Research Paper

Volume : 2 | Issue : 12 | December 2013 • ISSN No 2277 - 8179

Investigation of the Phenology of Pistachio (Pistacia Vera L.) on Different Soil Types Using MODIS NDVI Data

Geography

KEYWORDS : Pistachio, biomass, phenology, soil, MODIS NDVI

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ABSTRACT

Temperature and precipitation pattern changes in the 21st century due to the increased emission of greenhouse gases in the atmosphere. Turkey is located in a semi-arid climate belt, which is under constant threat of global drought. Potential climate change in the 21.centuy is expected to further increase this drought. Therefore, data on agriculture, which is of great importance for all living things in the world, should be obtained constantly, regularly and at adequate frequency. In this study, phenology of Pistachio (Pistacia vera L.,) on different soil types was monitored using MODIS data in 2000-2010 period. Origins and the most important gene source of Pistachio is the Near East Region including Caucasia, Iran and Turkmenistan. Gaziantep province in Turkey has the largest pistachio gardens in southeastern Turkey. Pistachio test sites were determined in Nizip district of Gaziantep, which is located in east of Gaziantep. Determined test sites were identified from the areas with different soil properties. Thus, the effect of changing soil characteristics on pistachio phenology was determined. In conclusion, it was found that pistachio showed the highest biomass activity in April and May and showed a decrease in biomass activity in June. Pistachio stages show similarities in all soil groups. However, it was observed that pistachio specimens selected from sloped areas in northern section of Nizip district showed highest biomass activity.

Introduction

Climate system has constantly changed during approximately 4.5 billion-year history of the Earth. However, in addition to natural changeability since the middle of 19. century, a new era started, in which, human activities also affected the climate for the first time [18]. Today, climate still shows changes due to the increase of water vapor, carbon dioxide, methane and ozone gases, which are naturally found in the atmosphere. IPCC reported that the 20-year period after 1990, was the hottest period of the world. In this period, temperatures showed an increase of 0.6 ºC at global scale [14].

Climate changes due to global warming will have negative effects on Turkey. Thus, in 2080s, Turkey is estimated to show changes in precipitation pattern and temperatures due to increase greenhouse gases. Increased temperatures and changes in precipitation pattern, loss of water sources, forest fires, drought and desertification will cause ecologic problems [17]. However, the most significant negative effect of climate change on Turkey will be drought, due to its location in a semi-arid climate belt under the constant threat of drought. Increased drought will cause significant fluctuations in agricultural production. Currently, problems are experienced in agriculture and potable water supply. Drought due to the potential climate change in the 21.centyury is expected to further increase these problems. Global climate change will also have impacts on temperature, salinity and moisture content of soil [15]. This will make the soil unusable due to the reasons such as desertification and erosion. As a result, increased temperatures due to global climate change will have direct and indirect significant effects on agricultural production. For this reason, monitoring and recording phenology of agricultural products is of great importance for the counties like Turkey, which will be significantly affected from global climate change. Natural events such as climate changes and human activities cause significant changes on important agricultural areas in the world [19]. Although the changes in agricultural product pattern or phenology are generally the result of a long process, they can be accelerated by changing technology and natural events, such as global climate change. Data on agriculture, which is of great importance for all living things in the world, should be obtained constantly, regularly and at adequate frequency. The fact that information is constant and involves large areas increases its volume. Remote sensing methods is superior to other known method in terms of speed, continuity, reliability and cost which are required for data at this size [3].

In remote sensing, agricultural products can be identified by using different modelings and satellites. Normalized Difference Vegetation Index (NDVI) is one of the most commonly used model to monitor climate and manmade vegetation changes [13], [14]. MODIS NDVI data, which was used in our, study allow for the monitoring of agricultural changes in large areas thanks to their spatial and temporal resolution. In 1988, NASA reported that MODIS data can be intensively used in a wide variety of areas from natural resource management, analysis of climate change, studies on drought, to studies on agriculture and drought. Indeed, this came true and MODIS data is being used in a wide variety of areas [6].

In this study, phenology of Pistachio (Pistacia vera L.,) on different soil types was monitored. Origins and the most important gene source of Pistachio is Near East Region including Caucasia, Iran and Turkmenistan. Turkey is the largest pistachio producer in Turkey together with Iran, the USA and Syria [10].

Gaziantep province in Turkey has the largest pistachio gardens in southeastern Turkey. Pistachio test sites were determined in Nizip district of Gaziantep, which is located in east of Gaziantep, using MODIS data in 2000-2010. Determined test sites were selected from areas with different soil characteristics. Thus, the effect of changing soil characteristics on pistachio phenology was analyzed.

Test Site and Data

Nizip is the largest district of Gaziantep province. The district has a population of 97.956 according to 2011 census. Nizip is surrounded by Şanlıurfa (Birecik) in the east; Karkamış, Yavuzeli in the south; Gaziantep and Oğuzeli in the west. Latitude and longitude of Nizip is 36°28 00'N and 36°38 00'E. It has an elevation of 400-500m above sea level. It has an area of 76.195 hectares. Annual mean temperature is 16 C. The highest temperature was 43; the lowest temperature was -15 C. Nizip is located in Fırat basin and generally shows the characteristics of a plateau opening to the east and a lain in the south. The district has a flat topography with low surface roughness (Figure 1).

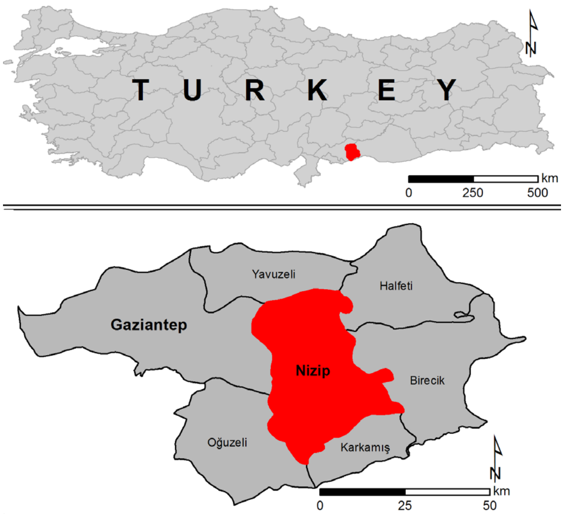

Figure1. Location map of study area

MODIS satellites, which are launched by NASA (National Aeronautical and Space Administration) on their orbit in the space can view the Earth at global scale. MODIS satellites, which are termed as Moderate Resolution Imaging Spectroradiometer, began to take images of the Earth with their sensor called TERRA in 1999 for the first time. MODIS satellites, which were first used in ocean and atmosphere studies, offer significant convenience with their high spatial and spectral resolution in studies on vegetation, land use, drought and agriculture. MODIS satellites consist of 36 bands within 0.4 mm and 14.4 mm wavelength. In MODIS satellites, 1. and 2. band has 250 m; 3. and 7. band has 500 m and the remaining 29 bands have 1 km spatial resolution.

MODIS NDVI images are found in hdf extension package called MOD13Q1 under MODIS Terra platform. 2.band in MODIS is MODIS NDVI images. These images are taken two times a day and broadcasted in every 16 days. Among the images which are taken two times a day for 16 days, the ones with the highest radiometric resolution and those de-bugged from brdf and clouds are combined and found in MOD13Q1 file. MODIS NDVI images contain 4800 lines and 4800 columns. They make it possible to analyze the changes in vegetation activity in a wide area.

The study used a total of 250 MODIS NDVI images between the years of 2000 and 2010, in 18-day periods. A total of 23 NDVI images were prepared for each month, excluding 2000 January.

Table 1. MODIS NDVI data used in experimental study

Date	Data	Number
2000	MODIS NDVI	20
2001	MODIS NDVI	23
2002	MODIS NDVI	23
2003	MODIS NDVI	23
2004	MODIS NDVI	23
2005	MODIS NDVI	23
2006	MODIS NDVI	23
2007	MODIS NDVI	23
2008	MODIS NDVI	23
2009	MODIS NDVI	23
2010	MODIS NDVI	23

Methodology

Remote Sensing Technologies and Vegetation Analysis

Radiation, which is not absorbed in the atmosphere and which is not scattered, reaches the earth and undergoes interaction. When the energy strikes the surface of the Earth, three interactions take place, which are absorption, transmission and reflection. This total energy interacts with the Earth through one or several of these three states. Ratio of each of these varies according to wavelength of energy, material and qualities. Absorption occurs when radiation (energy) is absorbed by the target. Transmission occurs when the radiation passes through the target. Reflection occurs when the radiation strikes the target and changes direction. Remote sensing, on the other hand, is mostly interested in measuring the radiation which is reflected from the target. Reflection is categorized in two types: Complete and diffusing reflection. Complete reflection occurs on a smooth surface and all of the energy is reflected back from the surface to a single direction. When the surface is rough, diffusion refection occurs and energy is reflected into all directions almost in the same form. A large part of the earth has between complete and diffusion reflective characteristics. Rather than the wavelength of the incoming radiation, target radiation is reflected both in complete and diffusion form or a mixture of two, depending on the surface roughness. Diffusing reflection will be significant when wavelengths are much smaller than surface variations or specific particles which constitute the surface. Spectral variations, which occur in visible areas by physical and chemical properties of objects produce the phenomena called color. Reflective properties of objects are of great importance since various remote sensing systems function in wavelength region, where basically reflection energy is dominant. Each object varies in terms of reflection properties and this behavior is indicated with a curve, which is called spectral reflection curve. The objects with spectral reflectance properties, which vary in certain spectra regions, are represented with different numerical color value in remote sensing images sensitive to these regions. Therefore, recognition of spectral reflectance properties of objects plays an important role in selection of wavelength region which is required to obtain remote sensing data for a certain application. Spectral reflectance properties of objects show a wide variety. Even the same object types might have different reflections depending on time and spatiality. Understanding of the factors which affect spectral reflections of analyzed objects is important for an accurate interpretation of the object and electromagnetic radiation [16].

3.2 Spectral Reflectance Characteristics of Plants

Vegetation is a terrestrial object that can be most easily and properly identified and analyzed by remote sensing method. The most important reason for this is that there is no object between the sensor and the vegetation to affect image quality. Another important factor is that plant species show specific typical reflectance. Plants absorb or reflect lights at various wave lengths in a specific way depending on their cell structures, leaf and surface width, water amount in their structure and locations in their natural environment. Each plant has a specific cell structure and posture in the nature. Thus, it is possible to distinguish plant species from each other. Plants generally absorb lights at 0.4–0.7 µm wavelengths, which are called visible beam area. On the other hand, infrared lights are absorbed at quite low ratios; a large portion of them are reflected. Reflection of infrared lights by the plats in strıng however varying ratios makes a great contribution to their perception and analysis [2].

3.3. Vegetation Indexes

Vegetation index generally refers to obtain a single value showing the intensity of vegetation by applying mathematical operations to reflection values with different wavelengths in electromagnetic spectrum. Pixels with a high vegetation index show reliable vegetation. The image is enriched following the operations between different wavelengths where the vegetation shows strong reflectance.

3.3.1 Normalized Difference Vegetation Index

Vegetation indexes, which are mainly developed for vegetation and agricultural studies, consist of the combination of the reflectance of near infrared and visible red band. It was reported that the use of these indexes, which are obtained by numeric conversions, are more advantageous

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than original bands. These advantages include developing vegetation reflections; providing better data for comparisons by improving standardization and minimization of the impacts of soil and other external factors [12]. NDVI is a vegetation index, which is commonly used to detect land vegetation change, forest classification and agricultural studies [13]. Many vegetation indexes can be used to enrich characteristics of spectral vegetation from the visible and near infrared regions of electromagnetic spectrum. These indexes are generally associated with certain bio-physical parameters such as biomass or leaf area indexes. This band arithmetic is based on the near infrared and visible red bands of electromagnetic spectra. The software provides information from near infrared and visible red bands for plant analysis during the analysis study performed by selecting various bands. Plants particularly reflect in near infrared region. The contrast between the plant and water is visible in this region. In visible red band of the spectra, plants, barren land, rocky area and manmade objects provide a very good contrast. When compared to manmade objects in the barren land or surface, plants tend to be included in the visible red band of the spectra and therefore are visible in dark color. On the other hand, manmade objects in barren land or surface give light and bright image in this section of the spectra. Digital number value of different bands is used to calculate NDVI values. A DN value refers to the value of one pixel in data band. Similarly, DN value varies according to how much the atmosphere and terrestrial surface absorb radiation and how much reflectance is sent back to the sensor [11].

NDVI = (NIR – R) / (NIR + R)

NDVI results were then converted into Maximum Difference Vegetation Index by (NDVI+1)*100 formula to facilitate statistical analyses. Vegetation index values were confined in a band between 0-200 by applying the method defined by Holben [5]. Consequently, while the values smaller than 100 show the areas which lack vegetation, such as ice and cloud; the values of 100 and around show barren areas or sparse vegetation; while high values between 130-200 include the areas corresponding to vegetation [8].

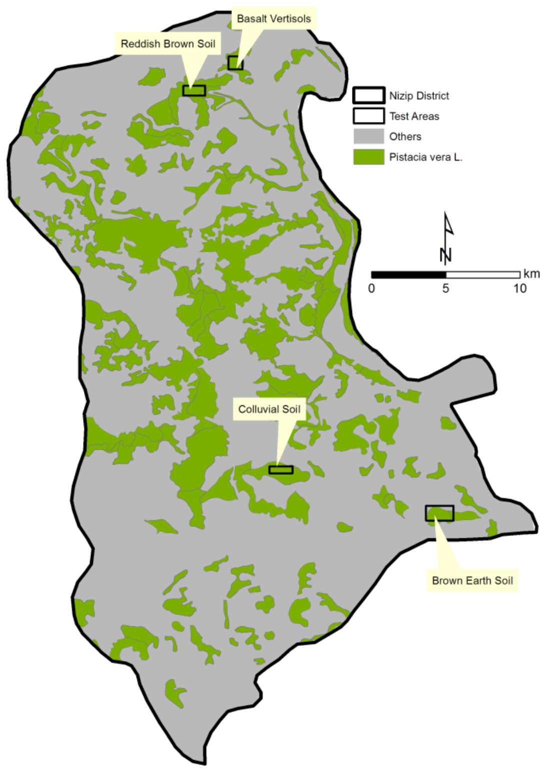
Results and Discussion

Test areas were determined from different regions of Nizip district in terms of soil characteristics, slope and erosions sensitivity (Table 2). Test areas were selected from northwest and southeast sections of Nizip (Figure 2 and 3). Analysis of the indication of test sites on provided maps shows that slope percentage and erosion sensitivity of northern sections were high. On the other hand, test areas determined in southern section are areas with low slope parentage and high soil thickness. Basaltic vertisol and reddish-brown soils are found in the northern section of the study area, while colluvial and brown earth soils are found in the south of the study area. Figure 2 indicates that pistachio is cultivated in a significant portion of pistachio distribution map in the study area. This is important in terms of indicating economic significance of pistachio in Nizip province.

Table 2. Soil, slope characteristics and erosion sensitivity of selected test areas.

Soil Type	Erosion vulnerability	Slope (%)	Soil Depth
Colluvial Soil	Moderate	2-6	Moderately Deep (50-90cm)
Brown Earth Soil	Moderate	2-6	Moderately Deep (50-90cm)
Reddish Brown Soil	Severe	12-20	Very Shallow (0-20 cm)
Basaltic Vertisol	Severe	12-20	Very Shallow (0-20 cm)

Nizip district has 4 large soil groups. Brown earth soils and reddish-brown soils are completely similar in terms of all characteristics, excluding their color. These soils cover a wide area in Nizip district, which shows arid and semi-arid characteristics. Brown earth soil and reddish-brown soils have a good natural drainage. These soils have low biological activity. They have high natural yield. Colluvial soils, which fall into azonal soil class, are the large soil groups in the study area. Colluvial soils are produced by the accumulation of materials of various sizes which weather along the slopes. They are produced on sandy, angular pebble sedimentary colluvial deposits. Since the colluvial deposit is thick, physiological depth is also high; however, water retention capacities are low. These soils are common in the skirts of mountains [1]. Colluvial soils in the study area are mainly found in deep valleys cut by Fırat River and its tributaries. Basaltic vertisols are other large soil group, which cover a wide area in the study area. These soils have high clay content; they are dark in color and have underdeveloped profile. Since basaltic soils have a high stone content, they should be cleared from stones in uses, which require intensive tillage. As pistachio can grow in stony soils, it is cultivated in basaltic soils in the study area. In addition to soil type, slope status of the land significantly affects agricultural products. In the study a particular attention was shown to select test sites with different soil and slope characteristics. Thus, we were able to answer the question as to what extent pistachio is phenologically affected from slope and soil characteristics. Varying slope and soil properties of determined test sites also caused different erosion sensitivity. Thus, many factors affecting pistachio were explained.



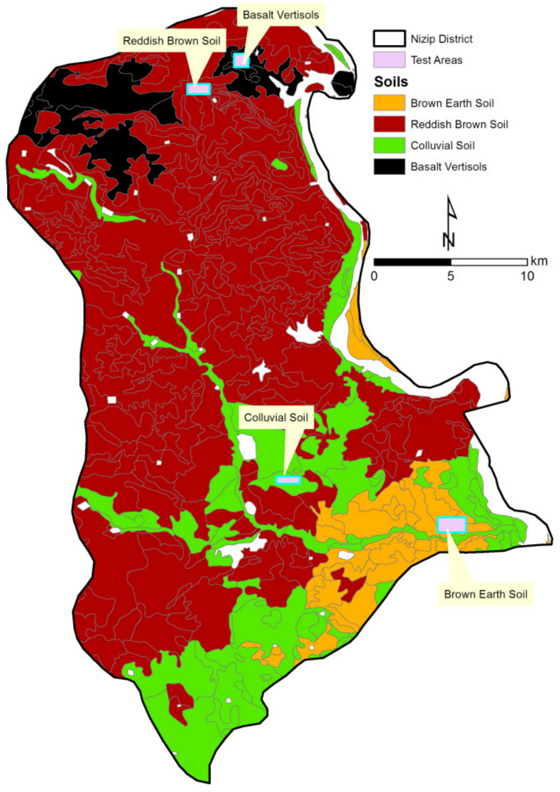
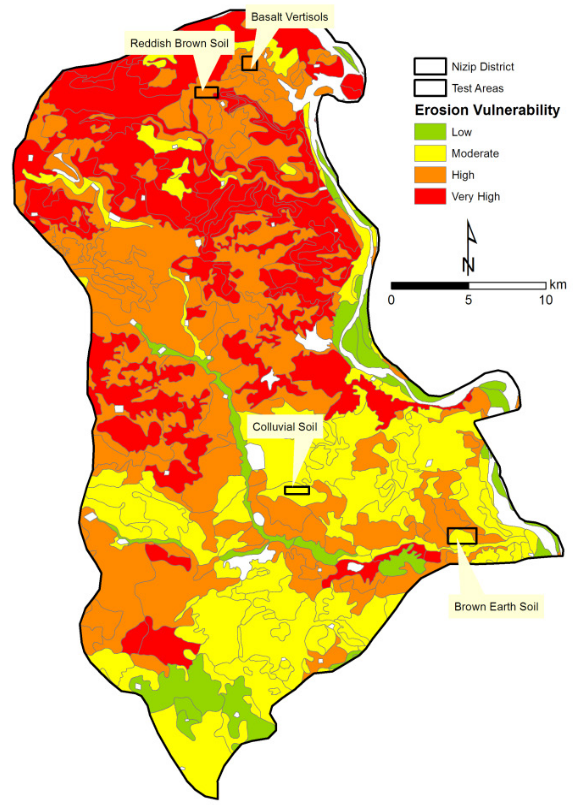


Figure 2. Distribution of Pistachio and Soil Types in Nizip District (Changed from Soil Data Inventory of Ministry of Food, Agriculture and Livestock, 1987).



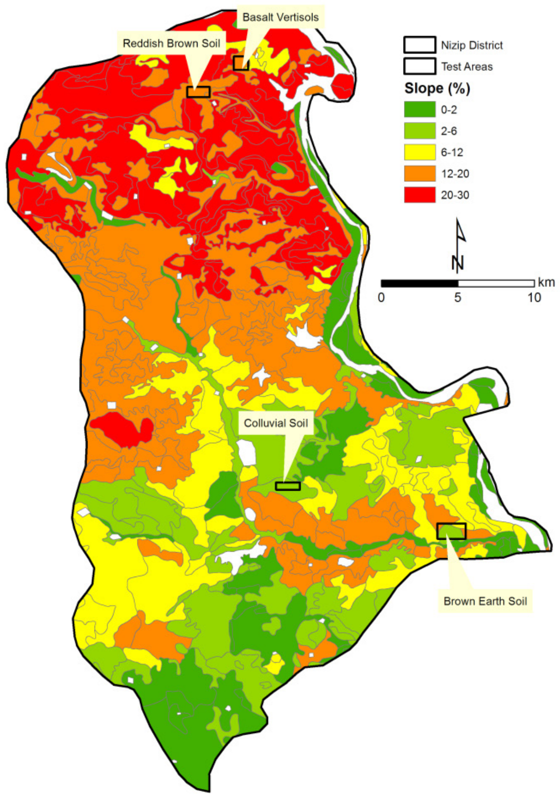


Figure 3. Slope and erosion sensitivity map of Nizip district (Changed from Soil Data Inventory of Ministry of Food, Agriculture and Livestock, 1987).

NDVI values of pistachio test sites with different soil and slope characteristics in different sections of Nizip district were measured. Phenology of pistachio in different localities was determined using NDVI images, which were obtained from MODIS data between 2000-2010. Changing spatial and soil characteristics were found to cause significant variations in pistachio phenology. It was found that, the pistachio with the highest biomass activity, grew on reddish-brown soil and basaltic vertisols. On the other hand, the pistachio belonging to these two soil groups, grew on the sloped lands with high erosion risk in the north of Nizip district (Figure 4 and 5). Analysis of NDVI values in 2000-2010 period showed that reddish-brown soils gave high NDVI values in all years. Another pistachio area, which showed high NDVI trend like reddish-brown soils were found to be basaltic vertisols. High NDVI value is important in terms of showing that pistachio growing in these soils makes higher biomass activity. Characteristics of reddish-brown and brown earth soils, which are common in arid and semi-arid climate zones, are significantly similar. However, it was interesting that reddish-brown soils showed a higher NDVI trend than brown earth soils. High slope can have significant impacts on pistachio. Accordingly, pistachio shows higher biomass activity in highly sloped lands. This further supports the view mentioned earlier in the study that pistachio can be easily cultivated in barren, rocky, calcareous and sloped lands.

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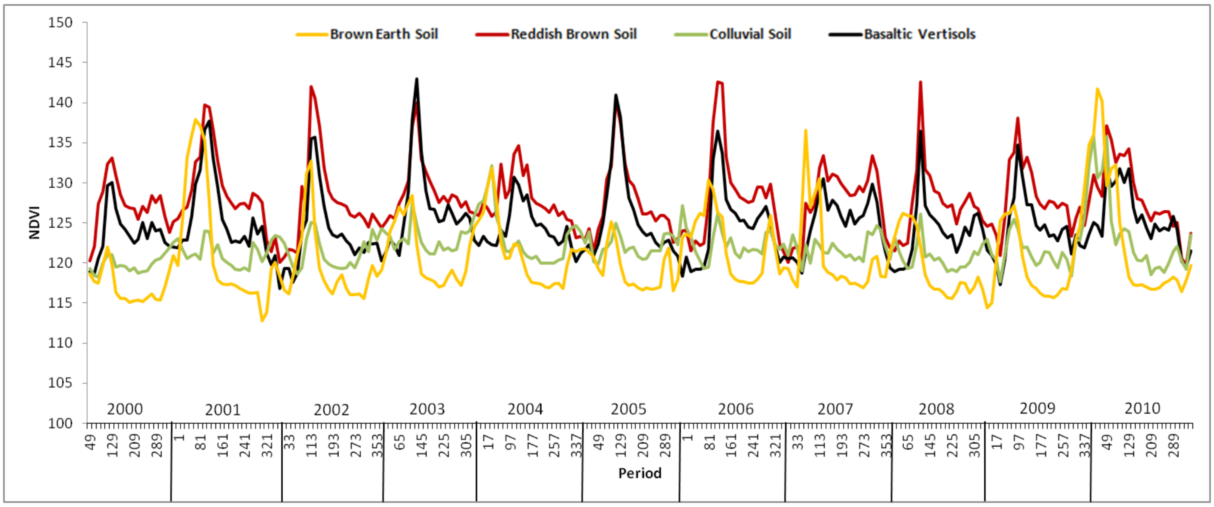


Figure 4. Variation of pistachio in lands showing different soil characteristics between 2000-2010

Phenological stages of pistachio in a year were more closely analyzed. Phenology of pistachio was determined by taking the means of the data in 2000-2010 period. It was observed that pistachio reached the greenest periods in April. Generally, pistachio NDVI shows an upward trend on all soil types starting from May. Pistachio reaches the highest biomass activity in April and May, however, biomass activity decreases after June.

Another striking point was that pistachio phenology changed on different soil types. However, pistachio reached the highest biomass activity in April in all soil groups. The pistachio in reddish-brown soils and basaltic vertisols in sloped areas in the north of Nizip district were found to give much higher NDVI values in April and May than the pistachio in other soil groups. Pistachio is found on reddish-brown soils in almost all periods of the year and gives higher NDVI trend than the pistachio on other soil groups (Figure 5).

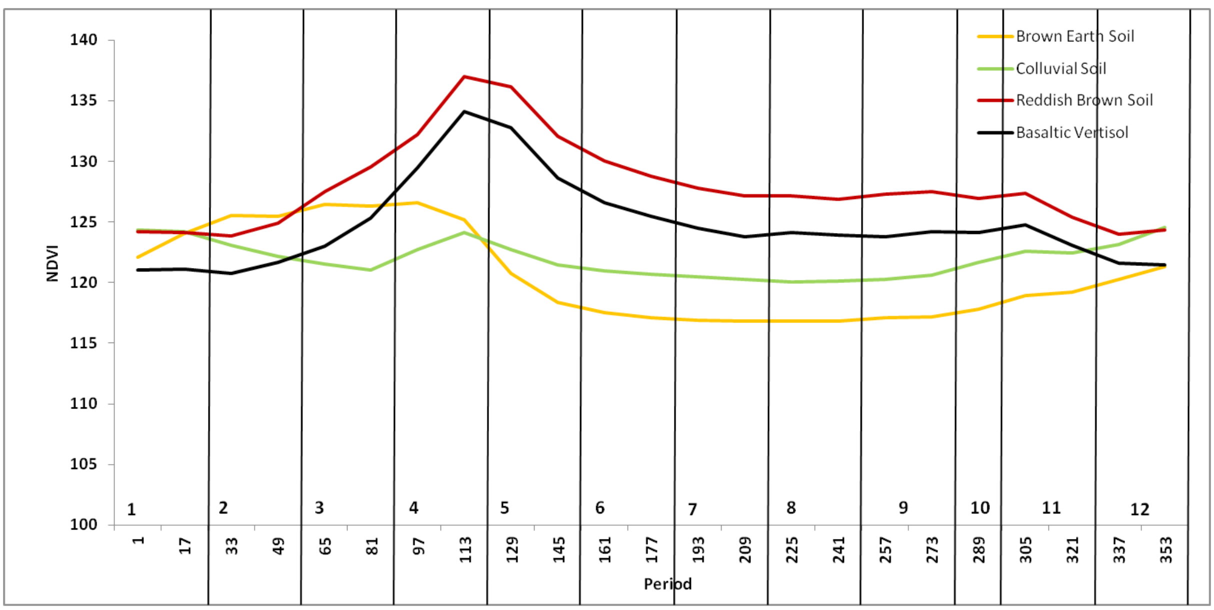


Figure 5. Average phenology of Pistachio in and showing different soil characteristics in 11-year period (2000-2010).

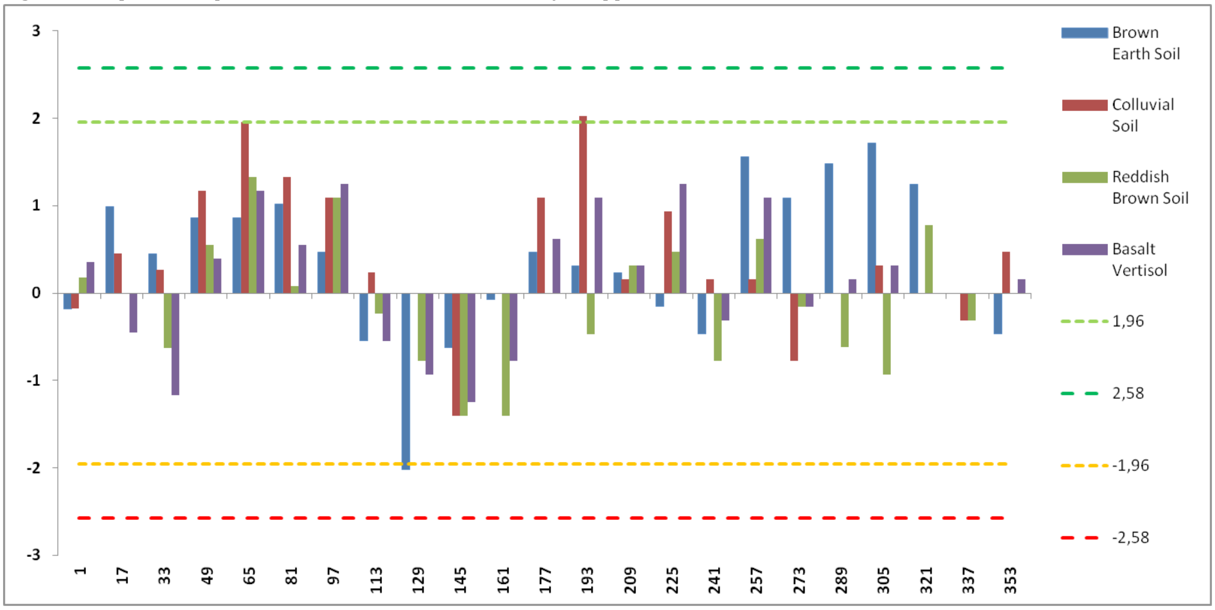
Table 3.Non-parametric Mann-Kendall Trend Analysis results applied on NDVI values of 2000-2010 (* shows significance level at 90% confidence interval)

Brown Earth Soil			Colluvial Soil		Reddish Brown Soil		Basalt Vertisol	
Months	Test Z	Signific.	Test Z	Signific.	Test Z	Signific.	Test Z	Signific.
January	-0,18		-0,18		0,18		0,36	
	0,99		0,45		0,00		-0,45	
February	0,45		0,27		-0,63		-1,17	
	0,86		1,17		0,55		0,39	
March	0,86		1,95	+	1,33		1,17	
	1,02		1,33		0,08		0,55	
April	0,47		1,09		1,09		1,25	
	-0,55		0,23		-0,23		-0,55	
May	-2,02	*	0,00		-0,78		-0,93	
	-0,62		-1,40		-1,40		-1,25	
June	-0,08		0,00		-1,40		-0,78	
	0,47		1,09		0,00		0,62	

July	0,31		2,02	*	-0,47		1,09	
	0,23		0,16		0,31		0,31	
August	-0,16		0,93		0,47		1,25	
	-0,47		0,16		-0,78		-0,31	
September	1,56		0,16		0,62		1,09	
	1,09		-0,78		-0,16		-0,16	
October	1,48		0,00		-0,62		0,16	
November	1,71	+	0,31		-0,93		0,31	
	1,25		0,00		0,78		0,00	
December	0,00		-0,31		-0,31		0,00	
	-0,47		0,47		0,00		0,16	

NDVI trend of pistachio was analyzed in 23 periods using non-parametric Mann-Kendall test. Mann-Kendall trend analysis on 16-day NDVI value found statistically significant variations. NDVI values of pistachio showed a general downward trend in April and May in all soil types. In other words, a decrease was detected in pistachio biomass activity in transition from spring to summer. On the other hand, statistically significant changes were only found in pistachio on brown earth soil and colluvial soil. These changes took place in the first period of March and June in the pistachio on colluvial soils. The pistachio on colluvial soils showed a positive statistically significant variation trend in the mentioned periods. While the pistachio NDVI values on brown earth soils show a negative statistically significant variation in early May; a positive variation was the case in the first period of November. In general terms, NDVI trends of pistachio were positive excluding April and May (Table 3 and Figure 6).

Figure 6. Graph of Non-parametric Mann-Kendall Trend Analysis applied on NDVI values of 2000-2010



Conclusions

At this stage, NDVI trend of pistachio on 4 large soil groups in Nizip district was monitored in 2000-2010 period. The variation caused by different soil types on pistachio phenology was determined. The results are presented below; This study determined 16-day phenology of the pistachio, which shows different oil and slope characteristics. It was found that pistachio showed the highest biomass activity in April and May; however, biomass activity decreased with the start of June. Non-parametric Mann-Kendall trend analysis showed that the pistachio showed lower biomass activity every passing year in the period from May to June. In addition to soil characteristics, slope factor was also found to affect pistachio phenology. Pistachio phenologic stages showed differences in all soil groups. However, the pistachio specimens on the sloped areas in the northern section of Nizip showed a higher biomass activity. Northern section of Nizip district has two large soil groups, which are reddish-brown soils and basaltic vertisols. Pistachio specimens on these two soil groups showed a higher biomass activity in all periods of the year when compared to the pistachio specimens detected in areas with lower slope in the south. Colluvial and reddish-brown soils, which are the 2 large soil groups in Nizip district, are found in areas with low slope percentage. Slope factor caused pistachio phenology on these soil groups to change. In conclusion, Turkey is located in a semi-arid climate belt, which is constantly under the threat of drought. Drought occasionally caused significant losses in transition periods in Turkey. Considerable fluctuations occurred in crop production, which is exposed to the effect of natural conditions especially in agriculture due to drought, giving rise to food shortage and high prices. Currently, there are still problems in agriculture and drinking water supply. It is expected that the drought which will occur due to climate change in the 21. century will further increase these problems. Therefore, data on agriculture, which is of great importance for all living things in the world, should be obtained constantly, regularly and at adequate frequency. It is important to use remote sensing, which provides significant advantages in terms of continuity, reliability and cost when compared to other methods. Thus, a potential risk of drought can be detected and measures can be taken in advance.

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