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Araştırma Makalesi (Research Article)

Assessment of Rangeland Vegetation Condition from Time Series NDVI Data

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Abstract

The great spatial extent of rangelands has prompted a need for more efficient and cost effective management tools. Satellite based normalized difference vegetation index (NDVI) data offers improved and timely monitoring of rangeland vegetation. Since elevation is one of the factors affecting vegetation phenology, it should be considered when assessing vegetation status of rangelands. In this study, rangeland condition was determined by classifying an elevation-normalized NDVI image (EN-NDVI) produced by a conditional rule approach based on elevation data representing active growing season of rangelands in whole project area. A supervised classification algorithm was used to obtain four rangeland conditions called “very good”, “good”, “moderate” and “poor”. The results revealed that the coverage of each range condition was; 10.02% “very good”, 20.55% “good”, 31.83% “moderate” and 37.60% “poor”. General classification accuracy and Kappa statistic values were 52.5% and 0.30 respectively.

Key words: Classification, Elevation, NDVI, Rangeland, SPOT-VEGETATION

Mera Vejetasyonu Durumunun Zaman Serisi NDVI Verileri ile Belirlenmesi

Öz

Geniş alanları kapsayan meraların daha etkin ve ekonomik yönetimi için yeni yöntemlerin geliştirilmesine gereksinim duyulmaktadır.Uydu verilerinden elde edilen normalleştirilmiş fark bitki indeksi (NDVI) verisi mera vejetasyonunun zamana bağlı olarak izlenmesine olanak verir. Yükselti vejetasyon gelişimini etkileyen önemli faktörlerden birisi olduğundan meraların vejetasyon durumunu belirlerken rakımın dikkate alınması gereklidir. Bu amaçla; çalışma alanındaki benzer yükseltiye sahip mera alanlarını temsil eden 10 yıllık (2000-2009) ortalama NDVI verisinden şartlı kural yöntemiyle yükseltiye göre normalleştirilmiş EN-NDVI verisi üretilmiştir. Daha sonra, EN-NDVI verisine kontrollü sınıflandırma yöntemi uygulanarak çalışma alanına ait dört farklı mera durum sınıfı elde edilmiştir. Bu sınıflar; “çok iyi”, “iyi”, “orta” ve “zayıf” olarak adlandırılmıştır. Sonuçlar, her bir mera durumu için kaplama alanının; “çok iyi” %10,02, “iyi” % 20,55, “orta” % 31,83 ve “zayıf” %37,60 şeklinde olduğunu göstermiştir. Yapılan değerlendirmede genel doğruluk %52,5 ve Kappa istatistiği 0,30 olarak bulunmuştur.

Anahtar kelimeler: Sınıflama, rakım, NDVI, mera, SPOT-VEGETATION

Introduction

Livestock farming is very important for many countries both as a food source, and for the livelihood of many families. Since livestock farming mainly depends on rangelands, it is necessary to monitor the quality of rangelands. Monitoring of rangelands can be performed by vegetation surveys on the field by counting plant species, but which is a tedious, time consuming and expensive method.

Monitoring of rangeland vegetation with remote sensing methods make use of relationship between ground truth data (biomass, ground cover, etc.) collected on live vegetation and pixel values (usually reflectance values) of satellite image (Friedl et al. 1994). The reflectance properties of plant species in vegetation significantly change during a growing season (Kennedy, 1989; Todd et al., 1998; Javzandulam et al., 2005). In addition to climatic conditions, topography and range management practices also cause a wide variation in vegetation. Changes in vegetation from green up to senescence can be monitored by vegetation indices. Normalized difference vegetation index (NDVI) produced from satellite images has been used for monitoring of vegetation (Dymond et al., 1992; Kogan et al.,

2004; Wessels et al., 2006). NDVI has been widely used to monitor plant growth, primer productivity and yield forecasting studies (Friedl et al., 1994; Jianlong et al., 1998; Gitelson, 2004; Ünal, 2011).

Rangeland condition describes current vegetation of a particular plant community in comparison to some perceived potential. Determining the condition is necessary for developing management strategies. One of the early practical studies for rangeland monitoring aiming to present rangeland condition was developed by Dyksterhuis (1949). Range condition was calculated as "very good", "good", "moderate" and "poor" based on percent cover of species in a plot measured in field surveys. In another study, instead of monitoring only one climax state, monitoring of multiple communities with "state and transition" models was suggested (Friedl, 1991; Laycock, 1991). Some other institutions working on rangelands suggested to use rating systems such as similarity index for monitoring of rangeland vegetation (USDA, 1997).

Vegetation development of rangelands in countries, such as Turkey, with extensive distribution of diverse topographic structure varies both temporally and spatially. Especially elevation can cause large temporal and spatial differences in vegetation cycle of rangelands. The differences in rangeland vegetation caused by the elevation should be minimized when monitoring the rangeland condition with remote sensing. This study proposes that long term average NDVI data be composited by elevation criteria to produce an elevation-normalized NDVI (EN-NDVI) image which represents active vegetation growing periods of rangelands in the area. The objective of this study is to determine the current vegetation condition of rangelands by applying a supervised classification method of elevation normalized NDVI data and to map its spatial extent throughout the country.

Material and Method

Study area

This study was carried out under the "National Rangeland Use and Management Project" of Turkey between 2007 and 2010. The study area is about 16.3 million ha which accounts 85% of total rangeland areas of the country. The area covers rangelands located at Eastern Anatolia, Central Anatolia, Black Sea, Mediterranean and Southern Anatolia regions of Turkey (Figure 1).

Data

The data used in this study were Systeme Probatorie de la Observation de la Terre (SPOT) NDVI dataset, digital elevation data, reference data of rangeland condition as point shape file, and vector data of rangeland boundaries as polygon shape file (ESRI 1998).

SPOT NDVI dataset

SPOT satellite carrying vegetation sensor (VGT) onboard the SPOT platforms provides ten-day synthesis product (S10) computed from all passes on each location acquired during 10-day intervals. S10 data are derived from P products (physical products) providing 10-day maximum value composite (MVC) NDVI syntheses (Holben, 1986) which are corrected for atmospheric effects. P products are surface reflectance's corrected for molecular and aerosol scattering, water vapor, ozone and other gas absorption.

SPOT 10-day MVC NDVI images at 1km2 spatial resolution, hereafter called NDVI, covering a 10 year (2000-2009) time period for whole Turkey were obtained through the ARTEMIS Project of Food and Agricultural Organization (FAO) of United Nations. Each year NDVI data consists of 36 ten-day MVC NDVI totaling 360 images for the 10 year time period, from which 36 "Mean NDVI" image was produced for each year.

Digital Elevation Model

Shuttle Radar Topography Mission (SRTM) data was used as source of elevation. SRTM is an international project pioneered by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA) aiming to obtain elevation radar data on a near-global scale to generate detailed topographic maps of Earth. The SRTM data has 3 arc-second spatial resolution (approximately 90 meter) for global coverage and is freely available. The original data was processed by Consortium for Spatial Information (CGIAR-CSI) to remove some defects, and available both in ArcInfo ASCII format and GeoTiff format (http://srtm.csi.cgiar.org/).

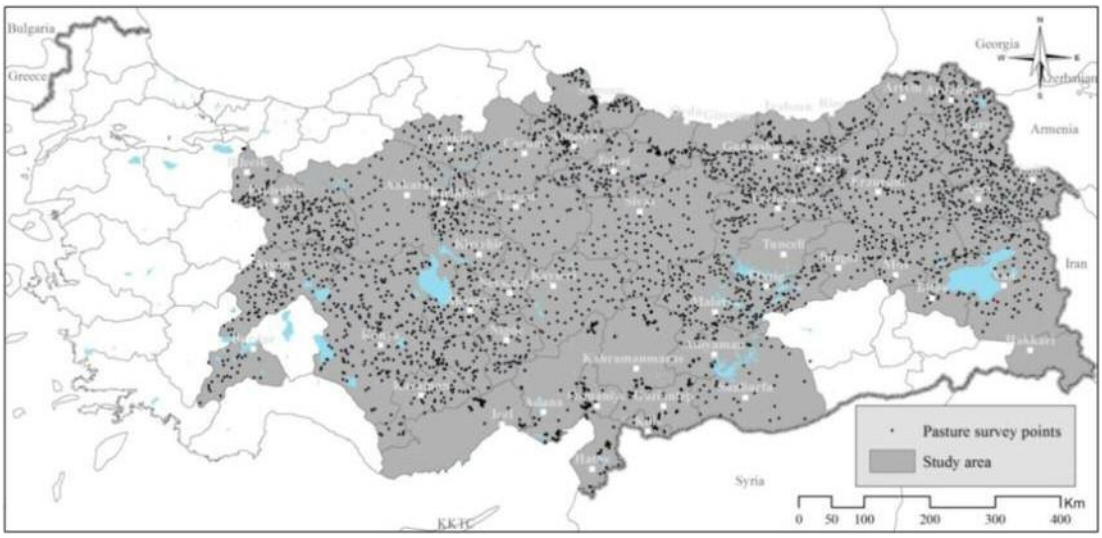

Figure 1. Study area and field survey sites
Şekil1. Çalışma alanı ve arazi çalışma durakları

Reference data

Vegetation survey data collected through “National Rangeland Use and Management Project” was used for both labeling the clusters of pixels in training stage for the classification of remotely sensed data (Avağ et al., 2012) and also validating classification results for accuracy assessment. The survey data consisted of 3444 sampling points distributed all over the entire project area (Figure 1). Rangeland scientists and botanists carried out vegetation sampling with modified wheel point method and calculated range condition classes on each sampling point according to method suggested by Dyksterhuis (1949), and Koç & Çakal (2004). Four range classes were defined as “very good”, “good”, “moderate” and “poor” attributed to an Arcview shape file. These data were used as reference data for classifying NDVI image produced by conditional rules from a NDVI composite data set.

Vector data

Rangeland borders were available as a polygon shape file covering whole project area. The polygon vector data were produced by on screen digitizing using satellite imageries from different sources as SPOT, Landsat and Ikonos (Mermer et al., 2012). They were used to subset NDVI image to mask land covers other than rangelands.

Methods

NDVI is a measure of photosynthetically active biomass on the ground, but it does not provide any information about plant species composition. However, NDVI could serve as an indicator of range health condition (Kogan et al., 2004). A high NDVI value for a rangeland area implies that biomass and plant cover is high and hereby high vigorous vegetation. As a general inference in this kind of steppe type rangelands, the higher the NDVI value the better the range condition and the more productive it is.

Although productivity has been suggested as a measure of range condition, it is not a universally accepted indicator of rangeland health. For example, range condition assessment methods, which focus on the climax approach, are not indicative of changes in total biomass production of a rangeland (Frost and Smith, 1991). Moreover, some current methods of determining rangeland condition place more reliance on change in species composition than on site productivity. Nevertheless, satellite based NDVI can identify productivity, indicating potential rangeland condition (Reeves et al., 2001).

Mean NDVI representing 10-year (2000-2009) average of NDVI of same dekad is produced from NDVI dataset. Thirty six NDVI were obtained. Mean NDVIs were then modelled with a “Conditional Rule” in which elevation was the base factor grouping of NDVI pixels to produce one complete elevation-normalized NDVI (EN-NDVI) image of whole area. The EN-NDVI image was then classified to obtain a range condition classes map (Figure 2).

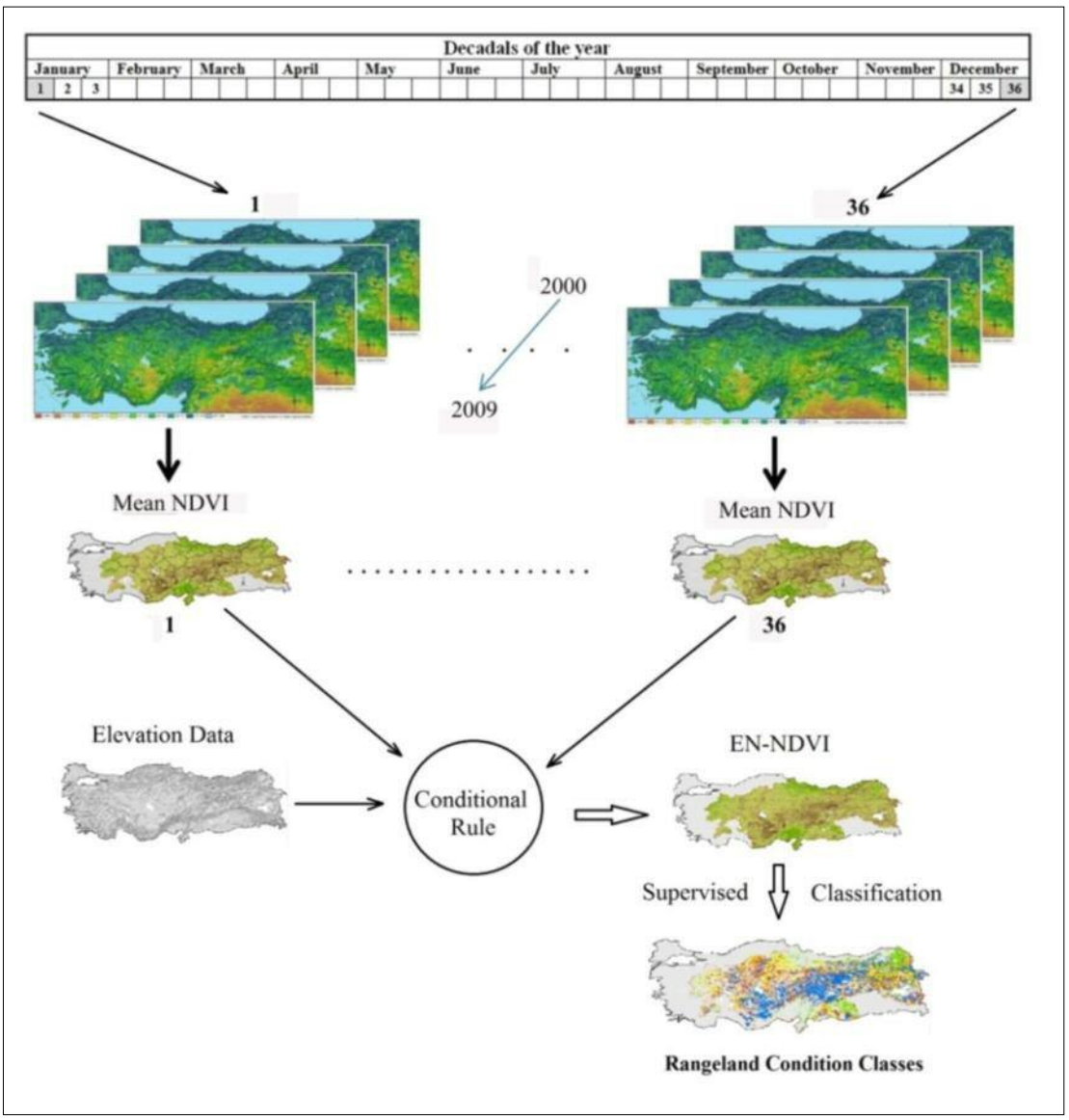

Figure 2. Graphical display of methodology
Şekil 2. Yöntemin grafik olarak gösterilmesi

Conditional rule approach

Turkey has different climatic regions with a very high topographic variation. Elevation is an important factor affecting development of climax vegetation in the country (Çomaklı et al., 2012). The effects of elevation on vegetation can be observed by looking into NDVI data. The Maximum NDVI values can be seen starting from low elevations and later at high elevations. For example, NDVI value can reach maximum value on 10-20th of May (14'th10-day period of the year) on the rangelands having average altitude of 500-1500 meters. On the other hand, maximum NDVI could be seen at 20-30th of June (18'th 10-day period of the year) on the rangelands of Eastern Anatolia with the average altitude of 2500 m (Figure 3).

EN-NDVI data was produced by considering both elevation and the phenology of rangelands. A conditional rule was applied to produce this data. When determining rules, NDVI variation graphic (Figure 3) showing the NDVI values of different elevation categories throughout the year was used. For each elevation category, the decadal periods from the onset of NDVI to start of senescence were determined (Table 1). This time period represents active vegetative growing period of rangelands. For each elevation group, decadal NDVI images of corresponding periods were merged using condition and average functions in ArcGIS. For instance, NDVI values of pixels corresponding to 1500-2000 meters elevation condition were averaged from

corresponding 7th-17th decadal NDVI period in the rule to construct elevation-normalized NDVI (EN-NDVI) data. This means that each pixel in EN-NDVI image represents a value which is the average of corresponding pixels from decadal NDVI images at the same elevation range. Figure 4 shows the EN-NDVI image produced by conditional rule.

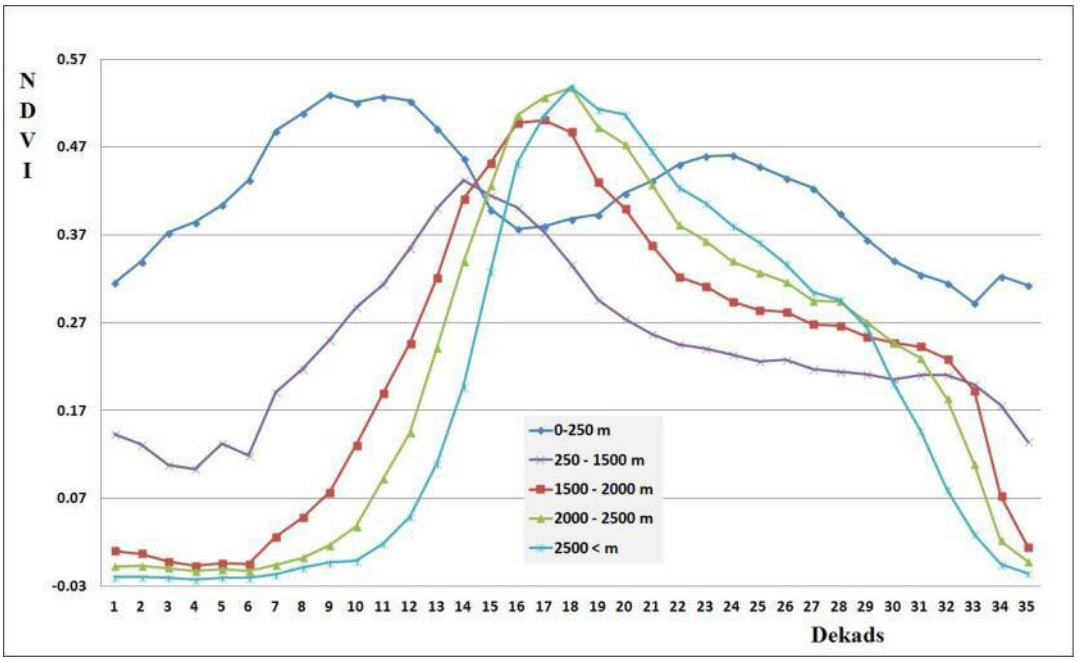

Figure 3. Variations in NDVI of rangelands by elevation
Şekil 3. Mera NDVI değerlerinde yüksekliğe göre değişim

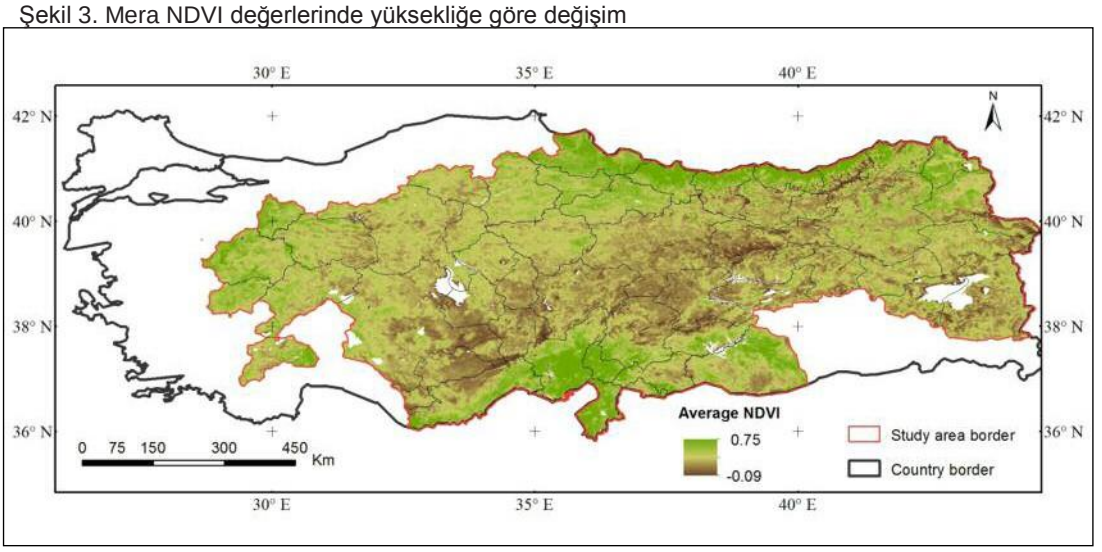

Figure 4. EN-NDVI produced by conditional rule
Şekil 4. Şartlı kural ile oluşturulmuş EN-NDVI

Table 1. Elevation categories and corresponding NDVI dekads
Çizelge 1. Yükseklik grupları ve bunlara karşı gelen 10 günlük dönem

Elevation (m)	NDVI Dekads
0-250	1 - 11
250-1500	6 - 16
1500-2000	7 - 17
2000-2500	10 - 20
2500 <	11 - 21

Image classification

A supervised maximum-likelihood algorithm was used for the classification of the EN-NDVI image. The point reference data showing range condition classes calculated from vegetation survey data were used to select training areas for supervised classification. A total of 115 reference signatures was collected to represent four range condition classes of “Very good”, “Good”, “Moderate” and “Poor”. After classification process, the output image was then subset using vector data of rangelands border to mask areas other than rangelands.

Results and Discussions

The supervised classification algorithm produced four distinct range condition classes are poor, moderate, good and very good covering 37.60, 31.8, 20.5, and 10.02% of total study area (16.325 million ha) respectively (Table 2). Classification of EN-NDVI data produced the final rangeland condition classes shown in Figure 5.

Table 2. Total areas and percentages of range condition classes

Çizelge 2. Mera durum sınıflarının toplam alan ve yüzdeleri

Condition	Area (Million) ha)	Percent (%)
Poor	6138	37.60
Moderate	5196	31.83
Good	3354	20.55
Very Good	1635	10.02
Total	16325	100

Classification Accuracy

Classification errors introduced by comparing reference data and classified data are principally used to assess the classification as a percentage of correctness which introduces user accuracy and producer accuracy. The definition and calculation of overall accuracy, user and producer accuracy, kappa coefficient and related terms have been extensively explained in literature (Congalton, 1991; Foody, 2002).

To assess the accuracy of the classification, approximately 15% of the ground truth data (randomly selected 568 points) collected throughout vegetation survey, were used as reference data which shows the actual range condition. The overall classification accuracy and average Kappa coefficient were 52.5% and 0.30 respectively (Table 3). Geerken et al (2005) reported higher accuracy (73.9 %) and kappa statistics (0.62). They applied Fourier transform and different classification algorithm to their NDVI data for classification of rangeland vegetation.

The results of classification showed that rangelands with good and very good are mostly located in Eastern Anatolia Region (Figure 5). These region are dominated by large areas of grasslands within the group of Alpine pasture whose floristic composition is dominated by grass species (Festuca sp., Bromus sp.) and many varieties of alfalfa (Fırıncıoglu, 2004). In addition, very good and good conditioned rangelands are also placed especially in northeast part of Şanlıurfa province where Karacadağ Mountain is located providing fair environment for range plants.

Good vegetation, high soil coverage and low grazing are indication of “Very Good” rangeland condition. The "good" category rangelands are mainly located in Eastern Anatolia region and Eastern Black Sea Region where Alpine pasture plants are dominant because of the some positive effects of higher precipitation. Unsuitable climatic conditions and long lasting grazing periods may cause "Moderate" and "Poor" range conditions to appear in Central Anatolia Region and transition zones. In addition, very low rainfall (300-400mm), long hot summer heats and dry conditions could lead to steppe vegetation. Plant community of steppe vegetation was dominated by common shrub species (Thymus sp. Artemisia sp., Crategus sp. etc.) and approximately 30% of the vegetation was composed of herbaceous species.

Accuracy assessment results were reported at Table 3. The results showed that overall accuracy was moderate. It is believed that higher accuracy results may be hampered by several factors; study area is large (more than 16 million ha) and has non-homogeneous landscapes having high variations in topography and vegetation, and satellite data used has low spatial resolution causing mixed pixel problem as well. Increasing the number of reference data, using a higher spatial resolution NDVI data and different classification techniques (Solorio and Fuentes, 2002) or methods (Alesheikh and Fard, 2007; Manandhar et al., 2009) could improve the classification accuracy.

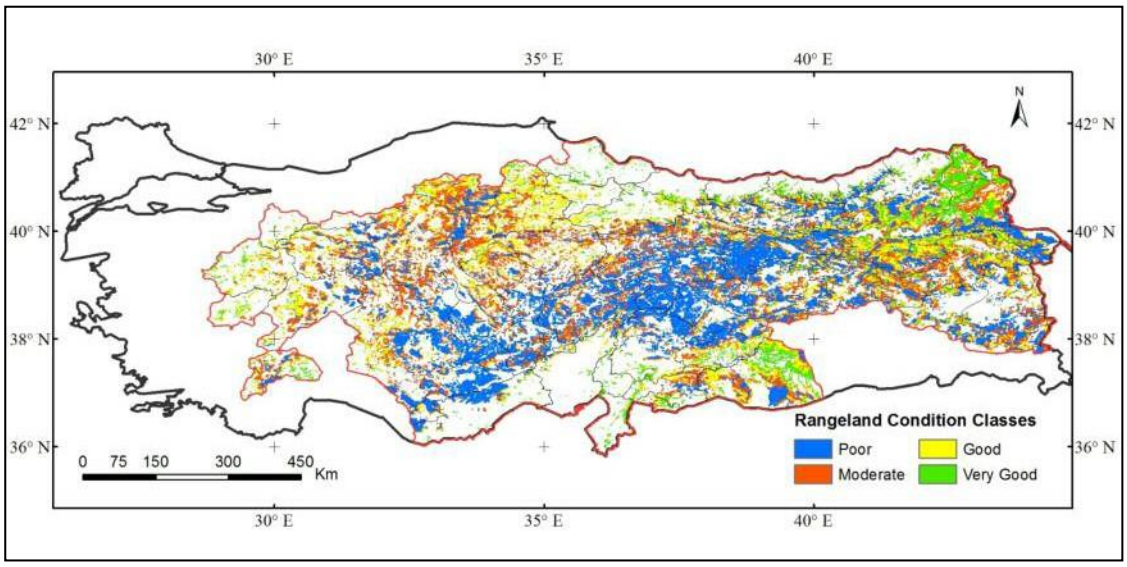

Figure 5. Rangeland condition classes
Şekil 5. Mera durum sınıfları

Table 3. Accuracy assessment report of the classification
Çizelge 3. Sınıflamaya ait doğruluk analizi

Classes	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)	Kappa statistics
Poor	193	200	111	57.51	55.50	0.282
Moderate	236	154	108	45.76	70.13	0.442
Good	64	93	33	51.56	35.48	0.261
Very Good	15	61	15	100	24.59	0.223
Total	508	508	267	-	-	-

Conclusions

Because of Turkey’s diverse topographic and climatic conditions with annual precipitation ranging from 260 mm to 2000 mm, it is not possible to obtain a reliable vegetation classification using single image acquired at a certain date.

Mean NDVI image of time series NDVI data produced based on elevation factor can eliminate time differences of vegetation phenology on diverse geographical regions. The above study demonstrates the importance of elevation normalized NDVI data when trying to analyze and map vegetation condition of rangelands for large areas. Remote sensing holds great potential not only for rangeland management, but also for a better assessment of the rangelands’ importance.

The SPOT-NDVI satellite data with 1 km spatial resolution may limits the accuracy of classification hence it restricts use of output data by decision makers. This base map would be used for macro planning and further studies should be carried out on regional or provincial scale with higher resolution satellite data and more detailed ground based surveys.

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