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Investigation of Phenology Events in a Broad Leaf Forest in Relation to Chlorophyll Content Change

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Abstract: Vegetation phenology, as used and studied the related studies, refers to the relationship between climate and periodic development of photosynthetic biomass. selected 15 Hornbeam plots (*Carpinus betulus*) from study area in a mountainous region from 520m to 1310m above sea level. Ground observations of hornbeam tree growth process from January to December 2004 in 15 day intervals were performed both visually and by measuring leaf chlorophyll concentration (Chlorophyll meter SPAD-502)and also we used a seasonal 8-day composite MODIS/NDVI. The Results for the regression analysis showed that the Leaved period positively correlated with the air temperature(r =0.894). Anthesis and SPAD measurement have negative relationship with air temperature and as temperature increases they appear earlier in year. Anthesis and SPAD measurement had correlation coefficients of r =-0.883 and r =-0.855 respectively. Regression analysis showed that there is a positive relationship between NDVI and SPAD measurement (chlorophyll contents) in hornbeam trees. The mid April was recognized as the mean onset period of vegetation green-up while late November as the mean onset period of vegetation dormancy for the entire national level. The development of remote sensing methods to measure leaf chlorophyll content and surface spectral reflectance has received much attention since variations in leaf chlorophyll content can provide information concerning the physiological state of a leaf or plant.

Key words: Air temperature · MODIS/NDVI · Hornbeam · Chlorophyll meter (SPAD)

INTRODUCTION

Assessment of vegetation phenology by remotely sensed data has a long history [1] and more recently satellite data have been used to examine the potential effects of climate change on phenology [2,3]. Vegetation phenology, as used and studied the related studies, refers to the relationship between climate and periodic development of photosynthetic biomass. Accurate estimates of canopy phenology are critical for quantifying carbon and water exchange between forests and the atmosphere and its response to climate change. Satellite monitoring of vegetation phenology has often made use of a vegetation index such as NDVI because it is related to the amount of green leaf biomass[4]. Repeated observations from satellite-borne multispectral sensors provide a mechanism to gather data from plant-specific to regional scale studies of phenology [5,6].The NDVI has been shown as a key indicator for inferring the dynamics of vegetation structure and function [7]. NDVI is related to several biophysical parameters including chlorophyll density [8], percent canopy cover [9], photosynthetically absorbed active radiation [10]. Since NDVI is varied due to changes of phenology of seasonal forest/vegetation, foliage activity and stress phenology information at large spatial scales is required. Within this discipline the potential of remote sensing data for inferring phenological characteristics of vegetation is increasingly regarded as key to understanding seasonal phenomena of the vast area.

Satellite monitoring displays its greatest force in observation of vast area but ground observation is of vital importance for validation. Several validation systems have been developed for precise ground observation [11]. As most satellite studies of phenology are at scales =1 km [11, 3], the chance that the entire forest to be represented by the changes observed in a small cohort of trees is relatively small. While ground-based phenologies are

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usually recorded from discrete events (such as bud break, leaf emergence, or first flower), current technology limits satellite observations to continuous functions of canopy cover [12]. Although field phenologies are generally reliable and replicable, derivations of phenology from satellite analyses have created a diverse set of non-comparable datasets [13]. A criterion by which we might start to understand the accuracy of satellite datasets while expanding the rich of field studies is through validation across instruments and scales and between satellite and field data. We studied phenological events of hornbeam tree's natural growth which are of dominant deciduous broadleaf species of *Carpinus betulus* in the study region at different altitudes above sea level and compared validation evaluation of these ground data for monitoring deciduous broadleaf forest phenology with periodical MODIS data in the north of Iran.

MATERIAL AND METHODS

Study Area: The research was performed in a mountainous region located in the north of Iran Fig (1a). The study area is bounded by geo-coordinates 46°45′ to 46°55′ E and 39°00′ to 39°04′ N (Fig.1b). The average rainfall is 1223mm per year and the area is covered by deciduous broadleaf forests and the hornbeam is dominant species in the region (Fig.1b).The range in elevation in the study area was from 100m to 1310m above

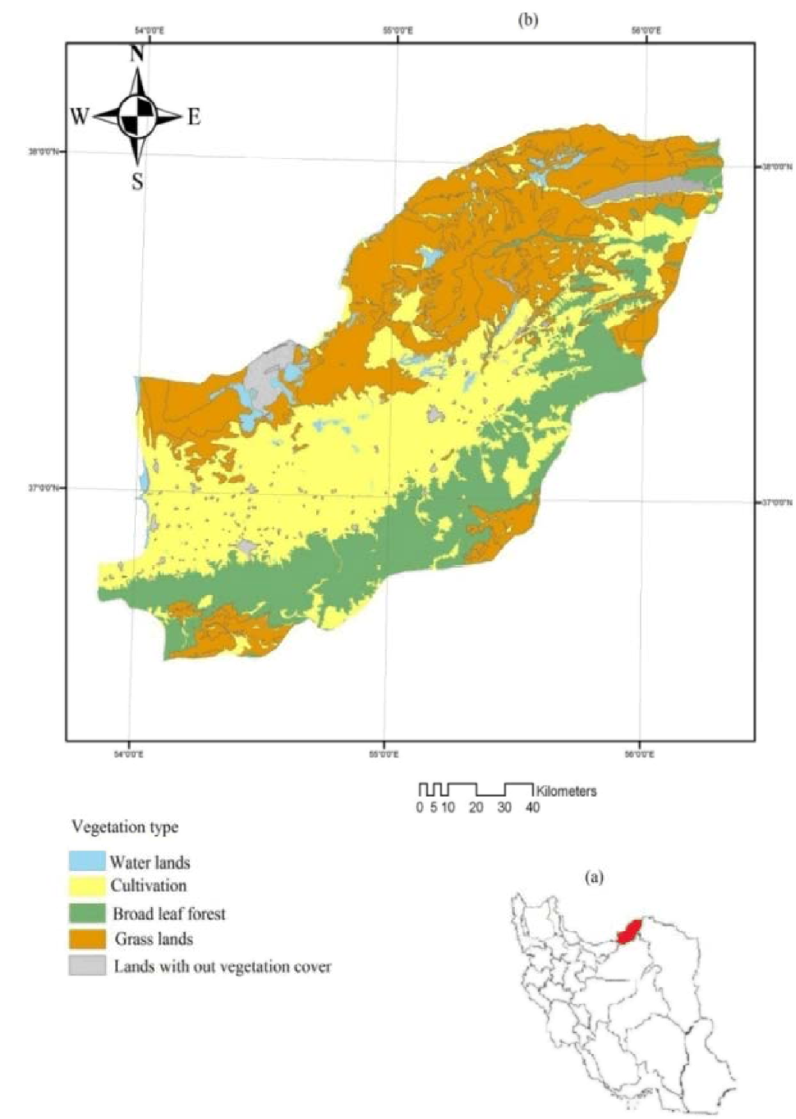

Fig. 1: Location of region in Iran (red-colour) (a), Distribution vegetation types in entire region in north of Iran (Forest, Range and Watershed Organization of Iran-2000). (b)

Table 1: Altitude levels for the selected 15 hornbeam plots

Plot	Altitude	Location
P1	520	Lower
P2	553	Lower
P3	615	Lower
P4	660	Lower
P5	738	Lower
P6	810	Middle
P7	830	Middle
P8	870	Middle
P9	920	Middle
P10	960	Middle
P11	1050	Upper
P12	1115	Upper
P13	1170	Upper
P14	1240	Upper
P15	1310	Upper

Table 2: Categorized phenological events of hornbeam plots and occurred DOY

Phenology events	stage	Lower zone Average Doy	Middle zone Average Doy	Upper zone Average Doy
bud bursting and leaf tip appearance	t1	109.0	116.1	117.3
Anthesis	t2	118.4	125.5	127.0
SPAD measurement possible	t3	120.0	127.0	130.0
Over 80% of maximum SPAD	t4	139.6	142.5	144.0
seed maturely	t5	303.7	306.6	309.3
Over 90% of maximum SPAD	t6	159.7	168.7	179.9
Maximum SPAD value	t7	220.9	226.8	230.9
Break 90% of max SPAD	t8	250.7	247.5	244.1
Break 80% of max SPAD (Start yellowing)	t9	279.8	271.9	269.1
Break 70% of max SPAD (Start defoliation)	t10	307.5	298.1	294.9
Defoliation completed	t11	321.4	315.0	312.4
Leaved period	d1= (t11-t1)	212.8	198.4	194.6
Stable production period	d2= (t9-t4)	140.2	129.4	125.1
Maximum photosynthesis period	d3= (t8-t6)	91.0	78.8	64.2

Phenology started from (t1) in spring, to leaf abscission (t11) in autumn.

sea level. The average annual temperatures, the coldest point and warmest point during the study (From January to December2004) were 12°C,-0.9°C in February and 25.70°C in August. Vegetation type data were obtained from a digitized vegetation map of Iran (Forest, Range and Watershed Organization of Iran). Vegetation was grouped as: deciduous broadleaf forest, grasslands, cultivation (Fig. 1b). As mentioned above, deciduous broad leaf forest was included in the study. Deciduous broadleaf forests are high canopy cover density and semi-high canopy cover density based from 500 to1310meters above sea level in the region.The study area is divided into three zones according to altitude levels: from 520 to738m above sea level, from810 to 960m above sea level and from 1050 to 1310m above sea level called as district with lower zone, district with middle zone and district with upper zone respectively (Table 1).

Data: The MODIS/NDVI data with a special resolution of 250×250 m² and 8-day intervals was acquired from the NASA MODIS products. The data collected from January to December 2004. 31 MODIS images were used in this study. A thermometer was used to study temperatures from 520 to 1310 meters above sea level. We set a thermometer at 15 different altitudes over the study site. We measured daily variations of air temperature at voluntary points in the study site from the difference of altitude and season. This device was used in 15 different altitude points from 520 to 1310 meters above sea level in points which we selected the plots.

Methods: This study was fulfilled in forestial regions of Gorgan in different altitudes and same aspect, fifteen sample plots were selected in one hectare and in each one of sample plots and 100 trees were selected.

All plots are pure stand of hornbeam trees *(Carpinus betulus)*.The plots were selected in an altitude limit of 520 to 1310 meters above sea level (Table 1). All trees have been considered in sample plots numbered through specific signs and were installed on trees. We studied phenological events of hornbeam tree's natural growths in the study area on different altitude above sea level and assessment of these ground data for monitoring deciduous broadleaf forest phenology using periodical MODIS data in the north of Iran. Phenological events studies were performed during one year from January to December 2004 on hornbeam trees. These trees were investgated regularly through 15day intervals during the months of January through December. The hornbeam phenology study was performed by using visual descriptions of growth and leaf expansion and anthesis processes to leaf senescence.

These stages are divided from bud burst and leaf tip appearance to leaf abscission (Table 2). Growth and development processes are divided as t1: bud bursting and leaf tip appearance t2: Anthesis t5: Seed maturely t9: Start yellowing t10: Start defoliation t11: Leaf abscission. At the end of the year, the collected information was classified and the date of commencement and completion of the appearance of each phenology event was identified with division in the year; besides, the required climate information such as average of monthly temperature for the year was collected. Another method for quantifying phonological development is measuring the chlorophyll content. The Chlorophyll meter (SPAD,Type 502, Minolta Co. LTD) is broadly used in agriculture to control nitrogen content of crop leaf-blade [14].The Minolta SPAD 502 chlorophyll meter has become recognized as a reliable substitute for total chlorophyll [15, 16].To measure the same leaflet during experiment, the test leaflet was marked and colored small label was used. From top of the canopies of the trees fifty sample leaves were randomly collected. As chlorophyll content varies in different part of a leaf, the middle part of a leaf was used for chlorophyll measurement.

Chlorophyll meter SPAD value generally increases during leaf development stages, maintains high value during summer and declines to the defoliation. Chlorophyll meter SPAD value was observed from leaf development (t3) until Leaf abscission (t11).Measurement of the Chlorophyll meter (SPAD-502) was recorded from every other week observations in the growing season. Table. 2 describes the times of Chlorophyll meter measuring for hornbeam trees at different altitudes.These chlorophyll meter measurements were recorded from January to December 2004 in in 15 day intervals. And, the correlation and relationship between the phenology event and the measured temperatures were determined by the regression analysis as well.

Determining NDVI Curves: There have been recent attempts to link satellite derived signals (e.g. the normalized difference vegetation index (NDVI)) to phenology [3, 17].We showed the NDVI curves for the deciduous broad leaf forest type at 8-day intervals from the entire data set during January to December 2004 per (Fig.1b).The selected areas of forest with over 80% deciduous broad leaf cover is based on the vegetation cover map(Fig.1b).By using the regression analysis, the amount of correlation coefficient between NDVI and SPAD measurement for the study area was calculated

RESULTS AND DISCUSSION

Hornbeam Phenology: Table 2 shows that the phonological events are varied among zones. Values of measured SPAD in seasonal changes are shown in Figure (2) and table (2).SPAD values generally increase during leaf development stages, maintain high value during summer and then decline to the defoliation (Fig.2).Bud bursting and leaf tip appearance (t1 stage) in lower, middle, and upper zone occurred in 109, 116.1, and 117.3 days of the year respectively. Anthesis (t2) for lower, middle and upper zones occurred in 118.4, 125.5 and 127.0 days of the year respectively. t3 process was occurred in lower zone and middle zone and upper zone in 120, 127 and 130 days of the year respectively.(t4) process for lower, middle and upper zones in 139.6, 142.5 and 144.0 days of the year respectively. Seed maturely (t5) process occurred in lower, middle and upper zones in 303.7, 306.6 and 309.3 days of the year respectively. t6 process in lower zone, middle zone and upper zone in 159.7, 168.7 and 179.9 days of the year respectively. t7 process-average days of year with maximum value of SPAD in lower, middle and upper zones in 220.9,226.8 and 230.9 days of the year respectively and t8 process occurred in lower, middle and upper zones in 250.7,247.5 and 244.1 days of the year respectively. Start yellowing (t9) process occurs in lower, middle and upper zones in 279.8, 271.9 and 269.1 day of the year respectively.t10 (Start defoliation) for lower, middle and upper zones is in 307.5, 298.1 and 294.9 days of the years respectively. Leaf abscission process (t11) for lower and middle and upper zones occurs in 321.4, 315.0 and 312.4 days of the years respectively.

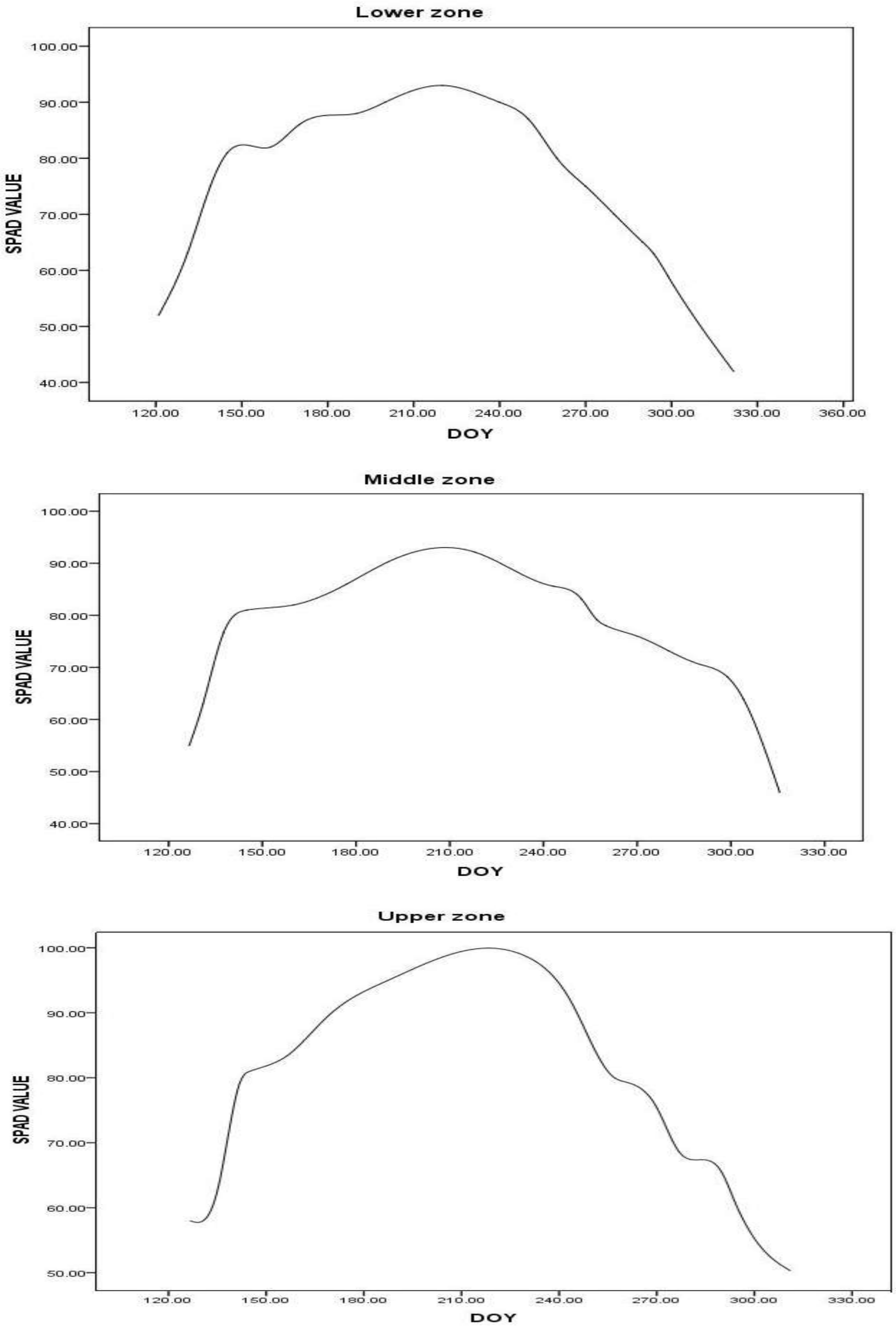

Fig. 2: Seasonal changes of SPAD value relatively. Data is averaged for each zone. Each data is expressed as relative value to the maximum SPAD value for each plot

Due to early leaf expansion and late defoliation in low altitude areas (lower zone), the leaf in the period in this zone is longer than middle and upper zones. Leaved period in lower and middle and upper zones lasts 212.8 and 198.4 and 194.6 days respectively (Table 2). With altitude increase from low to high altitudes t 9 and t10 processes occur earlier. T 11 process in lower zone occurs almost 9.0 days later than t 11 processes in upper zone.

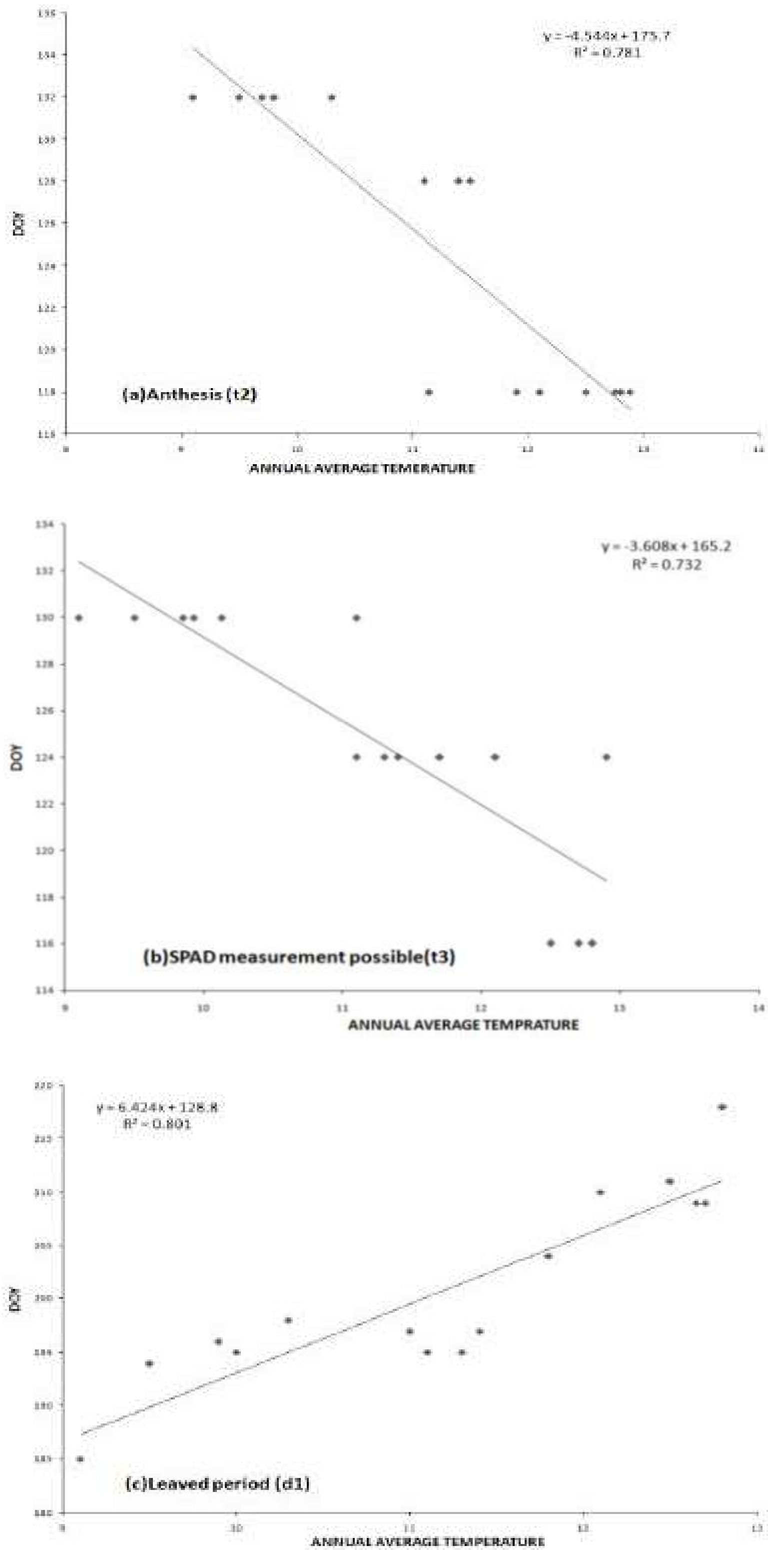

Fig. 3: Relationships between annual average of air temperature and DOY of phenology events for hornbeam plots.(All linear regressions were statistically significant, P=0.01), (a) Anthesis (t2), (b) SPAD measurement possible (t3), (c) Leaved period (d1)

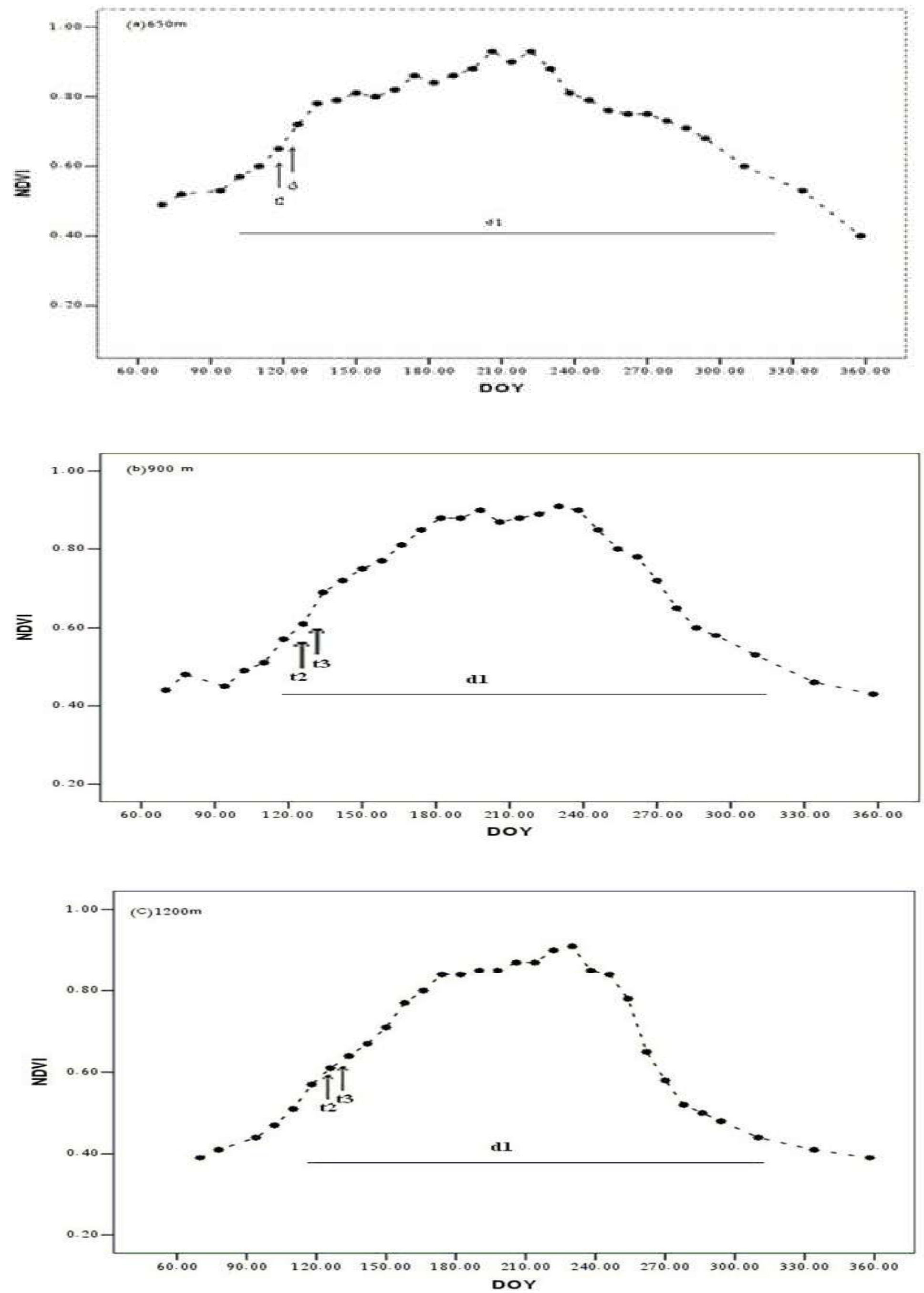

Fig. 4: Time trend of 8-day composite of MODIS/NDVI in (a) 650m, (b) 900m and (c) 1200 meters above sea level, respectively

And t10 process occurs 12.6 days later. Anthesis process (t2) in lower zone begins 8.6 days earlier than upper zone and also t5 appears 5.6 days earlier. The Maximum photosynthesis period for lower and middle and upper zones lasts 91.2 and 78.8 and 64.2 days respectively. This period shortens as altitude heightens. Also stable production period for lower and middle and upper zones lasts 140.2 and 129.4 and 125.1 days respectively (Table 2). Duration of d1 and d2 and d3 processes shortens as altitude heightens.

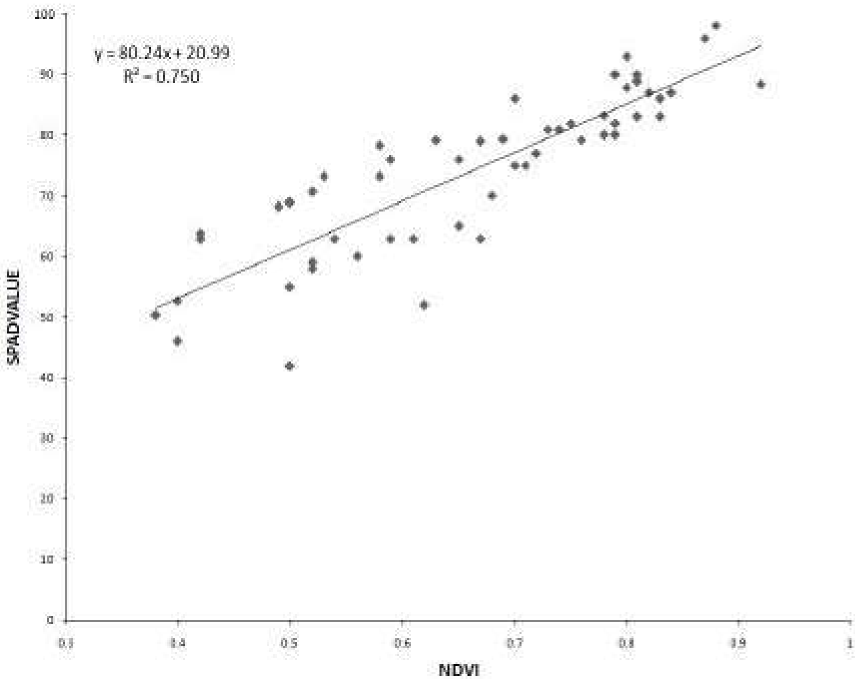

Fig. 5: The correlation coefficient between NDVI and SPAD value. (Linear regressions were statistically significant, P=0.01)

Relationship Between Air Temperature and Phenology Events: We also examined relationship between annual average air temperature and of phenology event occurrence for each plot. t2 and t3 processes have negative correlation with air temperature and as temperature lowers they appear earlier in year.t2 and t3 processes have correlation coefficients of r =-0.883(P=0.01) and r=-0.855(P=0.01) respectively (Fig. 3b,3a). Leaved period (d1) increases with increasing temperature and its correlation coefficient is: r =0.894(P=0.01) (Fig.3c).

Change in NDVI: The Time trend of 8-day composite of MODIS/NDVI in 650m, 900m and 1200 meters above sea level shown in (Fig.3).a (650m), b(900m) and c(1200m) are related to hornbeam groups in lower and middle and upper zone respectively. These altitudes are averaged from 250m by 250m area and represent almost over 90% of deciduous broadleaf forests. For each altitude zone in summer, maximum of NDVI goes over 0.9but initial rise was different in each case in terms of the days of the year. For example, NDVI values in 110 the days of the year were around 0.62, 0.55 and 0.51 for (a) 650m,(b) 900m and (c) 1200m respectively. The NDVI values in 310 the days of the year were around 0.59, 0.52 and 0.46 for (a) 650m, (b) 900m and (c) 1200 m respectively.The NDVI in high altitude c (1200m) has been decayed in 310 DOY, but didn't occur in low altitude a (650m).Prior to leaf expansion NDVI increased from 109DOY or earlier. It might be an effect of the process of snow melting. Another possibility is the effect of floor vegetation. Consequently an earlier NDVI increase could be due either to bud burst onset or to an earlier snowmelt [17].Ever green vegetation affects on in NDVI increase after snow melting in the beginning of spring, when tree's canopies aren't fully spread and in autumn when defoliation is completed. In study area, deciduous broadleaf forests are accompanied by evergreen floor vegetation such as *Ruscus hyrcanus.* Ever green floor vegetation are largely spread in mountainous areas from low to high altitudes in deciduous broadleaf forests in the study area. The NDVI might be an effect of the process of floor vegetation. These plants such as *Ruscus hyrcanus* affect on initial and precocious increase of NDVI. Early initial rise in MODIS/NDVI associated with appearing of such vegetation after snow melting [18]. At the same time, NDVI values after defoliation in autumn may be contribution of *Ruscus hyrcanus* during the period before snow fall.

Relationship between NDVI and SPAD Measurement: We also examined relationship between NDVI and SPAD measurement. Our regression analysis showed that there is a positive relationship between NDVI and SPAD measurement (chlorophyll contents) in hornbeam trees (Fig.5).NDVI increases with increasing chlorophyll contents. The NDVI of all zones provided the strongest correlation with SPAD value. The correlation coefficient between NDVI and SPAD measurement was determined for the entire study area(r= 0.86) (Fig.5).

The original satellite sensor data used for this study are known to be subject to a number of potential problems. One common problem reported in the literature is the question of whether the sudden increase of NDVI in spring at high latitudes coincides with snowmelt or is really the emergence of leaves [11]. If the two events occur at significantly different times, then the beginning of the growing season derived from NDVI may just catch snowmelt—which is definitely not desired. In land surface models this error will not necessarily transfer to excessive plant activity due to temperature limitations and the explicit simulation of snow cover but this problem may affect greening season length estimates. Another weakness of satellite radiometry in visible wavelengths is the extended data dropouts in high latitudes during winter. The correction method used here is able to recover a continuous dropout of around 2 months and assumptions are made to estimate NDVI values for longer data dropouts. Sudden data dropouts in autumn may nevertheless limit the estimation of the growth period length in our phenological analysis. Apart from the uncertainty associated with remote sensing the length of the growing period and the phenological autumn phases cannot be simply linked to temperature and precipitation averages. The NDVI is a good estimator for large-scale plant photosynthesis and phenology but they cannot account for many of the factors that drive land surface processes (such as soil moisture availability, nutrients availability and vapor pressure deficit).We believe that further research, longer NDVI time-series, ground validation and long-term ground measurements of phenological data are needed to gain more confidence; furthermore, Disease, competition, soil factors and weather conditions can profoundly influence plant phonological status [19].The global warming has been suggested to be the major cause of the extension of the growing season [20, 21] Appearance of different phenological steps in trees on the one hand depend on different factors and role of regional factors are so effective that commencement of growth is under direct effect of air temperature. On the other hand the altitude from sea level plays the main role on phonological event appearance. This fact has been confirmed in the present and in other studies conducted in the field and in different heights [22]. In the present study altitude from sea level had given priority over other factors and delay of appearance of phonological event had more obvious role. It suggests that some events such as germinating, anthesis have been occurred with delay with altitude heightening and some other events such as yellowing and specially leaf abscission have been happened sooner with altitude rise from sea level. Furthermore the Maximum photosynthesis period decreased as altitude increased. The mid April was recognized as the mean onset period of vegetation green-up while late November as the mean onset period of vegetation dormancy for the entire national level**.** In recent decades, the development of remote sensing methods to measure leaf chlorophyll content and surface spectral reflectance has received much attention since variations in leaf chlorophyll content can provide information concerning the physiological state of a leaf or plant. Several vegetation indices estimated from remote sensing data have been considered for assessing the status of leaf chlorophyll content, plant biomass, production and vegetation health status. The phonological phase of autumn leaf coloring signalizes the end of the vegetation period. Since chlorophyll contents in the assimilatory apparatus are lowered, a change thereby happens in the color of leaf blade.

Our regression analysis showed that there is a positive relationship between NDVI amounts and chlorophyll contents. The ecological significance of this study is based on the speed and efficiency by which vegetation indices can detect chlorophyll content of complex forest vegetation. Nonetheless, further investigative work remains to be carried out, especially in leaf chlorophyll contents and remote sensing applications.

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