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Evaluation of soil fertility in citrus planted areas by geostatistics analysis method

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Abstract

The aim of this study is to map citrus planted areas, which have been detected by traditional methods to date, with a high accuracy method and to reveal the land characteristics and fertility conditions. A database was created for citrus planted areas with the help of high-resolution Worldview 2 satellite images in this study. By creating the digital elevation model, orthorectification of satellite images was made and slope, aspect and elevation characteristics were determined. Using soil maps, maps showing terrain characteristics were produced. 43 soil samples were taken to represent citrus planted areas; geostatistical maps showing their pH, salinity, lime, texture, organic matter, total N, available P; exchangeable K, Ca, Mg, Na, available Fe, Cu, Zn, Mn levels were created and their statistical analyses were performed 2,132.08 ha citrus planted area was found in the study area. The parameters obtained from the digital elevation model (slope, aspect, elevation), the data of the land from the soil maps and the physical properties-macro/micro nutritional contents of the soil produced by the geostatistics method were evaluated together. It was determined that the features in all areas mapped as citrus planted area are quite suitable for citrus production. However, it is thought that Fe and Zn uptake from the soil will decrease due to the fact that the pH level is slightly alkaline and high lime contents. Identifying and sustainable monitoring of citrus production areas, which are very important in terms of economy, accurately, up-to-date, without causing loss of time and labor, will be possible with integrated use of GIS and RS techniques.

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Introduction

Citrus, which can be grown in tropical and subtropical climate regions, is a plant association containing the citrus fruit tree species of Rutaceae family including not only the ones that are common and have economical value such as orange, mandarin, grapefruit, bitter orange and lemon species but also shaddock, citron and bergamot (Uysal and Polatöz, 2017). Especially rich in vitamin C, it can be consumed as fresh fruit, fruit juice, and jam; extracts can be taken from its flowers, fresh sprouts, and peels; whereas its peels can also be used in making animal feed. (Gamze and Kısmalı, 2003). Total phenolic matter, mineral matter and vitamin content of the peels were found to be higher than fruit and fruit juice (Belitz and Grosch, 1999; Güzel and Akpınar, 2017). Our country is extremely suitable for the production of citrus fruits in terms of ecological conditions. Turkey is located on the northern edge of the world citrus fruit production (Akgün, 2006). The production of citrus fruits, which is an economic vegetable product, has seen to increase considerably in recent years. The most important factors in the choice of citrus production are the presence of multiple uses in the national economy, its importance in the health-nutrition chain, its high employment potential and its ability to adapt to regional conditions. For this reason, it has become a necessity of our age to use more modern and reliable methods in order to increase the productivity of citrus production areas, to maintain its sustainability and to meet the nutritional needs of people accurately and healthily.

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The Geographical Information System (GIS) and remote sensing technique have emerged as reliable and effective data providers and methods for sustainable management of agricultural areas. Remote sensing including satellite images, aerial photographs, LIDAR images, different image processing techniques and algorithms (NDVI, EVI, SAVI, NDWI) pixel/object-based classification are used in many applications such as determination of the plant pattern in agricultural activities, yield estimation and determination of field use and disease/ harm/damage detection. On the other hand, GIS is an application that has the ability to visualize information obtained from different sources (vector, raster, text data) as well as to produce, store, process and analyze. Das et al. (2009) by using the remote sensing technique and GIS in their study, made an assessment of the yield that can be obtained from citrus planted areas. Areas that may affect crops such as different plant conditions, water stress, and soil erosion are mapped. Lopez et al. (2010) conducted a multistage classification study to identify citrus orchards in the Comunidad Valenciana region of Spain using GIS. By automatic classification, an accuracy of 85% was achieved. Supported by field studies, the method reached 94.38% accuracy with the proposed methodology in recent conditions. In a study conducted in Iran, temperature, co-elevation maps and topographic maps produced for 30 years since 1980 were transferred into GIS and statistical analyses were performed. In this study, it was determined that minimum temperature value and elevation from the sea had a significant negative effect on citrus production. As a result, it was emphasized that citrus fruits are affected more from low temperatures and the maximum elevation is suitable up to 700 m for a profitable production (Zabihi et al., 2016). In Pakistan, Naseem et al. (2016), has aimed to reveal the relationship between citrus and environmental conditions in order to identify the citrus tristeza virus. The geographic information system was used to determine the spatial distribution of citrus areas, the formation of citrus tristeza virus and effects of environmental factors; temperature and precipitation. The effect of yearly incidence of temperature, precipitation, and associated citrus tristeza virus has shown that the annual average temperature has a negative correlation with the frequency of citrus tristeza virus. However, a positive correlation was observed between the incidence of citrus tristeza virus and precipitation factor. Digital maps created by the data involving topography, land use, soil, and climate were used to determine the characteristics of citrus planted areas in Chongqing, China. A total of 50 randomly selected orchards (2032 ha) were examined and the topographic features of the orchards were determined using the digital elevation model DEM. The data obtained and produced were analyzed and it was determined that approximately 33% of the total area of Chongqing city was suitable for citrus development (Wu et al., 2011). In the study carried out in citrus fields in Ramsar region of Iran, it was aimed to form a citrus land conformity assessment model based on five (slope, elevation, lowest temperature, highest temperature, precipitation) biophysical factors. A number of decision strategies and scenarios have been successfully developed by changing the critical factors by using the Ordered Weighted Averaging (OWA) and the analytical hierarchy process (AHP) method together. As a result, it was determined that citrus cultivation was suitable in 6.7% of the study area (Zabihi et al., 2019).

In recent years, multivariate geostatistics and spatial analyzes have been used to determine the relationship between soil properties and soil fertility in spatial analysis (Goovaerts 1997, 1998). In addition to GIS, geostatistical methods are a different technique for evaluating the spatial variability of land and soil (Foroughifar et al., 2013). These techniques can fully characterize soil properties according to their distribution (Chen et al., 2009). The variogram is generally used in geostatistics. The interpolation technique, known as kriging, provides an unbiased, linear estimation of a regional variable in an unsampled area, where it is best defined in terms of least squares (Oliver and Webster, 2014). Başayigit and Şenol (2009) made an application for the preparation of efficiency maps of the areas where fruit growing potential of Isparta province is high with GIS. For this purpose, soil samples at two different depths (0-20 cm, 20-40 cm) were collected from 120 different points and available P, exchangeable cations and extractable Fe, Cu, Mn, Zn analyses were performed. By using inverse distance weighting technique (IDW), point data were converted to spatial data and thematic maps were produced for each soil characteristic. Shen et al. (2019) have compared inverse distance weighted (IDW) interpolation methods, radial basis functions (RBF), ordinary kriging (OK), co-kriging (COK), multiple linear regression (MLR), geographic weighted regression (GWR), regression kriging (RK) and geographically weighted regression (GWRK) methods. In four Mollisol regions in Northeast China, the areas where landscape pattern, land use type, topographic characteristics, soil tillage method, sample density, sample accuracy, and total phosphorus content are different were selected as research areas. As a result, GWRK and RK were determined as the most suitable interpolation methods and when the cost, time and process were considered, it was explained that the OK method was also relatively acceptable. Santos France et al. (2017a,b) used the kriging interpolation method to produce the spatial distribution of heavy metal content of soils in northern Spain and northern Peru. In a study conducted in

Bara, Nepal, 109 surface soil samples (0-15 cm depth) were taken and pH, organic matter (OM), nitrogen (N), phosphorus (P,), potassium (K), zinc (Zn) and boron (B) contents were determined. Digital map layers were produced by kriging method for each soil chemical properties. It was emphasized that these maps will enable farmers to evaluate their land, allowing them to make easier and more efficient management decisions and to maintain the sustainability of productivity.

The aim of this study was to determine citrus planted areas in Aydın province by remote sensing technique and geographical information system. Soil samples (0-30 cm) were randomly taken from 43 different points in order to determine the soil fertility level of citrus production areas and their physical and chemical properties were analyzed in the laboratory. Each soil feature spatial distributions were determined and a digital database was created in which every existing and produced data could be evaluated.

Material and Methods

Research area and geographical location

Aydın Province; is located between the 37th and 38th northern latitudes and 27th and 29th eastern longitudes in the southwest of Turkey. The area of the city is 811,600 ha and according to data provided from TUIK in 2017, 366,608 thousand ha (approximately 45%) of the region is used for agricultural activities. Aydın is surrounded by the Aegean Sea from the west, Denizli from the east, İzmir and Manisa from the north and Muğla from the south (Figure 1). It is the Menderes basin that affects the agricultural structure of the city at a high rate. The city of Aydın is known as the Lower Greater Menderes section of the Greater Menderes basin, formed by the Greater Menderes River and its tributaries. There are 17 districts in Aydın, including the central district. Development levels of agriculture, industry and tourism sectors vary according to districts (Anonymous, 2018). Citrus planted areas distributed in Kuyucak, Nazilli, Sultanhisar and Yenipazar districts constitute the research area.

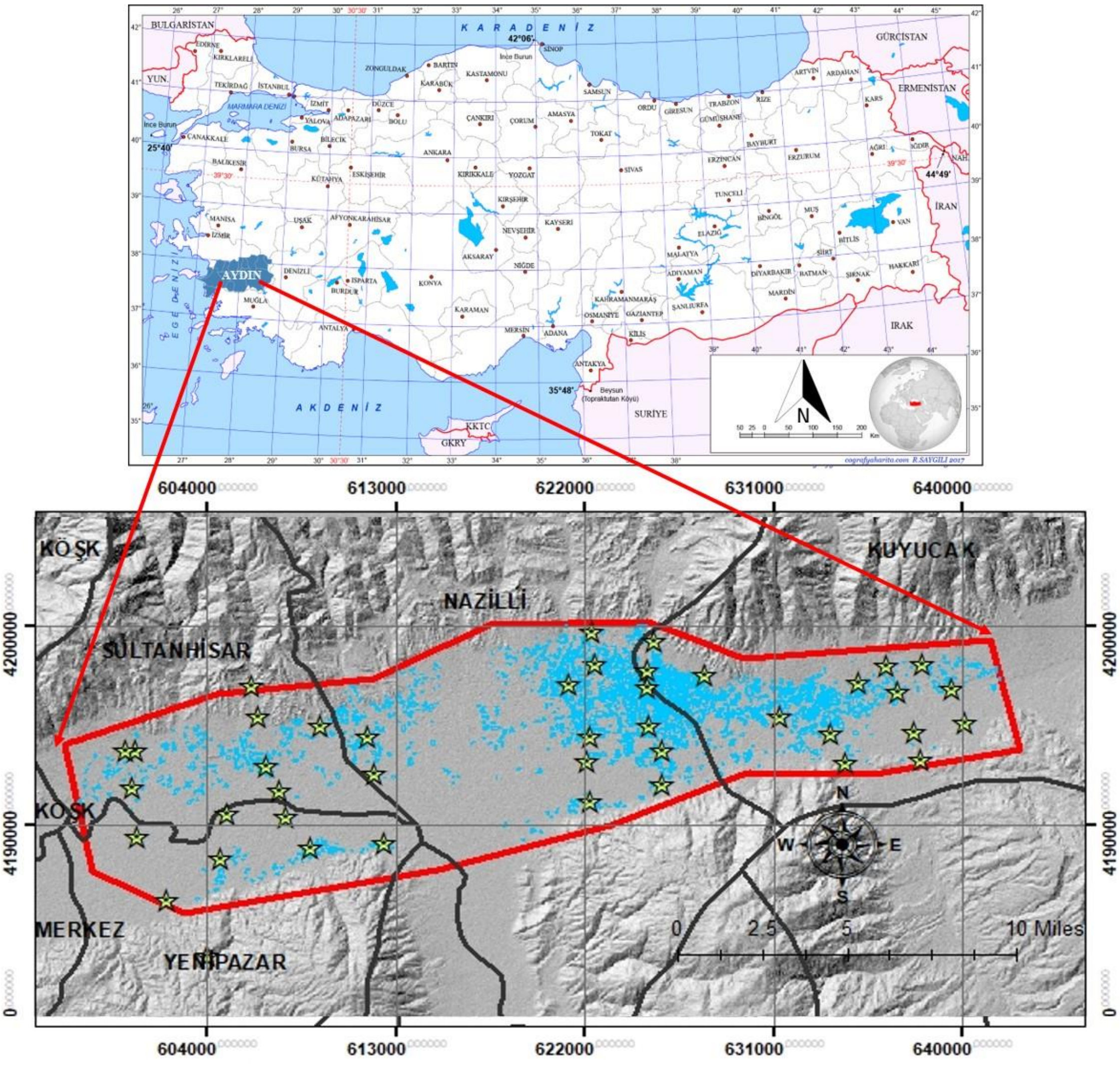

Figure 1. The geographical location of the research area, distribution of citrus planted areas and soil sampling points

The city of Aydın has a Mediterranean climate and the average annual rainfall is 645.1 mm. Most of the annual rainfall occurs in winter, spring, and autumn. 8.9% of precipitation occurs in summer, 44.5% in winter, 22.7% in autumn and 23.9% in spring. When long-term meteorological data are analyzed, the average temperature was found to be 8.2 ^{0}C in January and 28.4 ^{0}C in July (Anonymous, 2017). The average relative humidity is 61.2% (Anonymous, 2018).

Material

Sultanhisar, Yenipazar, Nazilli and Kuyucak Köşk districts where the citrus planted areas in Aydın province are found as orchard facilities were chosen as the research areas. The purchase of 10 1/25.000 scaled contour maps that are necessary for the creation of the digital elevation model and which covers the research area was made by the General Directorate of Mapping. Three Worldview-2 satellite images of 45 cm resolution belonging to June 2013 were used for the determination of citrus areas. During the research, Trimble Geoexplorer 2005 series GPS was used in field studies. ArcGIS 10.5 was used to create a digital elevation model (DEM) by using contour curves, ENVI software was used to transform images into pansharpened, and PCI software was used for orthorectification of images. Forthythree soil samples, which were representative of the characteristics of the research area were taken by random sampling method. Depth of taking soil samples is approximately 30 cm depending on soil properties. SPSS 15.0 software was used to interpret the results of the analysis. Soil characteristics required to determine the fertility status of citrus planted areas were evaluated in ArcGIS 10.5 software in the digital database and mapped geostatistically.

Method

Topographical maps, soil maps, satellite imagery and similar data of the research area were collected and entered into the database by using GeoMedia and ArcGIS, which are GIS software, and an updateable database was created. Universal Transverse Mercator (UTM) projection and WGS-84 (World Geodetic System 1984) datum were used for all data. Field surveys were carried out for orthorectification of Worldview-2 satellite images and points were collected from 71 points with sensitive GPS. Orthorectification of the satellite images was performed using DEM generated from contour lines. Digital terrain models with elevation information are used to rearrange the numerical reflection values according to the topography (topographic normalization) by eliminating the shadow effect which is a problem in the classification of satellite images (McCormick, 1999). The main purpose of orthorectification is to eliminate the differences that occur due to topographic changes seen on the surface of the earth, and shifts in satellite and aerial photographs (Düzgün, 2010). Image sharpening process was carried out in satellite images by "Gram-Schmidt Spectral Sharpening" method in ENVI software. (Yuhendra et al., 2011; Matsuoka, 2012, Özdemir, 2017). This method allows benefiting from the spectral characteristics of the sensors with a high spatial resolution of the image (Marangoz et al., 2005). In order to enrich the properties of the soil layer in the digital database, each feature in 1/25.000 scaled soil maps was transferred as attribute information.

Soil samples were taken from 0-30 cm depth according to general rules (Ballinger et al., 1966). Soil samples brought to the laboratory were dried in the laboratory and passed through 2 mm sieves and prepared for analysis (Soil Survey Staff, 1951). Contents of the soils including pH (Jackson, 1967), electrical conductivity (Jones, 2001), structure (Bouyoucos, 1962, Black, 1965), $CaCO_3$ (Schlichting and Blume, 1966), organic matter (Rauterberg and Kremkus, 1951), total nitrogen (Bremner, 1965), available phosphorus (Olsen and Sommers, 1982), exchangeable potassium, calcium, magnesium and sodium (Knudsen et al., 1982), available iron, zinc, copper and manganese (Lindsay and Norvell, 1978) were determined. Statistical Package Program named SPSS 15.0 (Statistical Package for Social Science) was used to compare the soil analysis values, to perform statistical analyses and to interpret the results. 95% confidence level (5% level of significance) was taken into consideration in performing these analyses.

Soil characteristics show spatial variability due to the effects of the basic and external factors that form them (Heuvelink and Webster, 2001) and this change may occur depending on soil type, topography, climate, vegetation and anthropogenic activities (Shi et al., 2009). Geostatistics, which is defined as the tools used to examine and estimate the spatial distribution of related variables, is used to show the spatial distribution of soil properties (Burrough 1993; Cambardella et al., 1994) and spatial variability in various natural phenomena (Mousavifard et al., 2013). The results of 17 soil properties analyzed for the determination of soil fertility were evaluated by using geostatistics analysis methods. In general, the concept of geostatistics refers to stochastic methods used to determine and estimate the distinctive characteristics of spatially referenced data (Mulla and McBratney, 2002). As being one of the stochastic interpolation methods, Ordinary Kriging (OK) was used to determine the spatial distribution of soil properties. Kriging is a linear geostatistics interpolation technique that provides the Best Linear Neutral Estimator (BLUE) for space-dependent variables. Kriging estimates are calculated as weighted sums of sampled adjacent densities (Robinson and Metternicht, 2006). In most cases, ordinary kriging proves that forest resistance values are sufficiently robust in unsampled areas. Ordinary kriging is the most common method of kriging (Krasilnikov and Sidorova, 2008; Mousavifard et al., 2013) and general equality is expressed as follows:

$$\gamma = 1/2\, N(h) \sum_{i=1}^{N(h)} [Z(\chi_i) - Z(\chi_j + h)]^2 \quad (1)$$

According to Yeşilkanat et al. (2014)," γ (x) semi-variance value, the distance between h, i and j points, N (h): the number of pairs of points on the h length (or the number of h vectors in the region), Z (xi): The measured value of the variable at point i, Z (xj + h): is the measured value at the point of the variable".

Results

Orthorectification and image sharpening processes were completed and Worldview 2 satellite images were manually vectorized by Geomedia 6.0 screen digitizing method. The satellite image was studied with NIR 1/Rededge/Red band combination to better determine the citrus trees and tree species that can be mixed with citrus in the study area (Figure 2). A significant part of the data collection studies carried out at this stage was executed as a result of field studies. Mapped citrus planted areas were accepted as boundaries, instead of the tree parcel boundaries. For this reason, artificial (home, other reinforced concrete structures, etc.) and natural (other tree species, etc.) elements outside the citrus tree, which is within the boundaries of the agricultural parcel are not included in the mapping. It was determined that citrus planted areas distributed in the research area occupy an area of 2132.08 ha.

Figure 2. Digitized citrus planted areas in Worldview 2 satellite images (Aydın-Nazilli)

The elevation varies between 53-830 m in the research area. Citrus planted areas at an elevation of 0-200 m, 201-305 m, 351-500 m, 501-650 m and 651-830 m cover respectively 94.66%, 3.27%, 1.59%, 0.41% and %0.07 of the areas. As the elevation up to 700 m is not seen as a limiting factor in citrus production (Zabihi et al., 2019), the entire area of the research area is suitable for citrus production. When the citrus production areas were examined for the aspect parameter, it was found that they showed an approximate distribution in all directions. While flat areas cover 10.28% of the total area; the northern, the northeastern, the eastern, the southeastern, the southern, the southwestern, the western and the northwestern directions have a distribution of 11.34%, 10.99%, 9.20%, 11.44%, 11.03%, 12.48%, 10.73% and 12.50% in the total area respectively. The slope characteristics of the areas where citrus production is made are as follows: Lands with a slope of 2-6%, 0-2%, 6-12%, +30%, 12-20% and 20-30% have a distribution of 54.71%, 18.78%, 18.77%, 3.04%, 2.74% and 1.95% in the total area respectively.

1/25.000 scaled soil maps containing the great soil group, slope, depth, land use capability class (LUCC), stoniness, rockiness, erosion, drainage, texture, land use and other characteristics (salinity-alkalinity) of the research area were vectorized. The thematic map of each soil feature was produced and their spatial size and % distributions were determined. Due to various land types and geological structures, colluvial soils occupy the most area with 51.06%, followed by alluvial soils with 46.21% and non-agricultural areas, regosols, rendzinas and limeless brown soils with a total of 2.73%. When the distribution of land use capability classes in the area was examined, it was determined that citrus planted areas were mostly on Class I lands (41.54%). In terms of the area they occupy, Class III lands (33.37%), Class II lands (20.46%), Class IV lands (1.93%) and others (Class VI, VII, VII, 2.71%) follow Class I. In terms of soil depth, most of the citrus planted areas are located in areas with a depth of 90 cm and above (97.05%). It is known that in citrus the effective root depth is between 30-90 centimeters in aerated and well-drained soil conditions (e.g. sandy-loamy) (YAYÇEP, 2010). Therefore, the research area meets the soil requirements of citrus in terms of its characteristics. When the erosion characteristics of the area are examined, the areas defined as having little or no erosion show a distribution of 85.42%, while the areas exposed to moderate erosion cover an area of 11.97%. The remaining areas have a very small area, even though they are considered non-agricultural and severe in terms of erosion severity. When the research area is classified according to other soil properties, the areas that do not have any problems have a value of 47.84%. Additionally, 26.96% of the areas are found to have slightly saline or insufficient drainage, 15.31% of the areas to have insufficient drainage, 5.67% of the areas to be stony, 1.56% of areas to have salty-insufficient drainage, 0.06% of the areas to have poor drainage and non-agricultural areas to cover 2.60% of the area.

The coefficient of variation, which is considered as an important index for explaining changes in soil properties, is classified as low (<15%), medium (15-35%) and high (> 35%) according to the values it takes (Wilding, 1985; Mulla and Mc Bratney, 2000; Özyazıcı et al., 2016). In this study, except the properties including pH (4.75%), sand (27.19%) and P (33.64%), the soil properties were determined to have high variability, while the most variable soil property was found to be Mn (117.08%) (Table 1). In many studies, it was explained that the coefficient of variation of pH contents found in soil was low (Tsegaye and Hill, 1998; Aimrun et al., 2007; Dengiz et al., 2015).

Table 1. Some descriptive statistics of soil properties

Soil properties	Min	Max	Avarege	Variance	Standart Deviation	Standart Error	Variance Coefficients
pH	6,08	7,82	7,46	0,1263	0,3554	0,0542	4,7534
EC, µs/cm	97,20	1542	531,08	0,0003	0,0186	0,0028	54,7362
$CaCO_3$, %	0,62	22,51	7,87	52,8930	7,2728	1,1091	92,3757
Sand, %	19,52	84,96	58,85	260,9826	16,1550	2,4636	27,1922
Silt, %	7,28	42,56	27,49	99,4464	9,9723	1,5208	36,9026
Clay, %	6,32	41,76	13,66	82,5271	9,0844	1,3854	67,1926
OM, %	0,41	6,62	2,27	1,6795	1,2960	0,1976	57,0497
N, %	0,02	0,33	0,11	0,0042	0,0648	0,0099	57,0008
P, mg kg $^{-1}$	3,30	141	38,90	16,9080	4,1119	0,6271	33,6403
K, mg kg $^{-1}$	116,40	970	281,98	0,2174	0,4663	0,0711	64,6586
Ca, mg kg $^{-1}$	588	4900	3132,58	37,7459	6,1438	0,9369	39,2229
Mg, mg kg $^{-1}$	16,86	242,15	139,81	0,2234	0,4727	0,0721	40,5594
Na, mg kg $^{-1}$	9,60	422,40	110,51	0,0857	0,2927	0,0446	64,5504
Fe, mg kg $^{-1}$	2,86	19,97	8,83	25,8747	5,0867	0,7757	57,5754
Zn, mg kg $^{-1}$	0,16	6,30	1,11	1,4136	1,1890	0,1813	106,7328
Cu, mg kg $^{-1}$	0,32	8,78	2,14	2,9585	1,7200	0,2623	80,5680
Mn, mg kg $^{-1}$	1,24	58,30	11,18	171,2380	13,0858	1,9956	117,0806

Correlation analysis results of soil chemical properties are given in Table 2. According to the analysis results, 58 of 153 correlation pairs between soil properties were found to be statistically significant at 1% and 5%. The most positive significant correlation was found between N and OM ($p < 0.01$) and lowest between Mn and $CaCO_3$ (0.291*). On the other hand, the highest negative correlation was found between sand and clay values (-0.857**), while the lowest correlation was found between sand content and Ca (-0.293*).

Distribution maps showing soil physical and chemical properties were classified using limit data belonging to different groups of each parameter. The distribution maps of the research area soils according to pH, salinity, lime, sand, alluvion, clay, and organic matter contents are given in Figure 3.

Table 2.Correlation analyzes results of soil chemical properties

	pH	EC	$CaCO_3$	Sand	Silt	Clay	OM	N	P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn
pH	1.000																
EC	0.420**	1.000															
$CaCO_3$	0.519**	0.448**	1.000														
Sand	-0.517**	-0.385**	-0.654**	1.000													
Silt	0.449**	0.270ns	0.468**	-0.857**	1.000												
Clay	0.422**	0.387**	0.644**	-0.829**	0.423**	1.000											
OM	0.189ns	0.256ns	0.183ns	-0.211ns	0.144ns	0.223ns	1.000										
N	0.189ns	0.255ns	0.183ns	-0.210ns	0.144ns	0.222ns	1.000**	1.000									
P	-0.530**	-0.413**	-0.600**	0.476**	-0.394**	-0.415**	-0.102ns	-0.103ns	1.000								
K	0.328*	0.425**	0.290*	-0.449**	0.296*	0.473**	0.340*	0.341*	-0.321*	1.000							
Ca	0.672**	0.340*	0.583**	-0.293*	0.265ns	0.228ns	0.101ns	0.102ns	-0.463**	0.281ns	1.000						
Mg	0.662**	0.580**	0.761**	-0.737**	0.611**	0.635**	0.239ns	0.237ns	-0.503**	0.418**	0.423**	1.000					
Na	0.516**	0.658**	0.325*	-0.439**	0.343*	0.396**	0.172ns	0.173ns	-0.532**	0.331*	0.316*	0.405**	1.000				
Fe	-0.147ns	0.100ns	0.086ns	-0.116ns	0.040ns	0.160ns	0.280ns	0.280ns	0.140ns	-0.078ns	-0.246ns	0.048ns	0.091ns	1.000			
Zn	-0.133ns	0.152ns	-0.045ns	0.164ns	-0.120ns	-0.156ns	0.154ns	0.154ns	-0.202ns	0.076ns	-0.006ns	-0.048ns	0.096ns	-0.176ns	1.000		
Cu	-0.214ns	-0.087ns	-0.173ns	-0.202ns	0.315*	0.011ns	-0.034ns	-0.035ns	0.342*	0.145ns	-0.143ns	-0.002ns	-0.147ns	0,122ns	0,114ns	1.000	
Mn	0.156ns	0.177ns	0.291*	-0.268ns	0.025ns	0.431**	-0.024ns	-0.025ns	-0.155ns	-0.011ns	0.192ns	0.209ns	0.081ns	0,086ns	-0.138ns	-0.024ns	1.000

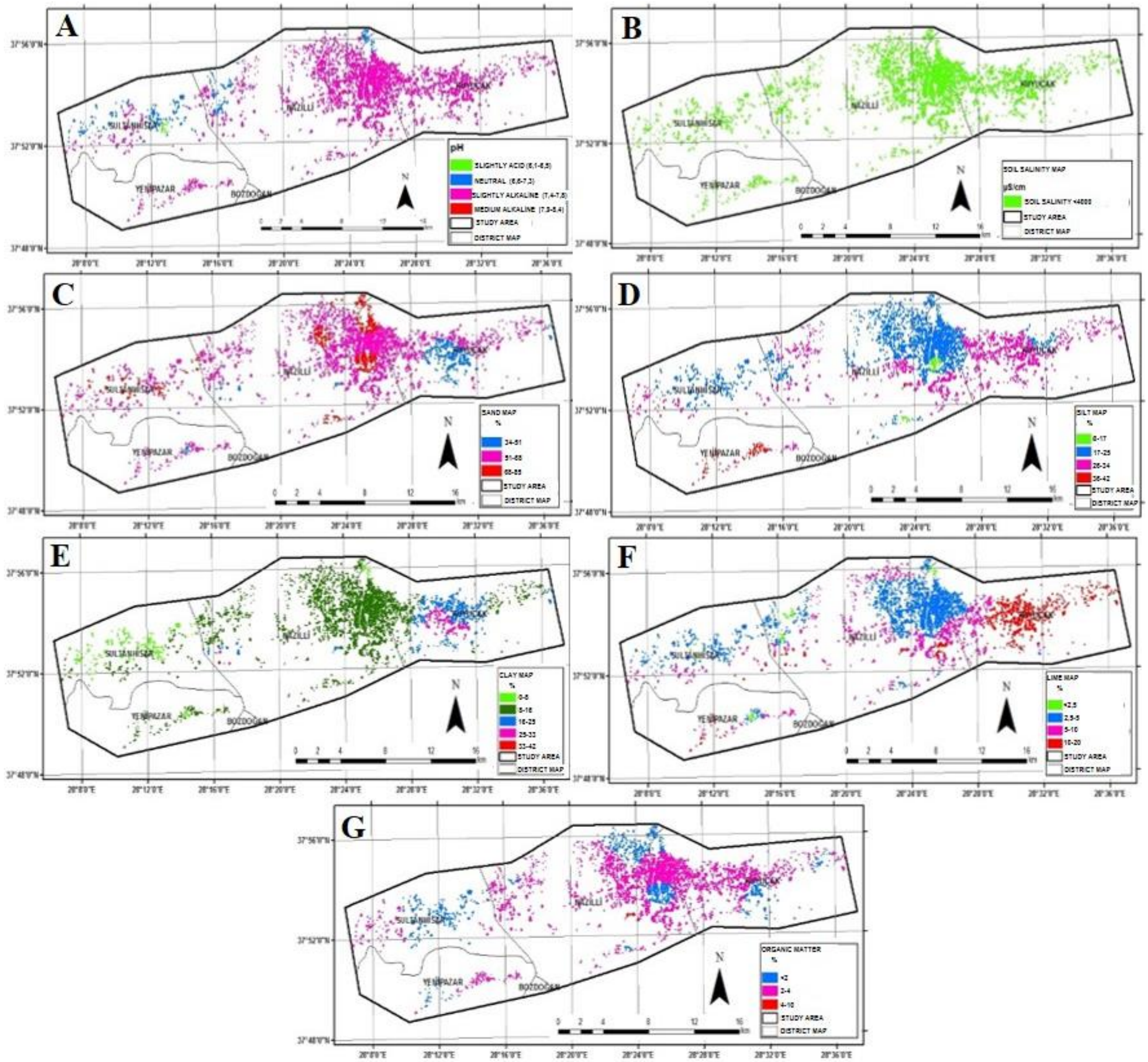

Figure 3. pH (A), salinity (B), sand (C), silt (D), clay (E), calcium carbonate (F) and organic matter (G) distribution maps of the study area.

The pH of soil samples varies between 6.08- 7.82 and when classified according to limit values (Richards, 1954; Ülgen and Yurtseven, 1995), the largest area is covered by the light alkaline soils (90.88%). This is followed by neutral soils (8.58%), light acid soils (0.51%), and moderate alkaline soils (0.03%). Citrus trees are highly susceptible to excess salts and their tolerance to soil salinity is associated with the ability to restrict the entry of toxic ions [sodium (Na), chlorine (Cl) and boron (B)] into roots and their transportation to shoots (Srivastava and Singh, 2009). Total salt values of soil samples range between 0.006-0.099. Due to the total salt content of soil samples being less than 0.150% (US Soil Survey Staff, 1951), there is no salt problem that will cause the above-mentioned effects to occur. Lime contents of soil samples vary between 0.61% and 22.5%. When the lime contents of soils are classified, 57.21% of the areas are found to be limy (2.5-5%), 22.80% to be rich in lime (5-10%), 17.46% to have texture+marn (10-20%) and 2.53% to be lime-poor (0-2.5%). The structure of the soil samples taken in the study is generally light and moderate. It was found that 65.1% of the soil was sandy loam and 18.6% had a loamy texture (Black, 1965). The soil content of ideal citrus cultivation is required to be between 8-10% (not exceeding 20%), sand content to be 50% and loam content to be 20% (Yayçep, 2010). The class of the soil in the research area, where the sand amount is distributed the most (51-68%), covers 69.08% of the whole area. According to the clay quantity, the areas containing 8-16% of clay have a distribution of 69.94%. According to the findings obtained in terms of the properties of the structure, it was determined that the desired properties for citrus production were present in the research area. The level of organic matter in the soil is important to help maintain an active population of microorganisms. Organic matter is therefore considered as an indicator of the sustainability of the soil management system (Srivastava and Singh, 2009). Organic matter contents of the research area range from 0.41% to 6.62%. When the soils are examined in terms of the amount of organic matter, 74.53% are found to be in the class of humic (2-4%), whereas 24.94% to be poor and 0.53% to be in the class of strong humic (4-10%) (Akalan, 1965).

The distribution maps according to the contents of the soils in the research area, which includes: total nitrogen (N), available phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), exchangeable sodium Na, available iron (Fe), available copper (Cu), available zinc (Zn), and available manganese (Mn) are given in Figure 4.

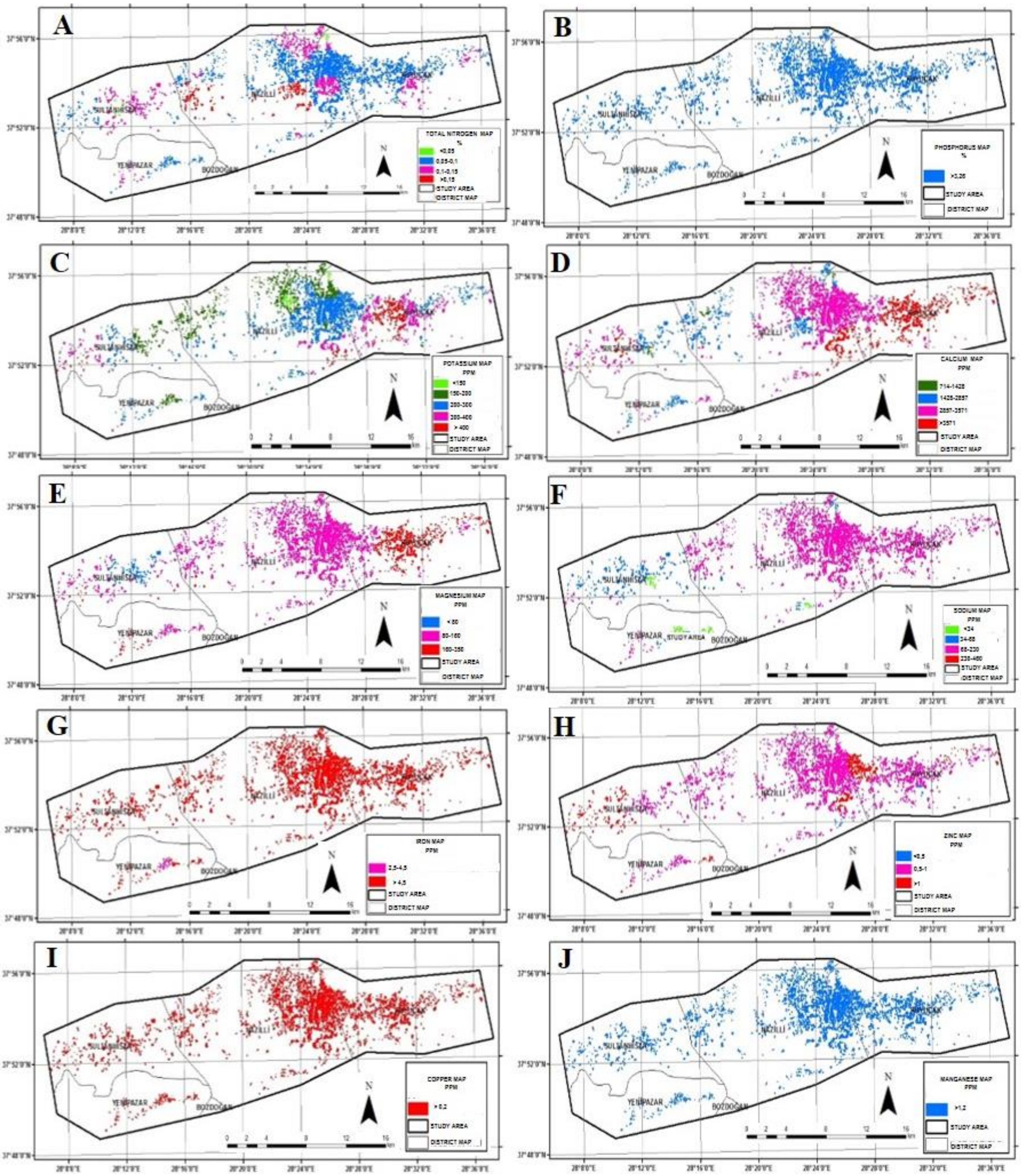

Figure 4. N (A), P (B), K (C), Ca (D), Mg (E), Na (F), Fe (G), Zn (H), Cu (I) and Mn (J) distribution maps of the study area.

Total nitrogen content of the soils varies between 0.021% and 0.331%. According to the total nitrogen distribution map, the areas in the good category with N content of 0.1-0.15% have 72%, the areas with the N content in the moderate category (0.05-0.1%) have 25.15%, the areas with N content in the rich category (> 0.15%) have 1.62% and the areas with N content in the poor category (0-0.05%) have 1.23% of the distribution (Çokuysal and Erbaş, 2004). Nitrogen content is in parallel with the organic matter content of soils. Soils are characterized as humus, which confirms the high amount of beneficial nitrogen. The absorbable phosphorus content of the soils varies between 4.2 and 19.9 mg kg^{-1}. According to Çokuysal and Erbaş (2004), soils with beneficial phosphorus content being >3.26 mg kg^{-1} are classified as a good level. Accordingly, the useful phosphorus content in the entire area is defined as good. The exchangeable potassium content of the soils was determined between 116.40 and 970 mg kg^{-1}. The class defined as sufficient according to the exchangeable potassium content (200-300 mg kg^{-1}) was distributed in the research area by 50.01% ratio. This was followed by the class with 23.37% ratio, which is defined as low according to the potassium content (200-300 mg kg^{-1}), the class defined as high (300-400 mg kg^{-1}) with 16.16% ratio, the class defined as very high (>400 mg kg^{-1}) with 8.85% ratio and the class defined as deficient (<150 mg kg^{-1}) with 1.61% ratio (Çokuysal and Erbaş, 2004).

The variable calcium content of the soils was determined between 588 and 4900 mg kg^{-1}. The class, defined as excess relative to the exchangeable calcium content (2857-3571 mg kg^{-1}), is the most common with 58.02%. This is followed by the class with 20.87% ratio, which is defined as good according to the calcium content (1428-2857 mg kg^{-1}), the class defined as to excess (> 3571 mg kg-1) with 19.77% ratio and the class defined as poor (715-1428 mg kg^{-1}) with 1.34% ratio (Çokuysal and Erbaş, 2004). The exchangeable magnesium content of the study area soils was determined between 16.86 and 242.15 mg kg^{-1}. The class defined as moderate according to the exchangeable magnesium content (80-160 mg kg^{-1}) has 80,70%, the class defined as high (160-350 mg kg^{-1}) has 14.49% and the class defined as poor (<80 mg kg^{1}) has 4.81% of the distribution (Çokuysal and Erbaş, 2004). The varying sodium content of the research area soils was determined between 9.60 and 422.40 mg kg^{-1}. The class defined as moderate (68-230 mg kg^{-1}), according to the exchangeable sodium content, has an 86.95% ratio, the class defined as low (34-68 mg kg^{-1}) has a 10.41% ratio, the class defined as very low (<34 mg kg^{1}) has a 2.58% ratio and the class defined as very high (230-460 mg kg^{1}) has a 0.06% ratio (Loue, 1968).

The available iron contents of the study area were determined between 2.86 and 19.97 mg kg^{-1}. The class, defined as sufficient according to the exchangeable iron content (>4.5 mg kg^{-1}) covers a very large proportion of the area with 99.998% (Lindsay and Norvel, 1978). However, due to the fact that the majority of citrus production areas are at the level of mild alkaline and medium level alkaline pH, have high lime content and sufficient levels of P and Cu in the soil, it is likely that Fe will be transformed into ineligible form by plants (Kacar and Katkat, 2007). According to the exchangeable zinc content (0.5-0.1 mg kg^{-1}), the class is defined as deficient and is in the first place with 88.04% rate. This is followed by of the class defined as sufficient (> 0.1 mg kg^{-1}) with 10.87% and the class defined as deficient (<0.5 mg kg^{-1}) with the ratio of 1.09% (Lindsay and Norvel, 1978). Since high soil pH lime content is determined in citrus production areas, it is predicted that this situation may have negative effects on Zn availability (Kacar and Katkat 2007; Karaman et al., 2007; Karaçal 2008). In addition, because of the antagonistic interaction between P and Zn (Kacar and Katkat, 2007), Zn uptake of plants decreases and Zn deficiency can be seen as the P content of soils increases. Considering the good P content of the research area, it may be a problem in terms of Zn nutrition. The copper contents of the study area were determined between 0.32 and 8.78 mg kg^{-1}. It covers the entire class area defined as sufficient according to the exchangeable copper content (>.2 mg kg^{-1}) (Lindsay and Norvel, 1978). The available manganese contents in the study area were determined between 1.24 and 58.30 mg kg^{-1}. The class, which is defined as sufficient according to the exchangeable manganese content (> 1.2 mg kg^{-1}) covers the entire area (Lindsay and Norvel, 1978).

Conclusion

As a result, it was determined that citrus planted areas distributed in the research area occupy an area of 2132.08 ha. In a topographic look, these areas are on an elevation of <200 m, are mostly flat and slightly slopped and distributed to 69.78% of the land facing to the north and south. Their production areas are mainly concentrated on alluvial and colluvial soil groups, they have land use talent classes I II and III, +90 cm soil depth, and are on areas that erosion and other problems are mostly not observed. Soil pH levels have a slightly alkaline reaction, the salt content is very low and lime content is high. The structure classes in most of the areas are determined as sandy loam and loam for citrus production. The organic matter coverage of the soils is mostly sufficient. In terms of macronutrients; total nitrogen, available phosphorus contents of soils are good and exchangeable potassium contents are sufficient. Exchangeable calcium, magnesium, and sodium scopes are again generally determined to be sufficient. When the levels of micronutrients were examined, it was found that exchangeable iron, copper and manganese element contents were sufficient and zinc contents were deficient.

The citrus products, which are important in many ways for both the agricultural sector and a country's economy, provide employment opportunities to many people in sectors including production, market development, industry-processing, transportation, imports and exports in the world and in Turkey. For this reason, citrus planted areas have an important potential to be followed within environmentally friendly production strategies and sustainable production/consumption concepts. With the research carried out, an updateable database was created for mapping the production areas, revealing the productivity conditions, determining the disease and pest control, determining the infrastructure opportunities for the sub-industries, preparing fertilizer production and consumption plans and most importantly for examining the yield/quality values in the coming years. In addition, it is thought that it will be an important source of information for future studies on the subject.

References

Aimrun, W., Amin, M.S.M., Ahmad, D., Hanafi, M.M., Chan, C.S., 2007. Spatial variability of bulk soil electrical conductivity in a Malaysian paddy field: Key to soil management. *Paddy Water Environment* 5(2): 113-121.

Akalan, İ.,1965. Toprak Oluşu, Yapısı ve Özellikleri. Ankara Üniversitesi Ziraat Fakültesi Yayınları No: 231. 332s. [in Turkish].

Akgün, C., 2006. Turunçgiller Sektör Profili. Dış Ticaret Şubesi Uygulama Servisi. Ankara. [in Turkish].

Anonymous, 2017. Turkish State Meteorological Service. Available at [Access date: 14.02.2017]: https://mgm.gov.tr/?il=Aydin

Anonymous, 2018. Aydın Tarım Master Planı. Aydın Tarım ve Orman İl Müd. Available at [Access date: 14.02.2017]: https://aydin.tarimorman.gov.tr/Belgeler/Ayd%C4%B1n%20Tar%C4%B1m%20Master%20Plan%C4%B1/MASTER%20PLAN%20%20%2816.01.2019%29-converted.pdf

Ballinger, W.E., Bell, H.K., Childers, N.F., 1966. Peach nutrition. In: Fruit Nutrition. Childers, N.F. (Ed.). Somerset Press, New Jersey, pp. 276-390.

Başayiğit L., Şenol H., 2009. The production of fertility maps of potential land for orchards using geographical ınformation systems. *Journal of Plant & Environmental Sciences* 1: 36-45 [in Turkish].

Belitz, H.D., Grosch, W., 1999. Fruits and fruit products. In: Food chemistry. Belitz, H. D., Grosch, W. (Eds.). Springer, Berlin, Heidelberg. pp. 748-800.

Black, C.A., 1965. Method of soil analysis. Part 1 Chemical and Microbiological Properties. Agronomy No. 9. American Society of Agronomy, Madison, Wisconsin, USA.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal* 54(5): 464-465.

Bremner, J.M., 1965. Total Nitrogen. In: Method of Soil Analysis, Part 2. Chemical and Microbiological Properties. Black, C.A. et al. (Eds.) American Society of Agronomy, Madison, Wisconsin, USA. pp. 1149-1178.

Burrough, P.A., 1993. Soil variability: a late 20th century view. *Soils and Fertilizers* 56: 529-562.

Cambardella, C.A., Moorman, T.B., Parkin, T.B., Karlen, D.L., Novak, J.M., Turco, R.F., Konopka, A.E., 1994. Field-scale variability of soil properties in central Iowa soils. *Soil Science Society of America Journal* 58(5): 1501-1511.

Chen, H., Shen, Z., Liu G., Tong, Z., 2009. Spatial heterogeneity of available zinc, copper, and manganese in Xiangcheng tobacco planting fields, Henan Province, China. *Frontiers of Biology in China* 4(4): 469–476.

Çokuysal, B., Erbaş, E., 2004. Bitkilerde besin maddeleri noksanlıkları ve toprak tahlillerinin değerlendirilmesi. Ege Üniversitesi Tarımsal Uygulama ve Araştırma Merkezi, Çiftçi Broşürü: 55, İzmir. [in Turkish].

Das, P.T., Tajo, L., Goswami, J., 2009. Assessment of citrus crop condition in Umling block of Ri-Bhoi district using RS and GIS technique. *Journal of the Indian Society of Remote Sensing* 37: 317–324.

Dengiz, O., Özyazıcı, M.A., Sağlam, M.. 2015. Multi-criteria assessment and geostatistical approach for determination of rice growing suitability sites in Gokirmak catchment. *Paddy and Water Environment* 13(1): 1-10.

Düzgün, Ş., 2010. Uzaktan Algılamaya Giriş Ünite 6: Görüntü Ortorektifikasyonu. TÜBA-Türkiye Bilimler Akademisi, Ulusal Açık Ders Malzemeleri. Available at [Access date: 14.02.2017]: http://www.acikders.org.tr/pluginfile.php/637/mod_resource/content/0/Ders_Notlari/Unite6_Goruntu_Ortorektifikasyonu.pdf

Foroughifar, H., Jafarzadeh, A.A., Torabi, H., Pakpour, A., Miransari, M. 2013. Using geostatistics and geographic information system techniques to characterize spatial variability of soil properties, including micronutrients. *Communications in Soil Science and Plant Analysis* 44(8), 1273-1281.

Gamze, Ö., Kısmalı, Ş., 2003. An investigations on the population, distribution and damage of the Wooly whitefly, Aleurothrixus floccosus (Maskell) (Homoptera: Aleyrodidae) on citrus areas in Izmir province of Turkey. *Turkish Journal of Entomology* 27(1): 61-72. [in Turkish]

Goovaerts, P., 1997. Geostatistics for natural resources evaluation. Oxford Univ. Press, NewYork, USA. 483 p.

Goovaerts, P., 1998. Accounting for estimation optimality criteria in simulated annealing. Mathematical Geology, 30(5); 511–534.

Güzel, M., Akpınar, Ö., 2017. Turunçgil kabuklarının biyoaktif bileşenleri ve antioksidan aktivitelerinin belirlenmesi. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi* 7(2): 153-167. [in Turkish]

Heuvelink, G B.M., Webster, R., 2001. Modelling soil variation: past, present, and future. *Geoderma* 100(3-4): 269-301.

Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 498p.

Jones, Jr.J.B., 2001. Laboratory guide for conducting soil tests and plant analysis. CRC Press, New York, USA. 363p.

Kacar, B, Katkat, V., 2007. Bitki Besleme. Nobel Yayın Dağıtım, Ankara, Turkey. 678s.[in Turkish].

Karaçal, I., 2008. Toprak Verimliliği. Nobel Yayın Dağıtım, Ankara. Turkey. 222s.[in Turkish].

Karaman, R., Brohi, A.R., Müftüoğlu, N.M., Öztaş, T., Zengin, M., 2007. Sürdürülebilir Toprak Verimliliği. Detay Yayın Dağıtım, Ankara, Turkey. 224s. [in Turkish].

Krasilnikov, P., Sidorova, V., 2008. Geostatistical analysis of the spatial structure of acidity and organic carbon in zonal soils of the Russian plain. In: Soil geography and geostatistics: Concepts and Applications. Krasilnikov, P., Carré, F., Montanarella, L. (Eds.). Institute for Environment and Sustainability, European Communities, Luxembourg, pp. 55-67.

Lindsay, W.L., Norvell, W.A., 1978. Development of a DTPA Test for zinc, iron, manganese and copper. *Soil Science Society America Journal* 42(3): 421-428.

Loue A.T., 1968. Diagnostic petiolaire des prospectian etudes sur la nutrition at la fertilization potassiques de la vigne. Societe Commerciale des Potasses d'Alsace. Services Agronomiques, pp.31-41

López-García, F., Andreu-García, G., Blasco, J., Aleixos, N., Valiente, J.M., 2010. Automatic detection of skin defects in citrus fruits using a multivariate image analysis approach. *Computers and Electronics in Agriculture* 71(2): 189-197.

Marangoz, A.M., Karakış, S., Oruç, M., Büyüksalih, G., 2005. Nesne-tabanlı görüntü analizi ve ıkonos pan-sharpened görüntüsünü kullanarak yol ve binaların çıkarımı. TMMOB Harita ve Kadastro Mühendisleri Odası 10. Türkiye Harita Bilimsel ve Teknik Kurultayı 28 Mart - 1 Nisan 2005, Ankara, Turkey. [in Turkish]

Matsuoka, M., 2012. Comparison of the spectral properties of pansharpened images generated from AVNIR-2 and prism onboard Alos. XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia.

Mc Cormick, N., 1999. Satellite-based forest mapping using the silvics software, user manual. Space Applications Institute, EGEO, Commission of the European Communities, Joint Research Centre, I-21020 Ispra (VA), Italy, 13-28 p.

Mousavifard, S.M., Momtaz, H., Sepehr, E., Davatgar, N., Sadaghiani, M.H.R., 2013. Determining and mapping some soil physico-chemical properties using geostatistical and GIS techniques in the Naqade region, Iran. *Archives of Agronomy and Soil Science* 59(11): 1573-1589.

Mulla, D.J., Mc Bratney, A.B., 2000. Soil Spatial Variability. In: Handbook of Soil Science. Sumner, M.E. (Ed.). CRC Press, New York, USA. pp. A321-A352

Mulla, D.J., McBratney, A.B., 2002. Soil spatial variability. In: Soil physics companion, Warrick, A.W. (Ed.). CRC Press, New York, USA. pp.343-373.

Naseem, S., Mahmood, S., Ali, Z., 2016. Occurrence of Citrus tristeza virus in Pakistan: a GIS based approach combining host distribution and disease reports. *Pakistan Journal of Agricultural Sciences* 53(3): 513-521.

Oliver, M.A., Webster, R., 2014. A tutorial guide to geostatistics: Computing and modelling variograms and kriging. *Catena* 113: 56–69.

Olsen, S.R., Sommers, L.E., 1982. Phosphorus. In: Methods of Soil Analysis Part 2 Chemical and Microbiological Properties. Page, A.L. (Ed.). American Society of Agronomy, Soil Science Society of America, Madison, USA. pp. 403-430.

Özdemir, M., 2017. Evaluation of image pan-sharpening methods in terms of object-oriented classification. *Harita Dergisi* 158: 26-34. [in Turkish].

Özyazıcı, M.A., Dengiz, O., Aydoğan, M., Bayraklı, B., Kesim, E., Urla, Ö., Yıldız, H., Ünal, E., 2016. Levels of basic fertility and the spatial distribution of agricultural soils in Central and Eastern Black Sea Region. *Anadolu Journal of Agricultural Sciences* 31(1): 136-148.

Panday, D., Maharjan, B., Chalise, D., Shrestha, R.K., Twanabasu, B., 2018. Digital soil mapping in the Bara district of Nepal using kriging tool in ArcGIS. *PloS one* 13(10): 1-20.

Knudsen, D., Peterson, G.A., Pratt, P.F., 1982. Lithium, Sodium, and Potassium. In: Methods of Soil Analysis Part 2 Chemical and Microbiological Properties. Page, A.L. (Ed.). American Society of Agronomy, Soil Science Society of America, Madison, USA. pp. 225-246.

Rauterberg, E., Kremkus, F., 1951. Bestimmung von Gesamthumus und Alkalilöslichen Humusstoffen im Boden. Z.F. Planzenernaehrung, Düngung und Bodenkunde, Verlag, Chemice Gmbh, Weinheim.

Richards, L.A., 1954. Diagnosis and improvement of saline and alkali soil. U.S. Salinity Lab. Staff, U.S. Department of Agriculture, Agricultural Research Service, Handbook 60. Washington D.C. USA. 160p.

Robinson, T.P., Metternicht, G., 2006. Testing the performance of spatial interpolation techniques for mapping soil properties. *Computers and Electronics in Agriculture* 50(2): 97-108.

Santos-Francés, F., Martínez-Graña, A., Zarza C.A., García Sánchez, A., Rojo, P.A., 2017a. Spatial distribution of heavy metals and the environmental quality of soil in the Northern Plateau of Spain by Geostatistical Methods. *International Journal of Environmental Research and Public Health* 14(6):568.

Santos-Francés, F., Martínez-Graña, A., Rojo, P.A., García Sánchez, A., 2017b. Geochemical background and baseline values determination and spatial distribution of heavy metal pollution in soils of the andes mountain range (Cajamarca-Huancavelica, Peru). *International Journal of Environmental Research and Public Health* 14(8): 859.

Schlichting, E., Blume, H.P., 1966. Bodenkundliches Praktikum, Verlag Paul Parey, Hamburg-Berlin.

Shen, Q., Wang, Y., Wang, X., Liu, X., Zhang, X., Zhang, S., 2019. Comparing interpolation methods to predict soil total phosphorus in the Mollisol area of Northeast China. *Catena* 174: 59-72.

Shi, W., Liu, J., Du, Z., Song, Y., Chen, C., Yue, T., 2009. Surface modelling of soil pH. *Geoderma* 150(1-2): 113-119.

Srivastava, A.K., Singh, S., 2009. Citrus decline: Soil fertility and plant nutrition. *Journal of Plant Nutrition* 32(2): 197-245.

Soil Survey Staff, 1951. Soil survey manual. Agricultural Research Administration, United States Department of Agriculture, Agricultural Handbook No.18, Washington, USA. 503p.

Tsegaye, T., Hill, R.L., 1998. Intensive tillage effects on spatial variability of soil test, plant growth and nutrient uptake measurement. *Soil Science* 163(2): 155-165.

Uysal, O., Polatöz, S., 2017. Dünyada ve Türkiye'de turunçgil üretimi ve dış ticareti. TÜRKTOB Dergisi 22: 6-11 [in Turkish].

Ülgen, N., Yurtsever, N., 1995. Türkiye gübre ve gübreleme rehberi. Toprak ve Gübre Araştırma Enstitüsü Yayınları, Genel Yayın No: 209, Teknik Yayınlar No: T.66, Ankara. [in Turkish].

Wilding L.P., 1985. Spatial Variability: It's documentation, accommodation and implication to soil surveys. In: Soil Spatial Variability. Nielsen, D.R., Bouma J. (Eds.). Pudoc, Wageningen, The Netherlands, pp: 166-194.

Wu, W., Liu, H.B., Dai, H.L., Li, W., Sun, P.S., 2011. The management and planning of citrus orchards at a regional scale with GIS. *Precision Agriculture* 12(1): 44-54.

Yayçep, 2010. Turunçgil Yetiştiriciliği. Televizyon Yoluyla Yaygın Çiftçi Eğitimi Projesi (YAYÇEP). Tarım ve Köyişleri Bakanlığı Yayın Dairesi Başkanlığı. Yayın No:54. Ankara. Available at [Access date: 17.03.2017] : http://www.katipogluziraat.com/kitap/turuncgil_cesitleri.pdf

Yeşilkanat, C., Kobya, Y., Taşkın, H., Çevik, U., 2014. Jeoistatistik tahmin ve simülasyon yöntemleri ile Artvin ilindeki doğal kaynak suları için toplam alfa ve toplam betanın ara değer modellemesi ve haritalanması. *Cumhuriyet Üniversitesi Fen-Edebiyat Fakültesi Fen Bilimleri Dergisi* 35(4): 11-35 [in Turkish].

Yuhendra, Sumantyo, J.T.,, Kuze, H., 2011. Performance analyzing of high resolution pan-sharpening techniques: Increasing image Quality for Classification using supervised kernel support vector machine. *Research Journal of Information Technology* 8(1): 12-28.

Zabihi, H., Vogeler, I., Amin, Z.M., Gourabi, B.R., 2016. Mapping the sensitivity of citrus crops to freeze stress using a geographical information system in Ramsar, Iran. *Weather and Climate Extremes* 14: 17-23.

Zabihi, H., Alizadeh, M., Kibet Langat, P., Karami, M., Shahabi, H., Ahmad, A., Nor Said, M., Lee, S., 2019. GIS multi-criteria analysis by ordered weighted averaging (OWA): toward an integrated citrus management strategy. *Sustainability* 11(4): 1009.