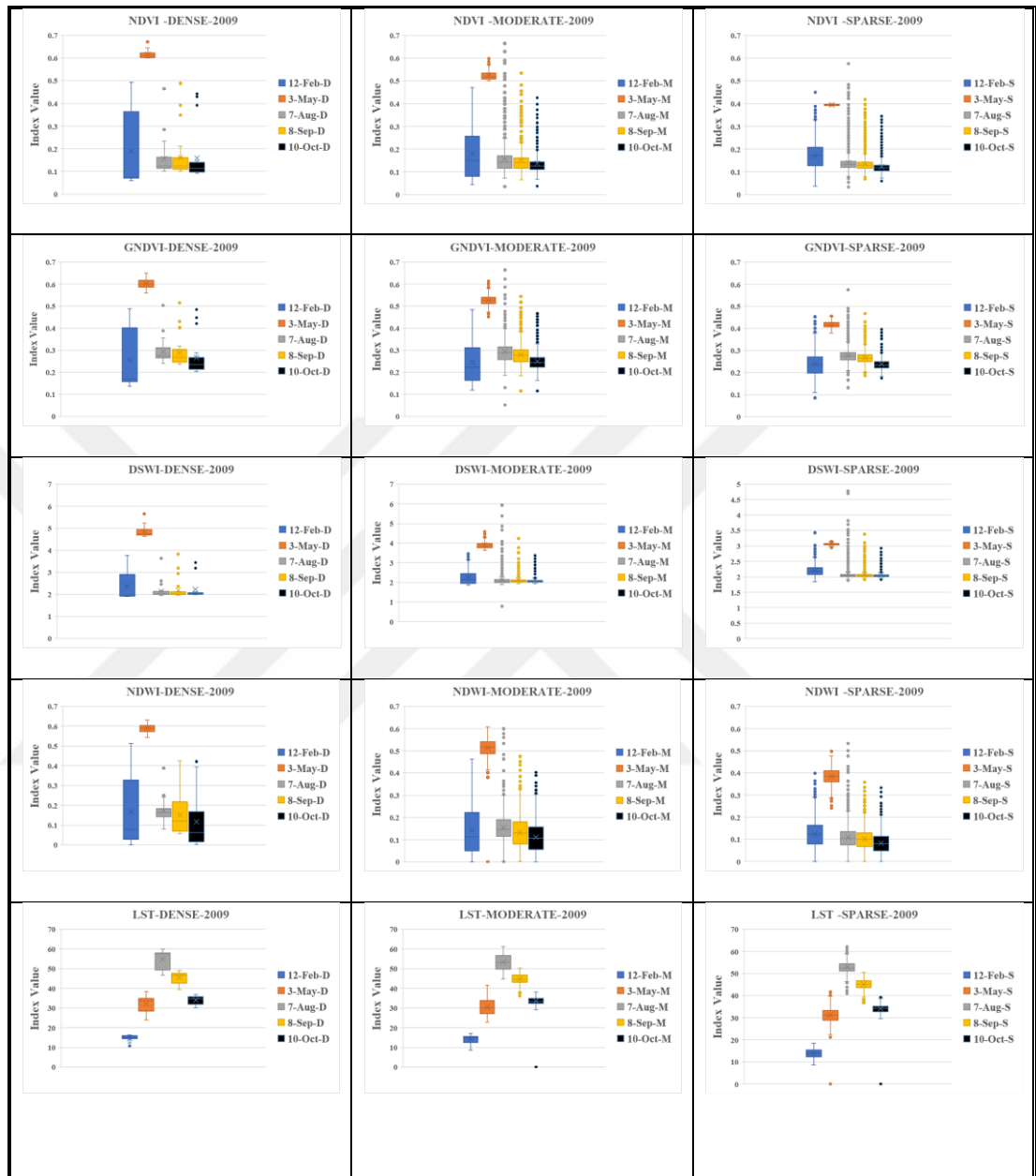
Appendix 8. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



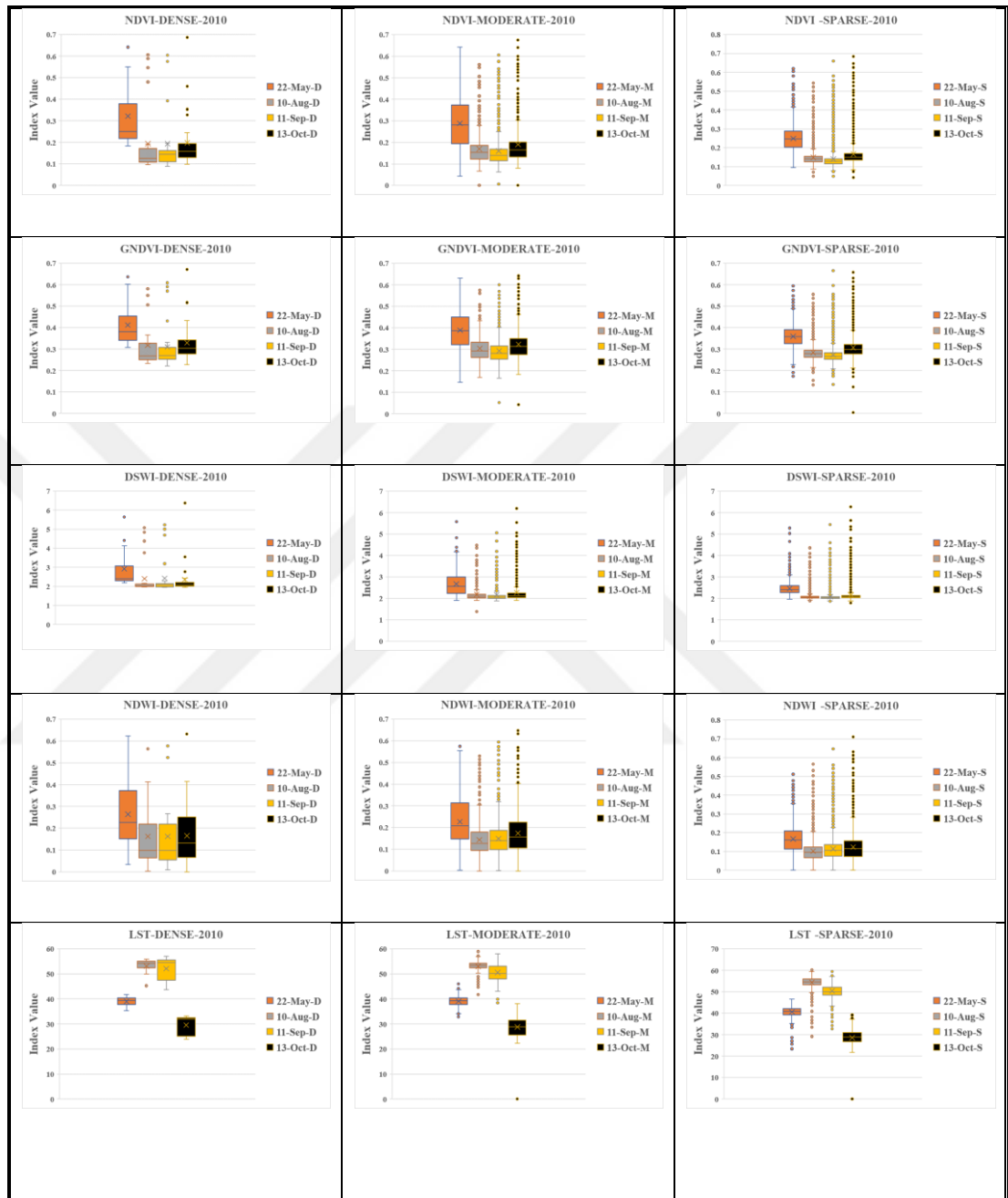
Appendix 9. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



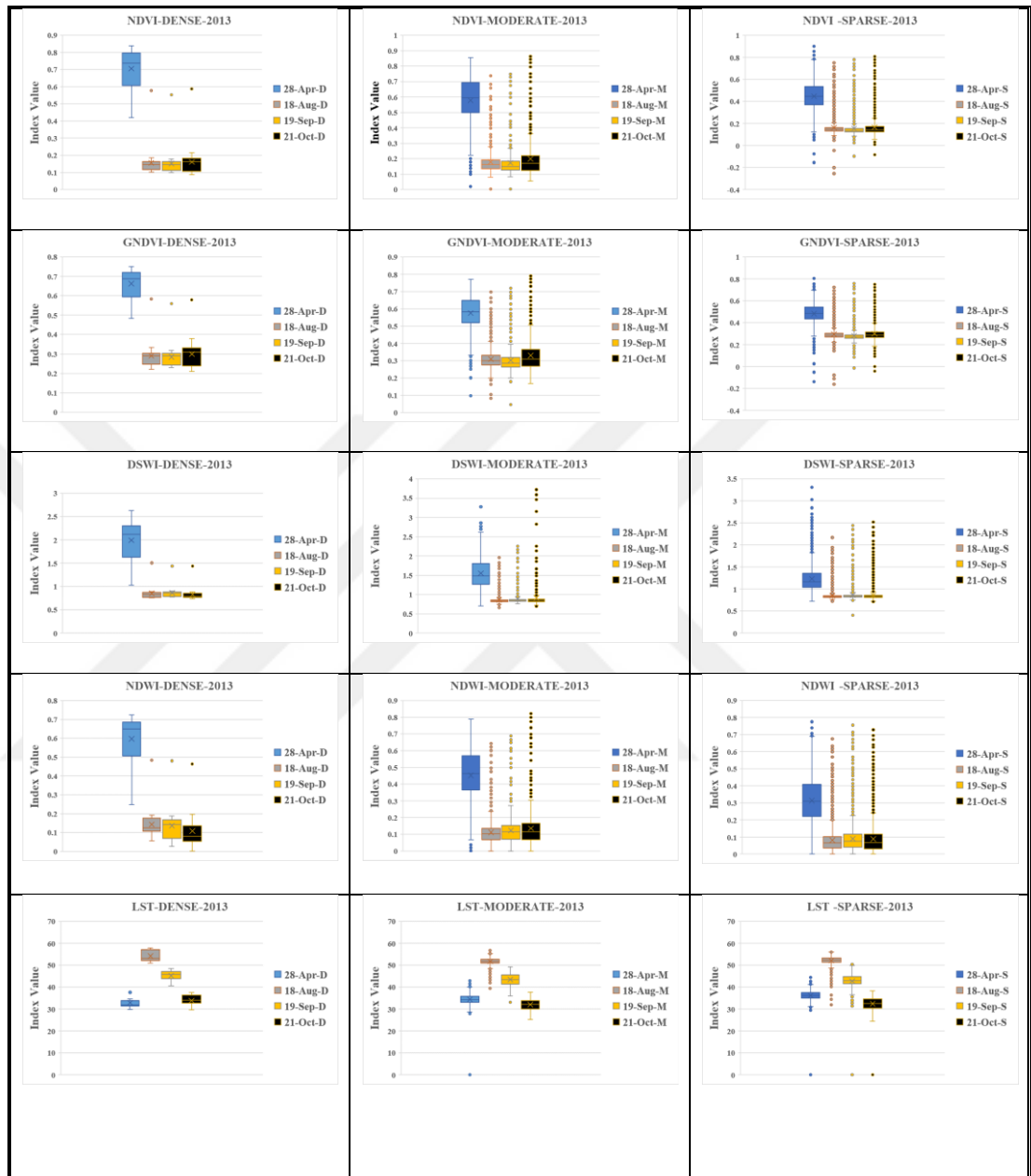
Appendix 10. Box plot shows temporal variation of re-scaled value of calculated vegetation index and LST



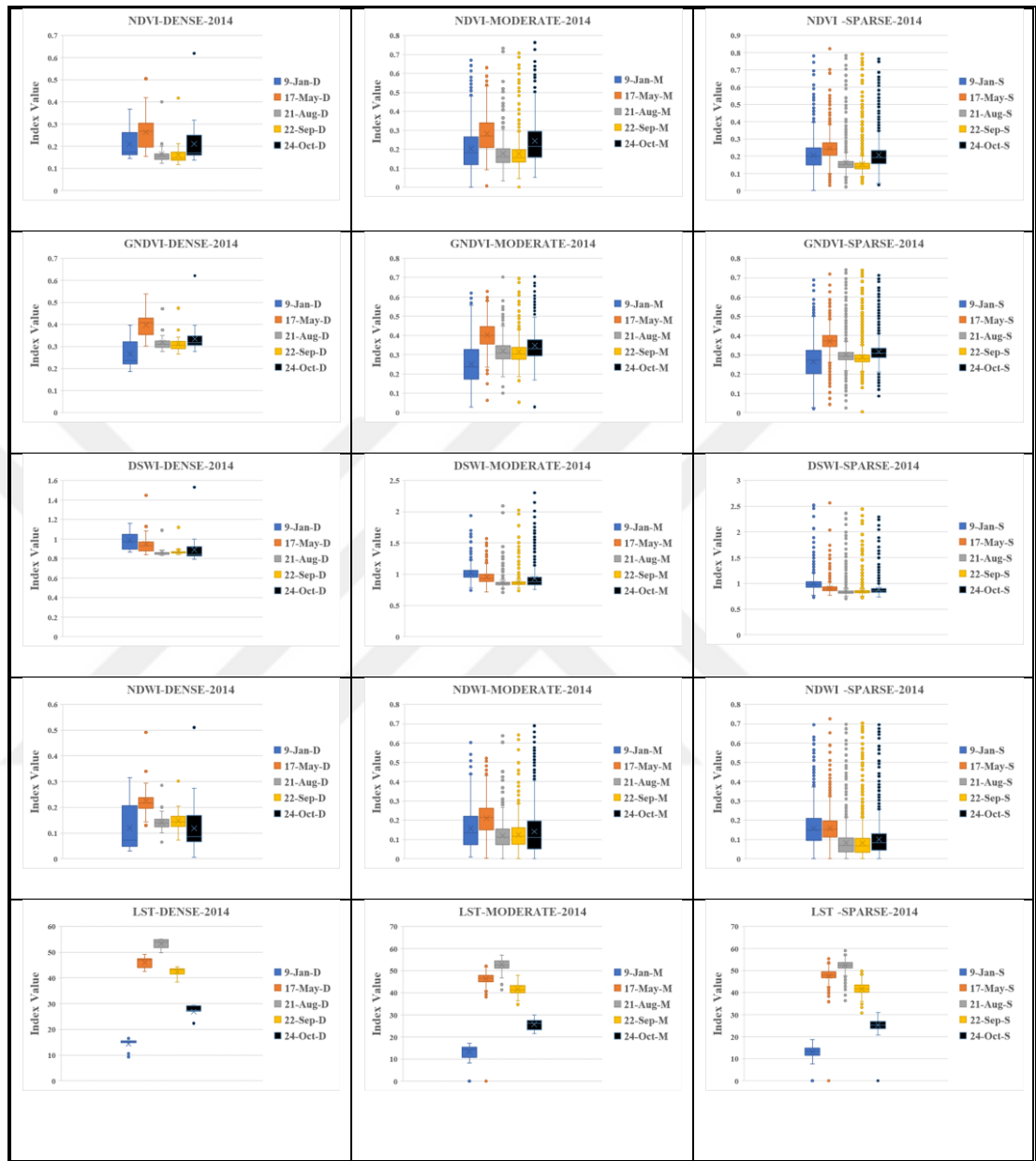
Appendix 11. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



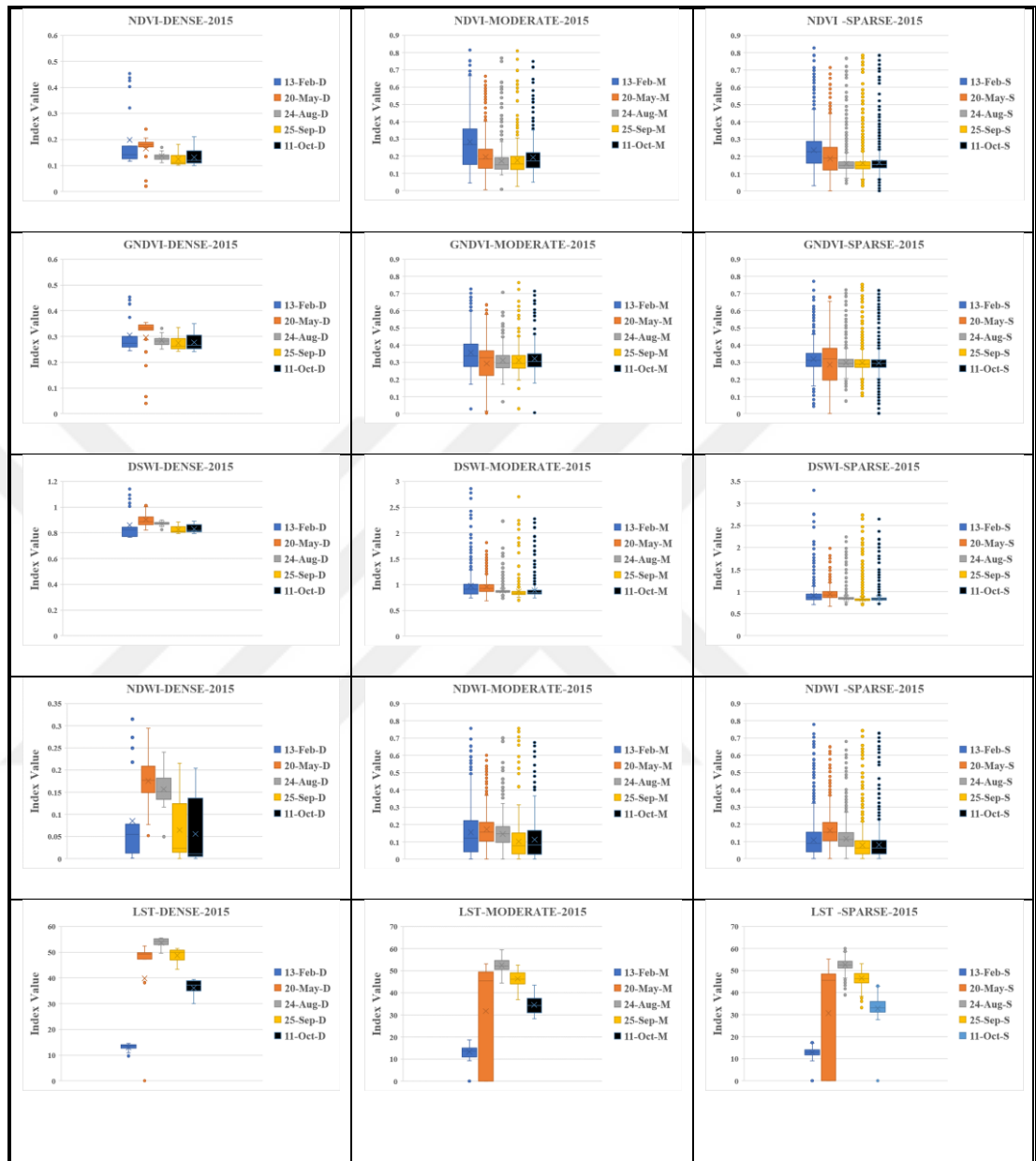
Appendix 12. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



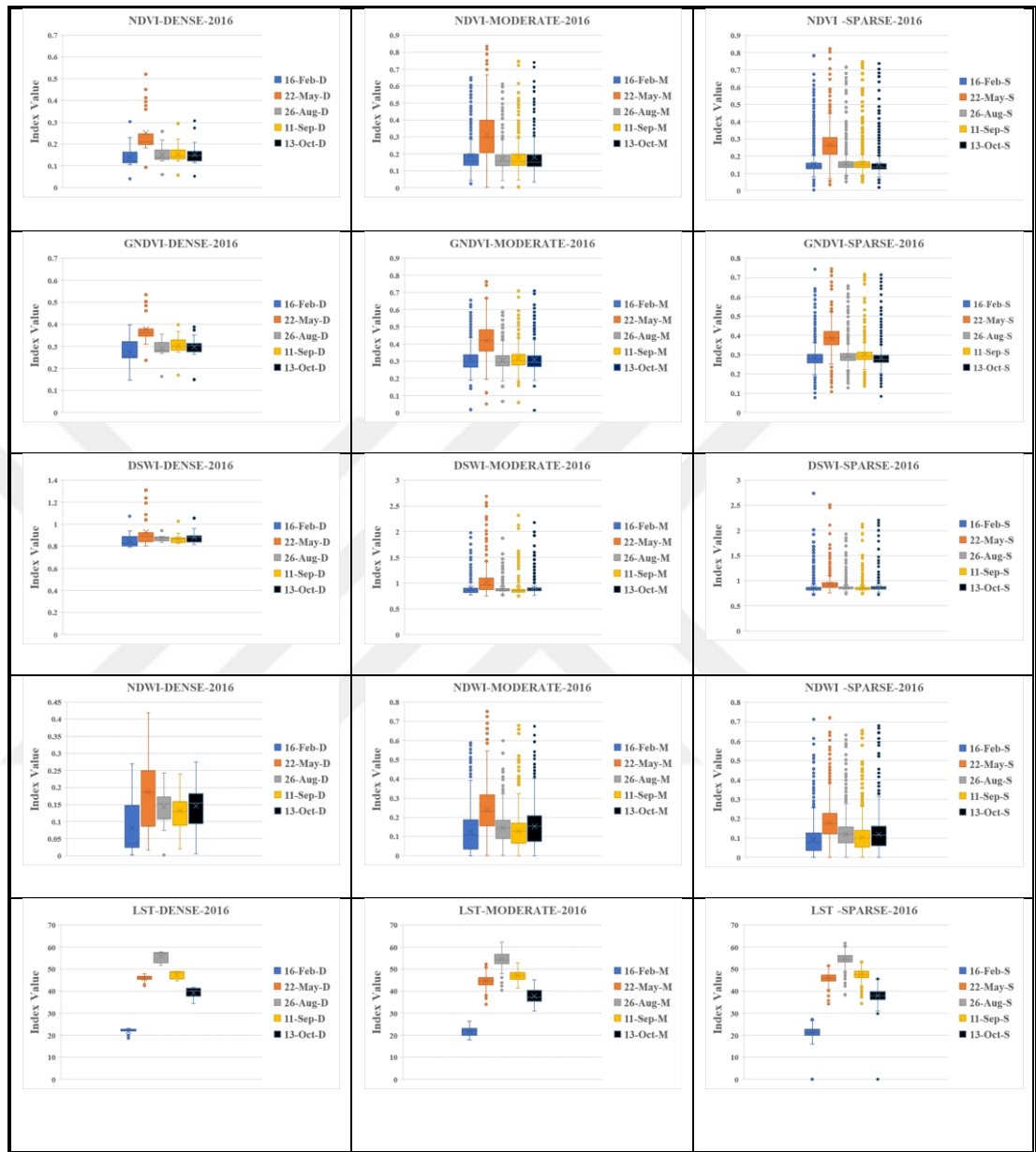
Appendix 13. Box plot shows seasonal variation of calculated vegetation index and Land surface temperature over difference vegetation cover (dense, moderate and sparse)



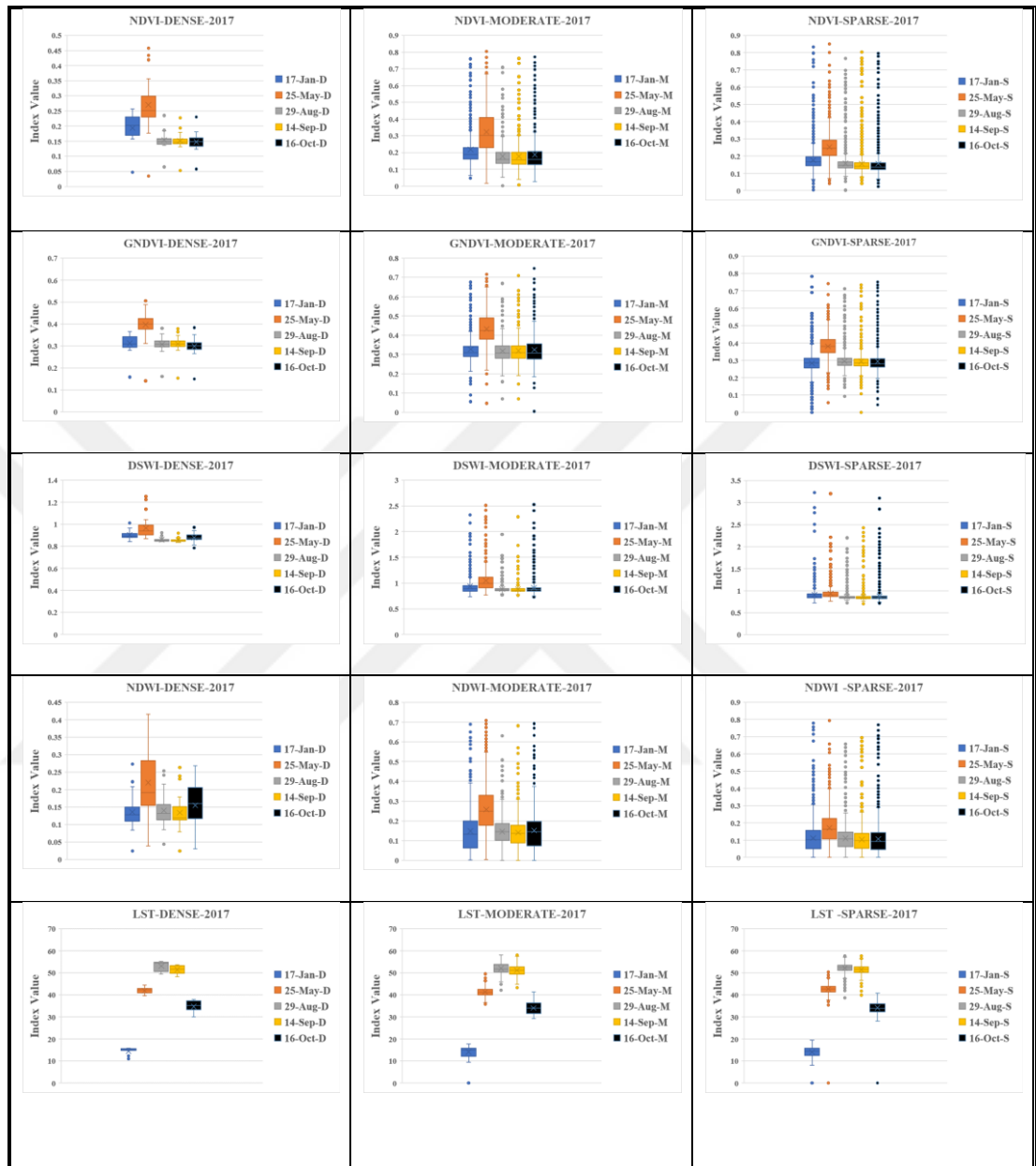
Appendix 14. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



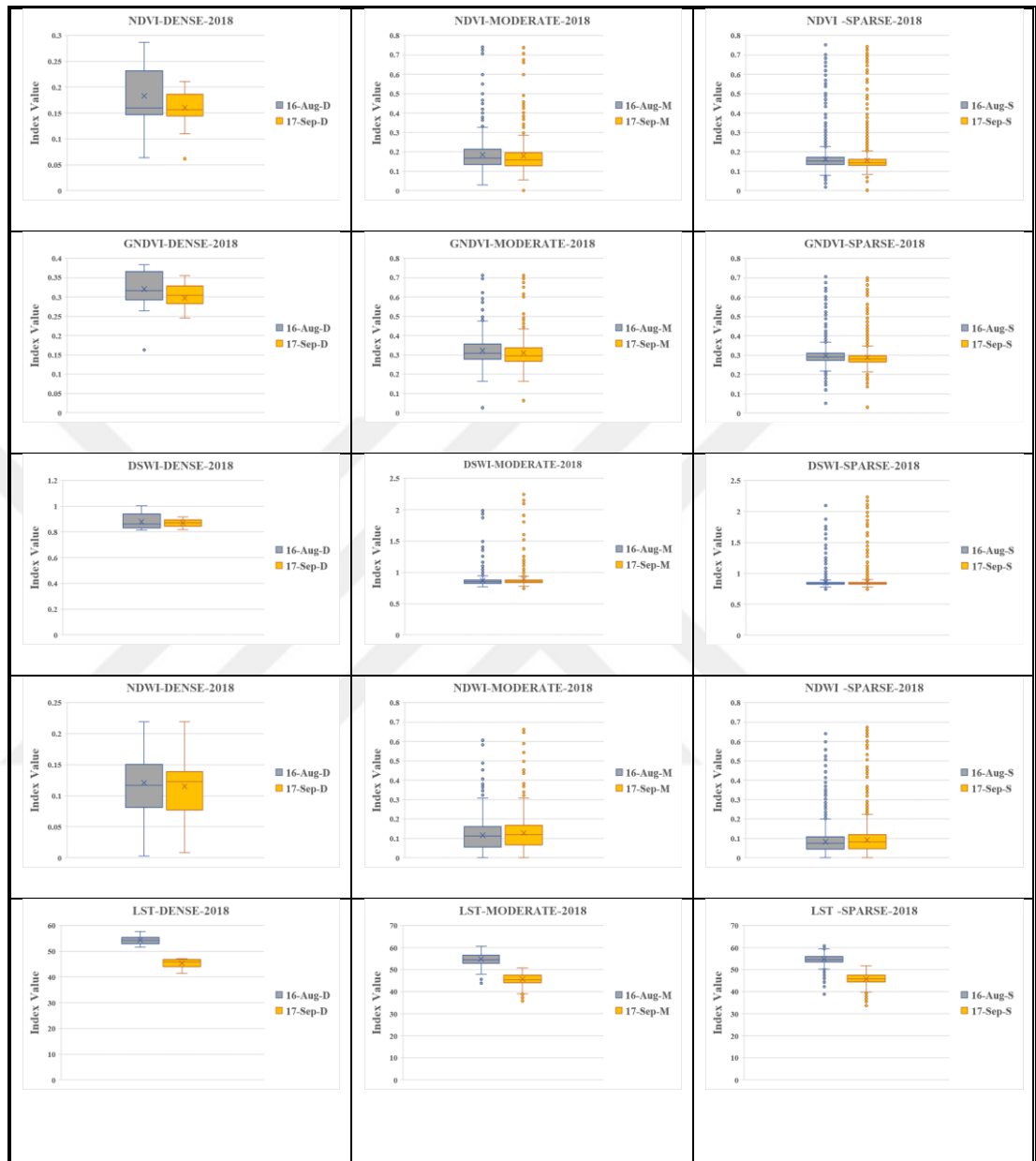
Appendix 15. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



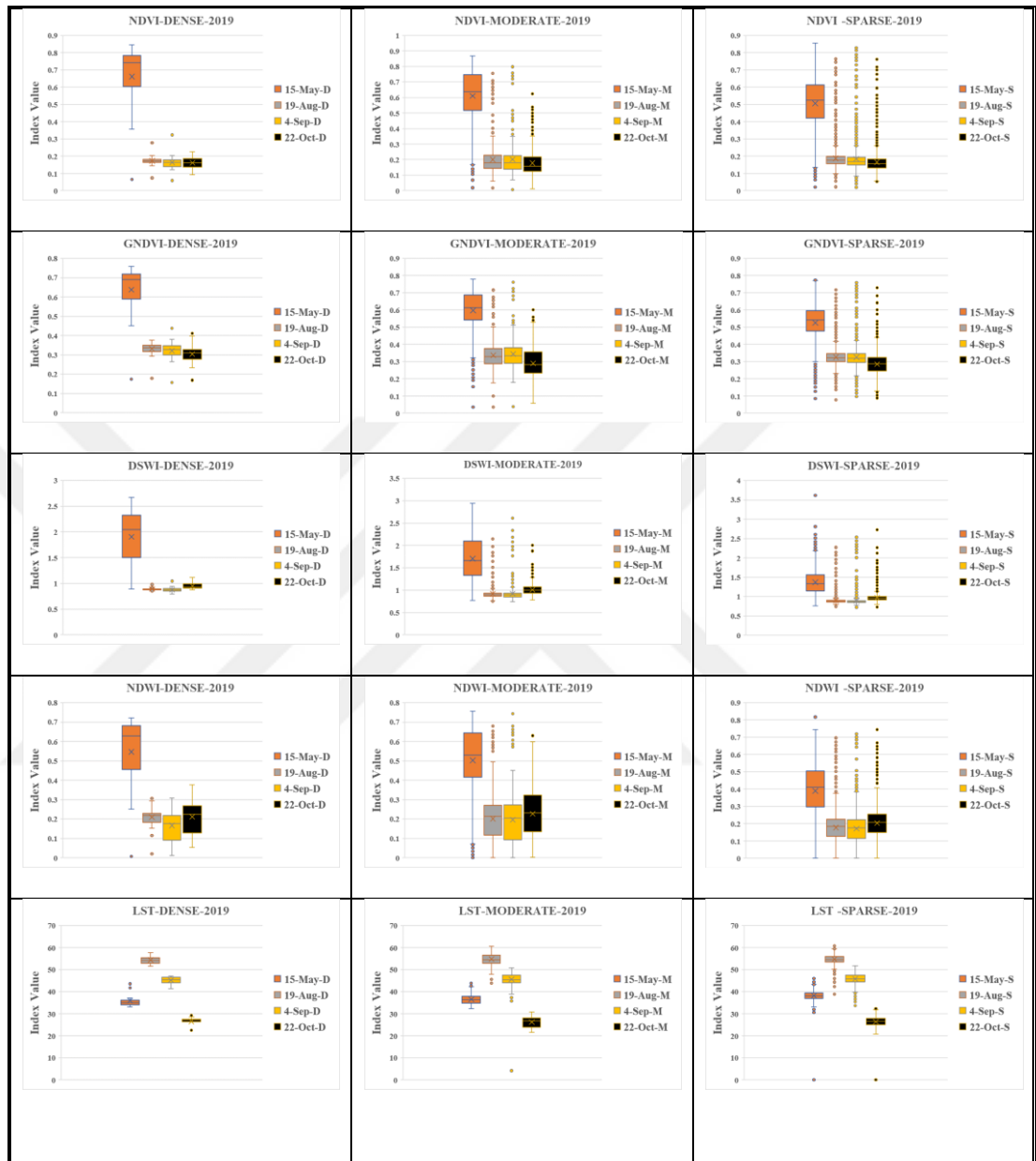
Appendix 16. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



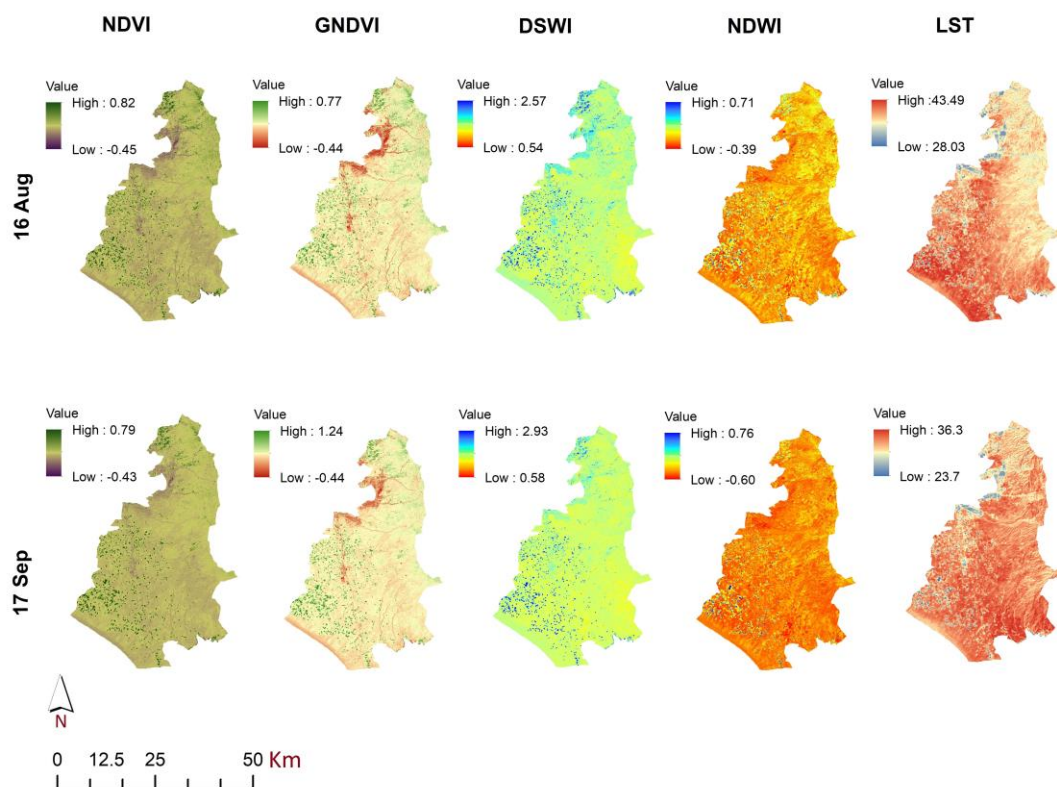
Appendix 17. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



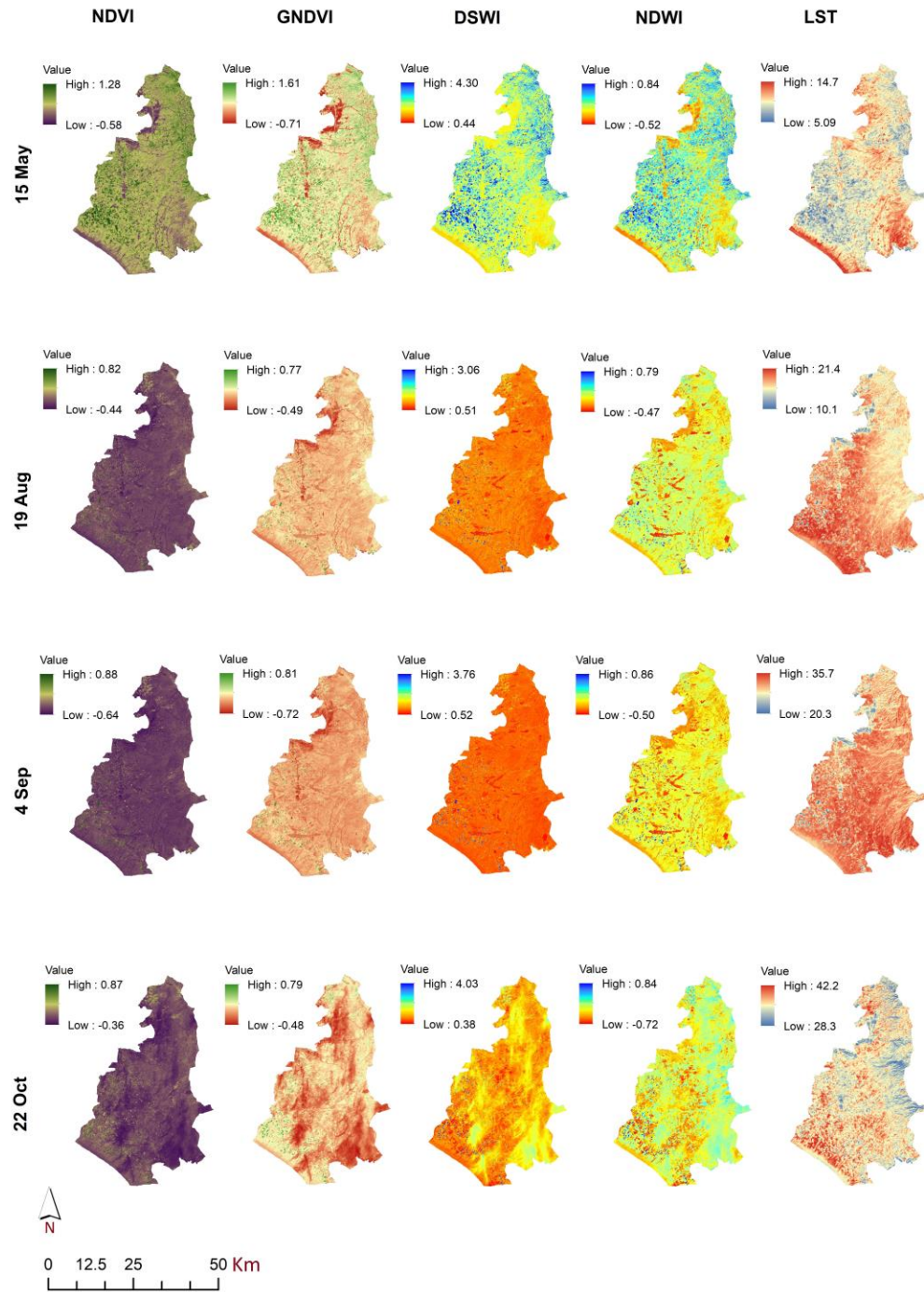
Appendix 18. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



Appendix 19. Box plot shows seasonal variation of calculated vegetation index and land surface temperature over difference vegetation cover (dense, moderate and sparse)



Appendix 20. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2018



Appendix 21. Maps of Temporal variation of measured spectral indices (NDVI, GNDVI, DSWI, NDWI and LST)-2019

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