ISTANBUL TECHNICAL UNIVERSITY ★ INFORMATICS INSTITUTE

DETERMINATION OF DROUGHT CONDITIONS IN TURKEY BETWEEN 2004 AND 2013 USING INDICES DERIVED FROM REMOTELY SENSED DATA

M.Sc. THESIS

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Department of Communication Systems

Satellite Communication and Remote Sensing Programme

DECEMBER 2014

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ BİLİŞİM ENSTİTÜSÜ

UZAKTAN ALGILAMA VERİLERİNDEN ELDE EDİLEN İNDEKSLER KULLANILARAK 2004 VE 2013 YILLARI ARASINDA TÜRKİYE'NİN KURAKLIK DURUMUNUN BELİRLENMESİ

YÜKSEK LİSANS TEZİ

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To my family,

FOREWORD

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December 2014 Nazila MOLAVIZADEH
(Computer Engineer)

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ABBREVIATIONS

MODIS	**:** Moderate Resolution Imaging Spectroradiometer
NDVI	**:** Normalized Difference Vegetation Index
LST	**:** Land Surface Temperature
AVHRR	**:** Advanced Very High Resolution Radiometer
EOS	**:** Earth Observing System
HDF-EOS	**:** Hierarchical Data Format-Earth Observing System
NASA	**:** National Aeronautics and Space Administration
GIS	**:** Geographic Information Systems
NOAA	**:** National Oceanographic and Atmospheric Administration
LP DAAC	**:** Land Processes Distributed Active Archive Center
TERRA	**:** EOS satellite-NASA flagship satellite under Earth System Enterprise
NIR	**:** Near-Infrared
IWMI	**:** International Water Management Institute
FAO	**:** Food and Agriculture Organization of United Nations
EROS	**:** Earth Resources Observation Systems
WMO	**:** World Meteorological Organization
TCI	**:** Temperature Condition Index
VCI	**:** Vegetation Condition Index
VHI	**:** Vegetation Health Index

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SUMMARY

Nowadays, global warming is one of the most important environmental problems that humanity faces which might cause several adverse effects. Droughts are the one of the most important possible outcomes of global warming.

Monitoring droughts and understanding their impacts are important for mitigation and decision-making regarding to drought process. There are a variety of methods applied by many researchers for the determination of droughts. The development of remote sensing, spatial drought monitoring and assessment has become possible in the last decades. Satellite data can contribute to monitor drought. Satellite remotely sensed data suggest significant advantages and be an integral part of monitoring drought, especially for the spatial and temporal evolution of drought. Remote sensing satellites could be used to observe large areas accurately, regularly and economically; also, these data have been widely used to investigate drought impacts. MODIS is one of the most well-known satellite system. MODIS have been used in many research applications like air pollution, mapping deforestation, identifying desertification, fire fuel estimation, burn scar identification, ecosystem evolution, invasive species' potential, grazing impacts.

In this study, Terra-MODIS (moderate resolution imaging Spectroradiometer) images of Turkey received in time interval of January 2004 - December 2013 was used to create different drought indices to analyze the drought conditions within the defined period. The Terra MODIS monthly composite NDVI with 1 km resolution (MOD13A3, collection v005) was downloaded from the EarthExplorer site for the period of January 2004 – December 2013. Healthy vegetation has a low reflectance in the visible portion of the electromagnetic spectrum owing to absorption by chlorophyll and other pigments, and the internal reflectance by the mesophyll spongy tissue of a green leaf because of high

reflectance in the NIR. NDVI values range from −1 to +1 and could be used to identify healthy and unhealthy vegetation due to the fact that healthy vegetation has low reflectance in the visible portion of the electromagnetic spectrum and high reflectance in the NIR. But, water bodies yield negative values of NDVI because nonvegetated surface has negative values of NDVI. Bare soil areas are closest to 0 due to high reflectance in both the NIR and visible portions of the electromagnetic spectrum. In addition to seasonal changes in NDVI values, decrease could occur in the presence of drought condition. Terra MODIS eight-day compound LST with 1 km resolution (MOD11A2, collection v005) from January 2004 to December 2013 was downloaded from the same website as NDVI. Land Surface Temperature (LST) values derived from thermal bands are important since temperature is sensitive to the drought phenomenon and it is negatively correlated with NDVI values. In accordance with temporal resolution (monthly) of NDVI the monthly values of LST are calculated weighting with the number of days belonging to each month based on eight-day LST provide metadata after masking the fill and missing values and LST values in the range of degrees Celsius (° C) unit.

In this study, Terra-MODIS (moderate resolution imaging spectroradiometer) images of Turkey received in time interval of January 2004 - December 2013 were used to create different drought indices to analyze the drought conditions within the defined period. By using this correlation, drought areas and periods for the research area were investigated. We used three different indices that were created using MODIS-derived NDVI and LST values including Temperature Condition Index (TCI), Vegetation Condition Index (VCI) and Vegetation Health Index (VHI) to determine drought conditions in Turkey for the last decade. Terra MODIS monthly composite Normalized Difference Vegetation Index (NDVI) images of 1 km resolution (MOD13A3, collection v005) and Terra MODIS eight-day composite Land Surface Temperature (LST) of 1 km resolution (MOD11A2, collection v005) for the period of 2004 –2013 were used in this research. The VCI has been used to estimate the weather impact on vegetation and it quantifies the weather component and also it changes from 0 to 1, corresponding to changes in vegetation condition from extremely unfavorable to optimize. The TCI algorithm is similar to the VCI one and its conditions are estimated relative to the maximum/minimum temperature in a given time series. Like as the VCI, under a drought process, the TCI is close or equal to 0, and in wet conditions the VCI is close to 1. And the last index is a Vegetation Health Index (VHI). Vegetation Health Index (VHI) is considered as the drought measurement which is addition of both VCI and TCI. But VHI needs a long term data sets and there are some issues in determining the ratio between TCI and VCI. The remote sensing-based Vegetation Health Index (VHI), develop from Advanced Very High Resolution Radiometer (AVHRR) imagery and it has been widely used in global drought monitoring because of the large area coverage offered by this polar orbiting system. The TCI indicates areas that are hotter than usual and the VCI's normalized NDVI anomalies identify areas where vegetation is more or less dense than usual. VHI reflects both vegetation cover and temperature anomalies and also it has been widely applied for the early drought warning, monitoring of crop yield and production, and assessment of irrigated areas and extreme wetness. According the results of remotely sensed derived index, 2007-2008 and 2013-2014 were found as serious drought years.

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ÖZET

Günümüzde küresel ısınma, ekolojik ısınma türlerinin en önemlilerinden biri olarak yer almaktadır. Kuraklık, Dünya'daki doğal yaşamı etkileyen çok sayıda iklimsel olaylardan biridir ve aynı zamanda kuraklık belirgin hale gelene kadar kimsenin farkına varmadığı, hissettirmeden başlayan bir doğal felakettir.

Bu çalışmada, kuraklık konusu tüm Dünya için olduğu gibi Türkiye için de incelenmesi gereken bir konu olarak ele alınmıştır. Burada kuraklığı belirleyebilmek için birçok araştırmacı tarafından uygulanan çok sayıda metot kullanılmıştır. Günümüzde, uzaktan algılama uyduları, büyük alanları gözlemleyip, bu alanlara yönelik araştırmalar yapmayı daha elverişli hale getirmiştir. Bu tez çalışmasında, uzaktan algılama uyduları kuraklığın etkilerini araştırmak için kullanılmıştır. MODIS , en çok bilinen uydu sistemlerinden bir tanesidir. MODIS, hava kirliliği, orman ağaçlarının yok olduğu bölgeri haritalama, çölleşmeyi belirleme, ekosistemdeki gelişmeyi inceleme ve yanmış alanları belirleme gibi birçok araştırma uygulamalarında kullanılmaktadır.

Bu tez çalışmasında, Türkiye ülke sınırlarını kapsayacak şekilde Ocak 2004 ile Aralık 2013 zaman aralığında elde edilen Terra-MODIS(moderate resolution imaging spectroradiometer) uydu görüntüleri kullanılmıştır. Terra-MODIS 1 km çözünürlüğe sahip olan aylık bileşeni Nomalleştirilmiş Fark Bitki İndeksi (NDVI) (MOD13A3, v005) Dünya gözlem sistemi veri geçidinden (the EarthExplorer) 2004-2013 zaman aralığı için indirilmiştir. Aynı zamanda 1 km çözünürlüğe sahip Terra-MODIS 8 günlük bileşeni olan yeryüzü sıcaklık parametresi (LST) (MOD11A2, v005) 2004-2013 yılları için aynı internet sitesi kullanılarak indirilmiştir. NDVI, elektromagnetik spektrumun yakın kızılötesi bölgesinde yüksek yansıtılırlığa sahip olduğundan -1 ile +1 aralığında değerler almaktadır. Sağlıklı bir bitki, 0.05 ile 1 arasında değişen, yüksek NDVI değerleri ile gösterilmektedir. Fakat su kütleleri,

üzerinde bitki örtüsü bulundurmadığından negatif NDVI değerleri almaktadır. Üzerinde bitki bulunmayan çıplak toprak ise elektromagnetik spektrumun görünür ve yakın kızıl ötesi bölgesinde yüksek yansıtım değerlerine sahip olduğu için 0'a yakın NDVI değerleri almaktadır. LST ise derece Celsius (° C) biriminde değerler ile temsil edilmektedir. 1 km konumsal çözünürlüğe sahip (MOD11A2, collection v005) LST verileri ile NDVI değerleri yakın komşuluk metodu (the nearest neighbor method) kullanılarak analiz edilip, 2004-2013 yılları arasında bu görüntülerden elde edilen TCI (Temperature Condition Index) ve VCI (Vegetation Condition Index) görüntüleri oluşturulmuştur.

Sıcaklık Durum Indeksi (TCI), Bitki Durum İndeksi (VCI) ve Bitki Sağlık İndeksi (VHI) olmak üzere üç indeks bu tez çalışması kapsamında kullanılmıştır. NDVI ve LST görüntüleri sırasıyla VCI ve TCI indekslerini hesaplamak için kullanıldı, daha sonra TCI ve VCI kullanılarak VHI değerleri hesaplandı. VCI, havanın bitki örtüsü üzerindeki etkisini tahmin etmek için ele alındı. VCI, 0-1 arasında değerler alarak bitki örtüsünün son derece elverişsiz durum ile ideal durum arasındaki değişimi ifade etmektedir. TCI algoritması da ,VCI'ya benzer şekilde verilen bir zaman aralığında maksimum ve minimum sıcaklık değerlerini tahmin eder. VCI da olduğu gibi, TCI değeri 0'a yakın veya 0'a eşit olduğunda kurak, ve VCI 1'e yakın değer aldığında ise yağışlı, kurak olmayan bir koşulu ifade etmektedir. Son olarak VHI indeksi, VCI ve TCI'dan oluşturulan kuraklık ölçümü olarak düşünülmektedir. TCI, normalden daha fazla sıcaklığa ulaşan alanları gösterirken VCI , vejetasyon miktarındaki yoğunluğu tanımlamaktadır. VHI ise hem vejetasyon örtüsü hem de sıcaklık anomalisini yansıtır, aynı zamanda VHI , erken kuraklık uyarısı, tarımsal üretimin takibi ve aşırı nemliliğin ve sulanan alanların değerlendirilmesinde yaygın olarak kullanılmaktadır.

Indeks sonuçlarına göre 2007-2008 ve 2013-2014 yıllarının ciddi düzeyde meteorolojik olarak kurak olduğu ortaya çıkmıştır. Aynı zamanda bu tez kapsamında TCI ve VCI indeksinin birleştirilmesiyle elde edilen , Bitki Sağlık İndeksi (VHI), kuraklık belirlemede daha fazla spektral bilgiye sahip olmasından dolayı kullanmıştır. Bu çalışmada Türkiye sınırlarında TCI değerlerinin sırasıyla 2007, 2008 ve 2012 yılları için daha yüksek olduğu ortaya çıkarılmıştır. Buna göre bu yılların muhtemel kurak yıllar olabileceği sonucuna ulaşılmıştır.

1. INTRODUCTION

Drought occurs in virtually all climatic regimes which is a slow-onset natural disaster, an insidious and creeping phenomenon. Each drought year is unique in its climatic characteristics and impacts, because drought is related to the timing and the effectiveness of the rains. Therefore, it is impossible to make a definition of drought that can be universally accepted (Li and Xiao 1992, Wilhite 1993). According to American Meteorological Society (1997) drought can be described by three characteristics: spatial coverage, duration and intensity (Wilhite and Glantz 1985). Intensity related to duration in the determination of its impacts and refers to the degree of precipitation shortfall. Sometimes, drought occurs with uncertainty at a micro-scale, and drought occurrence sites vary from time to time when studying spatial distributions of drought (Wang and Wei 1998). Meteorologically supported drought monitoring mention to point-based analyses, which might include simple presentations of particular events relative to their long-term historical averages. The point-based drought indices use extensively for making operational water management decisions and for monitoring drought. Drought impacts are usually first apparent in agriculture. Agriculture production is related to actual crop evapotranspiration, that is usually monitored by the water balance of the whole crop growing cycle. Therefore, a drought index, which is suitable for drought monitoring is closely describes temporal and spatial variations of crop water use status (Z. WAN et al., 2004).

Vegetation Condition Health (VHI) is one of the remotely sensed drought indices, which is used for the assessment of agricultural drought. VHI is a composition of the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI) derived from a long time series of the Normalized Difference Vegetation Index (NDVI) and channel 4 images from NOAA/AVHRR sensor. TCI and VCI have been used for the detection of agricultural drought in Greece and also, VCI has been successfully used in Greece for early cotton yield and assessment (E. Kanellou, C et al., 2008). VCI was not a spatially invariant indicator of drought and therefore it cannot directly be used to compare drought conditions in different areas in Texas and it is not highly correlated with in situ meteorological drought indices according to the study of Quiring and Ganesh (2010). The thermal stress of land surface also attracted the researchers’ interest and they developed an LST-based TCI (Kogan, 1995a, 1997; Bhuiyan et al., 2006; Jain et al., 2009). Some studies mention that the synthesizing TCI and VCI together were better than separately and they developed a vegetation health index (VHI) (Kogan, 1997; Kogan et al., 2004). In the humid regions of high-latitude, where vegetation growth is primarily limited by lower temperatures, using VHI to monitor the drought condition has to be undertaken with caution (Karnieli et al., 2006). The study of C. Bhuiyan, R.P. Singh, F.N. Kogan (2006) VHI, however, show the negative impact of adverse meteorological and hydrological conditions on water and vegetation, hence VHI present better image of drought in India. Unganai and Kogan (1998) specified the weights for VHI using the rank correlation coefficients of crop yield anomaly with TCI and VCI. The anticorrelated NDVI-LST relationship, upon which the VHI is based, is valid for most of the United States during the growing season. ForthermoreVHI might be less appropriate for times and places where vegetation growth is energy limited, such as during the beginning of the growing season or in locations at high latitudes or elevations (Karnieli et al. 2010).

1.1 Purpose of Thesis

The overall purpose of this study is to assess the drought conditions in Turkey during the period of 2004-2013 using remotely sensed data and indices and to analyze vegetation and land surface temperature changes and drought dynamics between January 2004 and December 2013. MODIS derived Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) data were used to create a Vegetation Condition Index (VCI), Temperature Condition Index (TCI) and Vegetation Health Index (VHI) to analyze vegetation and drought conditions in Turkey for the given period.

2. DROUGHT, DROUGHT TYPES AND DROUGHT INDICES

2.1 Drought definition

Drought is a complex disaster, that lack a universal definition, develops over time is with unobvious impacts (Wilhite, 1992). In the other meaning Drought is a slow-onset natural hazard, mostly related to decline in the amount of rainfall in an area for a period of time (Mishra and Singh, 2010). Furthermore, it is often difficult to determine the beginning and the end of a drought (UNESCO, 2005). Drought differs from other natural hazards such as floods, cyclones as it impacts accumulate slowly over a long time, and they might continue after drought termination (Wilhite, 1992). Droughts may be the major natural hazards if compare with the others in point of the damage to human life and property under various meteorological and environmental conditions (Sırdaş and Şen, 2003).

2.2 Types of drought

Drought can classify into four classes dependent upon the parameters, these four classes are: (1) Meteorological Drought. (2) Agricultural Drought. (3) Hydrological Drought. (4) Socioeconomic Drought. These drought classes are shown in figure 2.1 and figure 2.2;

Briefly, according to Heim, Keyantash and Dracup, 2002, meteorological drought is a precipitation deficit, agricultural drought is a total soil moisture deficit, hydrological drought is a shortage of stream flow, and socioeconomic drought is associated with the shortage of any economic goods affected by the drought process.

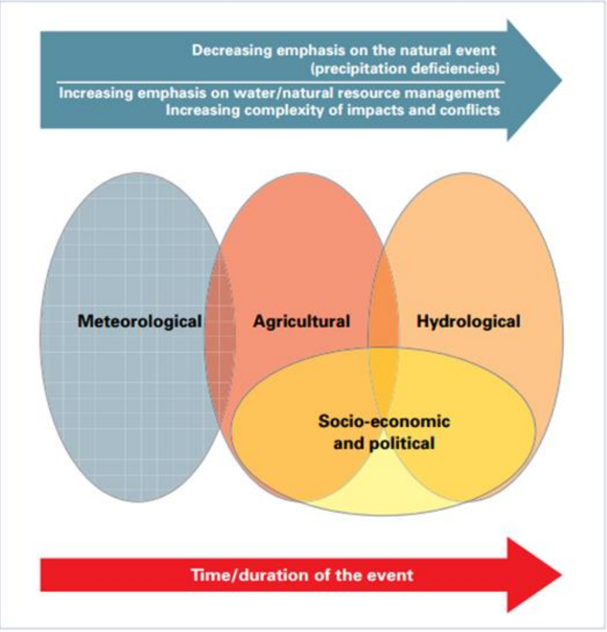


Figure 2.1: Interrelationships between meteorological, agricultural, hydrological and socioeconomic drought. (Source: National Drought Mitigation Center, University of Nebraska–Lincoln, USA).

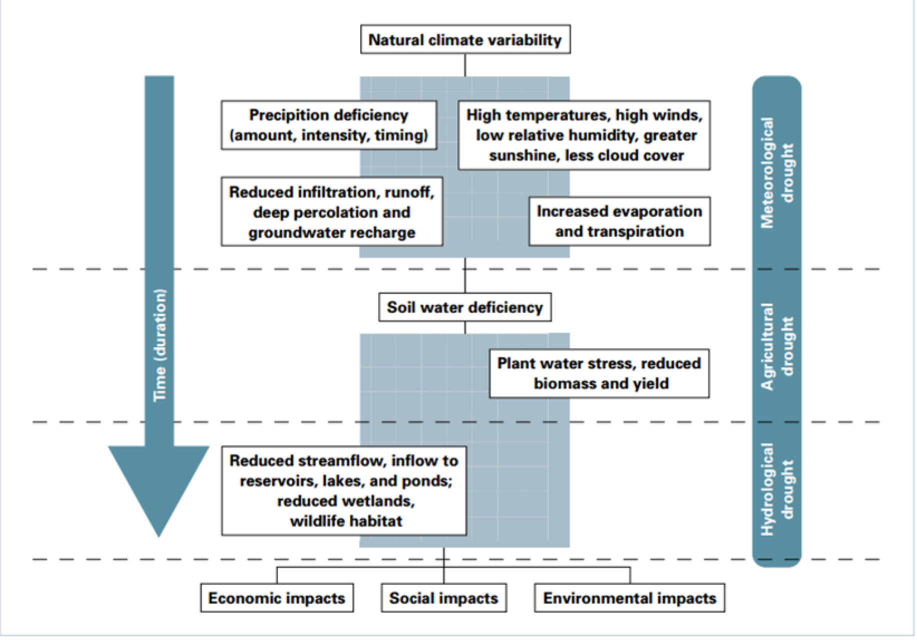


Figure 2.2: Sequence of drought occurrence and impacts for commonly accepted drought types. All droughts originate from a deficiency of precipitation or meteorological drought, but other types of drought and impacts cascade from this deficiency. (Source: National Drought Mitigation Center, University of Nebraska, Lincoln, USA)

2.2.1 Meteorological drought

Meteorological drought is the duration of the dry period and is defined usually based on the degree of dryness. A meteorological drought definition must be considered as region specific because the atmospheric conditions that result in lacks of precipitation are extremely variable from region to region (National Drought Mitigation Center NDMC). A different example of drought definitions ranges from the United States' less than 2.5 rnrn of precipitation in forty-eight hours to Libya's annual precipitation of less than 180 mm (Wilhite et al., 1985).

2.2.2 Agricultural drought

Agricultural drought links different characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, reservoir levels or decrease groundwater, soil water deficits, and so forth. Plant water request depended on prevailing weather states, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil (National Drought Mitigation Center NDMC).

2.2.3 Hydrological drought

Hydrological drought is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply. The frequency and severity of hydrological drought are often defined on a watershed or river basin scale. However, all droughts originate with a shortage of rainfall, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies show up in components of the hydrological system such as soil moisture, streamflow, and groundwater and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors (National Drought Mitigation Center NDMC).

2.2.4 Socioeconomic drought

Socioeconomic definitions of drought associate the supplier and request of some economic good with elements of meteorological, hydrological, and agricultural drought. It varies from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to recognize or classify droughts. The store of many economic goods, such as water, forage, food grains and hydroelectric power, depends on the weather. Because of the natural variability of climate, water supply is ample in some years. However, unable to meet human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply (National Drought Mitigation Center NDMC).

2.3 Impact of climate change on droughts

Climate change is now recognized as one of the major threats in the twenty-first century. Instrumental examinations over the past 157 years show that temperatures at the surface have risen globally, with notable regional variations. Warming in the last (20th) divided two parts, from the 1910s to the 1940s (0.35°C), and more powerfully from the 1970s to the present (0.55°C) (Intergovernmental Panel on Climate Change, IPCC, 2007).

2.3.1 Droughts as natural hazards

Drought is a kind of natural hazard which is further aggravated by the growing water demand and have a negative effect on people or the environment. *Droughts rank first among all natural hazards when measured in terms of the number of people affected (Obasi, 1994; Hewitt, 1997; Wilhite, 2000b).* Droughts are different from other natural hazards in several ways (Wilhite, 2000a). First, the beginning and the end of a drought are complex to determine because the impacts of a drought increase slowly. Second, it is difficult to explain a drought, which leads to doubt for not having a general definition of drought. Third, drought impact is spread over a large geographical area than damage that may result from other natural hazards. Fourth, human activities can directly trigger a drought, with exacerbating factors such as overfarming, excessive irrigation and erosion, adversely impacting the ability of the land to capture and hold water.

2.4 Drought Monitor (DM)

NOAA, USDA (United States Department of Agriculture) and national drought mitigation derived a weekly drought monitor (DM) product that incorporates climatic data and professional input from all levels (Svoboda, 2000). The key parameters are objectively scaled to five DM drought categories. The classification scheme (shown as Table 2.1) includes categories D0 (abnormally dry area) to D4 (exceptional drought event, likened to a drought of record) and labels indicating the sectors being impacted by droughts. A limitation of DM lies in its attempt to show droughts at several temporal scales on one map product (Heim, 2002).

Table 2.1: The Drought Monitor categories (adapted from Svoboda 2000).

Drought Monitor Category	Description
D0	Abnormally dry
D1	Moderate drought
D2	Severe drought
D3	Extreme drought
D4	Exceptional drought

2.4.1 The challenges of drought monitoring and early warning

Monitoring drought presents some distinctive challenges because of its specific characteristics. Some of the most prominent challenges are as follows:

- Meteorological and hydrological data networks are often inadequate in terms of the density of stations for all major climates and water supply parameters
- Data sharing is insufficient between research institutions and government agencies, and the high cost of data limits their application in drought monitoring, preparedness, response and mitigation;
- Information delivered through early warning systems is often too technical and detailed;
- Forecasts are often undependable on the seasonal timescale and absence specificity, reducing their usefulness for agriculture and other sectors;

- Drought indices are sometimes insufficient for detecting the early beginning and end of the drought;
- Drought monitoring systems should be integrated, soil parameters and socioeconomic indicators to fully characterize drought magnitude, potential impact and spatial extent;
- Impact assessment methodologies, a critical part of drought monitoring and early warning systems, are not standardized, obstructive impact estimates and the creation of regionally suitable mitigation and response programs;
- Delivery systems for disseminating data to users in a timely way are not well developed, limiting their usefulness for decision support

(WMO World Meteorological Organization).

Drought indices divided into two main groups, depending on the data and parameters. These are remote sensing drought indices and meteorological drought indices. In addition, these diverse types of each index involve each its own strengths and weaknesses.

3. STUDY AREA AND DATA

3.1 Study area

Turkey is located in Anatolia and the Balkans, bordering the Black Sea, between Bulgaria and Georgia, and bordering the Aegean Sea and the Mediterranean Sea, between Greece and Syria. The geographic coordinates of the Turkey: 39°00'N 35°00'E. The area of the Turkey is 783,562 km² (302,535 sq mi); land: 770,760 km² (297,592 sq mi), water: 9,820 km² (3,792 sq mi). Turkey expands more than 1,600 km (994 mi) from west to east, but generally less than 800 km (497 mi) from north to south. The total land area is about 783,562 km² (302,535 sq mi), of which 756,816 km² (292,208 sq mi) are in West Asia (Anatolia) and 23,764 km² (9,175 sq mi) are in Southeastern Europe (Thrace).

Geography of Turkey

Continent	Eurasia
Region	Southeastern Europe and Western Asia
Coordinates	39°00′N 35°00′E
Area	Ranked 37th
• **Total**	783,562 km² (302,535 sq mi)
• **Land**	98%
• **Water**	2%
Coastline	7,200 km (4,500 mi)
Borders	Total land borders: 2648 km Armenia 268 km, Azerbaijan 9 km, Bulgaria 240 km, Georgia 252 km, Greece 206 km, Iran 499 km, Iraq 352 km, Syria 822 km
Highest point	Mount Ağrı (Ararat) 5,137 m
Lowest point	Mediterranean Sea 0 m
Longest river	Kızılırmak 1,350 km
Largest lake	Van 3,755 km² (1,449.81 sq mi)

Figure 3.1: Geography of Turkey (http://en.wikipedia.org/wiki/Geography_of_Turkey).

Figure 3.2: Geographic Location of Turkey
(http://www.lib.utexas.edu/maps/turkey.html).

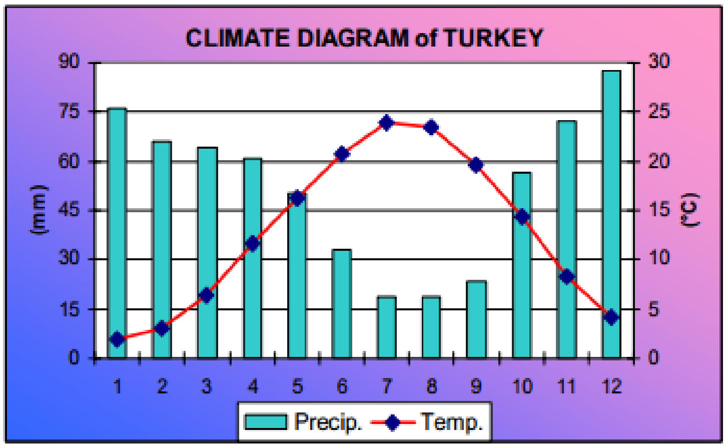


Figure 3.3: Climate diagram of Turkey (Sensoy, S. et al, 2008).

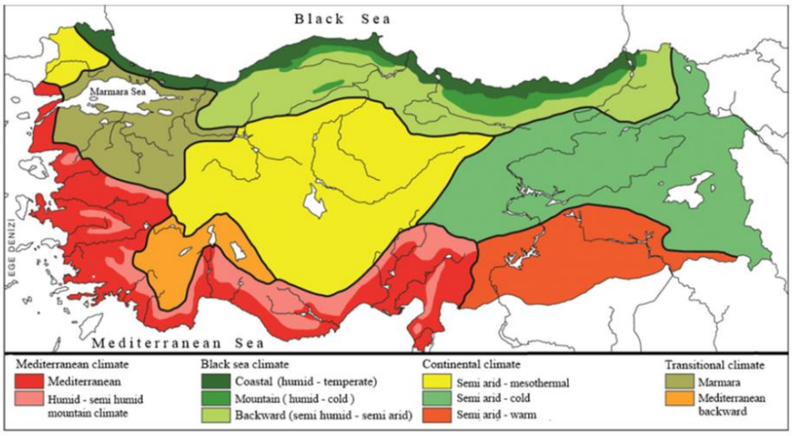


Figure 3.4: Climate types of Turkey (Atalay 2012).

3.2 Topography of Turkey

Turkey is a high altitude country with an average altitude of 1131m. Low (0–250 m), medium (250–1000 m) and high altitude areas (>1000 m) constitute 10.0, 34.5 and 55.5% of the total area respectively (Table 3.1). Turkey's topography displays considerable variation where ecological factors change in a very short distance. The European section (Thrace) is a prolific hilly land. The Asian part (Anatolia) contain of an inner high plateau with mountain ranges along the north and south coasts. The plateau enlarges from the west to the Aegean coast, with many river valleys. Southern mountain range (Taurus) at the east curves rounds in an arc to the South East Taurus Mountain, embracing the outer plateau, the Fertile Crescent which is the northern extension of the Syrian Desert. The plateau falls inchmeal to sea level in Western Anatolia, and terminates in a series of promontories which face the Aegean Sea. Central Anatolia is an elevated plateau at an elevation between 800 and 1000m. The inner part includes large salt lake flat. In the north of Anatolia, mountain ranges get higher and closer to the sea towards the east, forming a narrow green, fertile belt. Mountain ranges rise to over 3000 m, At many points of Black Sea region. Altitude falls slowly towards the west of the northern mountain range. Several rivers cut their way onto the plateau.

Eastern Anatolia is higher and much more mountainous. There are several volcanoes in the plateau rising up to over 3000 m. The highest mountain of the Turkey, Agri (5172 m) is in the east of the region (Dr. Alptekin Karagöz 2006).

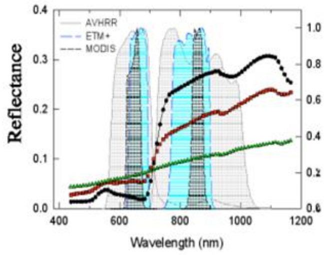
Table 3.1: Topography of Turkey.

Altitude (m)	Ratio of total land area (%)
0-250	10.0
250-1000	34.5
1000-1500	30.0
1500-2000	15.5
>2000	10.0

South East Anatolia is much lower and flatter than East Anatolia. Two main trans-boundary rivers, Firat (Euphrates) and Dicle (Tigris), are important water resources. The topography of the region is very acceptable for making of a series of dams to meet national energy and irrigation requirements. The region is hilly in the north and flat in the south. Karaca Dag (1919 m), a basaltic mountain, is the highest point in the area. The South Anatolian coastline is very fact with deep gorges separating the mountain range of Central Taurus massif which continues northeastward as the Anti-Taurus. The eastern arm continues southwards as the Amanus range, which runs close to the Gulf of Iskenderun until it reaches the Syrian frontier at Akra Dag. Thrace is topographically very heterogeneous. The Istranca mountains which border the Black sea are a low continuation of the northern range of Anatolia and are composed largely of schist. Most of this region is occupied by undulating plains drained by the river Ergene. On the northwest of the Sea of Marmara is the low sandstone range of Tekir Mountains, which continues southwards into the Gelibolu Peninsula.

3.3 MODIS (Moderate Resolution Imaging Spectroradiometer)

The Moderate-resolution Imaging Spectroradiometer (MODIS) is a payload scientific tool launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. The MODIS has 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. They are designed to supply measurements in large-scale global dynamics, including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. Three on-board Calibrators supply in-flight calibration. MODIS has used the Marine Optical Buoy for vicarious calibration.(http://en.wikipedia.org/wiki/ModerateResolution_Imaging_Spectroradio meter).



MODIS, Landsat ETM+, and NOAA-AVHRR normalized bandpass filters superimposed onto three hyperspectral reflectance signatures (Miura et al., 2002).

Figure 3.5: The optical (land) channel bandwidths for NOAA AVHRR, MODIS, and Landsat ETM+ instruments (Miura et al., 2002).

Table 3.2: Specifications of MODIS channels (NASA National Aeronautics and Space Administration).

Primary use	Band	Bandwidth (1)	Spectral Radiance (2)	Required SNR (3)
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230-1250	5.4	74
	6	1628-1652	7.3	275
	7	2105-2155	1.0	110
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21.0	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric Water Vapor	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250

(1) Bands 1 to 9 are in nm; Bands 20 to 36 are in µm

(2) Spectral Radiance values are (W/m²- µm –sr)

(3) SNR = Signal-to-noise ratio

Table 3.3: Specifications of MODIS channels (NASA National Aeronautics and Space Administration).

Primary Use	Band	Bandwidth (1)	Spectral Radiance (2)	Required NE[delta] T(K) (4)
Surface/Cloud Temperature	20	3.660-3.840	0.45(300K)	0.05
	21	3.929-3.989	2.38(335K)	2.00
	22	3.929-3.989	0.67(300K)	0.07
	23	4.020-4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433-4.498	0.17(250K)	0.25
	25	4.482-4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1.360-1.390	6.00	150(SNR)
	27	6.535-6.895	1.16(240K)	0.25
	28	7.175-7.475	2.18(250K)	0.25
Cloud Properties	29	8.400-8.700	9.58(300K)	0.05
Ozone	30	9.580-9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780-11.280	9.55(300K)	0.05
	32	11.770-12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185-13.485	4.52(260K)	0.25
	34	13.485-13.785	3.76(250K)	0.25
	35	13.785-14.085	3.11(240K)	0.25
	36	14.085-14.385	2.08(220K)	0.35

(1) Bands 1 to 9 are in nm; Bands 20 to 36 are in μm

(2) Spectral Radiance values are (W/m^2- μm –sr)

(3) SNR = Signal-to-noise ratio

(4) NE(delta)T = Noise-equivalent temperature difference

Note: Performance goal is 30-40% better than required

3.3.1 MODIS technical specifications

Orbit: 705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular.

Scan Rate: 20.3 rpm, cross track

Swath Dimensions: 2330 km (cross track) by 10 km (along track at nadir)

Telescope: 17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop

Size: 1.0 x 1.6 x 1.0 m

Weight: 228.7 kg

Power: 162.5 W (single orbit average)

Data Rate: 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)

Quantization: 12 bits

Spatial Resolution: 250 m (bands 1-2) ,500 m (bands 3-7), 1000 m (bands 8-36)

Design Life: 6years

NASA(National Aeronautics and Space Administration)

3.3.2 Comparing AVHRR and MODIS data

Historically, the most commonly used remote sensing tool for large-area drought monitoring has been the daily orbiting National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), partially because there is now a sufficiently long time series to let for the identification of anomalies to compare to "normal" conditions. The historical record for AVHRR data expands back over two decades globally at 4- to 8-kilometer (km) resolution (Tucker and others, 2005). Regional data series are also suitable, including a 19-year time-series dataset over the conterminous United States (CONUS) available from 1989 forward (Eidenshink, 2006). But, MODIS data have higher spatial resolution as it show above. Furthermore, MODIS data have the temporal resolution of 8 days and a single pixel level 10 by 10 km with AVHRR data and 0.5 by 0.5 km with MODIS, while the AVHRR data are monthly (Brown et al., 2008; IWMI, 2004). *MODIS has 36 spectral bands between 0.405 and 14.385µm which is more sensitive than AVHRR data and can be also used to produce NDVI imagery at*

250, 500, and 1000 m resolution (Gallo et al., 2004). MODIS is superior to AVHRR because they provide higher spatial and spectral resolutions (Figure3.5), improved atmospheric corrections and more precise geolocation. When compare the MODIS and AVHRR data sets such as liking $NDVI_{AVHRR}$ with $NDVI_{MODIS}$ atmospherically corrected MODIS NDVI generally displays a higher dynamic range than atmospherically corrected AVHRR NDVI. This is attributed to the small bandwidth of MODIS (Huete et al., 2002; IWMI, 2004).

3.4 Normalized Difference Vegetation Index (NDVI)

Many researchers able to determine the vegetation state using vegetation indices such as the (NDVI). Healthy vegetation has a low reflectance in the visible portion of the electromagnetic spectrum owing to absorption by chlorophyll and other pigments, and the internal reflectance by the mesophyll spongy tissue of a green leaf because of high reflectance in the NIR as shown in figure 3.6.

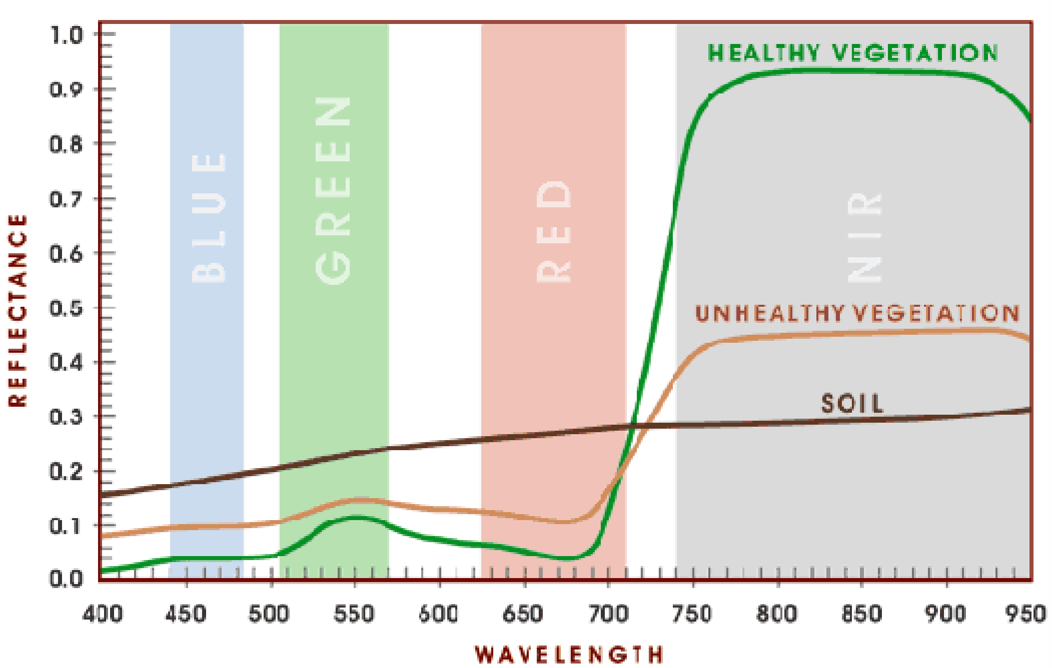


Figure 3.6: Difference between healthy and unhealthy vegetation (Utahstate university cooperative extension 2010, https://extension.usu.edu/nasa/htm/on-target/near-infrared-tutorial).

NDVI be calculated as the ratio of the NIR and the red bands of a sensor system and is delineated by the following equation **(3.1)**.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \tag{3.1}$$

NDVI values range from -1 to +1. Healthy vegetation is represented by high NDVI values between 0.05 and 1, because of high reflectance in the NIR portion of the electromagnetic spectrum. But, water bodies yield negative values of NDVI because nonvegetated surface has negative values of NDVI. Bare soil areas are closest to 0 due to high reflectance in both the NIR and visible portions of the electromagnetic spectrum (Parinaz Rahimzadeh Bajgiran et al., 2008). NDVI provides measures of the amount or condition of vegetation within a pixel and maps the presence of vegetation on a pixel basis (Z.WAN et al., 2004). In this study, the Terra MODIS monthly composite NDVI with 1 km resolution (MOD13A3, collection v005) was downloaded from the EarthExplorer site for the period of January 2004 – December 2013.

3.5 Land Surface Temperature (LST)

Land Surface Temperature (LST) related to surface energy balance and the united thermal state of the atmosphere within the planetary boundary layer (Jin 1996). It is a key parameter in land surface processes, and due to its control of the upward terrestrial radiation, and consequently, the control of the surface sensible and latent heat flux exchange with the atmosphere, also acting as an indicator of climate change (Aires, 2001; Sun 2003). On the other hand, it is one of the key parameters in the physics of land-surface processes on regional and global scales because it is a good indicator of the energy balance at the Earth's surface (Z.WAN et al., 2004). In my thesis, Terra MODIS eight-day compound LST with 1 km resolution (MOD11A2, collection v005) from January 2004 to December 2013 was downloaded from the same website as NDVI. In accordance with temporal resolution (monthly) of NDVI the monthly values of LST are calculated weighting with the number of days belonging to each month based on eight-day LST provide metadata after masking the fill and missing values (Rhee et al., 2010).

The LST of clear-sky pixels in MODIS scenes is recovered with the split-window algorithm in a general form (Wan & Dozier, 1996) **(3.2) (3.3)**.

$$T_{s,1} = A_0 + P_1 \frac{T_1 + T_2}{2} + M_1 \frac{T_1 - T_2}{2} \quad \textbf{(3.2)}$$

$$T_{s,2} = A_0 + P_2 \frac{T_1 + T_3}{2} + M_2 \frac{T_1 - T_3}{2} \quad \textbf{(3.3)}$$

Where T_1 is the brightness temperature for 1^{st}, T_2 is the brightness temperature for 2^{nd}, and T_3 is the brightness temperature for 3rd thermal infra- red band. A_0 is a constant, P_1, P_2, M_1 and M_2 can be expressed as functions of emissivity's (ε_1, ε_2, ε_3) in these four thermal infrared bands. Theoretically, $Ts,_1$ is equal to $Ts,_2$. MODIS has 5 thermal bands, 29,30,31,32, and 33. Band 33 located on the edge of thermal bands, because band 30 has too much ozone absorption to use, so bands 29, 31, 32 are used to constitute two groups to determine the LST (Xue et al., 2005).

3.6 Relationship of NDVI with LST

The relationship between vegetation indices, such as NDVI and LST has been extensively documented in the literature. The composite of NDVI and LST by scatter plot results in a triangular shape. The slope of the LST– NDVI curve related to soil moisture conditions and the evapotranspiration of the surface. Several methods have been developed to interpret the LST–NDVI space, including: (1) remote sensing based method (2) in situ measurement method and (3) the ‘triangle’ method using soil–vegetation–atmosphere transfer (SWAT) model.

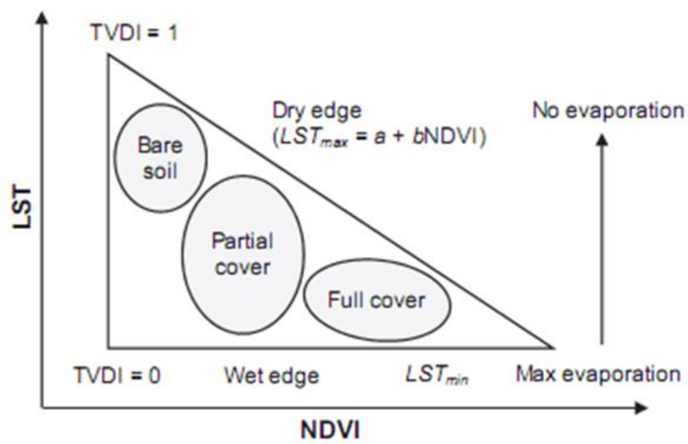


Figure 3.7: A conceptual LST-NDVI triangle (Sandholt et al., 2002)

4. METHODOLOGY

4.1 Remote sensing-based drought indices

The development of remote sensing, spatial drought monitoring and assessment has become possible in the last decades (E. Kanellou, C. et al., 2008). Satellite data can contribute to monitor drought. Special emphasis is given to agricultural drought, as the reflected radiation recorded by satellite sensors (Domenikiotis et al., 2004a). Satellite remotely sensed data suggest significant advantages and be an integral part of monitoring drought, especially for the spatial and temporal evolution of drought. Classification of the application of remote sensing for agriculture divided into three categories: a) land classification, b) mapping and monitoring of crop production and c) identification of stress in crops and vegetation according to Steven and Jaggrad (1995). In most cases, vegetation stress, identify and monitor by the use of vegetation indices. A number of satellite drought-monitoring indices are developed based on the Advanced Very High Resolution Radiometer (AVHRR) of NOAA (National Oceanic and Atmospheric Administration) polar-orbiting satellite series, MODIS (Moderate Resolution Imaging Spectroradiometer) and other satellite data. These indices are normally radiometric measures of vegetation situation and dynamics, exploiting the unique spectral signatures of canopy elements, particularly in the red and near-infrared (NIR) portions of the spectrum (e.g, Huete et al., 1997;2002). The Vegetation Health Index is one of the remotely sensed drought indices, which is used for the assessment of agricultural drought (Kogan, 2002). Also, it is a combination of a Vegetation Condition Index (VCI) and Temperature Condition Index (TCI) derived from a long time series of the Normalized Difference Vegetation Index (NDVI) and Channel 4 images from NOAA/AVHRR sensor (E. Kanellou et al., 2008).

4.2 Vegetation Condition Index (VCI)

The NDVI has been used to identify stress and damaged crops and pastures, however interpretive problems may get up when these results are extrapolated over non-homogeneous areas. Differences between levels of vegetation to be related to differences in environmental resources, in these areas. For example, a region with abundant resources displays NDVI values twice as large as compared to adjacent regions with insufficient resources, under similar vegetation conditions (Kogan, 1987). NDVI has two components: ecology and weather. The integrated area of the weather component is smaller than the ecosystem component, for vegetated regions. Therefore, the weather-related NDVI fluctuations are not easily detectable. So, the weather component must be separated from the ecosystem component, when NDVI is used for analysis of weather impact on vegetation. The VCI has been used to estimate the weather impact on vegetation (Kogan, 1995). VCI quantifies the weather component. The weather-related NDVI envelope is linearly scaled between 0 and 1 which 0 for the minimum and 1 for maximum NDVI for each grid cell and week. It is defined as **(4.1)**.

$$VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \qquad \textbf{(4.1)}$$

Where NDVI, $NDVI_{max}$, and $NDVI_{min}$ the smoothed weekly NDVI, multi-year maximum NDVI and multi-year minimum NDVI, respectively, for each grid cell. VCI changes from 0 to 1, and sometimes the values of VCI are represented in percent's ranging from 0 to 100. NOAA-AVHRR (advanced very high resolution radiometer) good correlations have been established between NDVI or VCI and precipitation and data have been extensively used for drought monitoring in various areas of the world (Karabulut, 2003; Wang et al., 2003).

4.3 Temperature Condition Index (TCI)

The land surface will meet a thermal stress, on drought progressing. Therefore, the temperature condition index (TCI), a remote sensing based thermal stress indicator is proposed to determine temperature-related drought phenomenon (Kogan, 1995a). There is a higher LST in the drought year than the same month of normal years and this index assumes that drought event will decrease soil moisture and cause land surface thermal stress. The TCI algorithm is similar to the VCI one and its conditions are estimated relative to the maximum/minimum temperature in a given time series. But, high land surface temperature in the vegetation growing season indicates unfavorable or drought conditions while the low land surface temperature indicates most favorable conditions, opposite to the NDVI (Singh et al., 2003). Thus, the TCI formula was modified as the following expression **(4.2)**.

$$TCI = \frac{LST_{max} - LST}{LST_{max} - LST_{min}} \quad \textbf{(4.1)}$$

Where LST, LST_{max} and LST_{min} are the values of LST, maximum LST and minimum LST of each pixel respectively in the same month during the study period of January 2004– December 2013. Like as the VCI, under a drought process, the TCI is close or equal to 0, and in wet conditions the VCI is close to 1 (Ling Tong Du et al., 2012).

Table 4.1: Classification of VCI, TCI and VHI drought conditions (Kogan, 2001).

VCI,TCI,VHI values	<10	10-20	20-30	30-40	40-60	> 60
Drought Conditions	Extreme	Severe	Moderate	Mild	Normal	Wet

The VCI show to be a good tool to determine drought and to measure time of its beginning, intensity, duration, dynamics, and impacts on vegetation. The VCI derived drought mix very well with those outlined from in-situ data. The VCI determines both well define, prolonged, widespread, intensive droughts and localize, short-term, and non well-define droughts. The TCI provides additional information about vegetation stress and also it indicates whether stress is owing to dryness or excessive wetness. The TCI improves VCI-derived drought assessments and the mix of these two indices, TCI and VCI should be employed as a tool to monitor both excessive wetness and drought (F. N. Kogan, 1995).

4.4 Vegetation Healt Index (VHI)

There are different methods to measure drought. During drought periods there is less soil moisture accessibility and a notable rise in temperature of leaves. The Land Surface Temperature (LST) measures the energy balance at the earth’s surface and Normalized Difference Vegetation Index (NDVI) calculates the amount of vegetation and its condition per pixel base. The NDVI and LST calculate the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI) to measure the vegetation stress and temperature stress according to Kogan (1990). Vegetation

Health Index (VHI) is considered as the drought measurement which is addition of both VCI and TCI. But VHI needs a long term data sets and there are some issues in determining the ratio between TCI and VCI. Highly vegetated areas maintain transpiration, when the surface becomes drier, but poorly vegetated locations are sensible in LST owing to the inadequacy of evaporative water (Higuchi, 2005). The mix of LST and NDVI by the scatter plot resulted in a triangular shape (Carlson et al., 1994; Gillies and Carlson, 1995; Gillies et al., 1997). The slope of the LST/NDVI curve related to the soil moisture conditions (Carlson et al., 1994; Gillies and Carlson, 1995; Gillies et al., 1997; Goetz, 1997; Goward et al., 2002) and the evapotranspiration of the surface (Boegh et al., 1998). The remote sensing-based Vegetation Health Index (VHI), develop from Advanced Very High Resolution Radiometer (AVHRR) imagery and it has been widely used in global drought monitoring because of the large area coverage offered by this polar orbiting system (Kogan, 1997) **(4.3)**.

$$VHI = 0.5\ (VCI + TCI) \qquad \textbf{(4.3)}$$

The TCI indicates areas that are hotter than usual and the VCI's normalized NDVI anomalies identify areas where vegetation is more or less dense than usual. VHI reflects both vegetation cover and temperature anomalies and also it has been widely applied for the early drought warning, monitoring of crop yield and production, and assessment of irrigated areas and extreme wetness (Karnieli et al., 2010). The five classes of VHI that show agricultural drought (Kogan 2001, Bhuiyan et al., 2001) are shown in Table 4.2. According to Kogan (2001) in VHI calculation, an equal weight has been assumed for both VCI and TCI, since moisture and temperature contribution during the vegetation cycle is currently not known.

Table 4.2: VHI drought classification schemes (Kogan, 2001).

VHI VALUES	Agricultural drought classes
< 10	Extreme drought
< 20	Severe drought
< 30	Moderate drought
< 40	Mild drought
>40	No drought

5. RESULTS AND DISCUSSION

5.1 Drought process monitored by VCI, TCI and VHI

In this study, I try to determine drought conditions in Turkey between January 2004 and December 2013 by TCI (Temperature Conditions Index), VCI (Vegetation Condition Index) and VHI (Vegetation Health Index). For this purpose, I downloaded satellite images from the earth explorer site. First of all, I choose four points to cover boundaries of Turkey and then downloaded Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) data from this web-site. For downloading the satellite images that related to LST and NDVI, I carry out items that mentioned in below. The NASA Lpdaac collection is chosen from the data set option. After that modis land surface temp and emiss selected. At least select MODIS MOD11A2 (terra- modis, moderate resolution imaging spectroradiometer). MODIS 11A2 taken one image every eighth day, therefore this satellite takes four images in one month. Because the study areas are too large I forested to four images to cover all areas of Turkey, which they are in Hierarchical Data Format (HDF) as shown in figure 5.1. Some of these satellite images have not pixel values may it can be because of weather conditions like as cloudy weather or etc. But I have to use this satellite image because of the specified data we have just one image.

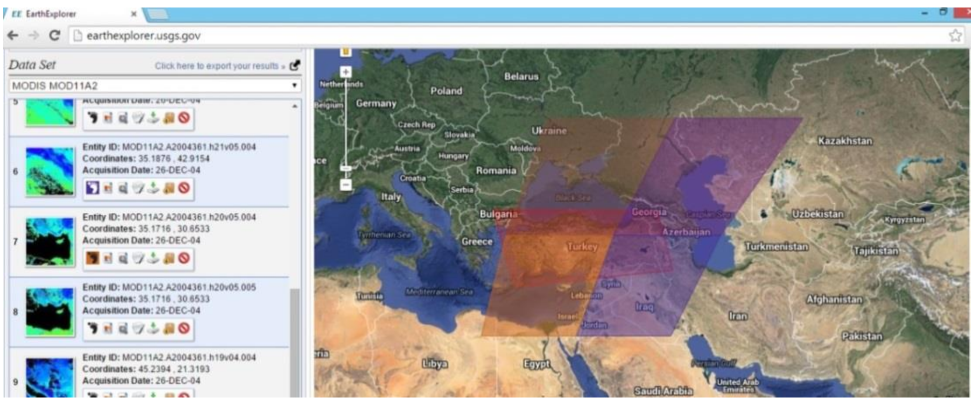


Figure 5.1: LST and NDVI downloaded from earth explorer.

(http://earthexplorer.usgs.gov/)

In this study, Terra-MODIS (moderate resolution imaging spectroradiometer) images of Turkey received in time interval of January 2004 - December 2013 was used to create different drought indices to analyze the drought conditions within the defined period. The Terra MODIS monthly composite NDVI with 1 km resolution (MOD13A3, collection v005) was downloaded from the EarthExplorer site for the period of January 2004 – December 2013. Healthy vegetation has a low reflectance in the visible portion of the electromagnetic spectrum owing to absorption by chlorophyll and other pigments, and the internal reflectance by the mesophyll spongy tissue of a green leaf because of high reflectance in the NIR. NDVI can be calculated as the ratio of red and the NIR bands of a sensor system and its values range from −1 to +1. Healthy vegetation is represented by high NDVI values between 0.05 and 1, because of high reflectance in the NIR portion of the electromagnetic spectrum. But, water bodies yield negative values of NDVI because nonvegetated surface has negative values of NDVI. Bare soil areas are closest to 0 due to high reflectance in both the NIR and visible portions of the electromagnetic spectrum. Terra MODIS eight-day compound LST with 1 km resolution (MOD11A2, collection v005) from January 2004 to December 2013 was downloaded from the same website as NDVI. In accordance with temporal resolution (monthly) of NDVI the monthly values of LST are calculated weighting with the number of days belonging to each month based on eight-day LST provide metadata after masking the fill and missing values and LST values in the range of degrees Celsius (° C) unit.

In this research, I created three indexes, including Temperature Condition Index (TCI), Vegetation Condition Index (VCI) and Vegetation Health Index (VHI). NDVI and LST to calculate respectively (VCI) and (TCI) to measure the vegetation stress and temperature stress, then calculated VHI from TCI and VCI. For created this three index there are several methods, but I used IDL (programming language). IDL, is abbreviation for Interactive Data Language, is a programming language used for data analysis. It is popular in particular areas of science, such as astronomy and medical imaging. For this purpose, first of all from pro read_ lst_1 combine four images into one image and then crop images for Turkey. Also from the this part I converted Fahrenheit to Celsius because LST values in the range of degrees Celsius

(° C) unit. Then from the pro read_lst_all, I calculated temperature condition index (TCI). Thus, the TCI formula was modified as the following expression **(5.1)**.

$$TCI = \frac{LST_{max} - LST}{LST_{max} - LST_{min}} \tag{5.1}$$

Where LST, LST_{max} and LST_{min} are the values of LST, maximum LST and minimum LST of each pixel respectively in the same month during the study period of January 2004– December 2013.

Like as the VCI, under a drought process, the TCI is close or equal to 0, and in wet conditions the VCI is close to 1. Methods of creating a Vegetation Condition Index (VCI) like as the Temperature Condition Index (TCI). From the pro read_ndvi_1 combine four images into one image after that cropped image for Turkey. Then I created a Vegetation Condition Index from the pro read_ndvi_all.

The VCI is used to estimate the weather impact on vegetation and it quantifies the weather component. The NDVI is between 0 and 1 which 0 for minimum NDVI and 1 for the maximum for each grid cell and week. It is defined as **(5.2)**.

$$VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \tag{5.2}$$

Where NDVI, $NDVI_{max}$, and $NDVI_{min}$ the smoothed weekly NDVI, multi-year maximum NDVI and multi-year minimum NDVI, respectively, for each grid cell. VCI changes from 0 to 1, and sometimes the values of VCI are represented in percent's ranging from 0 to 100. Like as the VCI, under a drought process, the TCI is close or equal to 0, and in wet conditions the VCI is close to 1. The VCI show to be a good tool to determine drought and to measure time of its beginning, intensity, duration, dynamics, and impacts on vegetation. The VCI derived drought mix very well with those outlined from in-situ data. The VCI determines both well define, prolonged, widespread, intensive droughts and localize, short-term, and non well-define droughts. The TCI provides additional information about vegetation stress and also it indicates whether stress is owing to dryness or excessive wetness. The TCI improves VCI-derived drought assessments and the mix of these two indices, TCI and VCI should be employed as a tool to monitor both excessive wetness and drought.

At least for calculating the vegetation health index, I used the PRO VHI part. It is defined as **(5.3)**.

$$VHI = 0.5\ (VCI + TCI) \quad \textbf{(5.3)}$$

The last index is a Vegetation Health Index (VHI). Vegetation Health Index (VHI) is considered as the drought measurement which is addition of both VCI and TCI. But VHI needs a long term data sets and there are some issues in determining the ratio between TCI and VCI. The remote sensing-based Vegetation Health Index (VHI), develop from Advanced Very High Resolution Radiometer (AVHRR) imagery and it has been widely used in global drought monitoring because of the large area coverage offered by this polar orbiting system. The TCI indicates areas that are hotter than usual and the VCI's normalized NDVI anomalies identify areas where vegetation is more or less dense than usual. VHI reflects both vegetation cover and temperature anomalies and also it has been widely applied for the early drought warning, monitoring of crop yield and production, and assessment of irrigated areas and extreme wetness. All codes that writing in IDL program are in the appendix C.

5.1.1 2004 TCI, VCI and VHI maps

The first Index that has been investigated is TCI, which gives information about temperature and tempeature anomaly. A legend in this index is between 0 and 1 like as VHI, that under 0.1 show the very excess hot weather, between 0.1 and 0.2 shows excess hot weather, between 0.2 and 0.3 shows Moderate weather, between 0.3 and 0.4 shows Mild weather, between 0.4 and 0.6 and upper 0.6 shows normal weather. When I look at to the 12 months of 2004, it is clear that in January, February and March had hot days. Next index is about the vegetation that value of this index is between 0 and 1 (0 is low vegetation, 1 is high vegetation). In 2004 I can say that, the first half of the year had better condition than the second half of the year. VHI's legend that obtain from VCI and TCI, are shown beside each photo. When I consider 2004, between 0 and 0.1 also between 0.1 and 0.2 intense drought can be seen, also have normal months. Between the months that does not include high amount rain and intense hot weather I can mention to the May, October, November and December.

5.1.2 2005 TCI, VCI and VHI maps

Approximately in the early day of the January, weather a little hotter than the past years, but this not much cool weather can be observed in February month, and on some days of March and April value of 0.1 as a hot weather can be observed. For the one of the coolest days of the year I can mention to an earlier day of June therefore again in middle of Aguste hot weather can be felt. Another good example for cool weather are the last days of August and also on 30th of September most areas of Turkey feel high temperature and also in the last month of year high temperature is clear. Next index is VCI, The months that low amount of vegetation has been observed are March and April and about VHI index, in January, Black sea area have a normal temperature and in February temperature increase, but in March in the inside area of Turkey, brightness is visible. I can mention in June as a month with normal temperature and without draughts and this condition continues until October.

5.1.3 2006 TCI, VCI and VHI maps

In the last 10 years Turkey observes two drought period, the firs one start from 2006. This drought period, is observed from November and December of 2006 until December of 2008. This long period between 2007 and 2008 clearly can be observed. In these years, decreasing in amount of rainfall in the most areas of Turkey was less than usual. Hot weather in January and February will be felt very well and this condition for first days of March became a little better, but in the last days of this month, its condition back to the previous condition. In the second half of the year conditions become better, but in the last two months of the year the intensely hot weather is visible. About VCI index, at the first mouths of the year vegetation is visible. In the March, vegetation is visible in all areas of Turkey. In August, that the hottest month of the year, the amount of vegetation decrease. Finally from the result that obtain from VHI index, approximately in the first months of the year, intense droughts is not visible, but as mentioned above, Turkey’s droughts start from the December.

5.1.4 2007 TCI, VCI and VHI maps

As it is mentioned in the 2006 year, Turkey's drought period start from this year and continued in 2007. During the first half of the year intense hot weather is very clear, this condition becomes a little better for the June, whereas of secondary half of this month hot days are visible. Additionally, these inappropriate conditions continue until 2007. About VCI index, vegetation condition in the first half of the year a little better than second half of the year. Whereas VHI index show a hot year without rainfall for Turkey, Furthermore hot weather and drought visible for all months of 2007.

5.1.5 2008 TCI, VCI and VHI maps

As mentioned Turkeys drought period starts from 2006 and continued until 2008**.** Approximately in all months of the year drought and low amount of vegetation are visible. This low vegetation in all months of the year, especially it is visible in the second half of the year. The concept of low amount of VHI index is intensely hot, that approximately observe in all mouths of the years for example January and February. Approximately 2008 year was a low rainfall and hot year**.**

5.1.6 2009 TCI, VCI and VHI maps

TCI index showed that January hotter than usual, but after a while, condition becomes better as weather in the first day of the May seen relatively better. In the second half of the year, most months have relatively good weather. In addition the excess hot weather is not visible. Images that related to VCI, approximately show vegetation condition for all mouths. Amount of VCI is between 0 and 1**.** A value near to one shows high vegetation and also the value of VHI index is between 0 and 1 that in the value over 0.4 there isn't any drought. In addition, in the most image of VHI, the value of index is over 0.4 and near to one.

5.1.7 2010 TCI, VCI and VHI maps

TCI index images, value of 0.1 and 0.2 is visible for January, February, 22th And 30th of March and also the fifth and the thirteenth days of August, the sixth of September, the first, the ninth and the seventeenth days of November. In addition the third and the nineteenth days of December. In images of VCI index, the value of index at most of the month is near to one and this show high vegetation days. The value of the VHI index in most of the months is higher than 0.4 and this value shows appropriate weather, rainfall and no drought. In addition the best examples are February, March, July and October.

5.1.8 2011 TCI, VCI and VHI maps

In TCI index, January can be observed with low rainfall and unusually hot weather and this condition for another months is visible. While in the next month condition become better, and also most areas of Turkey are visible with blue color (over 0.5) that show days without drought. VCI index value is between 0 and 1 and if the value of index become near to one it show high vegetation condition. When images of this index checked out can see most parts of Turkey in vegetation condition even in August. With respect to VHI images I obtain that most areas of Turkey have the value over 0.4 that means this year is a year without drought.

5.1.9 2012 TCI, VCI and VHI maps

When look the results of TCI index in ten years, the majority of first months have hot weather and values of TCI index are below 0.2, but in the next months, for example in May and after that values of TCI over 0.4 and even more than 0.4. The begging of 2012 year, first months have low vegetation and values of the VCI index over 0.3 and even closer to one which is the meaning of high vegetation. Last one, when investigation values of VHI index, can see images of this index have values below 0.3 and 0.4 in the first month of 2012 year. In fact, 2012 year is a second period, drought of turkey between January 2004 until December 2013. Center Anatolia and eastern Anatolia over turkey had meteorological drought in this year. Drought in this area with drought in the Black Sea region in the summer to start a serious drought in 2013 year.

5.1.10 2013 TCI, VCI and VHI maps

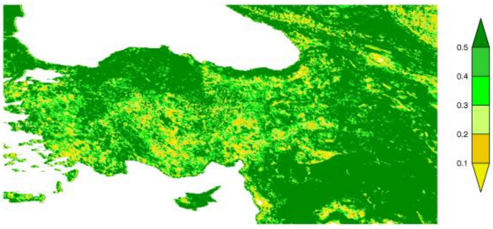
TCI show that value of this index in most months of the year is lower than 0.3. The value of TCI in fifteenth of April in most areas of Turkey upper than 0.3. However, in all of the months I can fill the low value of the index. For the visiting amount of vegetation in this year I should use VCI index. Value of this index in the early months near to 1 but in the June and July decrease. Therefore, decreases process continues in other months. The value of VHI in the early months, but after the

October value of the index decrease so I can say in the autumn and winter amount of rainfall decrease. It is worth noting in the 2007 and 2008 amount of rainfall rather lower than 2013. Therefore, drought in the 2013 lower than that years. In the fact this drought starts from 2012 and in some inner area of Anatoly and Eastern Anatoly, meteorological drought is visible. Drought in these areas with drought in summer in the Blach sea area causes of starting a serious drought in 2013.

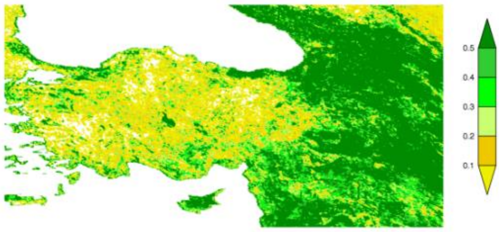
5.2 Comparisone 2004 and 2007 VCI and VHI maps

In this part, I compare July, August and September 2004 and 2007 VCI maps. VCI index is about the vegetation that value of this index is between 0 and 1 (0 is low vegetation, 1 is high vegetation). Value of VCI is closer to 1 in the most parts of Turkey in July 2004, especially in the Black sea region. This situation continues on August 2004 and many parts of Turkey have green color which is mean of high vegetation. Black sea region of Turkey has high value VCI and high vegetation value in July, August and September 2004. VCI values are closer to 1 and many parts of Turkey have Yellow color in July, August and September 2007. VCI value is below 0.1 and 0.2 in many parts of Turkey in July 2007 when compares it whit July 2004. Black sea region of Turkey has a Yellow color and values of VCI in this part is below 0.1 and 0.2 which is mean that Turkey has low rainfall and low vegetation values in July, August and September months to 2007 year. So, when compare same months of two years, 2004 has high vegetation values than 2007. A legend in VHI is between 0 and 1 like as VCI, that under 0.1 show the very excess hot weather, between 0.1 and 0.2 shows excess hot weather, between 0.2 and 0.3 shows Moderate weather, between 0.3 and 0.4 shows Mild weather, between 0.4 and 0.6 and upper 0.6 shows normal weather. The value of VHI is closer to 1 in many parts of Turkey in 2004 like in VCI value in July. Black sea region of Turkey has blue color which means this part has high vegetation in July, August and September 2004 like VCI. However, VHI values have closer to 0 and most parts of Turkey Yellow color in 2007. VHI value is below 0.1 and 0.2 like VCI in 2007. Black sea has high VCI and VHI values in 2004 but when compare it with 2007, it has low VCI and VHI values.

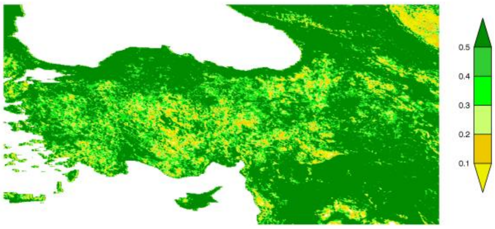
JULY 2004 VCI MAP



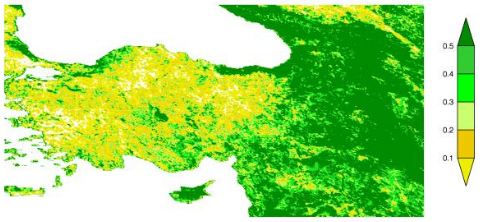
JULY 2007 VCI MAP



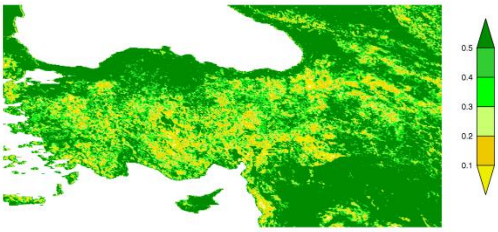
AUGUST 2004 VCI MAP



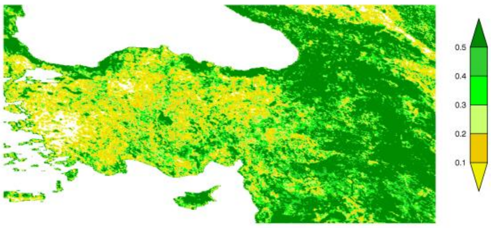
AUGUST 2007 VCI MAP



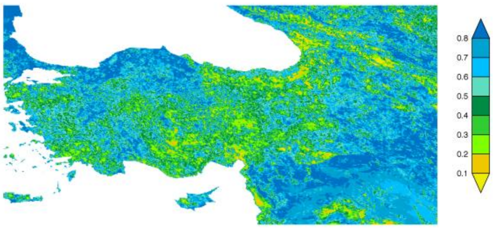
SEPTEMBER 2004 VCI MAP



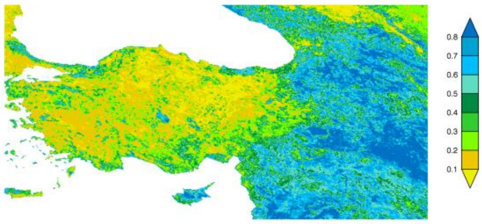
SEPTEMBER 2007 VCI MAP



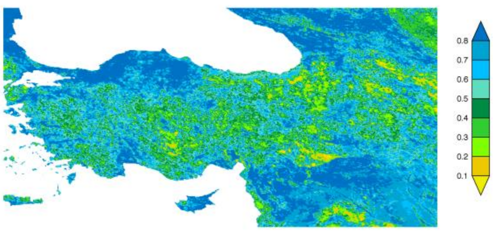
JULY 2004 VHI MAP



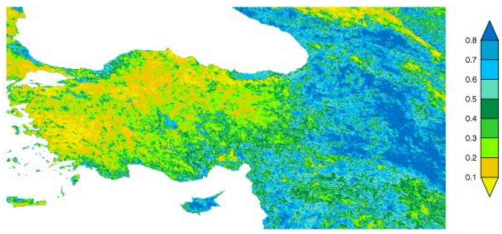
JULY 2007 VHI MAP



AUGUST 2004 VHI MAP



AUGUST 2007 VHI MAP



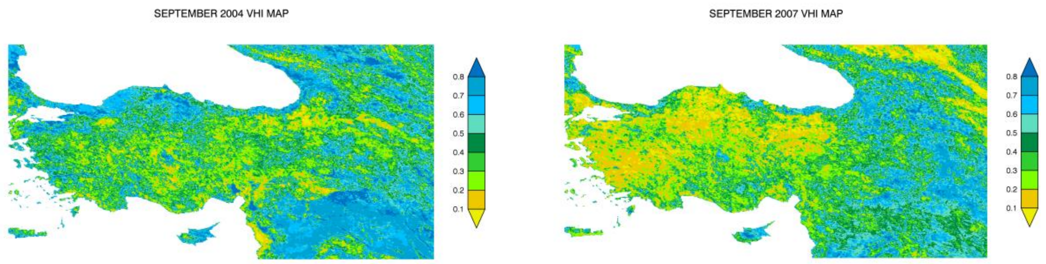


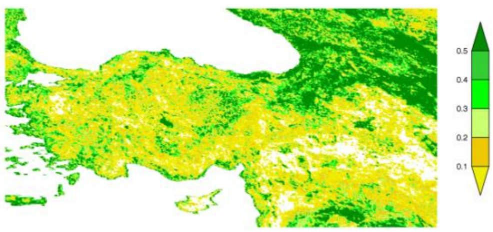
Figure 5.2: July, August and September 2004 and 2007 VCI and VHI maps

5.3 Comparisone 2008 and 2010 VCI and VHI maps

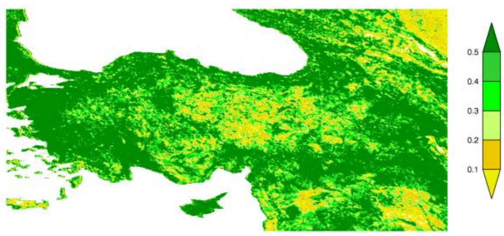
In the second part, I compare July, August and September 2008 and 2010 VCI and VHI maps. 2008 is one of the year that the amount of vegetation is low and in the otherwise 2010 is the year that the amount of vegetation is high in the most parts of Turkey, because of that, I select this two years and compare VCI and VHI maps of these two years. Value of VCI is closer to 1 in the most parts of Turkey in July 2010, especially in the Black sea region. This situation continues on August 2010 and many parts of Turkey have green color which is mean of high vegetation. Black sea region of Turkey has high value VCI and high vegetation value in July, August and September 2010. But, VCI values are closer to 1 and many parts of Turkey have Yellow color in July, August and September 2008. VCI value is below 0.1 and 0.2 in many parts of Turkey in July 2008 when compares it whit July 2010. Black sea region of Turkey has a Yellow color and values of VCI in this part is below 0.1 and 0.2 which is mean that Turkey has low rainfall and low vegetation values in July, August and September months to 2008 year. So, when compare same months of two years, 2010 has high vegetation values than 2008. A legend in VHI is between 0 and 1 like as VCI, that under 0.1 show the very excess hot weather, between 0.1 and 0.2 shows excess hot weather, between 0.2 and 0.3 shows Moderate weather, between 0.3 and 0.4 shows Mild weather, between 0.4 and 0.6 and upper 0.6 shows normal weather. The value of VHI is closer to 1 in many parts of Turkey in 2010 like in VCI value in July. Black sea region of Turkey has blue color which means this part has high vegetation in July, August and September 2010 like VCI. However, VHI values have closer to 0 and most parts of Turkey Yellow color in 2008. VHI value is below

0.1 and 0.2 like VCI in 2008. Black sea and Istanbul have high VCI and VHI values in 2004 but when compares it with 2008, it has low VCI and VHI values.

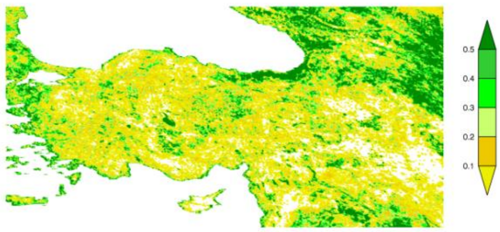
JULY 2008 VCI MAP



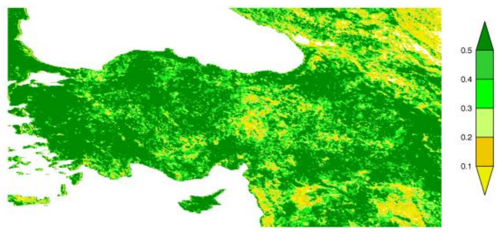
JULY 2010 VCI MAP



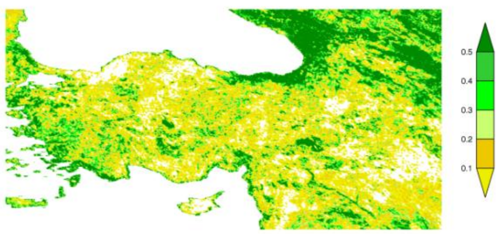
AUGUST 2008 VCI MAP



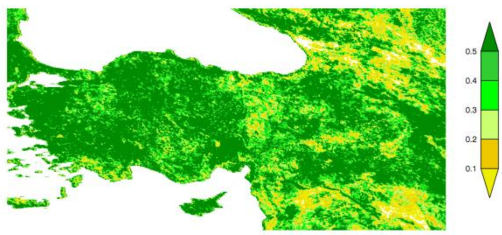
AUGUST 2010 VCI MAP



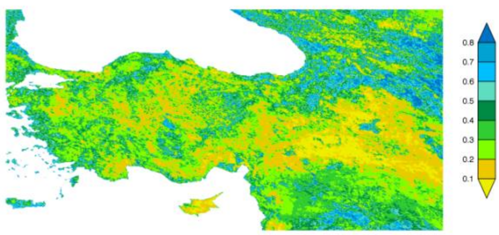
SEPTEMBER 2008 VCI MAP



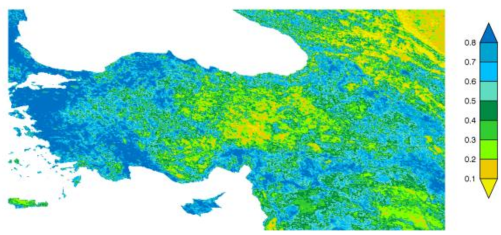
SEPTEMBER 2010 VCI MAP



JULY 2008 VHI MAP



JULY 2010 VHI MAP



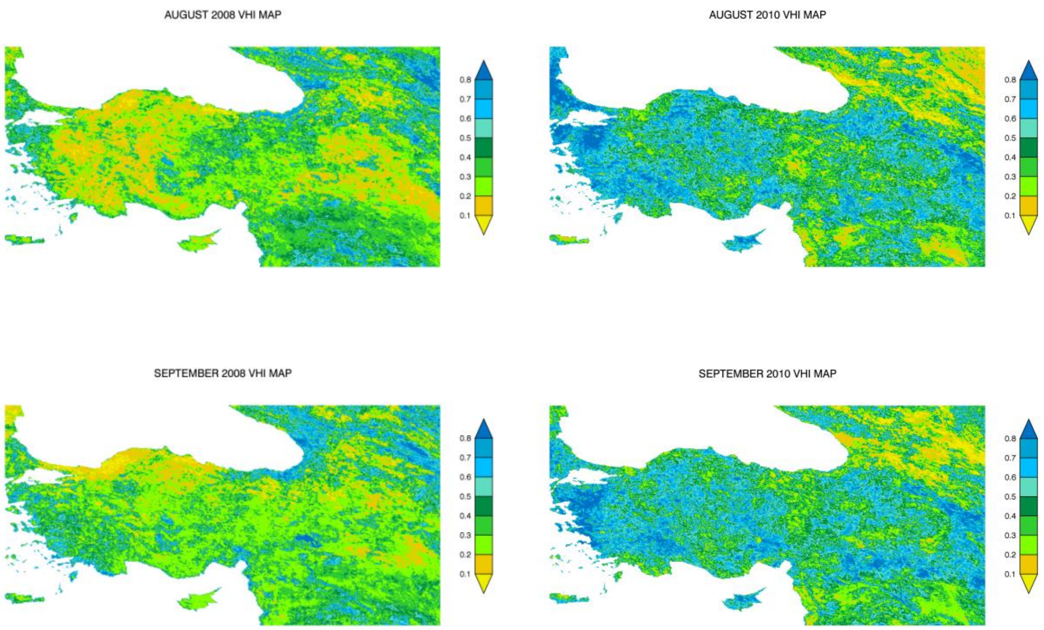


Figure 5.3: July, August and September 2008 and 2010 VCI and VHI maps

5.4 2013 VHI map

In this section, annual VHI map of Turkey was created for 2013 in order to conduct a comparison withs 2013 SPI map. 2013 SPI map was obtained from (Turkish State Meteorological Service). *The standardized precipitation index (SPI), which was proposed by McKee in 1993, can monitor the drought in different time scale. It change sensitively in response to drought, has strong space-time adaptability, the necessary information is easy to get and could calculate in a simple wa (Li Yan-jun et al., 2012).* SPI and VHI methods are different each other. Because, *SPI is an in situ drought index, the spatial drought conditions need to be estimated using spatial interpolation techniques (Lingtong Du et al., 2012)*, but in VHI method use VCI and TCI, which VCI is about amount of vegetation and TCI is about land surface temperature. However, to compare two methods, similar legend values were used for VHI and SPI. A legend in VHI index is between 0 and 1, that under 0.1 show the very excess hot weather (black), between 0.1 and 0.2 shows excess hot weather (brown), between 0.2 and 0.3 shows Moderate weather (red), between 0.3 and 0.4 shows Mild weather (orange), between 0.4 and 0.6 and upper 0.6 shows normal weather (yellow, white, light green, green and blue) and legend in SPI is between -

0.2 and 2.0, that under -0.2 show the exceptionally dry (black), between -1.60 and -1.99 show extremely dry (brown), between -1.30 and -1.59 show severely dry (red), between -0.80 and -1.29 show moderately dry (orange), between -0.51 and -0.79 show abnormally dry (yellow), between 0.50 and -0.50 show near normal (white), between 0.51 and 0.79 show abnormally mosit (light green), between 0.80 and 1.29 show modereately mosit (green), between 1.30 and 1.59 show very mosit (dark green), between 1.60 and 1.99 show extremly mosit (blue) and above 2.0 show exceptionally mosit (purple). For example, values of VHI is below 0.2 and below 0.3 in Istanbul, because this region has combination of brown, red and orange color which is mean this region has low vegetation in 2013. Like VHI, SPI values is low in Istanbul and this region has black, brown colors which is mean this region has low rainfall in 2013. Another region is Black sea. VHI and SPI have low values in this region, because this region has combinations of brown, red and orange color in VHI map and black, brown color in SPI map. Ege region is good exmple for high values of SPI and VHI map, because this region has green color which is mean high vegetation in VHI and high amount of rainfall in SPI map in 2013.

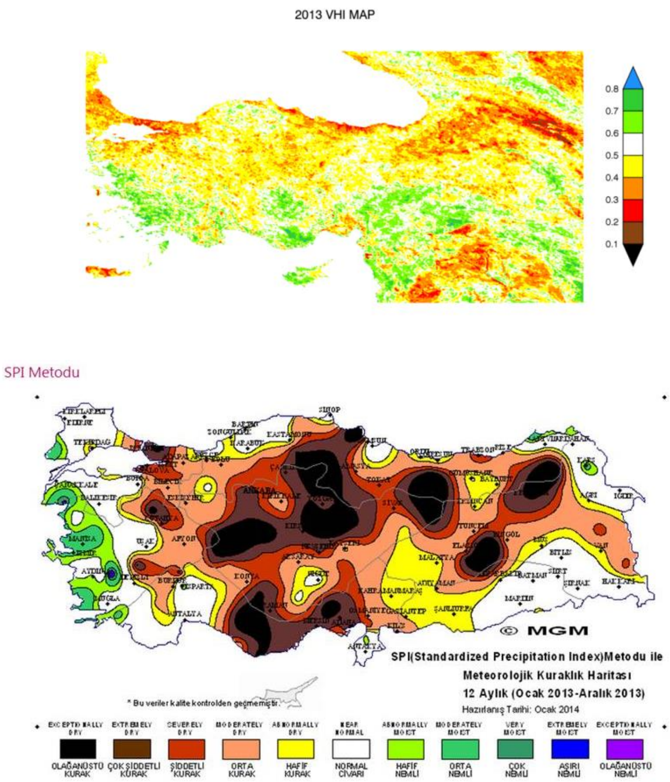


Figure 5.4: 2013 VHI and SPI map

6. CONCLUSION

Global warming is one of the most important environmental problems that humanity faces which might cause several adverse effects. Droughts are the one of the most important possible outcomes of global warming. Drought is a slow-moving and one of the major natural hazards when water scarcity occurred for a period of time (months or years) as a result of insufficient precipitation, high evapotranspiration, and high usage of water resources. It has significant adverse effect on the socioeconomy, agriculture, and ecosystem.

There are meteorological and remote sensing based drought indices applied by many researchers from various disciplines in order to determine spatio-temporal distribution of droughts. Since remote sensing satellites could monitor large areas rapidly, accurately, periodically, and economically; they have been widely used to examine drought impacts. Products of one of the well known satellite system, MODIS, have been used for numerous research applications including mapping deforestation, identifying desertification, fire fuel estimation, burn scar identification, ecosystem evolution, invasive species potential, grazing impacts, and crop yield estimation, natural and non-natural disasters, such as floods and droughts in many areas setting a global and regional scale applications due to the its high temporal resolution. It had been observed that these drought and aridity phenomena, which are occurred in the entire Turkey, reached up to a critical limit not only in terms of agriculture and energy production but also irrigation, sanitation, other water supply management that includes other hydrologic systems and activities. Therefore, it is important to monitor drought conditions and their changes. Also, Monitoring droughts and understanding their impacts are important for mitigation and decision-making regarding to drought process. Remote sensing indices could be used for this aim. In this research, TCI (Temperature Conditions Index), VCI (Vegetation Conditions Index) and VHI (Vegetation Conditions Index) were applied to analyze drought conditions in Turkey between 2004 and 2013. Decrease in precipitation such as rain and snow, increase in air temperatures, evaporation, heat waves may cause occurance of droughts. In the last 10 years Turkey observes two drought periods, the first one start from 2006. This drought period, is observed from November and

December of 2006 until December of 2008. This long period between 2007 and 2008 clearly can be observed. In reality, when making a comparison, it can be noticed that the tendencies observed in seasonal and annual precipitation are not as powerful as the tendencies seen in weather temperatures. Precipitation changes, like it happens worldwide, occur in various shapes of changes and fluctuations together with changes which are indicated in frequencies and in amount of dry and wet seasons rather than long term tendencies.

The study of Türkeş (1996,1998,1999,2003,2008), Türkeş and Erlat (2003,2005) and Türkeş and Tatlı (2009) demonstrated that territorial variability of the precipitation changes is also powerful. The most affected regions in Turkey are Aegean, Mediterranean, Marmara and South-East Anatolia regions whereof this tendency of becoming arid (or drought tendency). When annual precipitation changes in the last 40 years, especially winter rainfalls, have been taken into consideration; the most drastic and the most widely spread precipitation terms and single years are 1971-1974, 1983-1984, 1989-1990, 2007-2008 and 1996 and 2001.

In these years, decreasing in amount of rainfall in the most areas of Turkey was less than usual. Increase in temperature values in January and February will be felt very well and this condition for first days of March became a little better, but in the last days of this month, its condition back to the previous condition. In the second half of the year conditions become better, but in the last two months of the year the intensely hot weather is visible. About VCI index, at the first mouths of the year vegetation is visible. In the March, vegetation is visible in all areas of Turkey. In August, that the hottest month of the year, the amount of vegetation decrease. Finally from the result that obtain from VHI index, approximately in the first months of the year, intense droughts is not visible, but as mentioned above, Turkey's droughts start from the December. As it is mentioned in the 2006 year, Turkey's drought period start from this year and continued in 2007. In the first half of the year intense hot weather is very clear, this condition become a little better for the June, whereas of secondary half of this month hot days are visible. Additionally, these inappropriate conditions continue until 2007. About VCI index, vegetation condition in the first half of the year a little better than second half of the year. Whereas VHI index show a hot year without rainfall for Turkey, Furthermore hot weather and drought visible for all months of 2007. As mentioned Turkeys drought period starts from 2006 and continued until 2008**.** Approximately in all months of the year drought and low amount of vegetation are visible. This low vegetation in all months of the year, especially it is visible in the second half of the year. The concept of low amount of VHI index is intensely hot, that approximately observe in all mouths of the years for example January and February. Approximately 2008 year was a low rainfall and hot year**.** The second drought year of Turkey is 2013. When look the results of TCI index in ten years, the majority of first months have hot weather and values of TCI index are below 0.2, but in the next months, for example in May and after that values of TCI over 0.4 and even more than 0.4. The begging of 2012 year, first months have low vegetation and values of the VCI index over 0.3 and even closer to one which is the meaning of high vegetation. Last one, when I investigation values of VHI index, I can see images of this index have values below 0.3 and 0.4 in the first month of 2012 year. In fact, 2012 year is a second period, drought of turkey between January 2004 until December 2013. I can see meteorological drought in center Anatolia and eastern Anatolia over turkey in this year. Drought in this area with drought in the Black Sea region in the summer to start a serious drought in 2013 year. TCI show that value of this index in most months of the year is lower than 0.3. The value of TCI in fifteenth of April in most areas of Turkey upper than 0.3. However, in all of the months I can fill the low value of the index. For the visiting amount of vegetation in this year I should use VCI index. Value of this index in the early months near to 1 but in the June and July decrease. Therefore, decreases process continues in other months. The value of VHI in the early months, but after the October value of the index decrease so I can say in the autumn and winter amount of rainfall decrease. It is worth noting in the 2007 and 2008 amount of rainfall rather lower than 2013. Therefore, drought in the 2013 lower than that years. In the fact this drought starts from 2012 and in some inner area of Anatoly and Eastern Anatoly, meteorological drought is visible. Drought in these areas with drought in summer in the Blach sea area causes of starting a serious drought in 2013.

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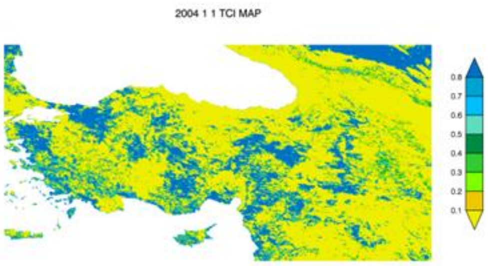
APPENDICES

APPENDIX A1: 2004 TCI, VCI and VHI Maps
APPENDIX A2: 2005 TCI, VCI and VHI Maps
APPENDIX A3: 2006 TCI, VCI and VHI Maps
APPENDIX A4: 2007 TCI, VCI and VHI Maps
APPENDIX A5: 2008 TCI, VCI and VHI Maps
APPENDIX A6: 2009 TCI, VCI and VHI Maps
APPENDIX A7: 2010 TCI, VCI and VHI Maps
APPENDIX A8: 2011 TCI, VCI and VHI Maps
APPENDIX A9: 2012 TCI, VCI and VHI Maps
APPENDIX A10: 2013 TCI, VCI and VHI Maps
APPENDIX B: VHI maps
APPENDIX C: IDL codes

APPENDIX A1


N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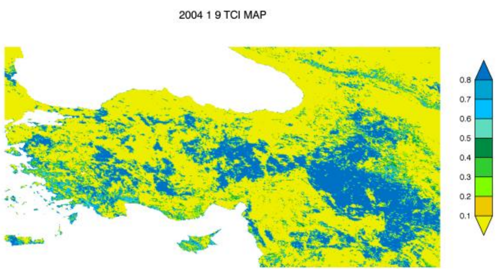
0.4
0.3
0.2
0.1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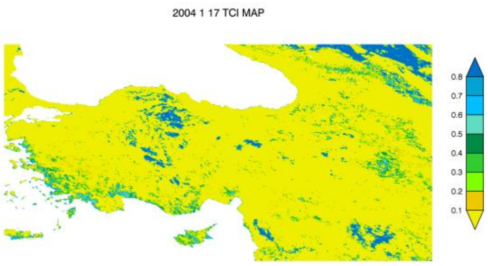
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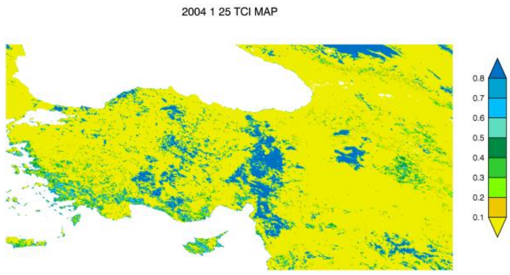
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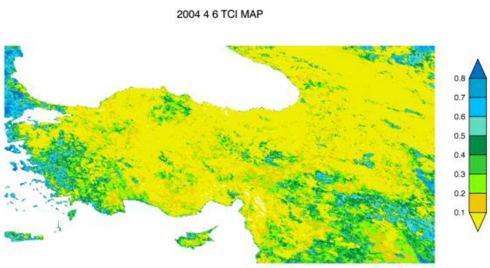
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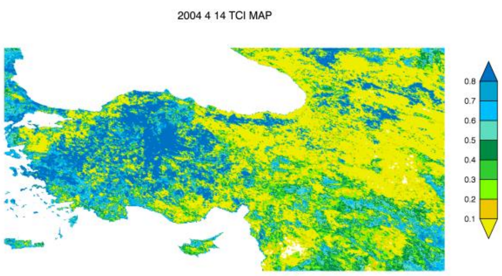
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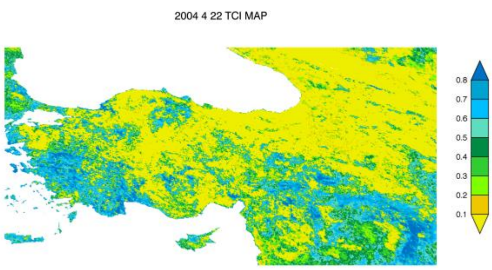
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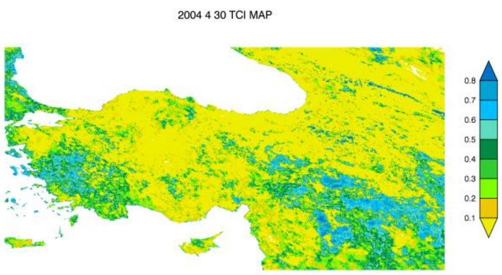
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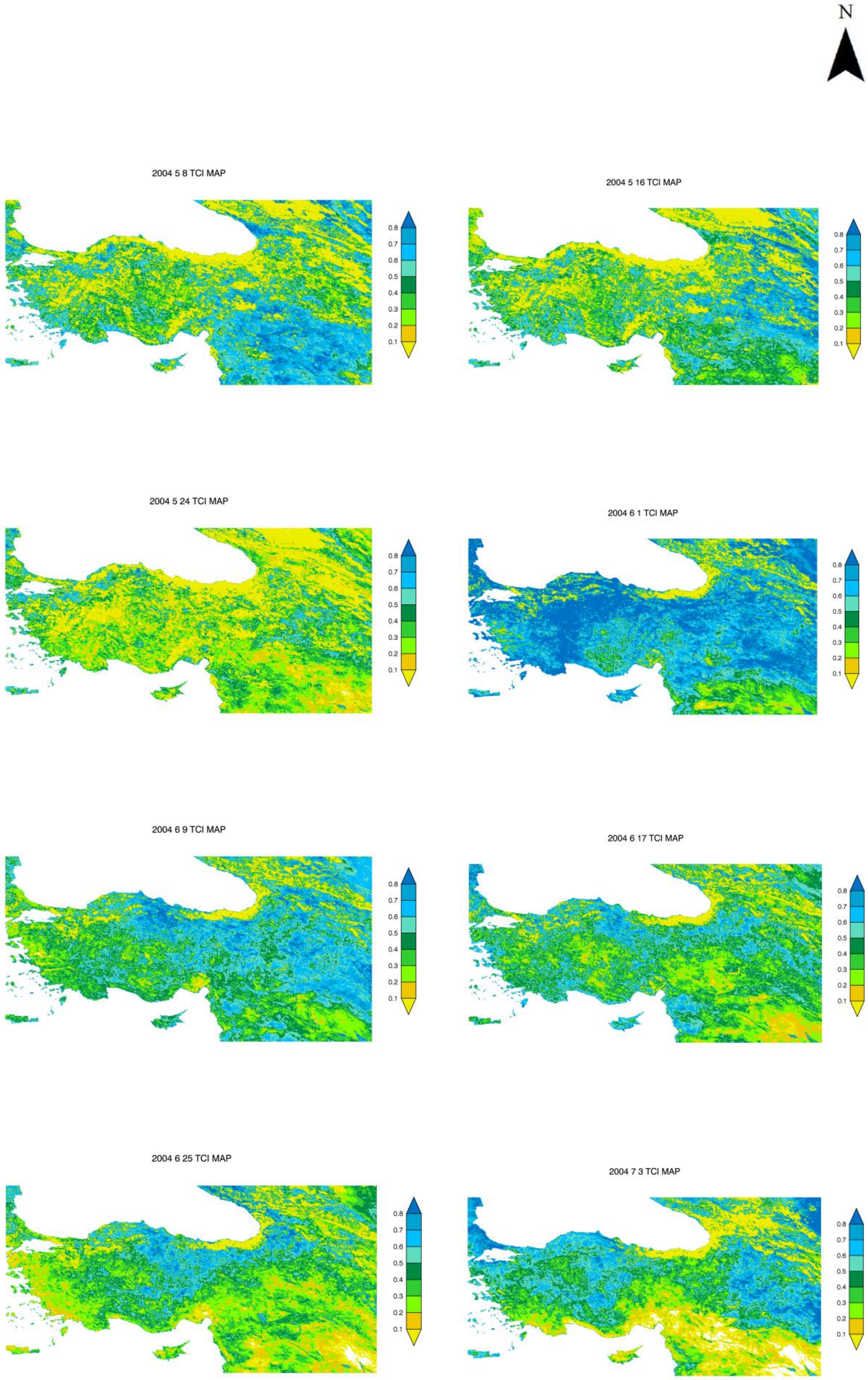
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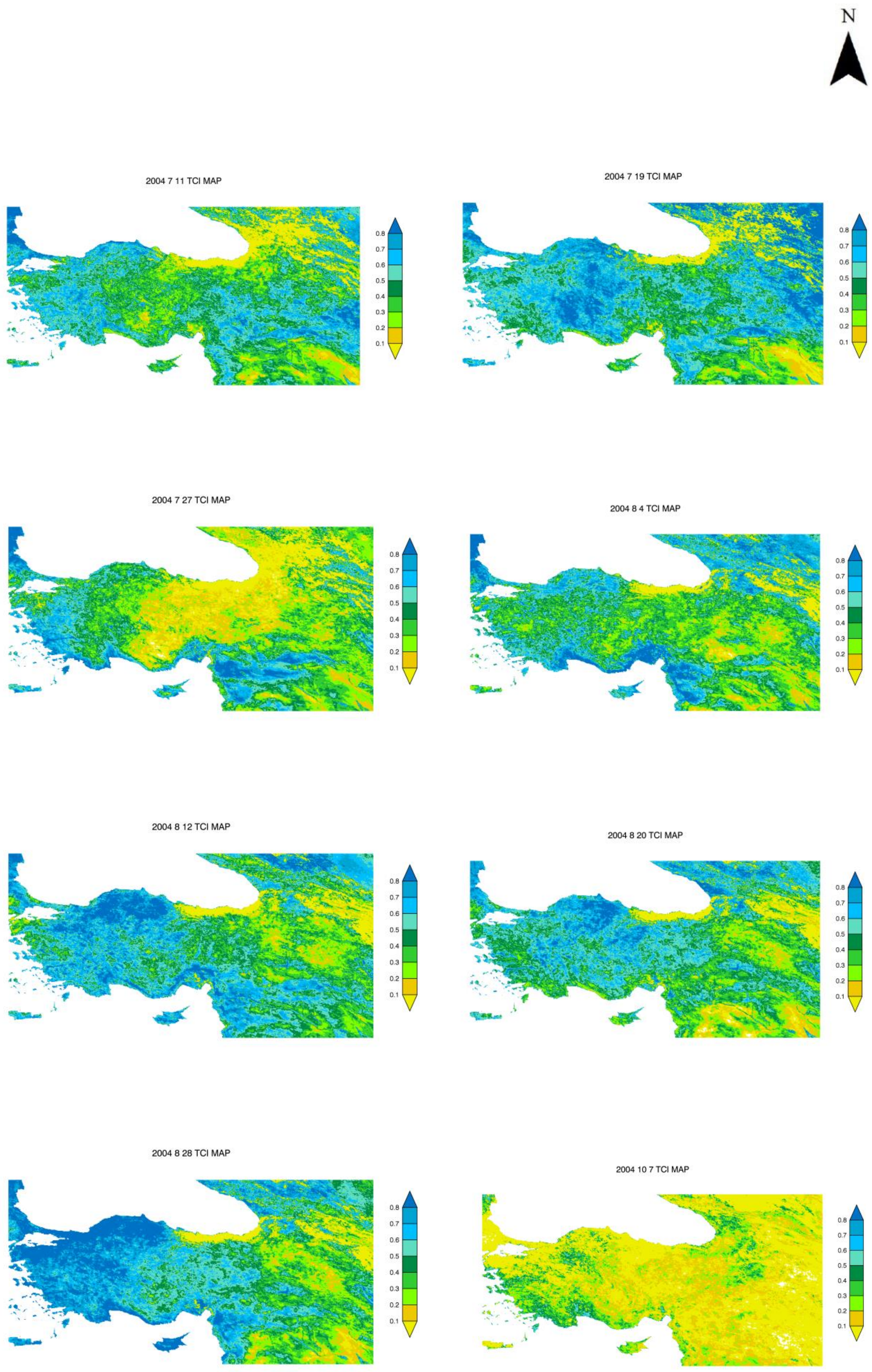
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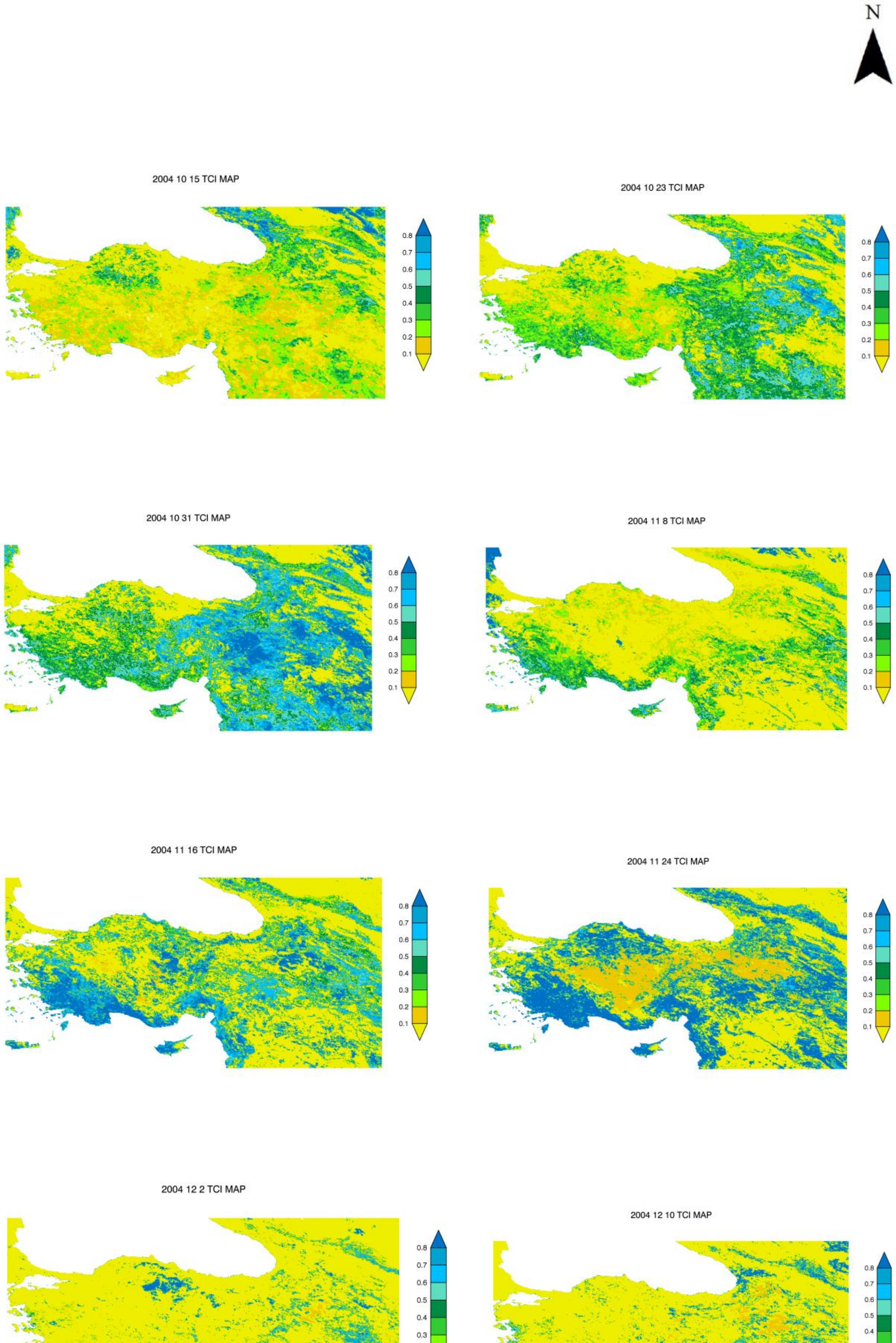
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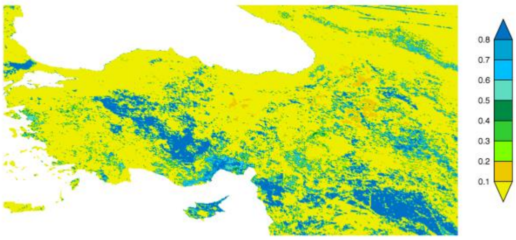
2004 12 18 TCI MAP



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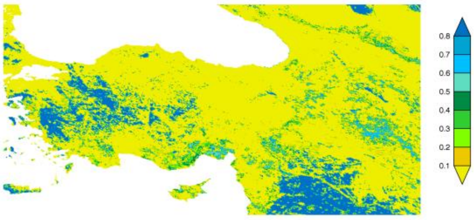

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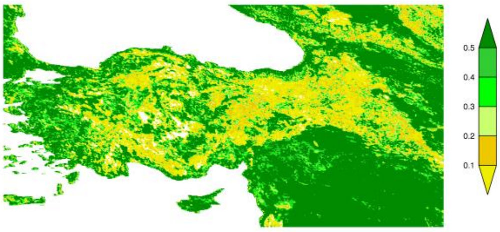

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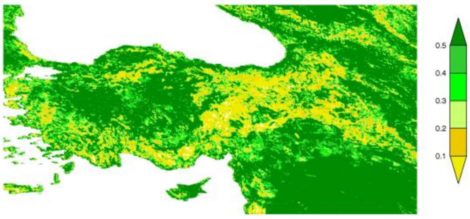

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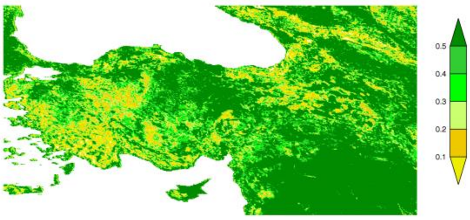

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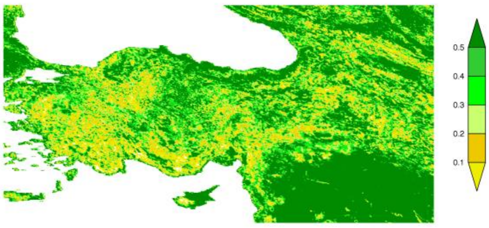

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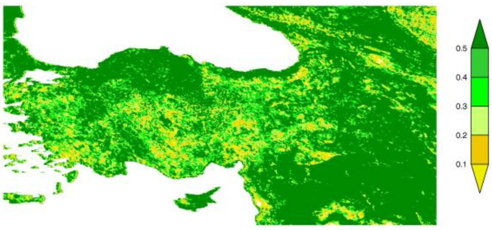

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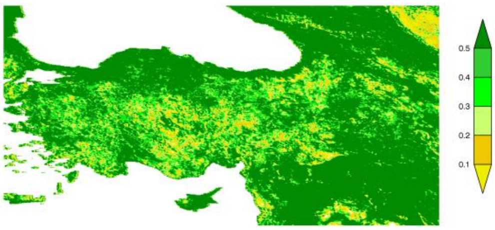

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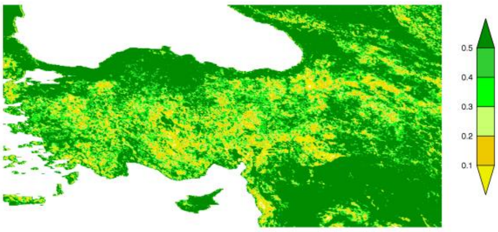

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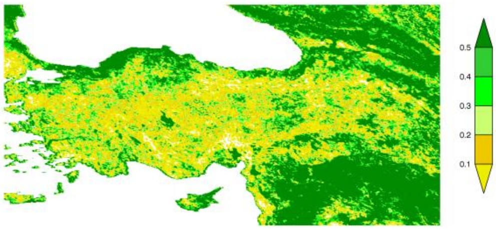

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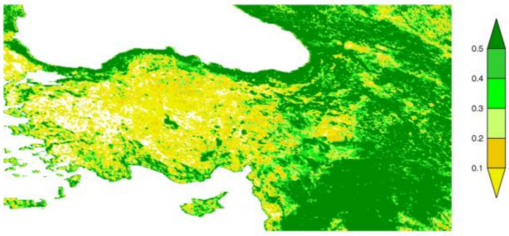

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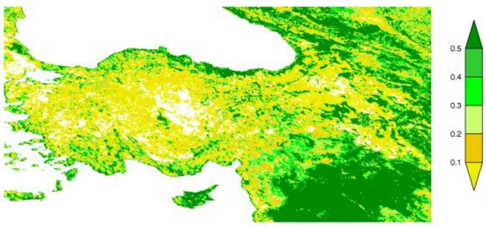
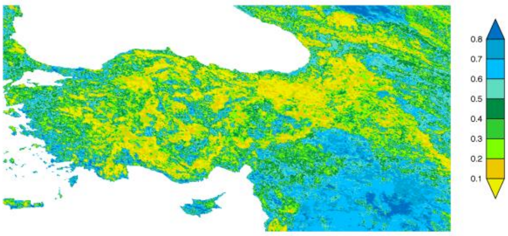


JANUARY 2004 VHI MAP



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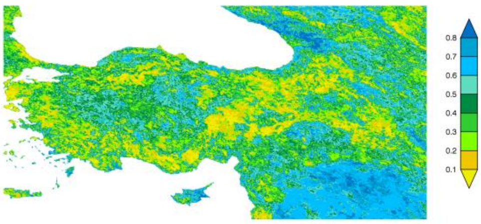

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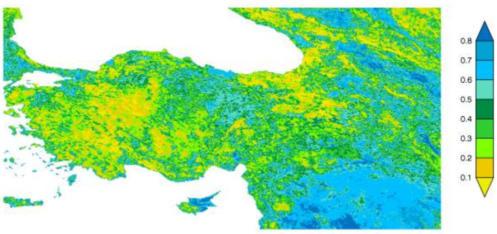

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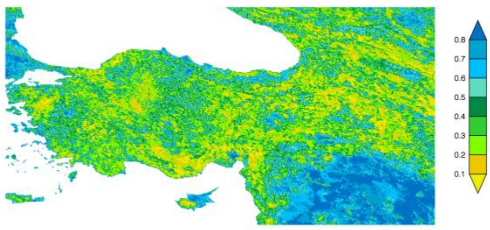

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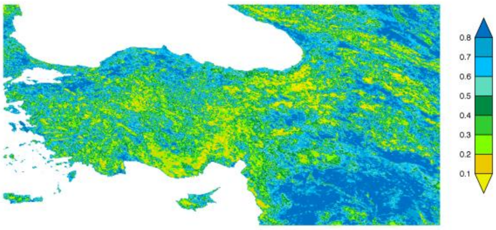

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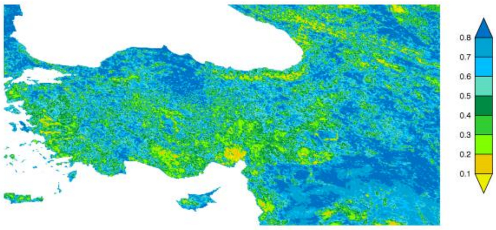
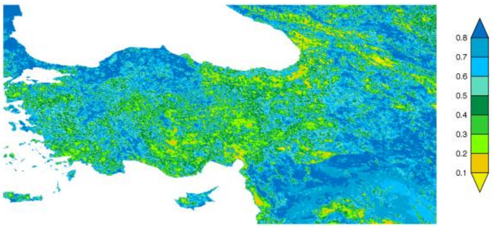
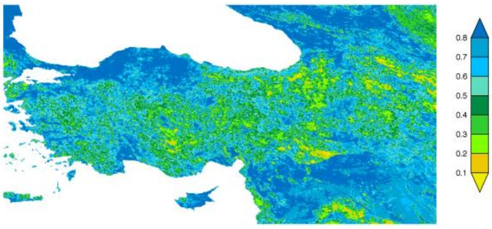


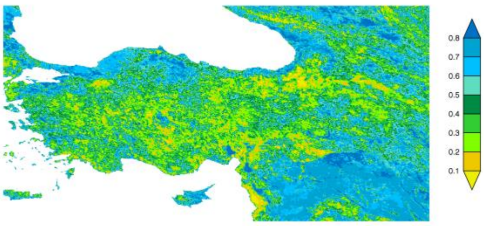
JULY 2004 VHI MAP



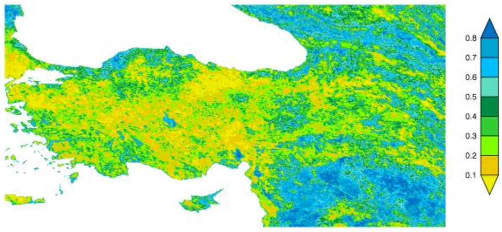
AUGUST 2004 VHI MAP



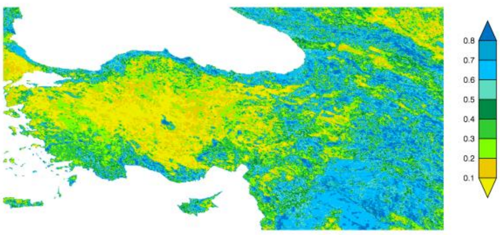
SEPTEMBER 2004 VHI MAP



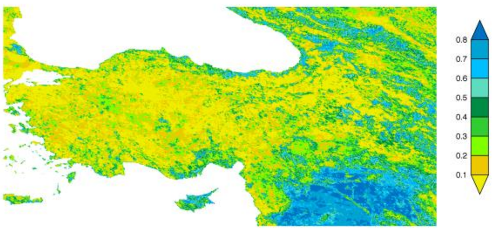
OCTOBER 2004 VHI MAP



NOVEMBER 2004 VHI MAP



DECEMBER 2004 VHI MAP

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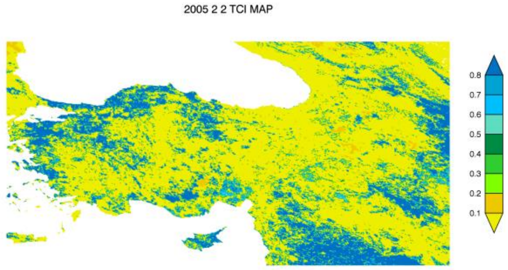
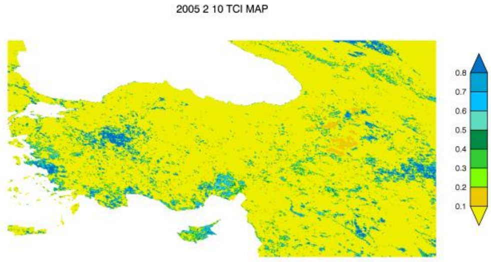
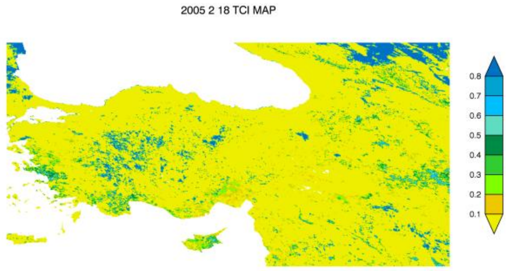
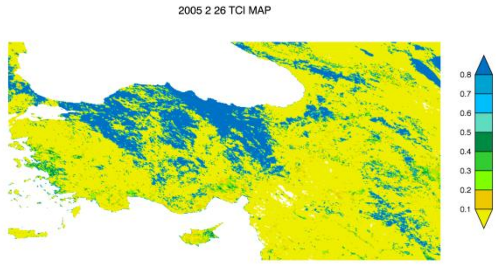
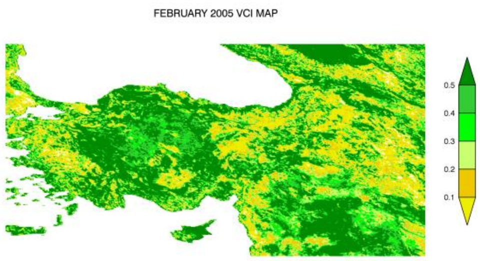
APPENDIX A2

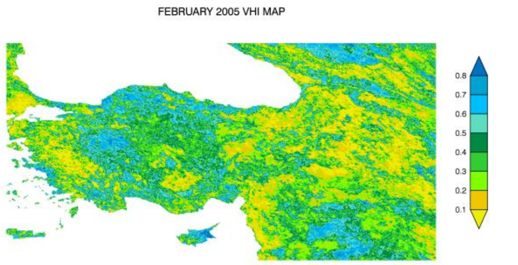

2005 2 2 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2005 2 10 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2005 2 18 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

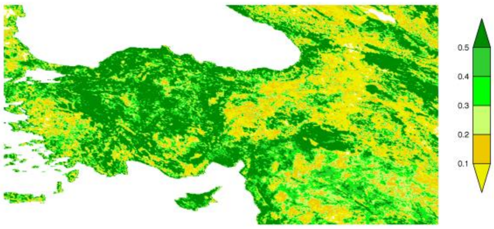

2005 2 26 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


FEBRUARY 2005 VCI MAP
0.5
0.4
0.3
0.2
0.1

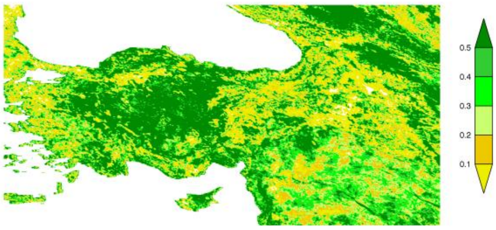

FEBRUARY 2005 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

APPENDIX A3

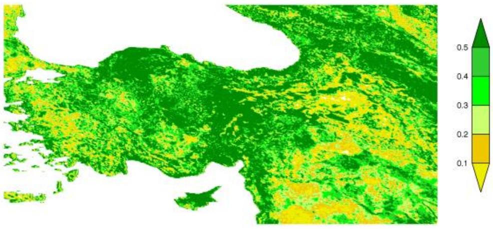
JANUARY 2006 VCI MAP



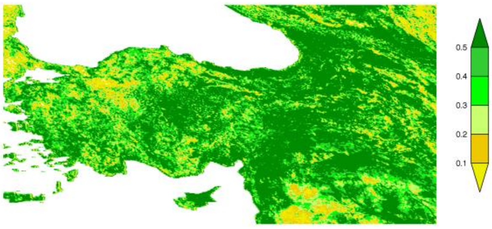
FEBRUARY 2006 VCI MAP



MARCH 2006 VCI MAP

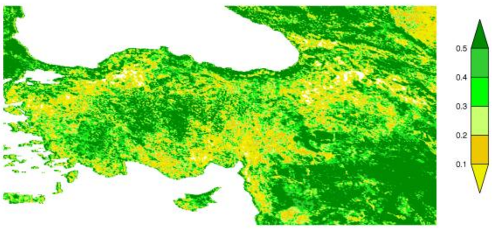


APRIL 2006 VCI MAP

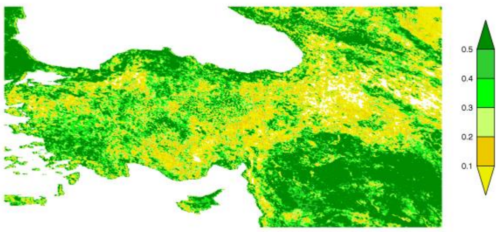


MAY 2006 VCI MAP

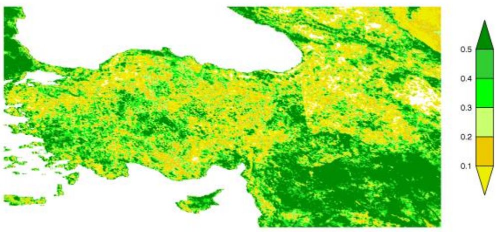
JUNE 2006 VCI MAP

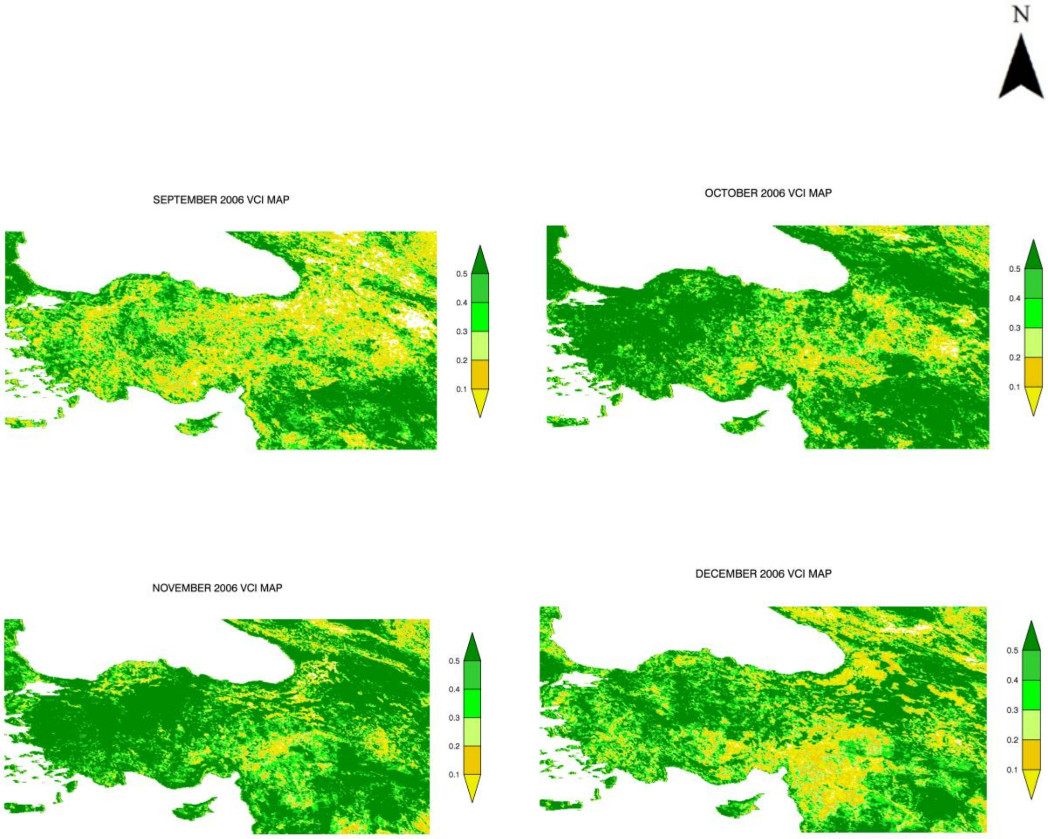


JULY 2006 VCI MAP

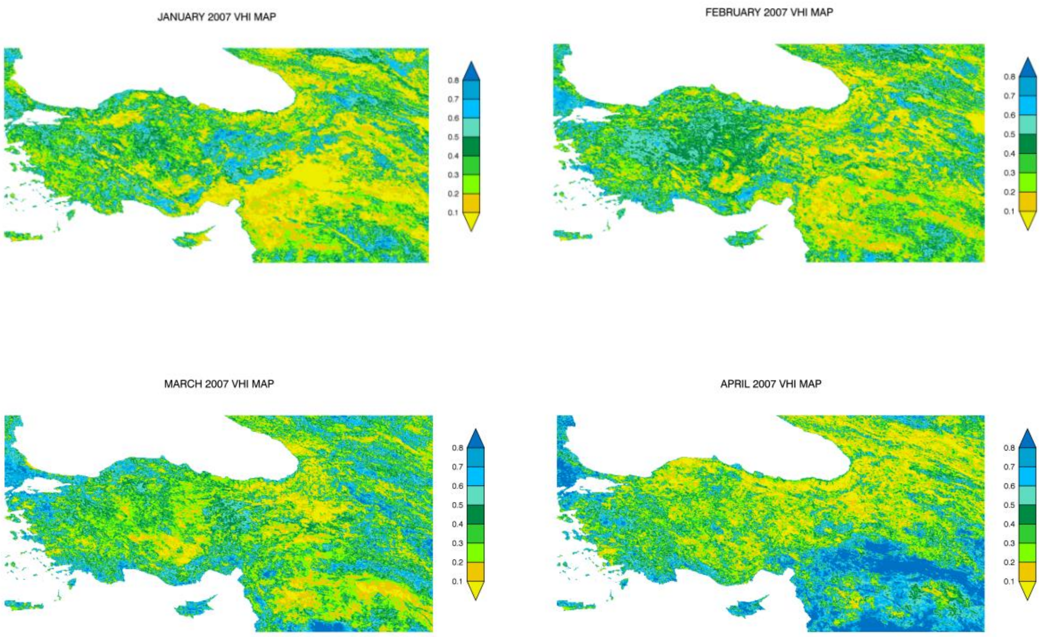


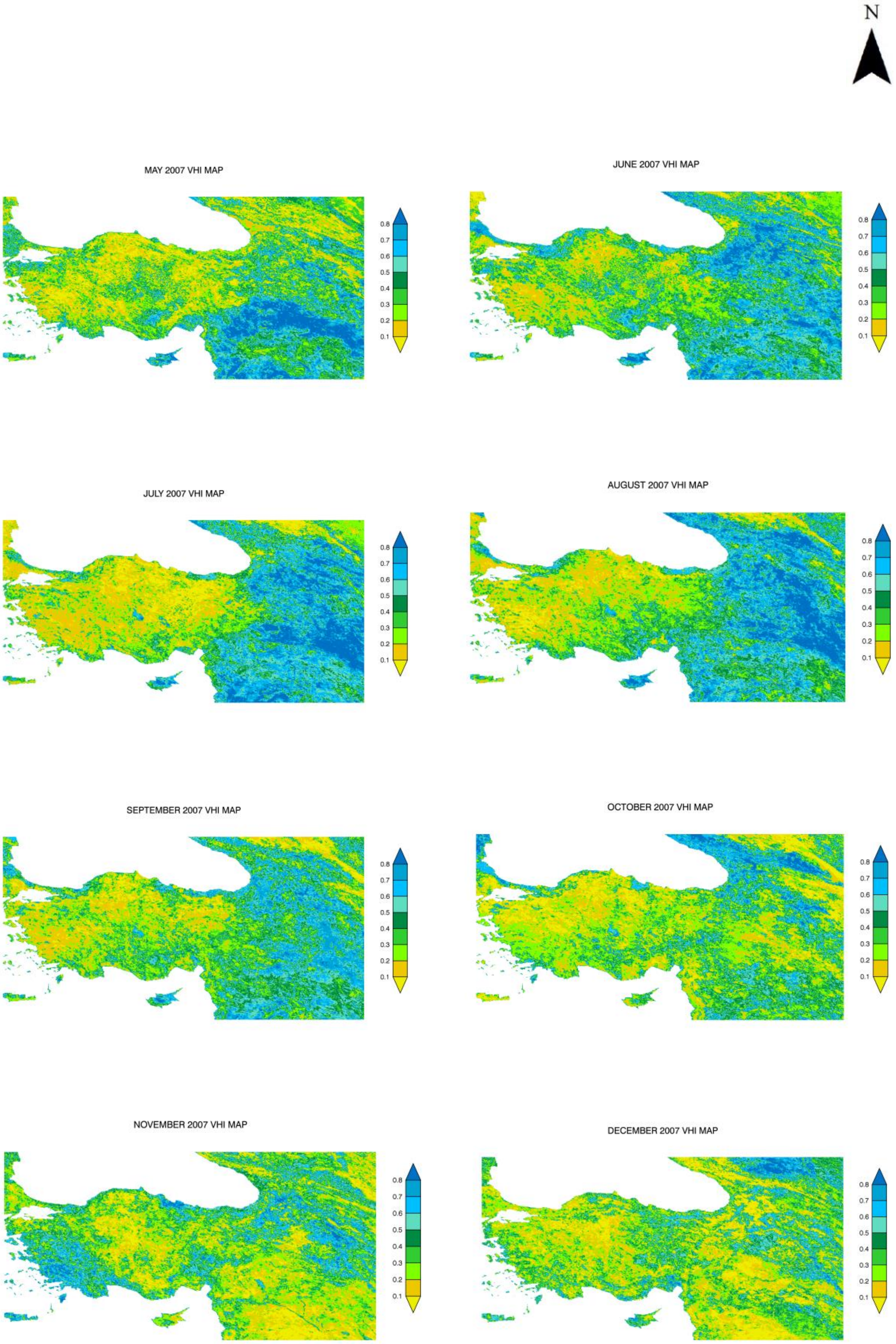
AUGUST 2006 VCI MAP




N
SEPTEMBER 2006 VCI MAP
OCTOBER 2006 VCI MAP
NOVEMBER 2006 VCI MAP
DECEMBER 2006 VCI MAP

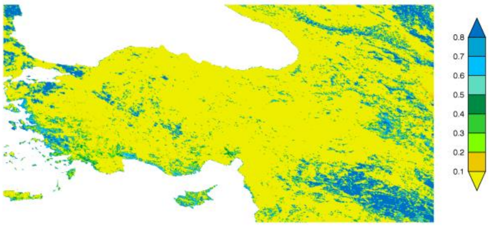
APPENDIX A4


JANUARY 2007 VHI MAP
FEBRUARY 2007 VHI MAP
MARCH 2007 VHI MAP
APRIL 2007 VHI MAP

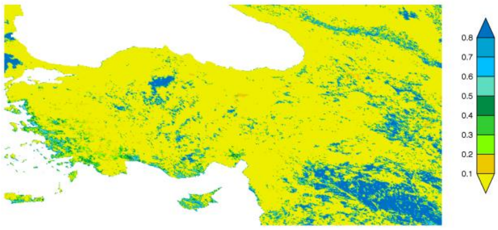

N
MAY 2007 VHI MAP
JUNE 2007 VHI MAP
JULY 2007 VHI MAP
AUGUST 2007 VHI MAP
SEPTEMBER 2007 VHI MAP
OCTOBER 2007 VHI MAP
NOVEMBER 2007 VHI MAP
DECEMBER 2007 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

APPENDIX A5

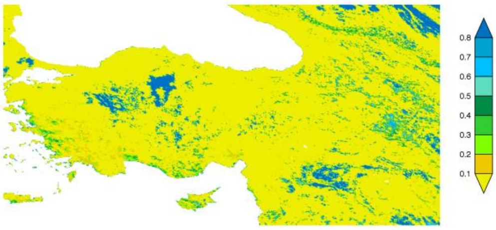
2008 1 1 TCI MAP



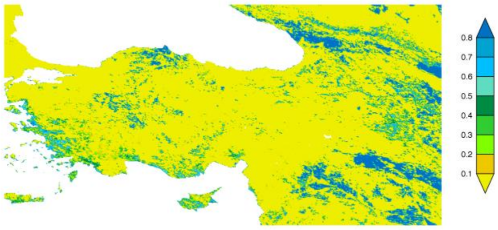
2008 1 9 TCI MAP



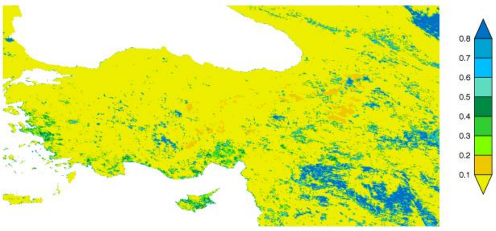
2008 1 17 TCI MAP



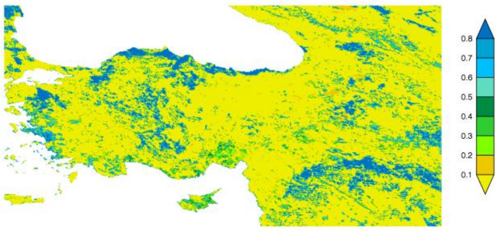
2008 1 25 TCI MAP



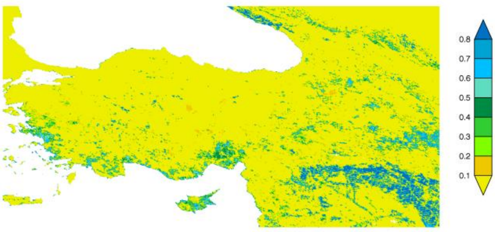
2008 2 2 TCI MAP



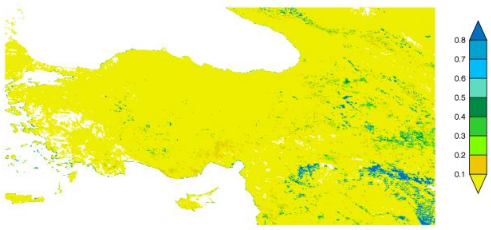
2008 2 10 TCI MAP

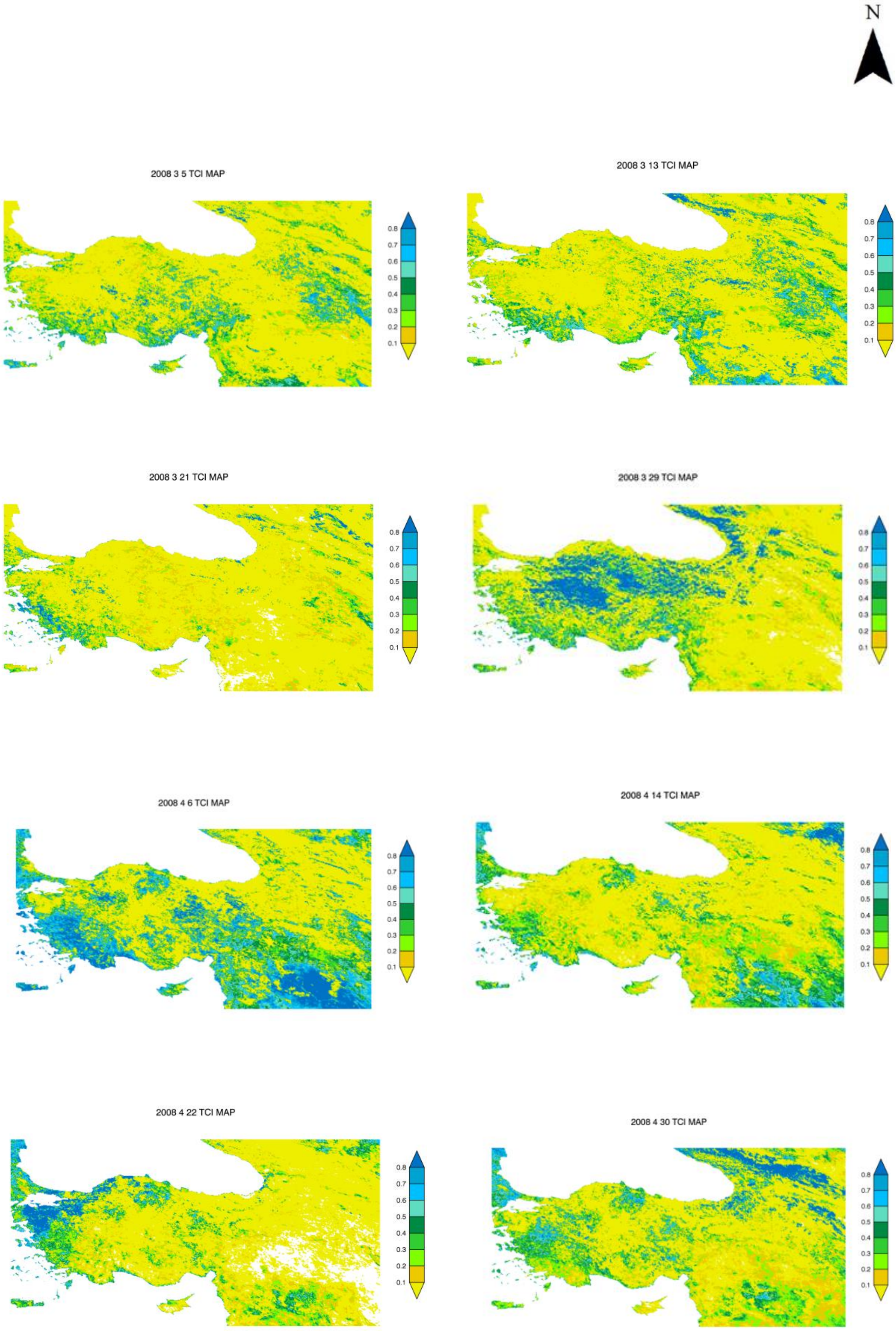


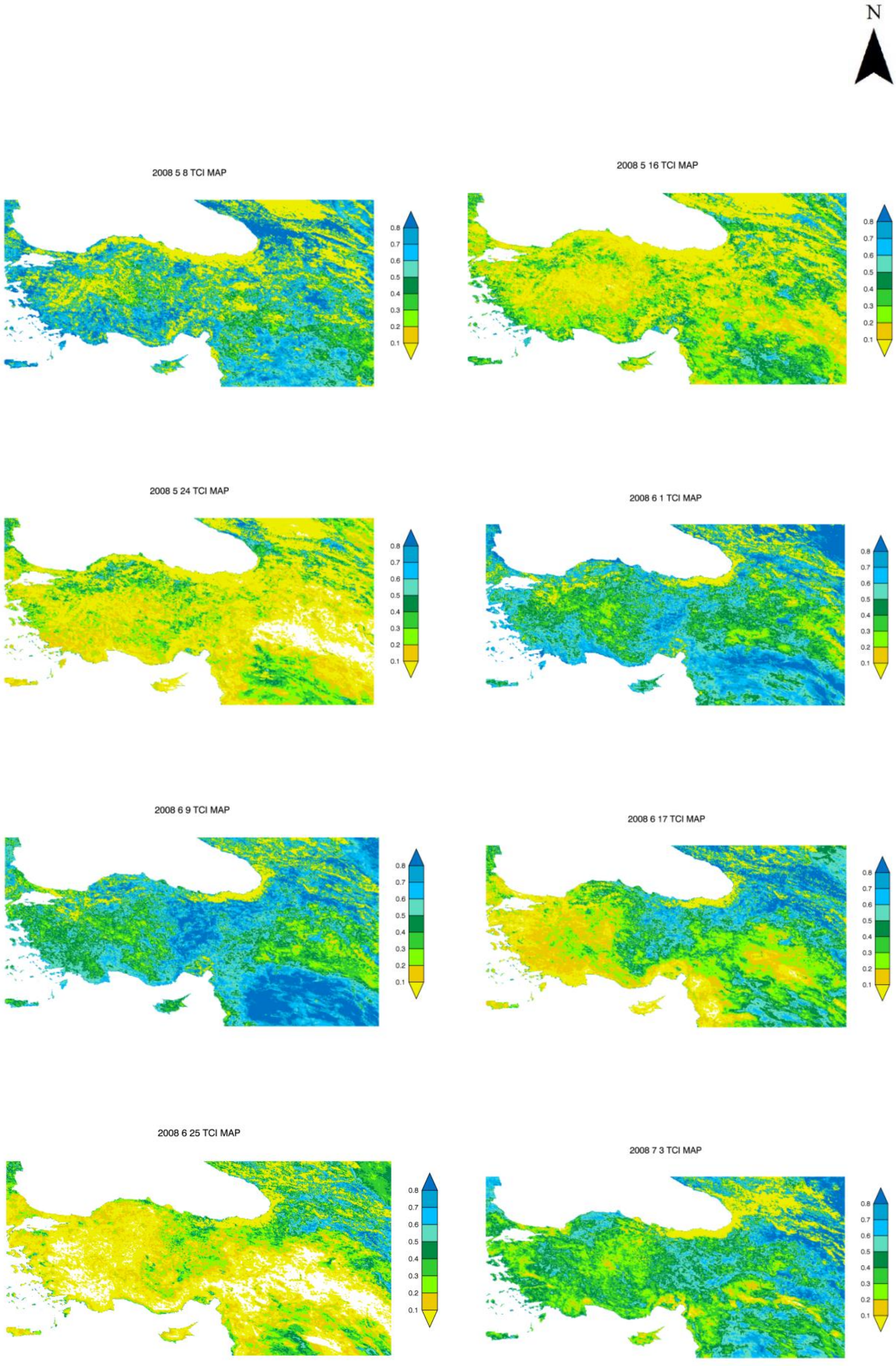
2008 2 18 TCI MAP

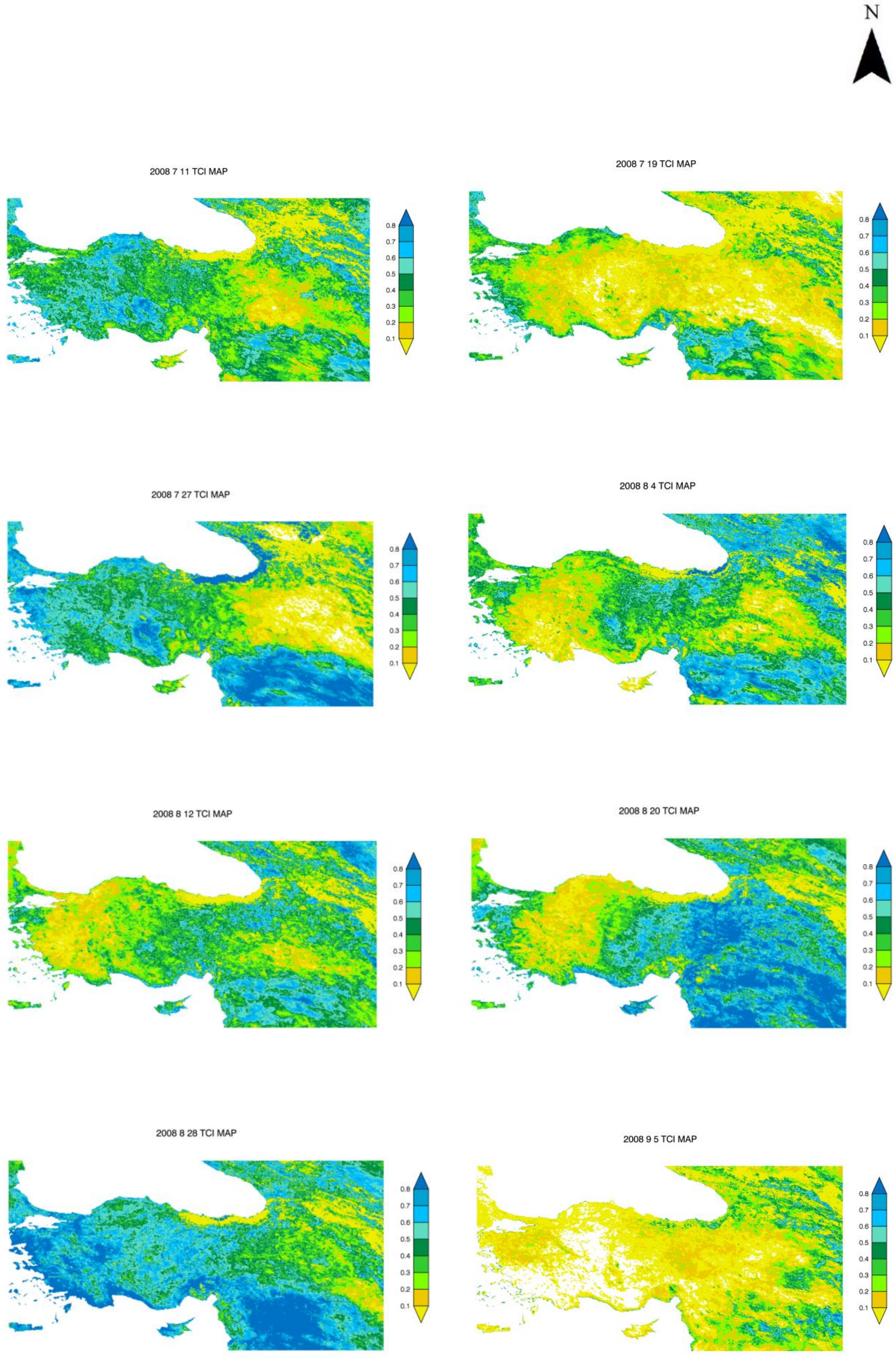


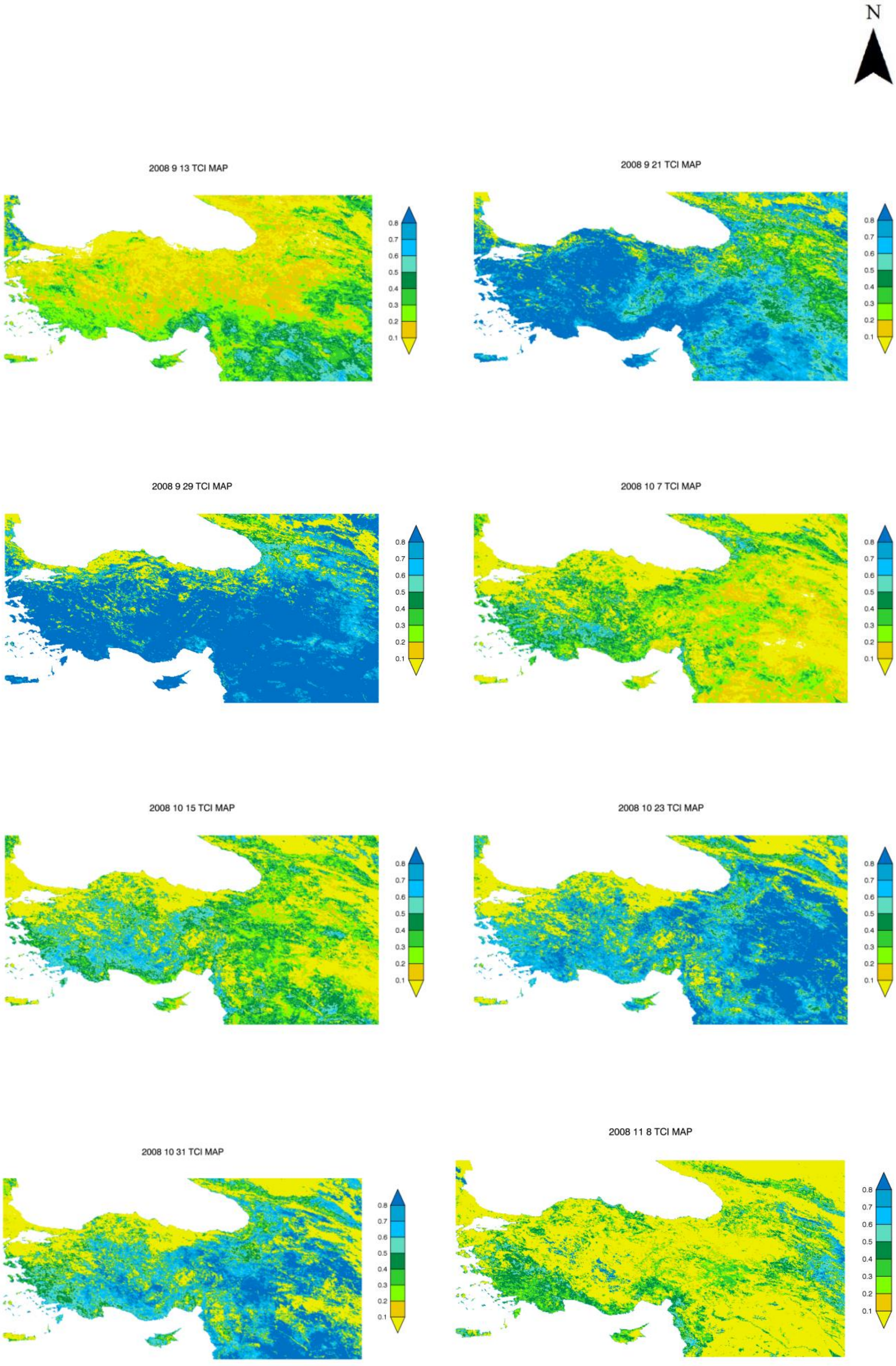
2008 2 26 TCI MAP



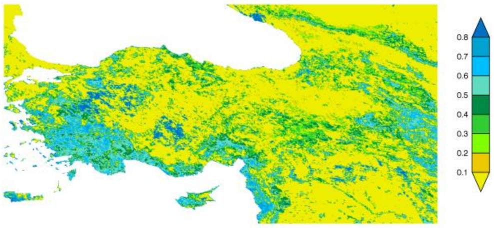

N
2008 3 5 TCI MAP
2008 3 13 TCI MAP
2008 3 21 TCI MAP
2008 3 29 TCI MAP
2008 4 6 TCI MAP
2008 4 14 TCI MAP
2008 4 22 TCI MAP
2008 4 30 TCI MAP


N
2008 5 8 TCI MAP
2008 5 16 TCI MAP
2008 5 24 TCI MAP
2008 6 1 TCI MAP
2008 6 9 TCI MAP
2008 6 17 TCI MAP
2008 6 25 TCI MAP
2008 7 3 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

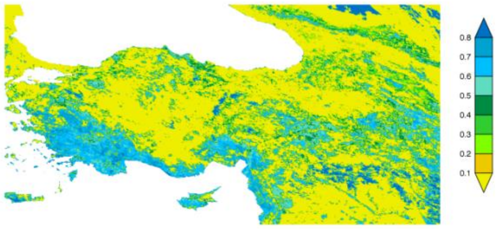

N
2008 7 11 TCI MAP
2008 7 19 TCI MAP
2008 7 27 TCI MAP
2008 8 4 TCI MAP
2008 8 12 TCI MAP
2008 8 20 TCI MAP
2008 8 28 TCI MAP
2008 9 5 TCI MAP


N
2008 9 13 TCI MAP
2008 9 21 TCI MAP
2008 9 29 TCI MAP
2008 10 7 TCI MAP
2008 10 15 TCI MAP
2008 10 23 TCI MAP
2008 10 31 TCI MAP
2008 11 8 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

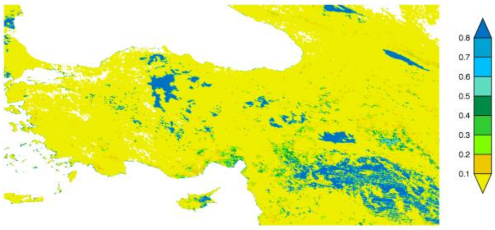
2008 11 16 TCI MAP



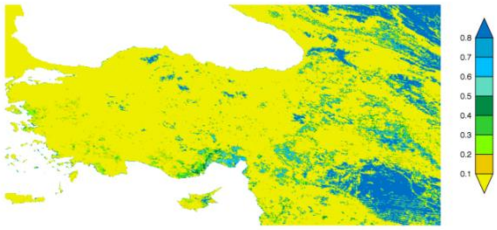
2008 11 24 TCI MAP



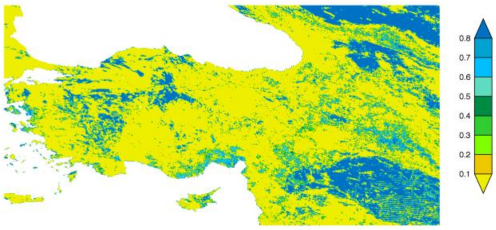
2008 12 2 TCI MAP



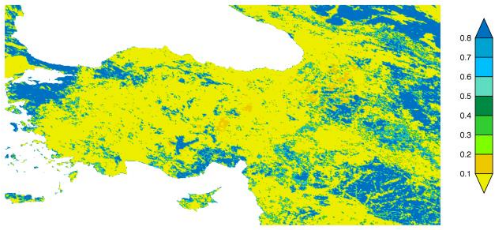
2008 12 10 TCI MAP



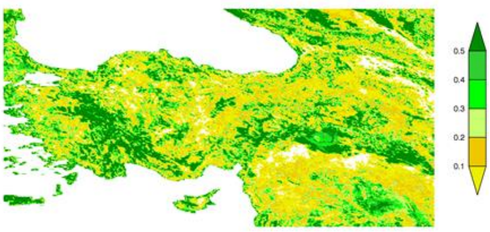
2008 12 18 TCI MAP



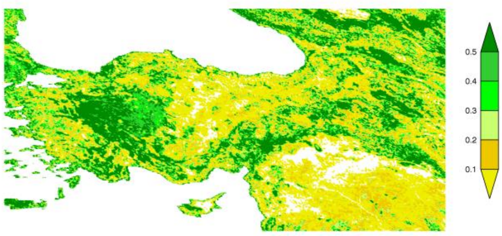
2008 12 26 TCI MAP

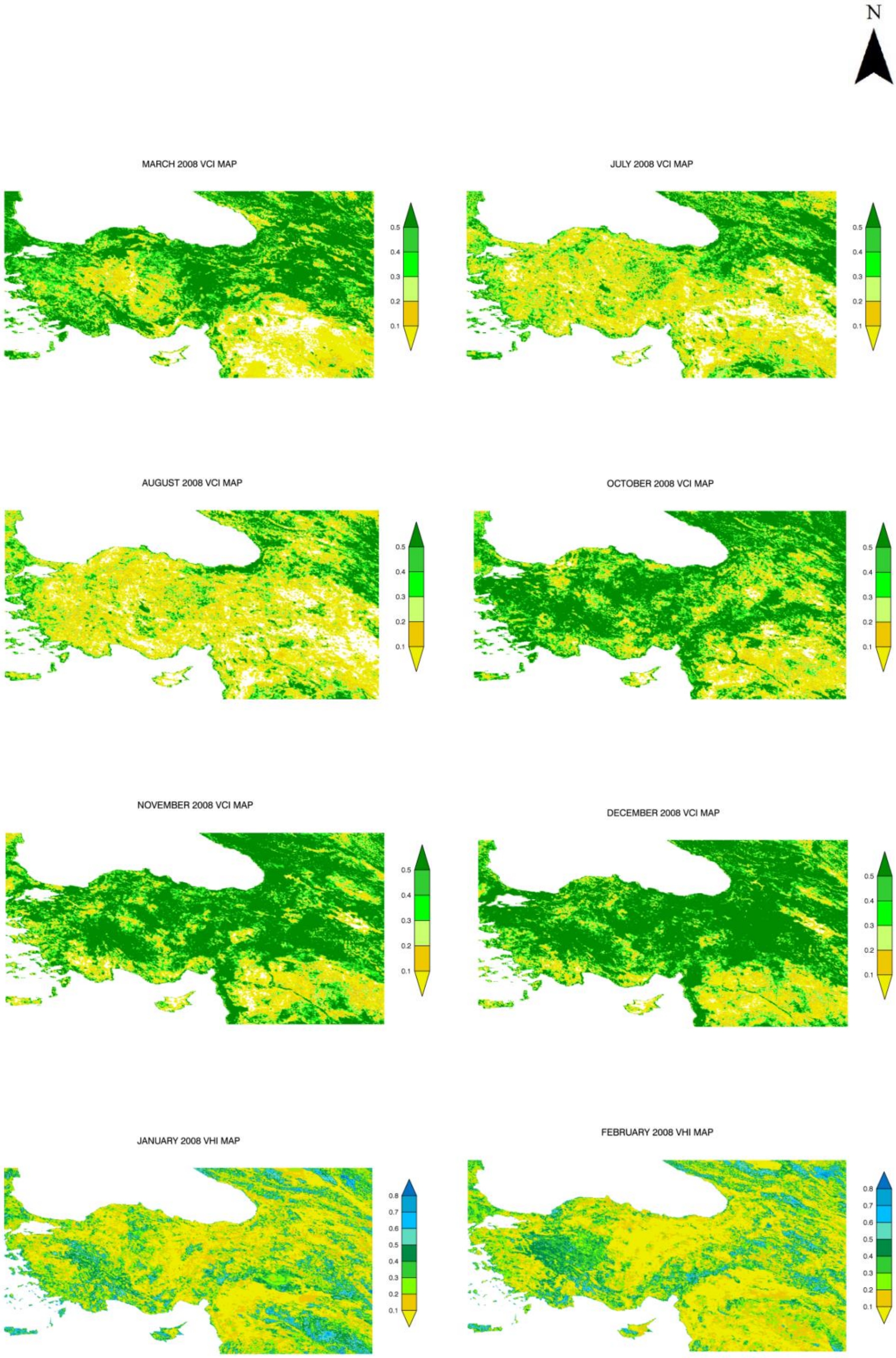


JANUARY 2008 VCI MAP

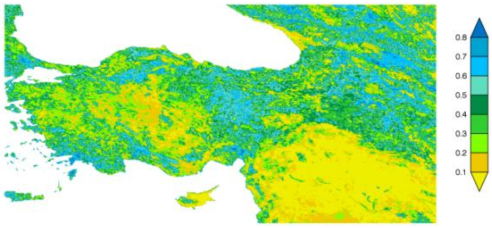


FEBRUARY 2008 VCI MAP

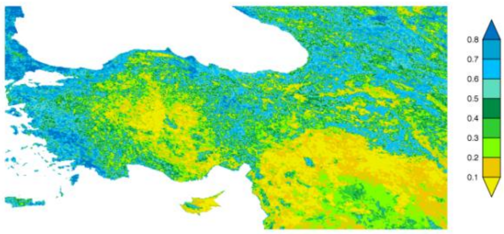



N
MARCH 2008 VCI MAP
JULY 2008 VCI MAP
AUGUST 2008 VCI MAP
OCTOBER 2008 VCI MAP
NOVEMBER 2008 VCI MAP
DECEMBER 2008 VCI MAP
JANUARY 2008 VHI MAP
FEBRUARY 2008 VHI MAP
0.5
0.4
0.3
0.2
0.1
0.8
0.7
0.6

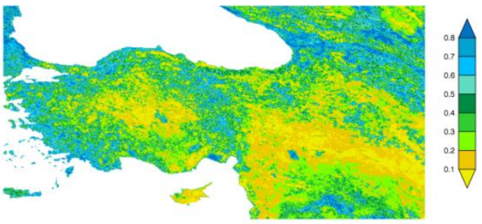
MARCH 2008 VHI MAP



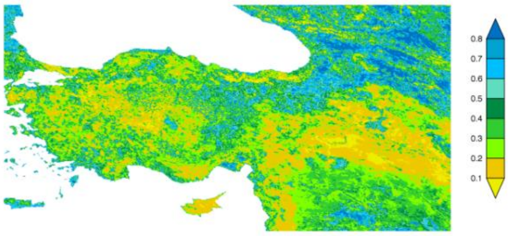
APRIL 2008 VHI MAP



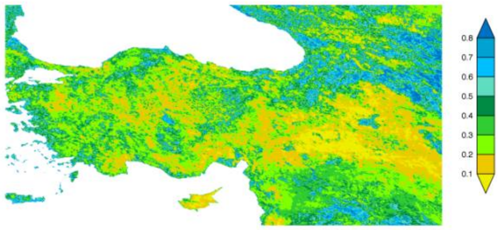
MAY 2008 VHI MAP



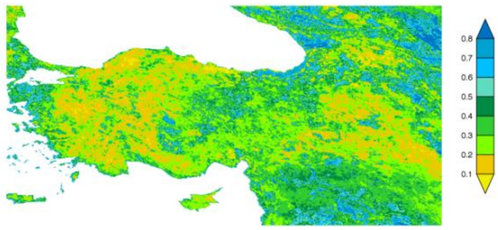
JUNE 2008 VHI MAP



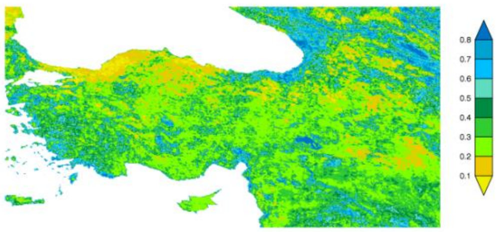
JULY 2008 VHI MAP



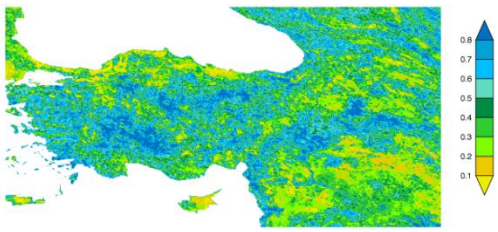
AUGUST 2008 VHI MAP



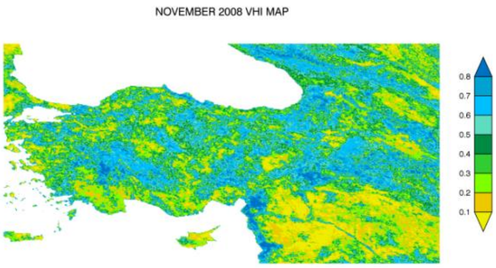
SEPTEMBER 2008 VHI MAP

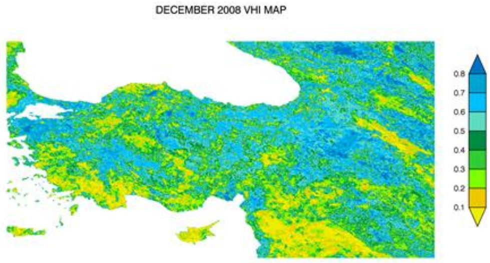


OCTOBER 2008 VHI MAP

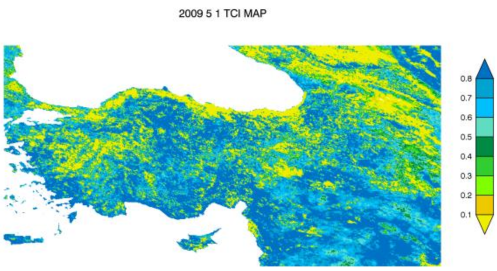


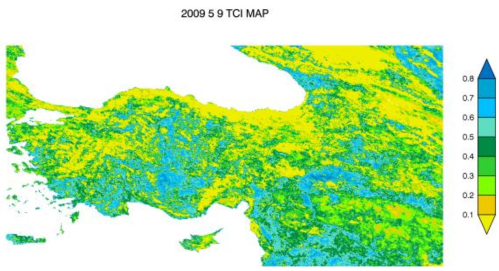

N

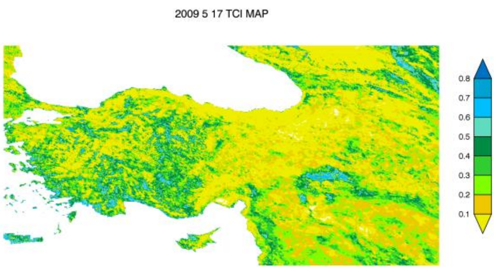

NOVEMBER 2008 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

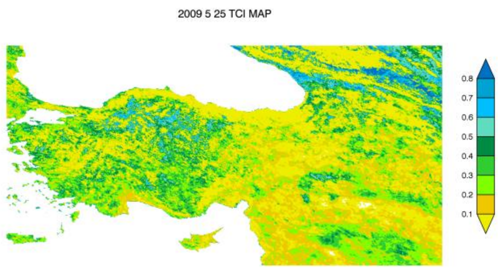

DECEMBER 2008 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

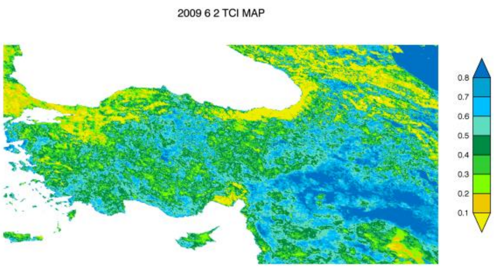
APPENDIX A6

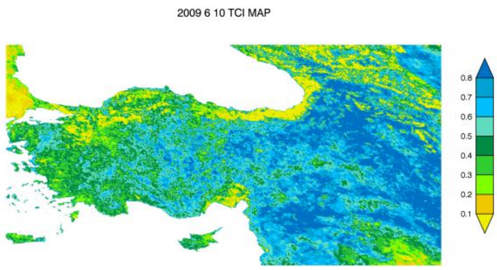

2009 5 1 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

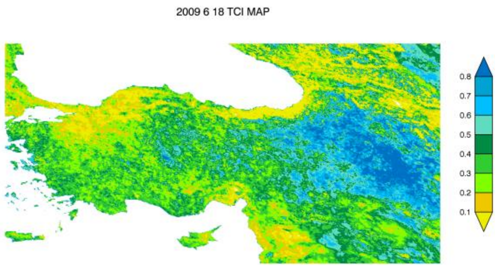

2009 5 9 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

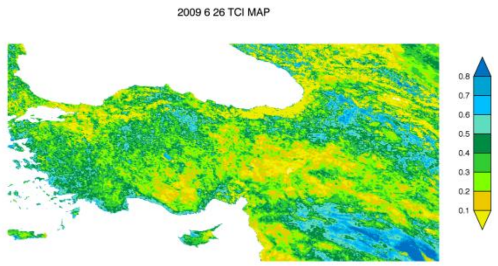

2009 5 17 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

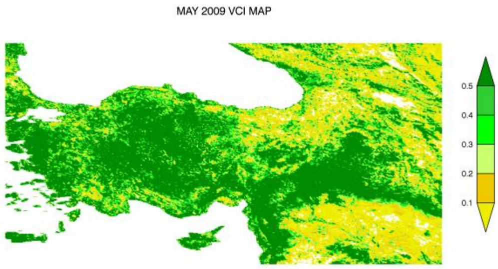

2009 5 25 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

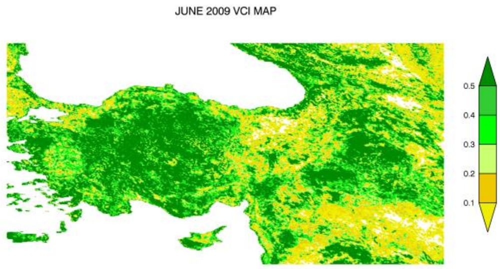

2009 6 2 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

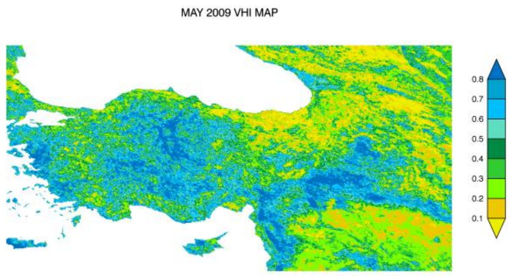

2009 6 10 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

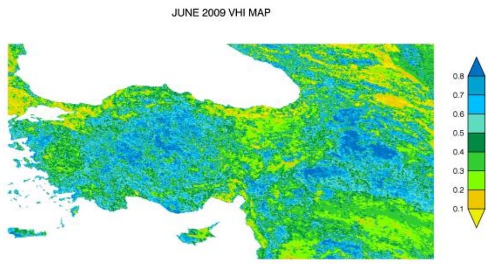

2009 6 18 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2009 6 26 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

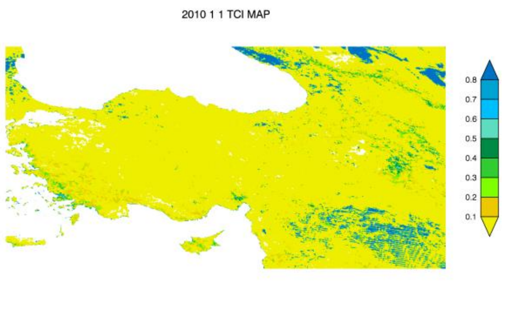

MAY 2009 VCI MAP
0.5
0.4
0.3
0.2
0.1

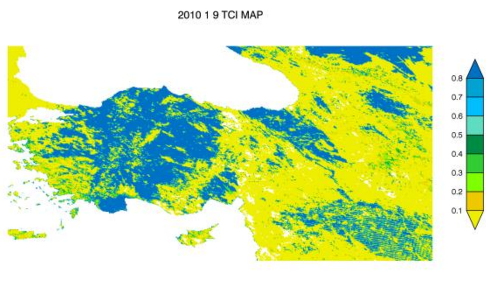

JUNE 2009 VCI MAP
0.5
0.4
0.3
0.2
0.1

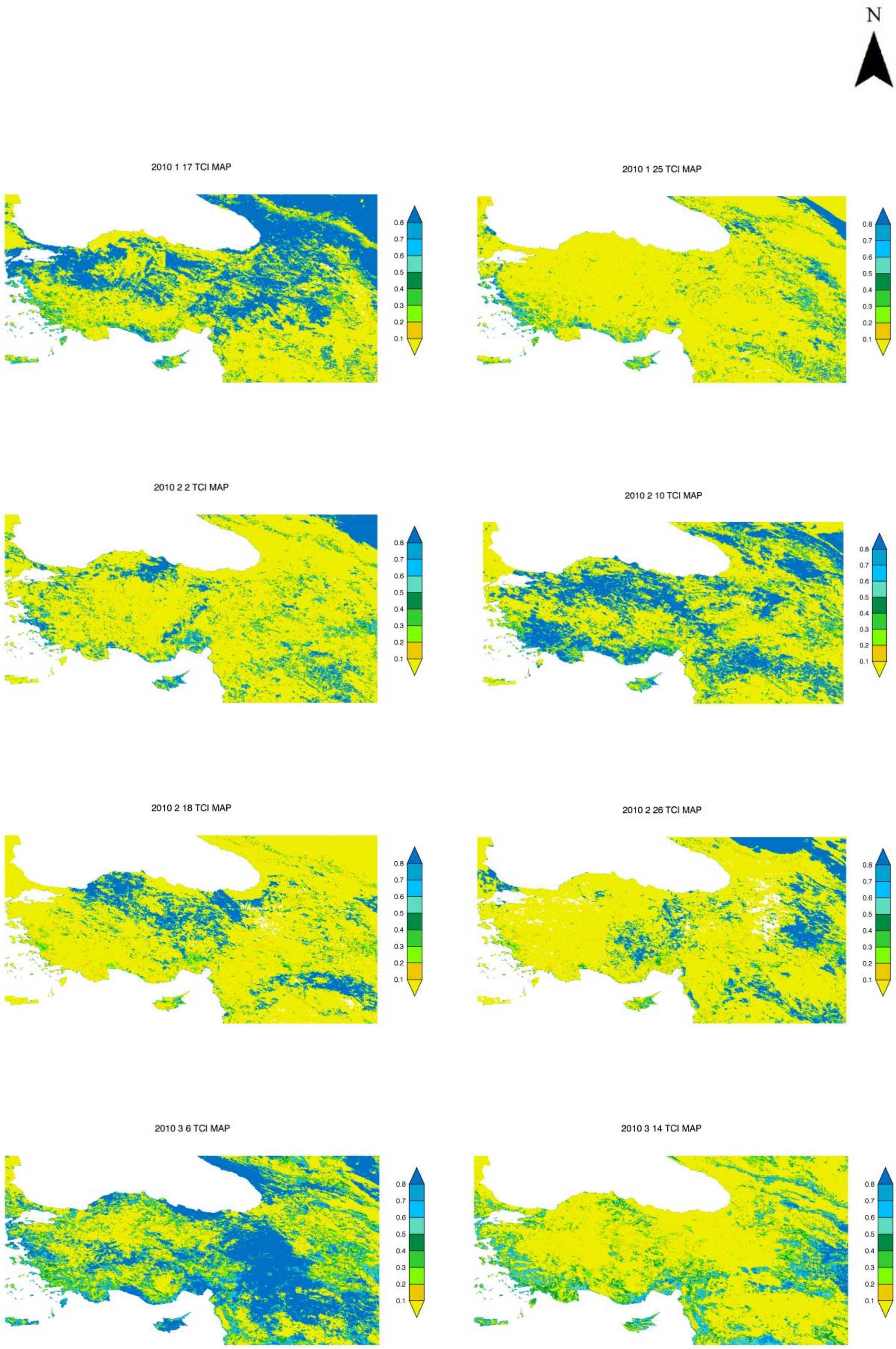

MAY 2009 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


JUNE 2009 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

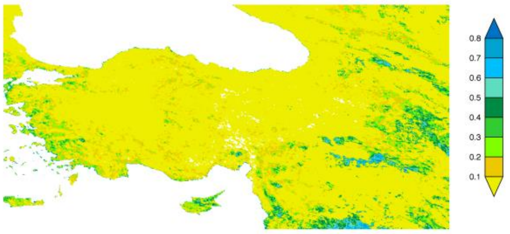
APPENDIX A7


2010 1 1 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

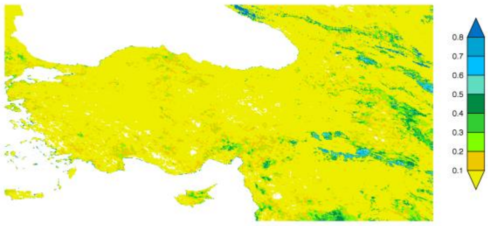

2010 1 9 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


N
2010 1 17 TCI MAP
2010 1 25 TCI MAP
2010 2 2 TCI MAP
2010 2 10 TCI MAP
2010 2 18 TCI MAP
2010 2 26 TCI MAP
2010 3 6 TCI MAP
2010 3 14 TCI MAP

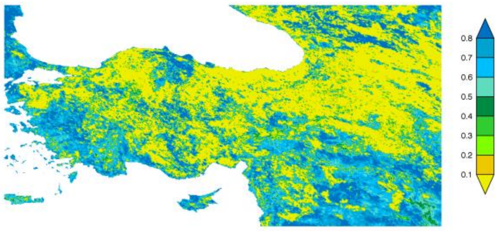
2010 3 22 TCI MAP



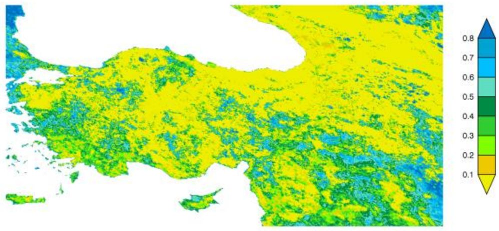
2010 3 30 TCI MAP



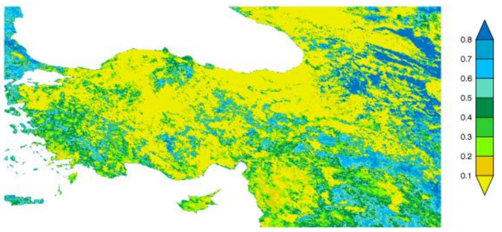
2010 4 7 TCI MAP



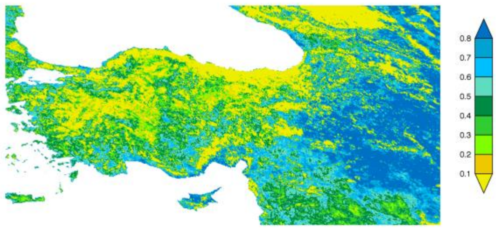
2010 4 15 TCI MAP



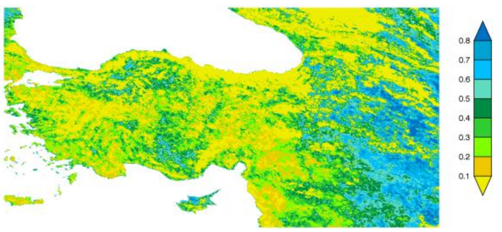
2010 4 23 TCI MAP



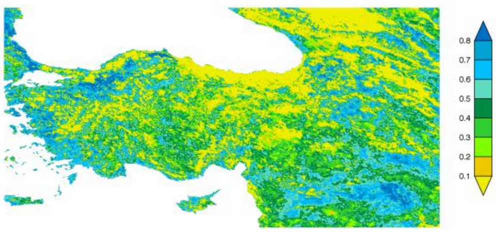
2010 5 1 TCI MAP

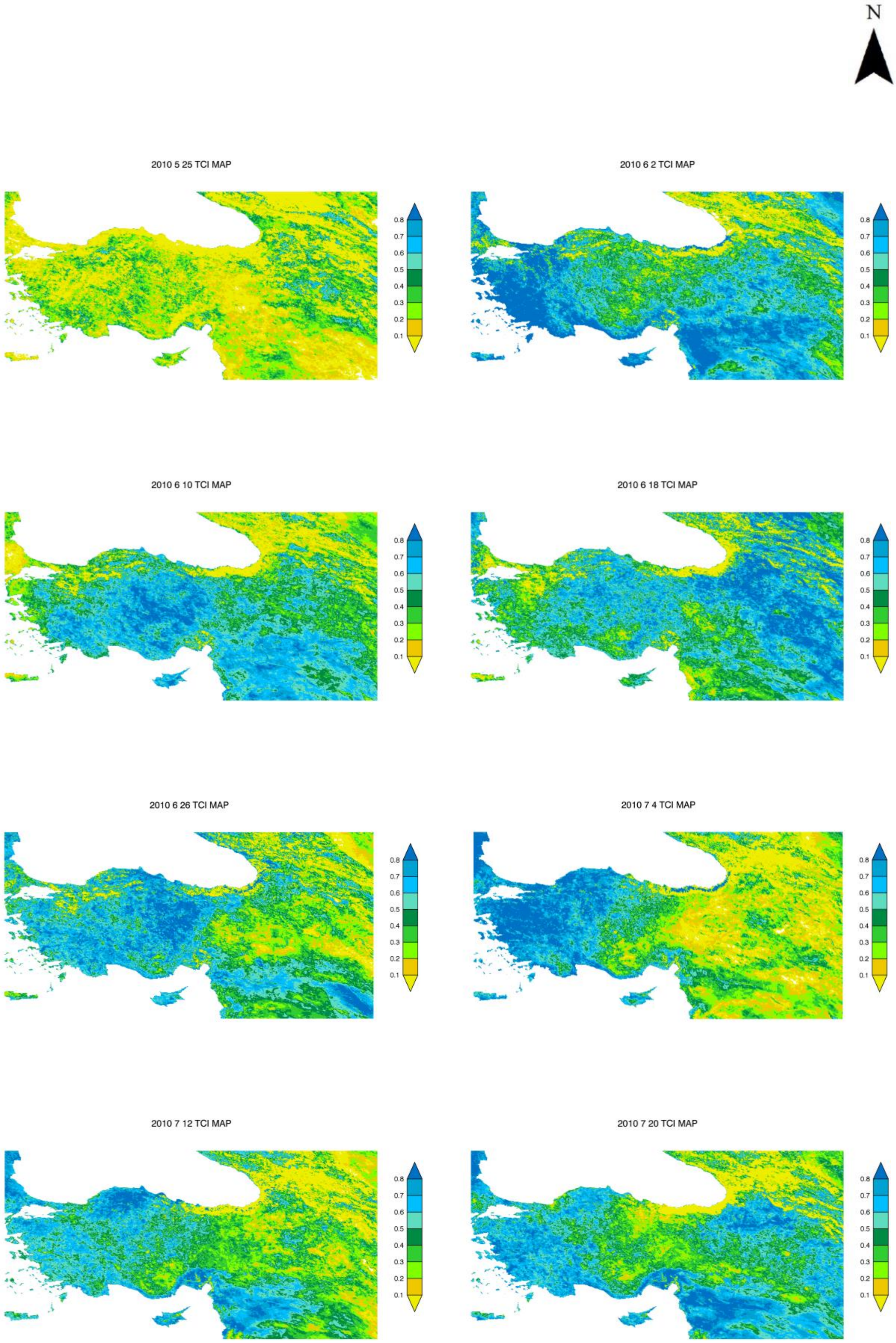


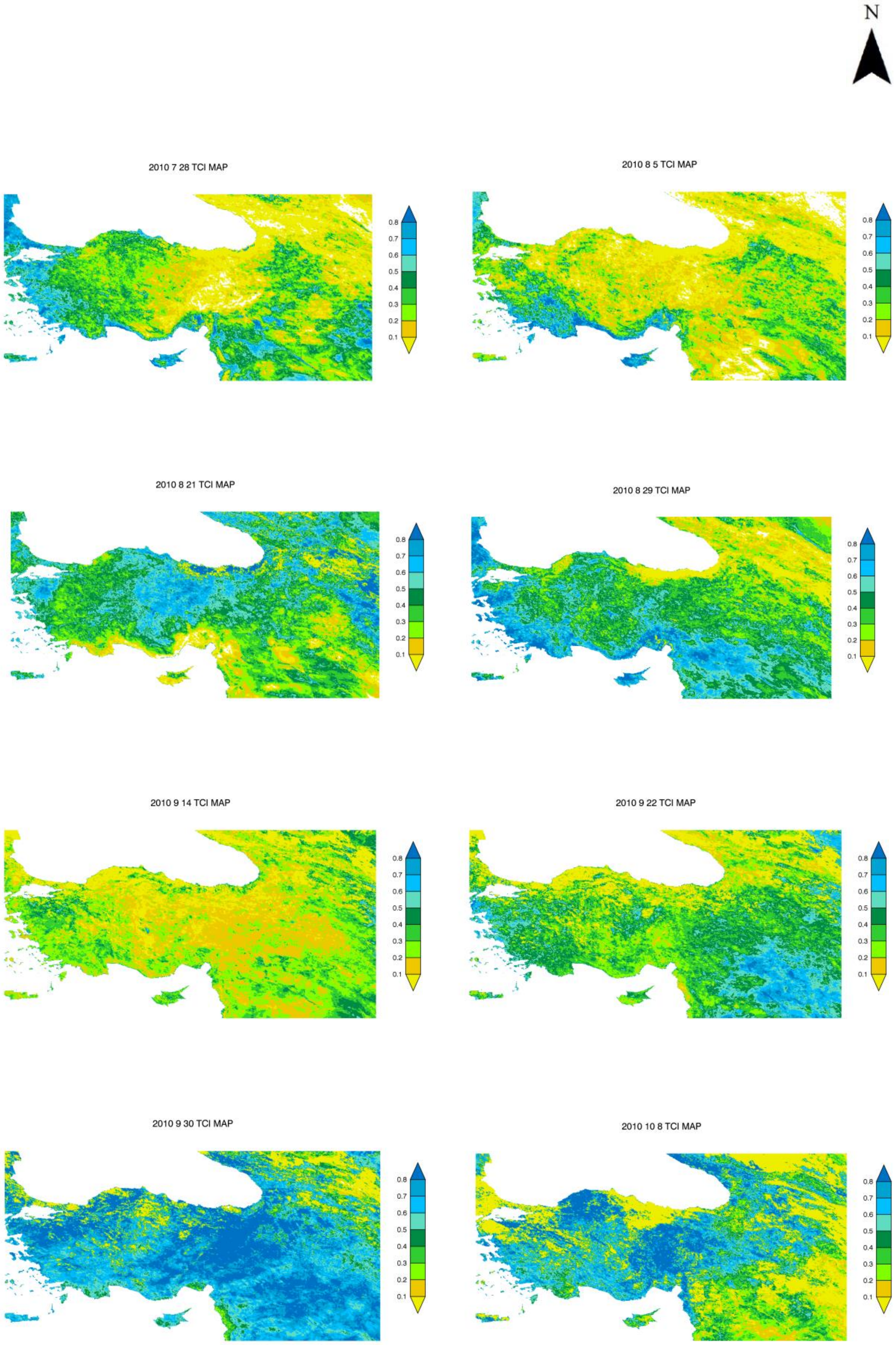
2010 5 9 TCI MAP

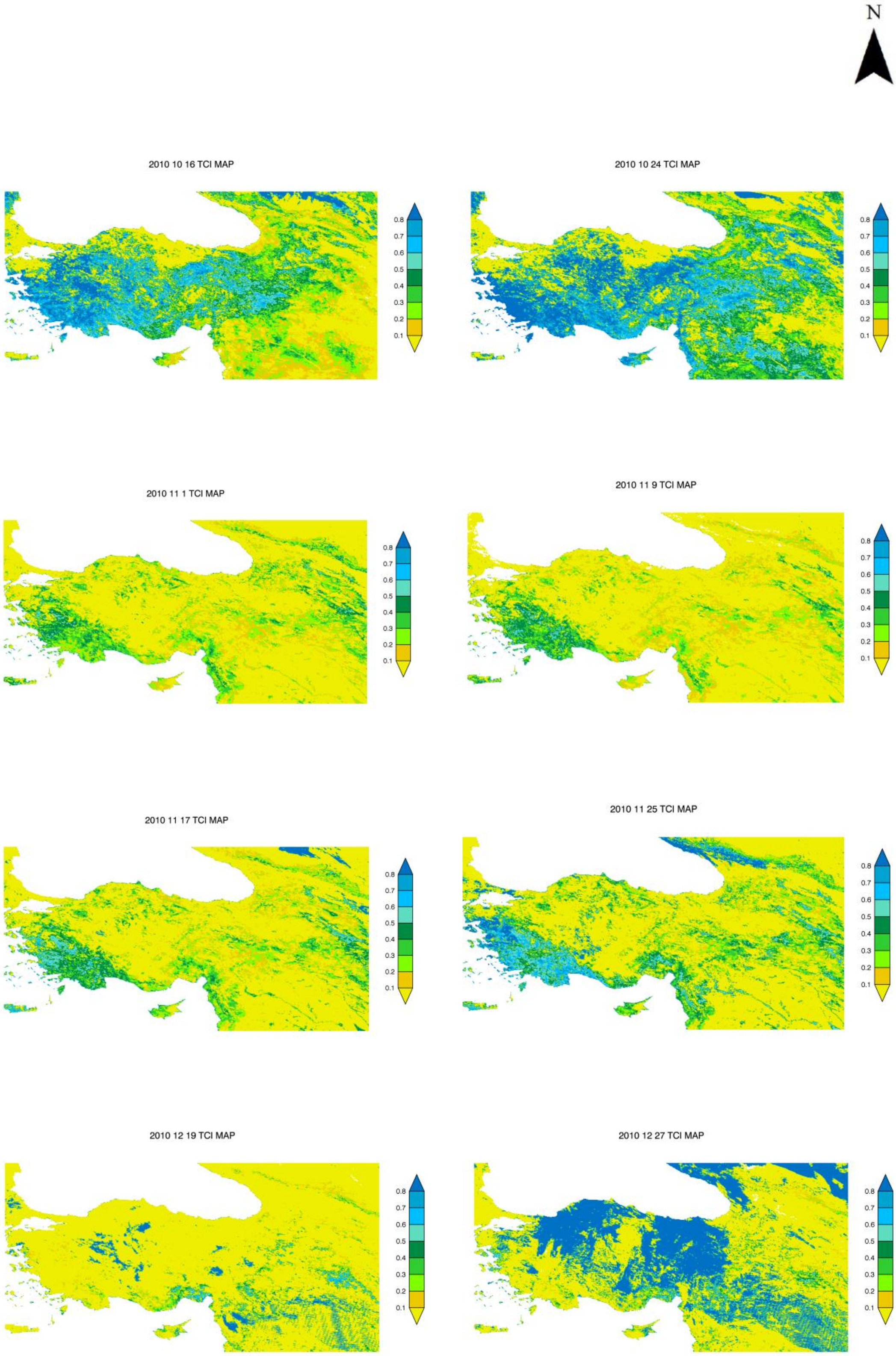


2010 5 17 TCI MAP

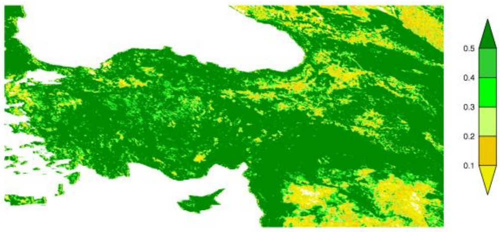



N
2010 5 25 TCI MAP
2010 6 2 TCI MAP
2010 6 10 TCI MAP
2010 6 18 TCI MAP
2010 6 26 TCI MAP
2010 7 4 TCI MAP
2010 7 12 TCI MAP
2010 7 20 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

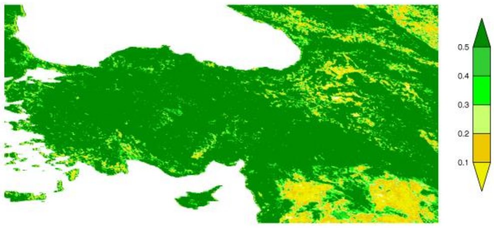

N
2010 7 28 TCI MAP
2010 8 5 TCI MAP
2010 8 21 TCI MAP
2010 8 29 TCI MAP
2010 9 14 TCI MAP
2010 9 22 TCI MAP
2010 9 30 TCI MAP
2010 10 8 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


N
2010 10 16 TCI MAP
2010 10 24 TCI MAP
2010 11 1 TCI MAP
2010 11 9 TCI MAP
2010 11 17 TCI MAP
2010 11 25 TCI MAP
2010 12 19 TCI MAP
2010 12 27 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

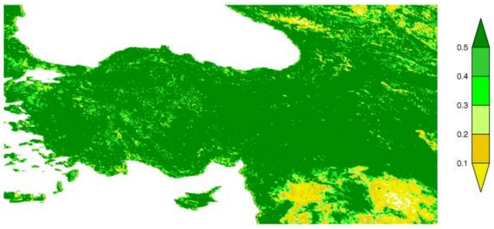
JANUARY 2010 VCI MAP



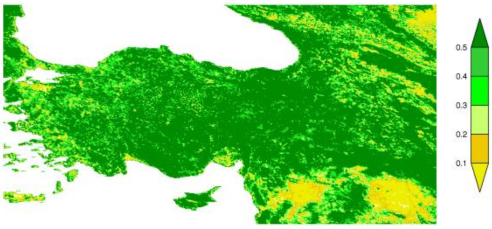
FEBRUARY 2010 VCI MAP



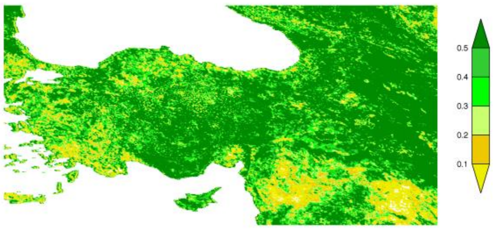
MARCH 2010 VCI MAP



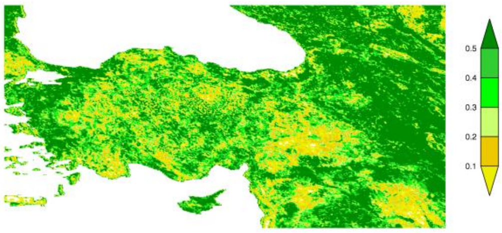
APRIL 2010 VCI MAP



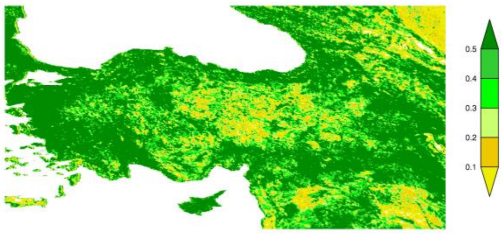
MAY 2010 VCI MAP



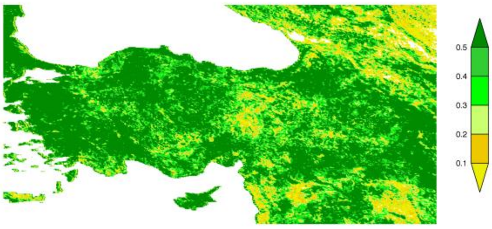
JUNE 2010 VCI MAP

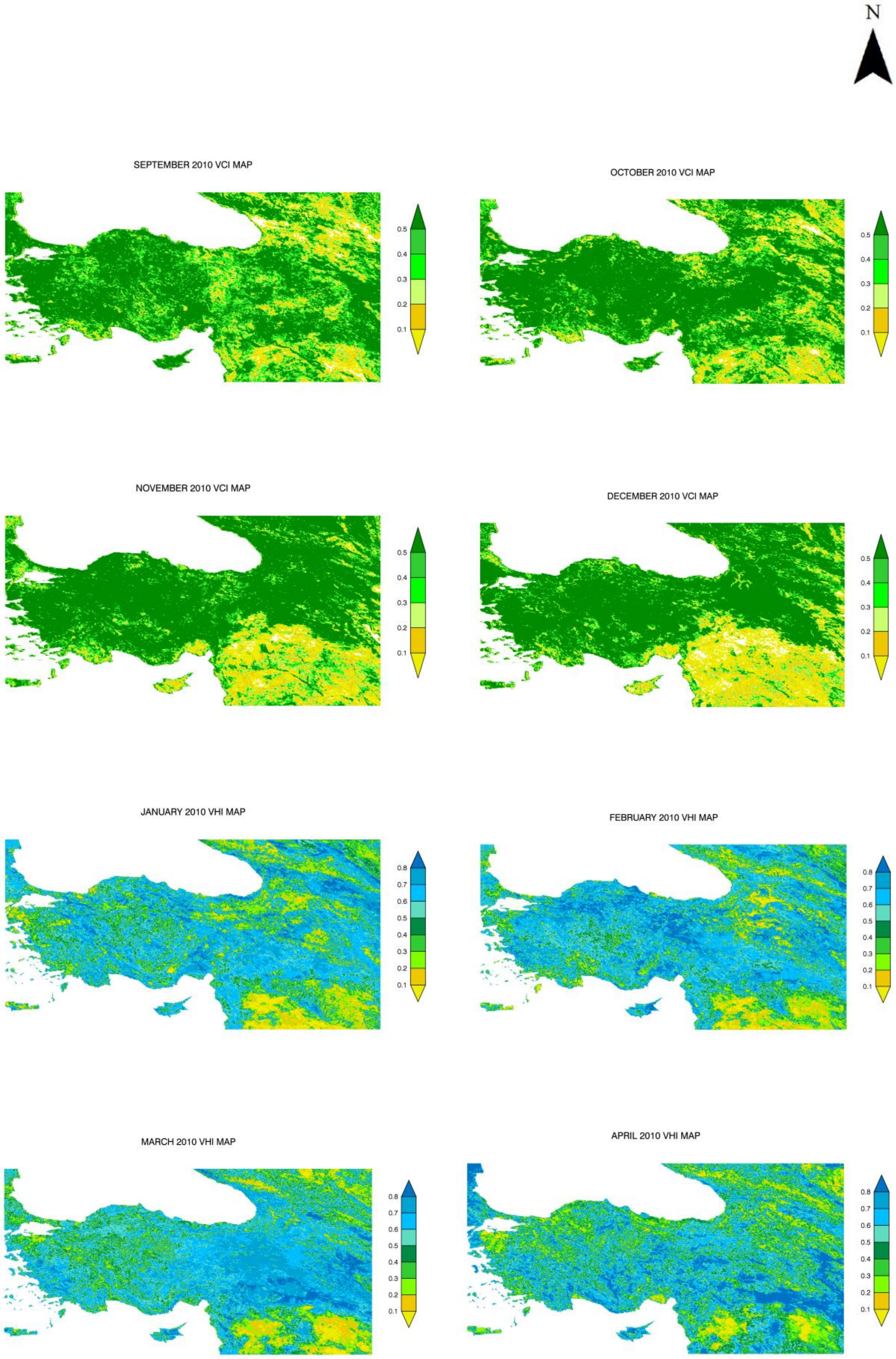


JULY 2010 VCI MAP

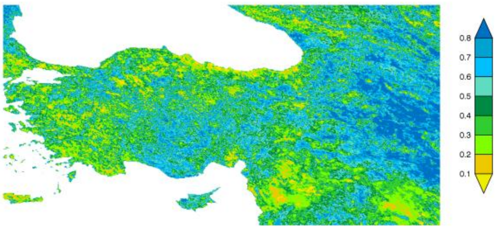


AUGUST 2010 VCI MAP

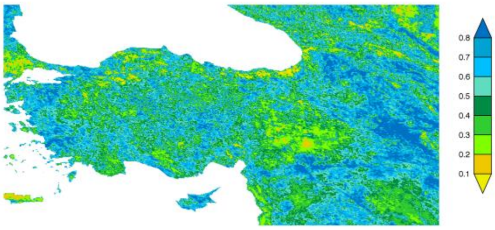



N
SEPTEMBER 2010 VCI MAP
OCTOBER 2010 VCI MAP
NOVEMBER 2010 VCI MAP
DECEMBER 2010 VCI MAP
0.5
0.4
0.3
0.2
0.1
JANUARY 2010 VHI MAP
FEBRUARY 2010 VHI MAP
MARCH 2010 VHI MAP
APRIL 2010 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

MAY 2010 VHI MAP



JUNE 2010 VHI MAP



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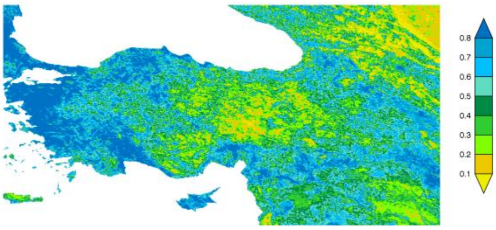
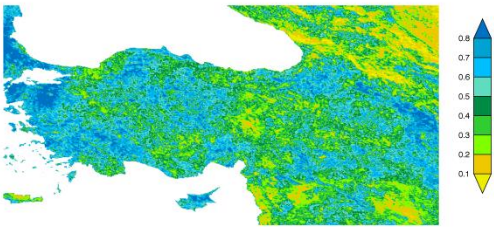
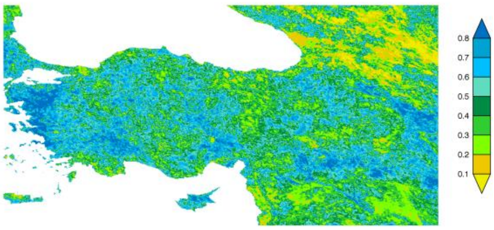


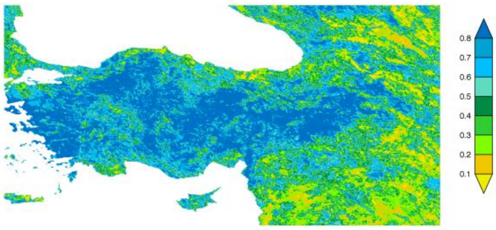
AUGUST 2010 VHI MAP



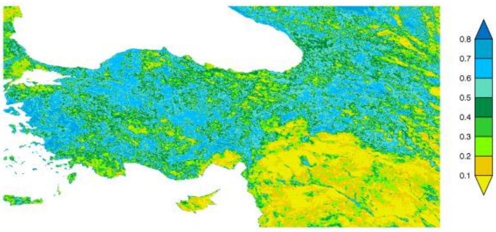
SEPTEMBER 2010 VHI MAP



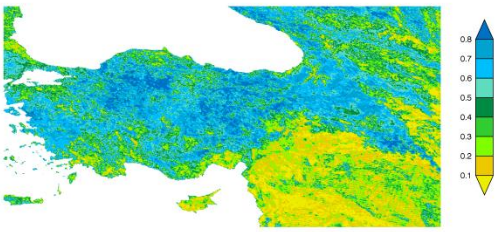
OCTOBER 2010 VHI MAP



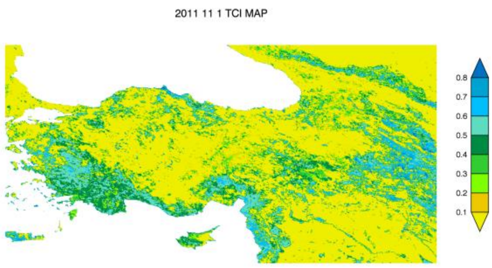
NOVEMBER 2010 VHI MAP

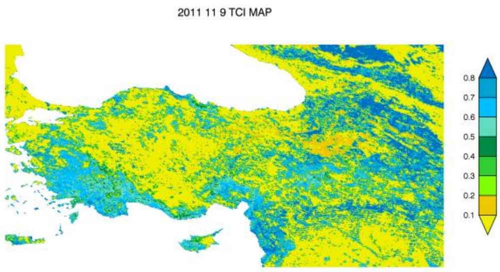


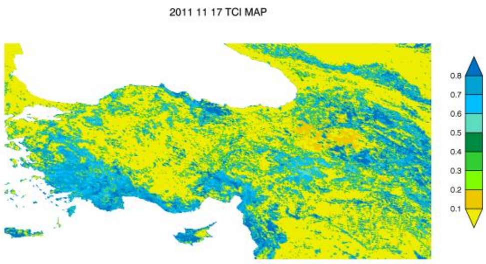
DECEMBER 2010 VHI MAP

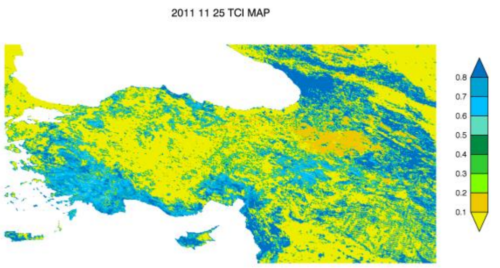


APPENDIX A8


2011 11 1 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2011 11 9 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2011 11 17 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1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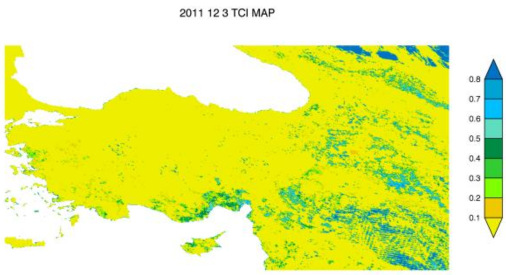
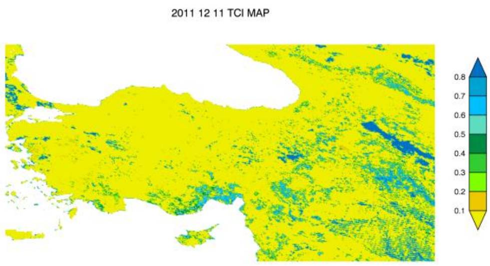
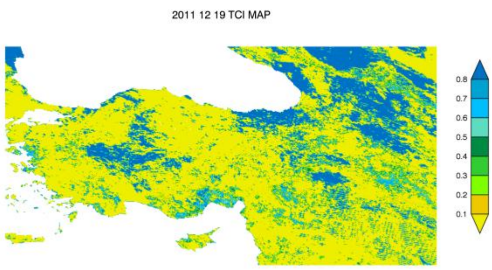
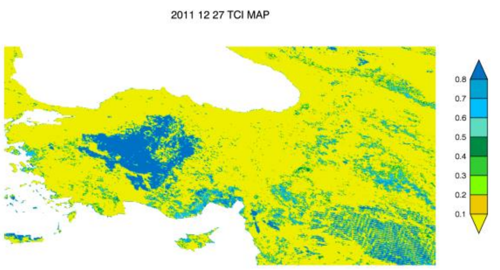
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

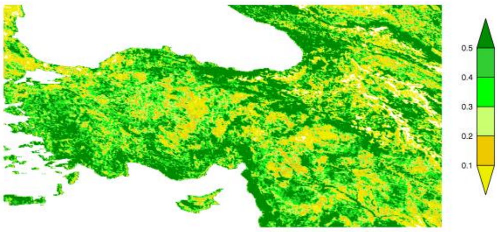

2011 12 3 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2011 12 11 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

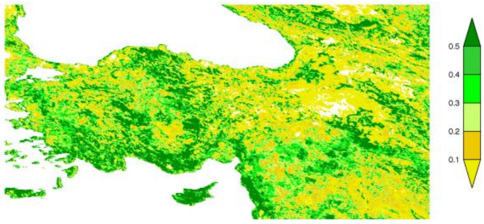

2011 12 19 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2011 12 27 TCI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

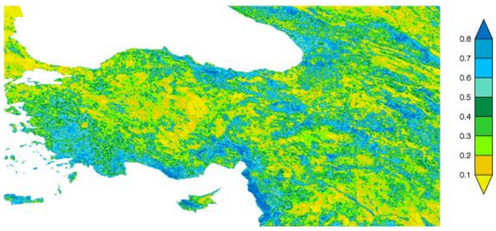
NOVEMBER 2011 VCI MAP



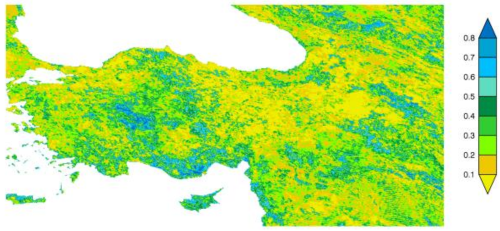
DECEMBER 2011 VCI MAP



NOVEMBER 2011 VHI MAP

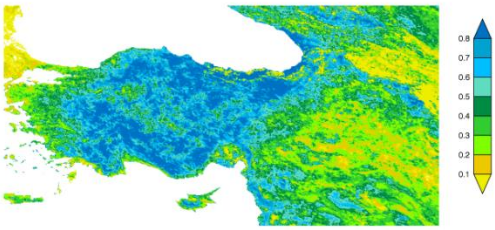


DECEMBER 2011 VHI MAP

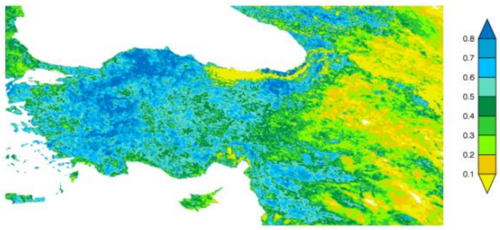


APPENDIX A9

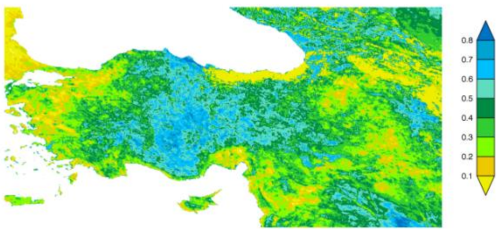
2012 8 4 TCI MAP



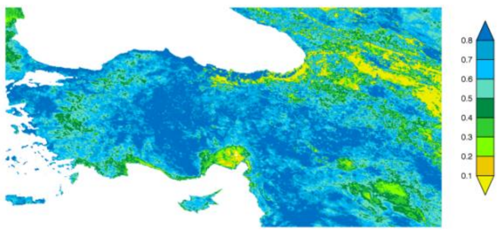
2012 8 12 TCI MAP

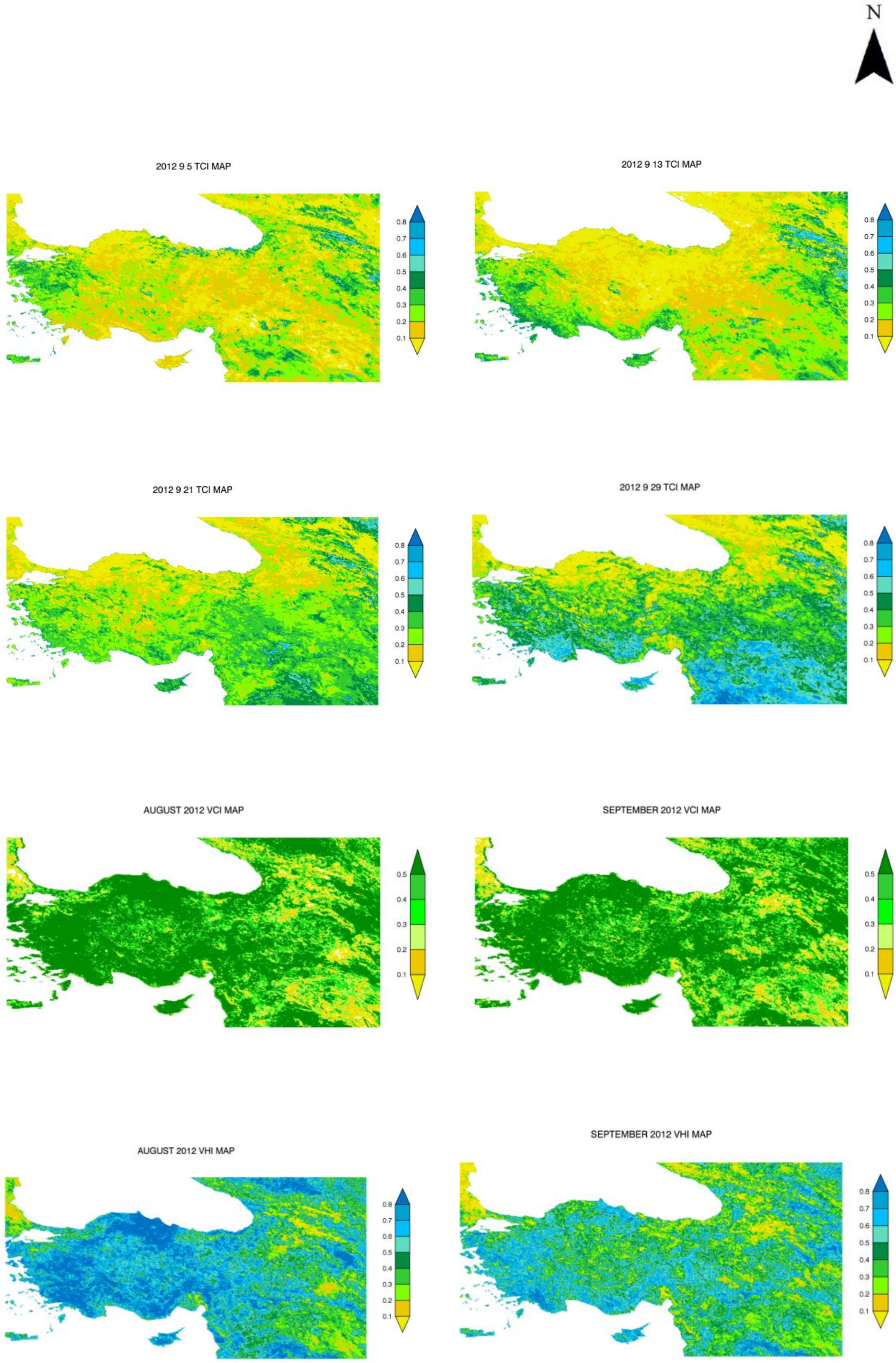


2012 8 20 TCI MAP

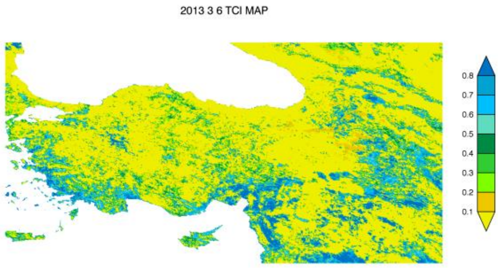


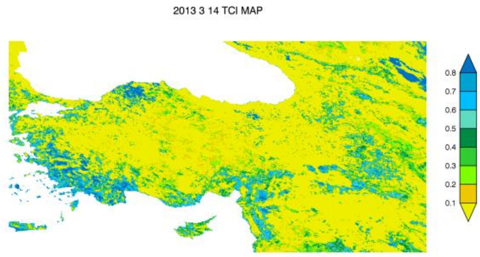
2012 8 28 TCI MAP

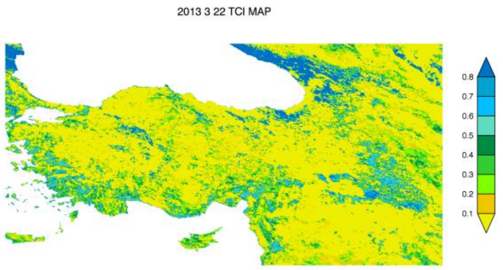


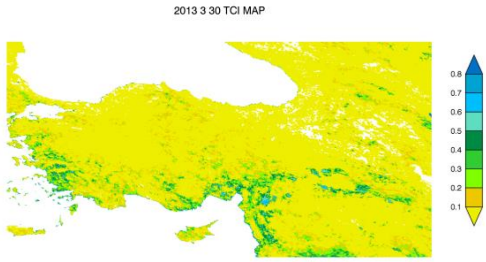

N
2012 9 5 TCI MAP
2012 9 13 TCI MAP
2012 9 21 TCI MAP
2012 9 29 TCI MAP
AUGUST 2012 VCI MAP
SEPTEMBER 2012 VCI MAP
AUGUST 2012 VHI MAP
SEPTEMBER 2012 VHI MAP

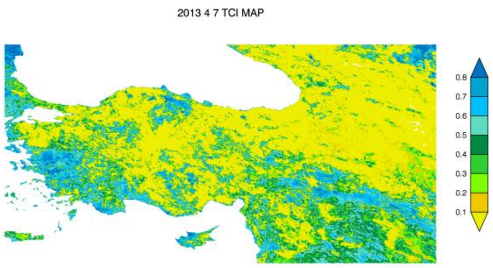
APPENDIX A10

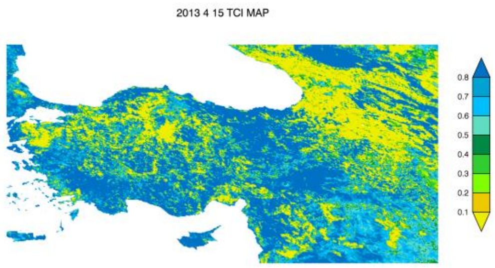


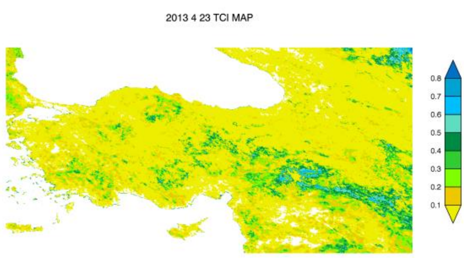


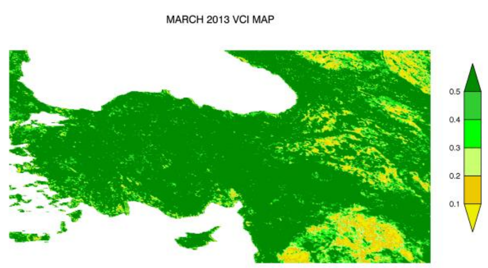




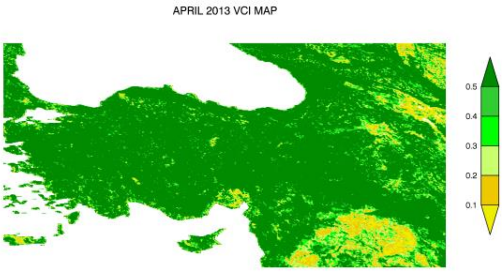


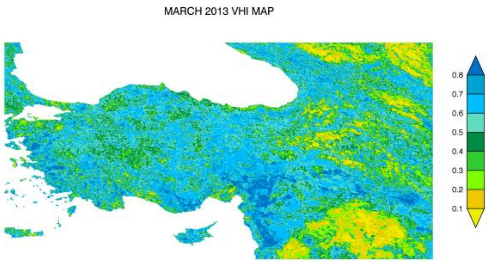


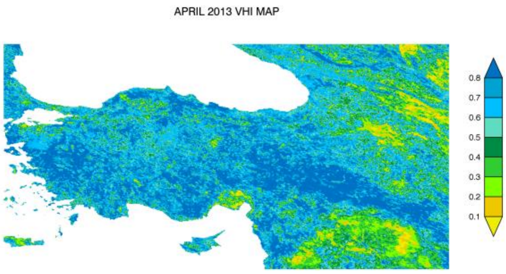


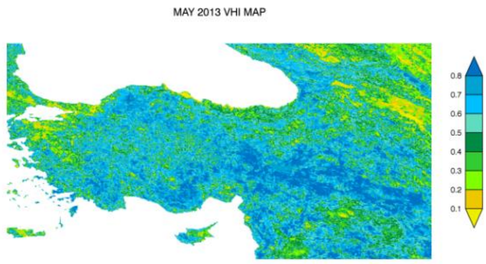



N

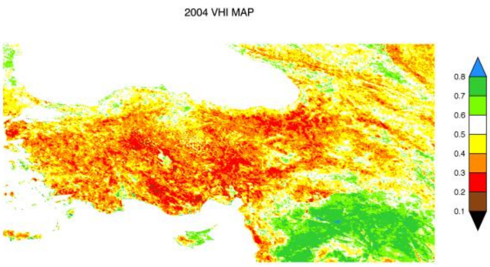

APRIL 2013 VCI MAP
0.5
0.4
0.3
0.2
0.1

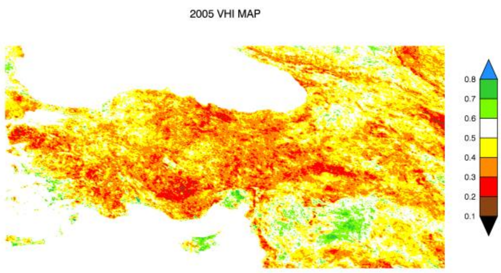

MARCH 2013 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

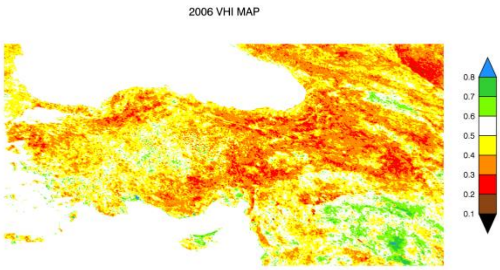

APRIL 2013 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

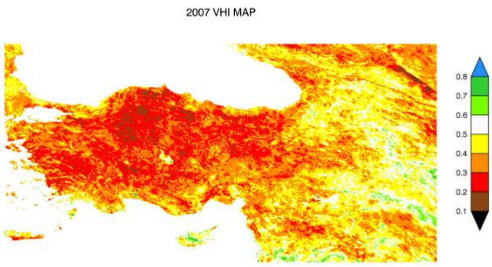

MAY 2013 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

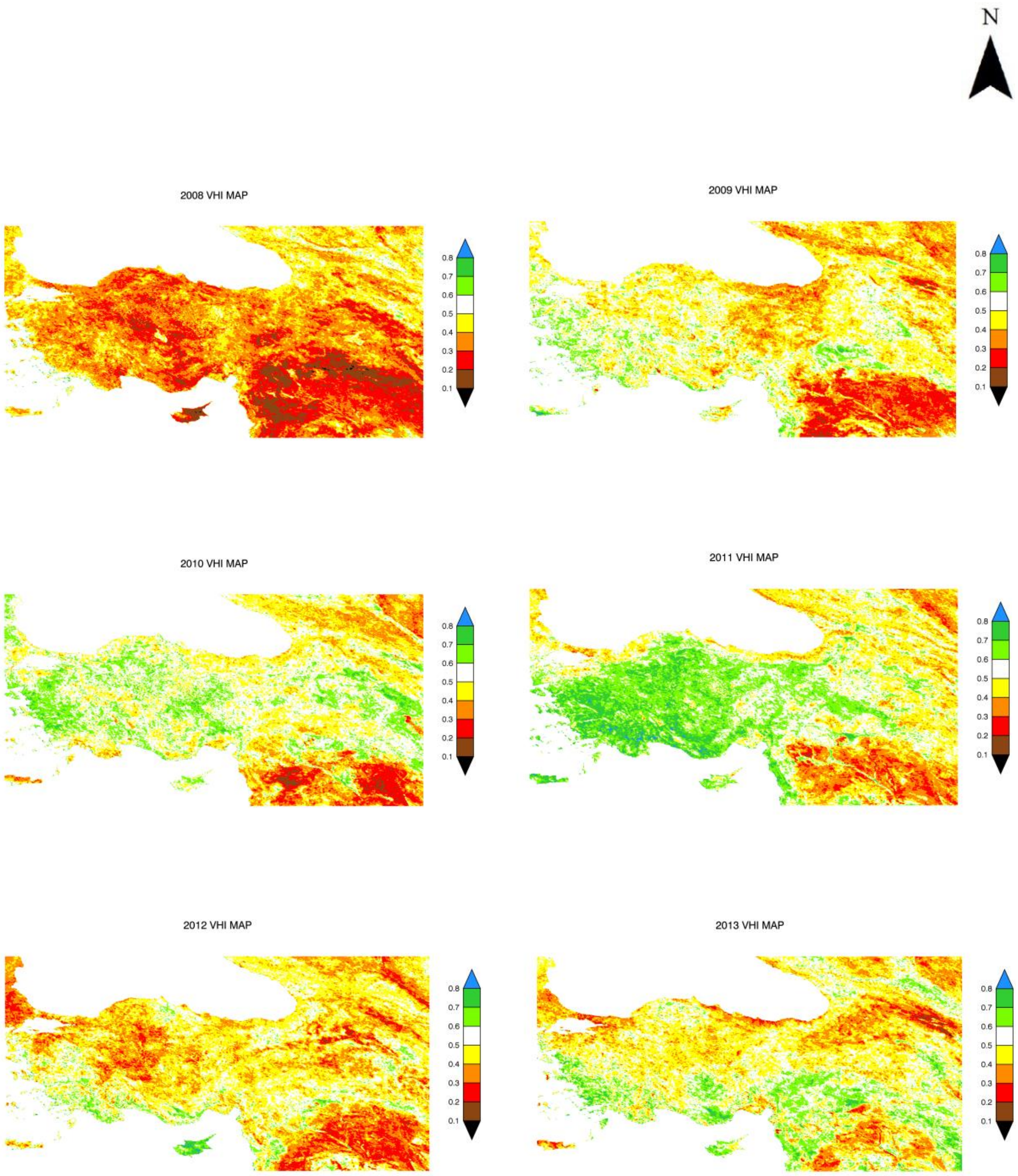
APPENDIX B


2004 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2005 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2006 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


2007 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


N
2008 VHI MAP
2009 VHI MAP
2010 VHI MAP
2011 VHI MAP
2012 VHI MAP
2013 VHI MAP
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

APPENDIX C

Pro read_lst_1

```
;input LST files
dir='D:\nazila\nazila_modis\nazila_modis_2013\nisan_2013\nisan_lst_2013\23_nisn'
CD, dir
files1 = FILE_SEARCH('*.hdf', COUNT=numfiles1)
counter = 0
WHILE (counter LT numfiles1) DO BEGIN
name = files1(counter)
Print, name
Fname=STRMID(name,9,7)
newFileID=HDF_SD_START(name, /READ)
thisSdsID=HDF_SD_SELECT(newFileID, 0)
HDF_SD_GETDATA, thisSdsID, data
; Convert the M-D data to 2D data at scan=0
data2D=data[*,*,0]
; transpose data
data2D=Rotate(transpose(data2D),3)
; Close file
 if (counter EQ 0) then begin
dim2 = Size(data2D, /Dimensions)
HDF_SD_FILEINFO, newFileID, datasets, attributes
bandas = fltArr(numfiles1, dim2[0],dim2[1])
endif
HDF_SD_END, newFileID
```

```
bandas[counter,*,*]=data2D

counter = counter+1

ENDWHILE

print, 'Each HDF File Size:',dim2[0],' X',dim2[1]

dataD =fltarr(2*dim2[0],2*dim2[1])

a=Reform(bandas[1,*,*],dim2[0],dim2[1])

b=Reform(bandas[3,*,*],dim2[0],dim2[1])

c=Reform(bandas[0,*,*],dim2[0],dim2[1])

d=Reform(bandas[2,*,*],dim2[0],dim2[1])

e=[[a],[c]] combine four images to one big image

f=[[b],[d]] combine four images to one big image

dataD=[[e,f]]

Print, 'min Pre fil',min(dataD)

Print, 'max Pre fil',max(dataD)

;output LST files

dir = 'D:\nazila\nazila_modis\output_read_lst_1\nisan'

CD, dir

dataD=dataD*0.02-273.0 convert fahrenheit to celsius

dataD2=dataD(1:1950,474:1673) crop image for Turkey

dim3 = Size(dataD2, /Dimensions)

print, 'New HDF File Size:',dim3[0],' X',dim3[1]

fileID = HDF_SD_START('LST_'+Fname+'_'+name, /CREATE)

NDVI=HDF_SD_CREATE(fileID, "LST Values", [dim3[0],dim3[1]], /FLOAT)

HDF_SD_ADDDATA, NDVI, Rotate(Transpose(dataD2),3)

HDF_SD_ENDACCESS, NDVI

HDF_SD_END, fileID
```

```
End

Pro read_lst_all
;input NDVI directory
dir = 'D:\nazila\nazila_modis\output_read_lst_1\nisan'
CD, dir
files1 = FILE_SEARCH('*.hdf', COUNT=numfiles1)
counter = 0
WHILE (counter LT numfiles1) DO BEGIN
name = files1(counter)
Print, name
 if (counter EQ 0) then begin
Fname=StrArr(numfiles1)
Endif
Fname[counter]=STRMID(name,4,7)
newFileID=HDF_SD_START(name, /READ)
thisSdsID=HDF_SD_SELECT(newFileID, 0)
HDF_SD_GETDATA, thisSdsID, data
; Convert the M-D data to 2D data at scan=0
data2D=data[*,*,0]
; transpose data
data2D=Rotate(transpose(data2D),3)
; Close file
if (counter EQ 0) then begin
dim2 = Size(data2D, /Dimensions)
HDF_SD_FILEINFO, newFileID, datasets, attributes
```

```
bandas = fltArr(numfiles1, dim2[0],dim2[1])
endif
HDF_SD_END, newFileID
bandas[counter,*,*]=data2D
counter = counter+1
ENDWHILE
print, 'Each HDF File Size:',dim2[0],' X',dim2[1]
 ;output NDVI directory
dir = 'D:\nazila\nazila_modis\output_read_lst_1\nisan\output_nisan_lst'
CD, dir
For i = 0, dim2[0]-1 Do Begin
For j = 0, dim2[1]-1 Do Begin
maks=max(bandas[*,i,j])
bandas[where(bandas[*,i,j] LE (-200), /NULL)]=100
mins=min(bandas[*,i,j])
;print,mins
For l=0, numfiles1-1 Do Begin
if bandas[l,i,j] LT 99 then bandas[l,i,j]=(maks-bandas[l,i,j])/(maks-mins)
EndFor
EndFor
EndFor
;bandas[where(bandas[*,*,*] GT 90, /NULL)]=-0.1
bandas[where(bandas[*,*,*] GT 90, /NULL)]=0.0
For k = 0, numfiles1-1 Do Begin
;print, Sname[k]
fileID = HDF_SD_START(Fname[k]+'_'+name, /CREATE)
```

```
NDVI=HDF_SD_CREATE(fileID, "LST Values", [dim2[0],dim2[1]], /FLOAT)

;print,numfiles1

HDF_SD_ADDDATA, NDVI, Rotate(Transpose(bandas[k,*,*]),3)

HDF_SD_ENDACCESS, NDVI

HDF_SD_END, fileID

newFileID2=HDF_SD_START(Fname[k]+'_'+name, /READ)

thisSdsID2=HDF_SD_SELECT(newFileID2, 0)

HDF_SD_GETDATA, thisSdsID2, data3

; Convert the M-D data to 2D data at scan=0

data3D2=data3[*,*,0]

; transpose data

data3D2=Rotate(transpose(data3D2),3)

; Close file

HDF_SD_END, newFileID2

dim3 = Size(data3D2, /Dimensions)

;print, 'Each HDF File Size:',dim3[0],' X',dim3[1]

im3c = CONGRID(data3D2, 600, 370, /INTERP)

LoadCT,0

TVLCT, 238, 238, 0, 0   ;canary

TVLCT, 238, 201, 0, 1   ; selective Yellow

TVLCT, 127, 255, 0, 2     ; citrine

TVLCT, 50, 205, 50, 3 ; citrus

TVLCT, 0, 139, 69, 4 ; olive drab

TVLCT, 94, 221, 193, 5 ;olive

TVLCT, 0, 191, 255, 6 ; olive

TVLCT, 0, 163, 209, 7 ; olive
```

```
TVLCT, 0, 114, 198, 8 ;olive

TVLCT, rgb, /GET

levels=[0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8]

kyear=FIX(STRMID(Fname[k],0,4))

dayofyear=FIX(STRMID(Fname[k],4,3

CALDAT, JULDAY(1, dayofyear, kyear), month, day

;if k EQ 0 then print, Fname[k], kyear, month, day

w=Window(DIMENSIONS=[800,500])

c = Contour(im3c, /CURRENT, C_VALUE=levels, /FILL,$

POSITION=[0.1, 0.1, 0.9, 0.8], AXIS_STYLE=0,$

RGB_TABLE=rgb, RGB_INDICES=Indgen(9), TITLE=STRTRIM(kyear,1)+'
'+STRTRIM(month,1)+'  '+STRTRIM(day,1)+' TCI MAP')

cb = Colorbar(TARGET=c, ORIENTATION=1,/BORDER)

print,k

EndFor

End
```

Pro read_ndvi_1

```
Nleft=8   ; lt nb/2 ?

Nright=8  ; lt nb/2 ?

Order=0

Degree=4

savgolFilter = SAVGOL(Nleft, Nright, Order, Degree)

;input NDVI directory

dir = 'D:\nazila\nazila_modis\nazila_modis_2013\ocak_2013\ocak_ndvi_2013'

CD, dir
```

```
files1 = FILE_SEARCH('*.hdf', COUNT=numfiles1)
counter = 0
WHILE (counter LT numfiles1) DO BEGIN
name = files1(counter)
Print, name
newFileID=HDF_SD_START(name, /READ)
thisSdsID=HDF_SD_SELECT(newFileID, 0)
HDF_SD_GETDATA, thisSdsID, data
; Convert the M-D data to 2D data at scan=0
data2D=data[*,*,0]
; transpose data
data2D=Rotate(transpose(data2D),3)
; Close file
if (counter EQ 0) then begin
dim2 = Size(data2D, /Dimensions)
HDF_SD_FILEINFO, newFileID, datasets, attributes
bandas = fltArr(numfiles1, dim2[0],dim2[1])
endif
HDF_SD_END, newFileID
bandas[counter,*,*]=data2D
counter = counter+1
ENDWHILE
print, 'Each HDF File Size:',dim2[0],' X',dim2[1]
dataD =fltarr(2*dim2[0],2*dim2[1])
a=Reform(bandas[1,*,*],dim2[0],dim2[1])
b=Reform(bandas[3,*,*],dim2[0],dim2[1])
```

```
c=Reform(bandas[0,*,*],dim2[0],dim2[1])
d=Reform(bandas[2,*,*],dim2[0],dim2[1])
e=[[a],[c]] combine four images to one big image
f=[[b],[d]] combine four images to one big image
dataD=[[e,f]]
Print, 'min Pre fil',min(dataD)
Print, 'max Pre fil',max(dataD)
;output NDVI directory
dir = 'D:\nazila\nazila_modis\output_read_ndvi_1\ocak'
CD, dir
data3D=dataD(1:1950,474:1673) crop image for Turkey
dim3 = Size(data3D, /Dimensions)
print, 'New HDF File Size:',dim3[0],' X',dim3[1]
fileID = HDF_SD_START('NDVI_'+name, /CREATE)
NDVI=HDF_SD_CREATE(fileID, "NDVI Values", [dim3[0],dim3[1]], /FLOAT)
data3D=data3D*0.0001
dataD2 = CONVOL(FLOAT(data3D), savgolFilter, /EDGE_TRUNCATE)
HDF_SD_ADDDATA, NDVI, Rotate(Transpose(dataD2),3)
HDF_SD_ENDACCESS, NDVI
HDF_SD_END, fileID
End
```

Pro read_ndvi_all

```
;input NDVI directory
dir = 'D:\nazila\nazila_modis\output_read_ndvi_1\aralik'
CD, dir
```

```
iles1 = FILE_SEARCH('*.hdf', COUNT=numfiles1)
counter = 0
WHILE (counter LT numfiles1) DO BEGIN
name = files1(counter)
Print, name
newFileID=HDF_SD_START(name, /READ)
thisSdsID=HDF_SD_SELECT(newFileID, 0)
HDF_SD_GETDATA, thisSdsID, data
; Convert the M-D data to 2D data at scan=0
data2D=data[*,*,0]
; transpose data
data2D=Rotate(transpose(data2D),3)
; Close file
if (counter EQ 0) then begin
dim2 = Size(data2D, /Dimensions)
HDF_SD_FILEINFO, newFileID, datasets, attributes
bandas = fltArr(numfiles1, dim2[0],dim2[1])
endif
HDF_SD_END, newFileID
bandas[counter,*,*]=data2D
counter = counter+1
ENDWHILE
print, 'Each HDF File Size:',dim2[0],' X',dim2[1]
;output NDVI directory
dir = 'D:\nazila\nazila_modis\output_read_ndvi_1\aralik\output_aralik_ndvi'
CD, dir
```

```
For i = 0, dim2[0]-1 Do Begin

For j = 0, dim2[1]-1 Do Begin

maks=max(bandas[*,i,j])

bandas[where(bandas[*,i,j] LE (-0.35), /NULL)]=10

;bandas[where(bandas[*,i,j] LE (-0.3), /NULL)]=10

mins=min(bandas[*,i,j])

;print,mins

For l=0, numfiles1-1 Do Begin

if bandas[l,i,j] LT 9 then bandas[l,i,j]=(bandas[l,i,j]-mins)/(maks-mins)

EndFor

EndFor

EndFor

bandas[where(bandas[*,*,*] GT 5, /NULL)]=0.0

;bandas[where(bandas[*,*,*] GT 5, /NULL)]=-0.2

Year=2004

For k=0, numfiles1-1 Do Begin

fileID=HDF_SD_START('NDVI_'+STRTRIM(Year,1)+name,/CREATE)

NDVI=HDF_SD_CREATE(fileID, "NDVI Values", [dim2[0],dim2[1]],/FLOAT)

print,k

HDF_SD_ADDDATA, NDVI, Rotate(Transpose(bandas[k,*,*]),3)

HDF_SD_ENDACCESS, NDVI

HDF_SD_END, fileI

newFileID2=HDF_SD_START('NDVI_'+STRTRIM(Year,1)+name,/READ)

thisSdsID2=HDF_SD_SELECT(newFileID2, 0)

HDF_SD_GETDATA, thisSdsID2, data3

; Convert the M-D data to 2D data at scan=0
```

```
data3D2=data3[*,*,0]

; transpose data

data3D2=Rotate(transpose(data3D2),3)

; Close file

HDF_SD_END, newFileID2

dim3 = Size(data3D2, /Dimensions)

print, 'Each HDF File Size:',dim3[0],' X',dim3[1]

im3c = CONGRID(data3D2, 600, 370, /INTERP)

LoadCT,0

TVLCT, 238, 238, 0, 0   ;yellow

TVLCT, 238, 201, 0, 1   ; gold

TVLCT, 202, 255, 112, 2     ; darkolivegreen

TVLCT, 0, 255, 0, 3 ; lawngreen

TVLCT, 50, 205, 50, 4 ; green1

TVLCT, 0, 139, 0, 5 ; green2

TVLCT, rgb, /GET

levels=[0.0, 0.1, 0.2, 0.3, 0.4, 0.5]

w=Window(DIMENSIONS=[800,500])

c = Contour(im3c, /CURRENT, C_VALUE=levels, /FILL,$

POSITION=[0.1, 0.1, 0.9, 0.8], AXIS_STYLE=0,$

RGB_TABLE=rgb, RGB_INDICES=Indgen(6),
TITLE='DECEMBER'+STRTRIM(Year,1)+' VCI MAP')

cb = Colorbar(TARGET=c, ORIENTATION=1,/BORDER)

Year=Year+1

print,k

EndFor
```

```
End

Pro vhi
dir='D:\nazila\nazila_modis\output_vhi\aralik\aralik_2013'
CD, dir
files1 = FILE_SEARCH('*.hdf', COUNT=numfiles1)
counter = 0
WHILE (counter LT numfiles1) DO BEGIN
name = files1(counter)
Print, name
newFileID=HDF_SD_START(name, /READ)
thisSdsID=HDF_SD_SELECT(newFileID, 0)
HDF_SD_GETDATA, thisSdsID, data
; Convert the M-D data to 2D data at scan=0
data2D=data[*,*,0]
; transpose data
data2D=Rotate(transpose(data2D),3)
; Close file
if (counter EQ 0) then begin
dim = Size(data2D, /Dimensions)
bandas = fltArr(numfiles1, dim[0]*dim[1])
endif
HDF_SD_END, newFileID
bandas[counter,*]=Reform(data2D,1,dim[0]*dim[1])
counter = counter+1
ENDWHILE
```

```
;VHI calculate
dir='D:\nazila\nazila_modis\output_vhi\aralik\aralik_2013'
CD, dir
vh=fltArr(dim[0]*dim[1])
vh=bandas[0,*]/(numfiles1-1)
for i=1,numfiles1-1 DO BEGIN
vh+=bandas[i,*]/(numfiles1-1)
endfor
vhi=0.5*vh+0.5*bandas[numfiles1-1,*]
vh1=Reform(vhi,dim[0],dim[1])
fileVID = HDF_SD_START('VHI'+name, /CREATE)
VHI=HDF_SD_CREATE(fileVID, "VHI Values", [dim[0],dim[1]], /FLOAT)
HDF_SD_ADDDATA, VHI, Rotate(Transpose(vh1[*,*]),3)
HDF_SD_ENDACCESS, VHI
HDF_SD_END, fileVID
mvh1 = CONGRID(vh1[*,*,0], 600, 370, /INTERP)
LoadCT,0
TVLCT, 238, 238, 0, 0   ;canary
TVLCT, 238, 201, 0, 1   ; selective Yellow
TVLCT, 127, 255, 0, 2     ; citrine
TVLCT, 50, 205, 50, 3 ; citrus
TVLCT, 0, 139, 69, 4 ; olive drab
TVLCT, 94, 221, 193, 5 ; citrus
TVLCT, 0, 191, 255, 6 ; olive drab
TVLCT, 0, 163, 209, 7 ; olive drab
TVLCT, 0, 114, 198, 8 ; olive drab
```

```
TVLCT, rgb, /GET

levels=[0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8]

w=Window(DIMENSIONS=[800,500])

c = Contour(mvh1, /CURRENT, C_VALUE=levels, /FILL,$

POSITION=[0.1, 0.1, 0.9, 0.8], AXIS_STYLE=0,$

RGB_TABLE=rgb, RGB_INDICES=Indgen(9), TITLE='DECEMBER 2013 VHI

MAP')

cb = Colorbar(TARGET=c, ORIENTATION=1,/BORDER);, TICKNAME=['-
0.1','0.0', '0.1' , '0.2', '0.3', '0.4', '0.5', '0.6', '0.8'])

End
```

CURRICULUM VITAE

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