Vineyard mapping using remote sensing technologies

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Key words: remote sensing, vineyard mapping, SPOT-5, IKONOS, Worldview-2

SUMMARY

This study investigates the usage of different satellite images having different spatial resolutions namely SPOT-5 (2.5 m pan-sharpened), IKONOS (1 m pan-sharpened) and Worldview-2 (50 cm pan-sharpened) for vineyard mapping, examines the impact of spatial resolution on vineyard parcel identification and proposes the most appropriate data for vineyard applications. Three pilot regions were selected in Sarkoy county of Tekirdag, Turkey to fulfilled the mentioned aims. Sarkoy has an area of 555 km2 providing the highest amount of grape production in Tekirdag city. With its mild climate near the shores of the Sea of Marmara, its topographic and climatic conditions are similar to Bordoux, France. Yearly grape production for winemaking is around 52000 tones and for table fruit is approximately 12.000 tones in Tekirdag. Several grape types namely Alphonse, Cinsault, Sauvignon Blanc, Semillon, Gamay, Riesling, Cardinal, Merlot and Shiraz have been growth in Sarkoy district.

Digitization technique was applied to each image to create the boundaries of vineyard parcels and vineyard maps. Boundaries obtained from different satellite images were compared with overlay analysis to find out the impact of spatial resolution on vineyard mapping and to suggest the most appropriate data for the purpose of the study.

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1. INTRODUCTION

The observation of Earth surface from the space has lead to new research possibilities in many fields like agriculture, hydrology, geology, geodesy etc. Different satellite image data have been widely used for agricultural monitoring for scales ranging from local to global. It is important to monitor agricultural field in local scale to determine the crop yield, diseases, and to provide Farmer Registries. Among the different agricultural applications, remote sensing technology can be used to derive information about vineyard areas regularly, rapidly and cost-effectively. Satellite images have been extensively used to estimate biophysical variables of vine like shape, size and vigor which are potential indicators of fruit quality and yield. Accurate identification of vineyard parcels is important for vineyard mapping, supporting agricultural policies and creating Land Parcel Identification System (LPIS) to provide information for area-based subsidies.

Remote sensing technology can be used to derive information about vineyard areas regularly, rapidly and cost-effectively. Spatial information about vineyard areas could be valuable input for vineyard management, precision viticulture and farmer registries. Satellite images have been extensively used to estimate biophysical variables of vine like shape, size and vigor which are potential indicators of fruit quality and yield (Zarco-Tejada et al. 2005; Hall et al 2002). Hall et al 2002 presented a detail review on optical remote sensing applications in viticulture. Johnson et al 2003 used IKONOS images in conjunction with ground measurements to derive leaf area on a per vine basis (LA_v) map of wine grape vineyards. They found significant relationship between ground-based and image-based LA_v.

Zarco-Tejada et al 2005 used Compact Airborne Spectrographic Imager (CASI), the Reflective Optics System Imaging Spectrometer (ROSIS) and the Digital Airborne Imaging Spectrometer (DAIS-7915) hyperspectral sensor images to assess vineyard condition with hyperspectral indices. They calculated several narrow-band hyperspectral indices for accurate chlorophyll a and b content estimation. Pierre Da Costa et al 2007 proposed a segmentation algorithm for high-resolution remote sensed images to delineate vine fields. They used textural properties of vine images obtained from a plane to create detailed maps of vine parcels. They found smooth borders and complete parcels without missing vine plants using their approach.

Cemin and Ducati investigated the correlation between grape varieties (cabernet sauvignon, merlot, pinot noir, and chardonnay) and their spectral signatures at five terroirs in France, Brazil and Chile using ASTER satellite images acquired in the phenological cycle of the grapes. Vine plots covering 1 to 3 hectares in rows were selected for each region. Their results showed the existence of coherent spectral features in near infrared that can be used to identify varieties. Also NDVI had great value to identify varieties, such as grapes like Cabernet Sauvignon that has characteristic spectra due to phenological factors.

This study aims to:

(i) investigate the usage of different satellite images having different spatial resolutions namely SPOT-5 (2.5 m pan-sharpened), IKONOS (1 m pan-sharpened) and Worldview-2 (50 cm pan-sharpened) for vineyard mapping,

(ii) examine the impact of spatial resolution on vineyard parcel identification and,

(iii) propose the most appropriate data for vineyard applications.

2. STUDY AREA, DATA AND METHODOLOGY

2.1 Study area

The study area is located in Sarkoy, Tekirdag, lying on northwestern part of Turkey and northern part of the Marmara Sea (Figure 1). Sarkoy has an area of 555 km^2 providing the highest amount of grape production in Tekirdag city. Sarkoy has a mild climate near the shores of the Sea of Marmara. Yearly grape production for winemaking is around 52.000 tones and for table fruit the production is approximately12.000 tones/year. Several grape types namely Alphonse, Cinsault, Cabernet Sauvignon, Semillion, Gamay, Cardinal, Merlot, Yapincak and Clairette have been growth in Sarkoy district.

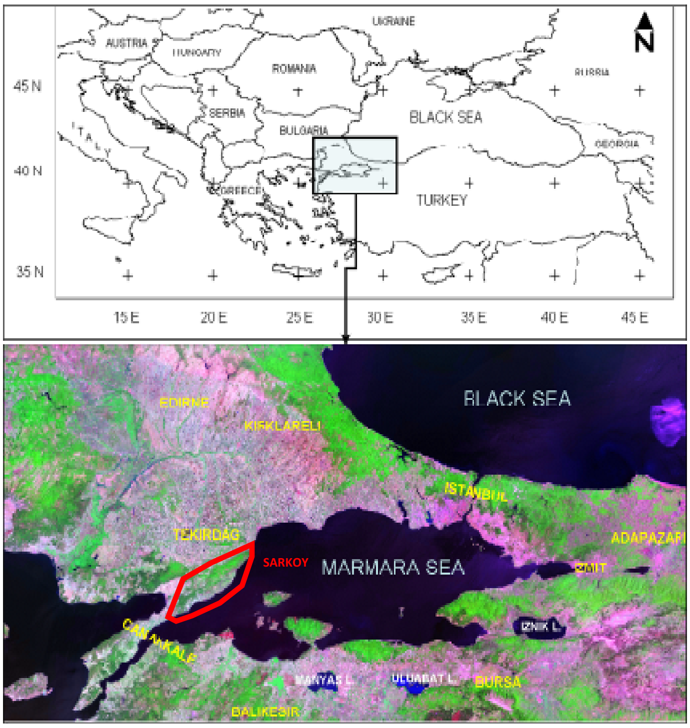

Figure 1. Study area

2.2 Data

30.07.2011 dated Worldview-2, 13.08.2011 dated SPOT-5 and 05.2007 dated IKONOS satelite data were used for this study.

11 bit Worldview-2 data has eight multispectral bands with 1.84 m spatial resolution, and one panchromatic with 0.52 m spatial resolution, bands. The spectral range of Worldview-2 data is between 396 to 1043 nm and respectively including Coastal (396-458 nm), Blue (442-515 nm), Green (506-586 nm), Yellow (584-632 nm), Red (624-694 nm), Red Edge (699-749 nm), NIR 1 (765-901 nm), NIR 2 (856-1043 nm) and Panchromatic (447-808 nm) bands.

8 bit SPOT-5 data has four multispectral bands including Green, Red, NIR bands with 10 m spatial resolution and a SWIR band with 20 m spatial resolution. There is also one panchromatic band with 2.5 m spatial resolution. The total spectral range of SPOT-5 data is between 480 to 1750 nm including Green (500-590 nm), Red (610-680 nm), NIR (780-890 nm), SWIR (1580-1750 nm) and Panchromatic (480-710 nm) bands.

11 bit IKONOS data has four multispectral bads of 3.
28 m spatial resolution, and one panchromatic band of 0.82 m spatial resolution. The spectral range of IKONOS data ranges from 445 to 853 nm. IKONOS syastem has Blue (445-516 nm), Green (506-595 nm), Red (632-698 nm), NIR (757-853 nm) and panchromatic (523-929 nm) bands.

A Digital Elevation Model of the study area resampled to 5m was created from 60 topographic maps with the scale of 1/25.000. ASTER GDEM digital elevation model was used to cover a small part where there were not any maps and that is approximately 8 % of the study area.

2.3 Methodology

IKONOS image obtained from the Ministry of Agriculture has an average horizontal accuracy of 1 m since it was orthorectified using high precision Digital Elevation Model (DEM) and Ground Control Points collected via Differential Global Positioning System technique. This image was used as reference to orthorectify SPOT-5 and Worldview-2 data. In addition to GCPs obtained from IKONOs image, a (DEM) generated from 1/25.000 scaled topographic maps was used for the orthorectification of SPOT-5 and Worldview-2 images. Root Mean Suare error of geometric corrections were 2.5 m fro SPOT-5 and 2 m fro Worldview-2 image. All images were registered into Universal Transversal Mercator (UTM) projection system and zone 35 North.

After geometric correction of satellite images three test sites were selected from all images to analyze the impact of spatial resolution on vineyard parcel identification. Vineyard boundaries were digitized from these three images for the related test sites to examine the performance.

3. RESULTS

Figure 2 illustrates vineyard parcels from the first study site. There are five big vineyard parcels with the areas changing from12 da to 40 da and two small parcels of 0.6 and 1 da. Digitization of three different images showed that although bigger parcels could be identified from three images, two small parcels could be only identified from Worldview-2 and IKONOS images but not from SPOT-5 image. These two small parcels seemed as the part of a big parcel within SPOT-5 image. All of these vineyard parcels were planted linearly making them easier to identify from different images.

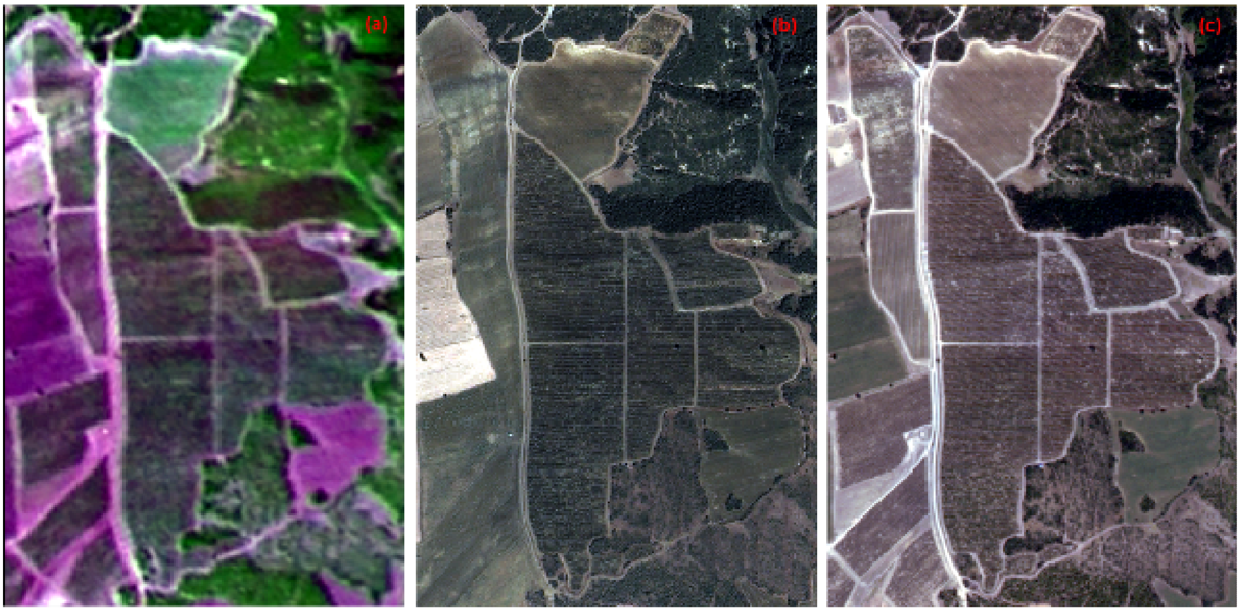

Figure 2. First test site a-)SPOT-5 data, b-)IKONOS data, c-) Worldview-2 data

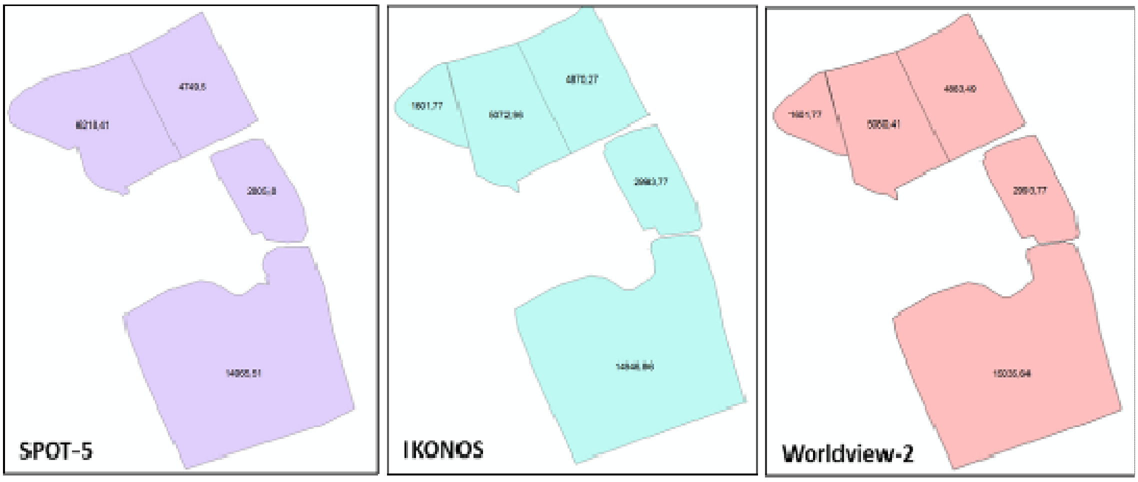

Figure 3. Digitization results from second test site

Vineyards in the second test site are shown in Figure 4. Areas of the vineyard parcels obtained from digitization illustrated that there are linearly planted parcels of 1.6 to 15 da within this site. Although all of these parcels could be individually identified from IKONOS and Worldview-2 data, the smallest parcel of this region with 1.6 da area could not be identified from SPOT-5 and this small parcel was identified as the part of the closest bigger parcel from this satellite image (Figure 3). However, total area of two parcels identified as only one parcel in SPOT-5 was found as 6.2 da which was smaller than those obtained from IKONOS and Worldview-2 data (total of two parcels were approximately 6.6 da from both images).

Figure 4. Second test site a-)SPOT-5 data, b-)IKONOS data, c-) Worldview-2 data

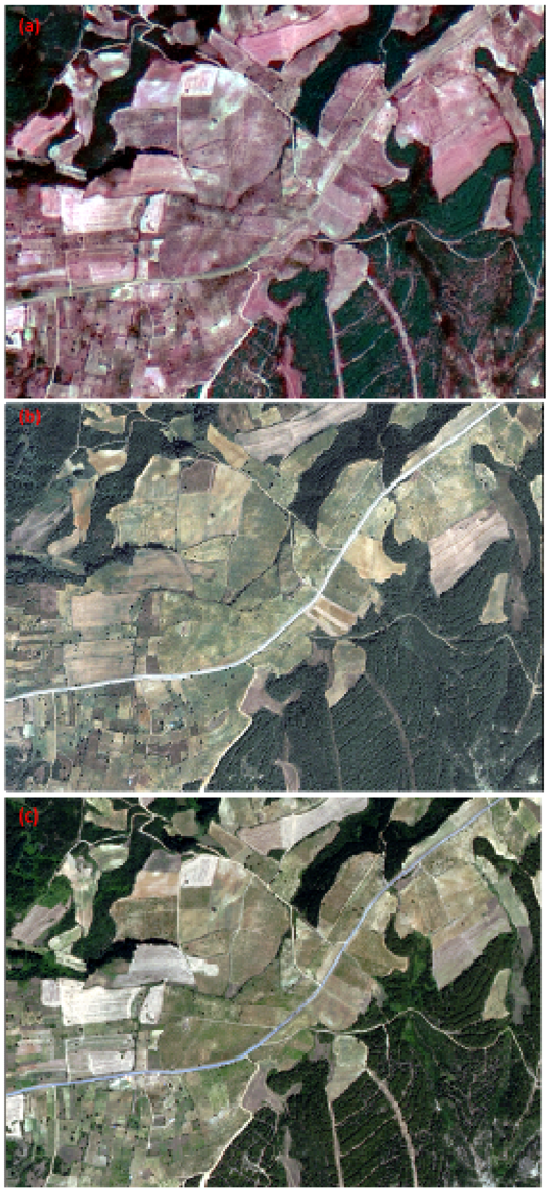

Figure 5. Third test site a-)SPOT-5 data, b-)IKONOS data, c-) Worldview-2 data

Figure 5 shows the vineyards of the third test site. All of the vineyards parcel planted in this region were either distributed or grid wise. Therefore the geometric distribution and texture of these parcels were different from the first two sites. Most of the parcels could not be identified individually from SPOT-5 data in this study area due to the texture but not size of the vineyard parcels. Even bigger parcels compared to the first and second site could not be extracted from SPOT-5 data due to the complex vineyard textures. Two or three individual parcels were labeled as only one parcel from this image. On the other hand, each individual vineyard parcel having areas between 0.5 to 12 da could be extracted from Worldview-2 data although their complex textures. Most of the individual parcels could be identified from IKONOS image however for two different parts of this site two parcels were identified as one parcel.

4. CONCLUSIONS

Overall results showed that all of three images (2.5 m SPOT-5, 1m IKONOS and 0.5 m Worldview-2) could be used for vineyard parcel identification; however, planting type and parcel size of vineyard parcels have significant importance for the parcel extraction.

SPOT-5 data was successful to extract linearly planted vineyard parcel having size of 1 da or more as shown in the first and second test sites. However, for the third test site where most of the vineyard parcels were planted distributedly or grid wise, SPOT-5 data was not successful to identify individual vineyard parcels due to their complex texture although most of the parcels had an area of 4 da or more.

IKONOS data could produce significant results for linear planted vineyard parcels; however, there are some minor problems for the identification of distributed or grid wise parcels.

Worldview-2 data was successfully used to distinguish all parcels of three different sites whatever the size and the texture of the vineyard parcels.

The results of this study illustrated the importance of remote sensing technologies to monitor and map vineyard areas accurately and emphasized the impact of spatial resolution on vineyard parcel identification. Also, spatial information about vineyard areas derived from satellite images could be valuable input for vineyard management, precision viticulture and farmer registries.

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