Journal of Applied Sciences 4 (3): 374-379, 2004
ISSN 1607-8926

Determination of Electromagnetic Energy Reflection Characteristics of Cotton Planted Areas During the Growth by Using Satellite Images and a Portable Spectrometer

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Abstract: In determination of cotton planted areas by using satellite images, surface coverage ratio and electromagnetic energy reflection characteristics of the plant constitute are the two most important parameters. In the study, surface covering ratio of cotton was measured every twenty day of its growing period. Using portable spectrometer compatible to LANDSAT 1, 2, 3 and 4 bands, soil and plant reflection values were measured. Considering the surface coverage ratios and reflection characteristics pixel reflection values (mixel) were calculated. Accordingly, surface coverage ratios were determined as 1-4% in April; 4-6 in May; 34% in June; 58% in July and 95% in August. Highest (maximum) reflection values, parallel to the coverage ratio were measured in July 31st and August 20th period. Mixel values and pixels that constituted the test areas in LANDSAT 7 ETM images were correlated and relations were searched. While a considerable negative relation (-0.55) was detected between radiometric measurements and the satellite image captured in May, as a result of correlations of radiometric measurements and July image a very important linear relation (0.97) was determined.

Key words: Cotton planted area, mixel, remote sensing, satellite images, spectrometer

INTRODUCTION

It is very important to know the area of cotton fields for Turkey's general agricultural policies due to its relatively greater economic importance among other agro-products. Knowing the areas of cotton fields is a useful data both for calculating the production yield and planning the labor, fertilizer and pesticide expenses. There are some difficulties in determining the areas of cotton-fields by using satellite images in areas especially where the Mediterranean climate is characteristic. Diversity of the vegetation depends on the climate. Changes in the humidity of soils depending on the season and irrigation affect the solar energy reflections in various ways. Therefore when the reflection values are taken in to account, while drawing maps of cotton plantations precision ratios are affected negatively. Within this project, soil coverage, solar energy reflection ratios and their wavelengths were determined for the cotton, grown in Aegean region, to ease the visual capturing in satellite images.

The principal rule of remote sensing (RS) is to perceive and record the energy either reflected or emitted by the surface of any object or being that are within the range of the sensor. Sensor of LANDSAT 7 ETM show different wave lengths according to their spectral characteristics and are able to perceive the photons within these wave-lengths such as; usual bands of the electromagnetic spectrum are 0.4-0.5 μm blue, 0.5-0.6 μm green, 0.6-0.7 μm red and the infrared reflection (0.7-1.35 μm close range infrared, 1.35-3.00 μm medium range infrared, 3-15 μm further infrared or thermal)[1]. Electromagnetic waves of solar photons are reflected, conducted, spread or absorbed at different wave lengths depending on the different cell structures of living creatures or different molecular structures of non-living objects. Therefore, resulting from these differences when the water content of the soil increases a decrease in reflection is observed and that causes black areas to appear on the image. In contrast when the energy is fully reflected, the image becomes light-bright. When the organic substances exceed 1% in the soil a decrease in reflection is observed. Reflection characteristics of clays are less than sands. Soils containing iron absorb the light more than the soils containing calcite and therefore reflect less. Plants on the other hand, reflect near infrared photons depending on its leaves types, width, cell shape, the soil coverage percentage and their stationary position to the surface. Each plant having significant physiological features, cell shape and different growth period with its location and intensity in the nature help RS technique identify them. Identical reflection values of plants can be determined by surface surveys using a portable spectrometer.

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Maas[2], identified min/max reflection values limits for cotton in California conditions using 7 images captured between June-September 1994. In the study, at 63 test points in south San Joaquin Valley, (California) radiometric measurements were taken in order to record plant surface areas together with soil and plant reflection values in band 3 and 4 following the field survey, reflection values in band 3 and 4 of the satellite image for the same test area were compared with the radiometer measurements values to find out the relation between. In result Maas reported that planted areas might be measured by determining the plants reflection values[2].

Franklin *et al.*[3], sampled the spectral reflectance of the shaded and unshaded components of Chihuahuan desert plant communities (shrubs, soil, subshrubs and perennial grasses) in the SPOT wavebands using a hand-held radiometer. They examined the mean reflectance differences between components to evaluate their spectral separability. Shrub canopy and shaded components have similar reflectance in the visible wavebands. However, in the near-infrared band, which is strongly scattered by green plant canopies, the shaded canopy and shaded background components were similar to each other and lower than either sunlit background or sunlit canopy. When reflectance measurements were transformed to normalized ratio (NDVI, SAVI) and orthogonal green vegetation indices, the shaded and sunlit portions of each component (canopy and soil) were similar, but the shaded components were intermediate between their sunlit counterparts. Different soil types and plant species with different life forms (e.g., shrubs, grasses) and phenologies exhibited different reflectance characteristics. However, the broadband reflectances of the three dominant shrub species were similar at the end of the growing season, in spite of their differences in morphology[3].

Kooistraa *et al.*[4] investigated the relation between vegetation reflectance and elevated concentrations of the metals Ni, Cd, Cu, Zn and Pb in river floodplain soils. High-resolution vegetation reflectance spectra in the visible to near-infrared (400-1350 nm) were obtained using a field radiometer. The relations were evaluated using simple linear regression in combination with two spectral vegetation indices: the Difference Vegetation Index (DVI) and the Red-Edge Position (REP). In addition, a multivariate regression approach using partial least squares (PLS) regression was adopted. The three methods achieved comparable results. They find out that the best R 2 values for the relation between metals concentrations and vegetation reflectance were obtained for grass vegetation and ranged from 0.50 to 0.73. Herbaceous species displayed a larger deviation from the established relationships, resulting in lower R 2 values and larger cross-validation errors. The results corroborate the potential of hyperspectral remote sensing to contribute to the survey of elevated metal concentrations in floodplain soils under grassland using the spectral response of the vegetation as an indicator. Additional constraints will, however, have to be taken into account, as results are resolution-and location-dependent[4].

MATERIALS AND METHODS

Study area: The study area lays 20 km south-west of Soke district of Aydin. It includes 10 test area of 18-70 da. Test areas are on the alluvial soils, classified as Typic xerofluvent in the East of state highway between Soke and Sazlikoy towns. Geographic coordinate of research area; Latitude 37°29' 30"-37°37' 30" N, Longitude 27°08' 00"-27°14' 30" E. The study area is on the delta formed by the river Great Meander.

The region of the study area, being hot and arid in the summer and worm and rainy in the winter has a mesothermal description of Mediterranean climate. The long-term annual rainfall average of the area has been 698.6 mm and the heaviest rainfalls have been recorded in December. Of the rainfalls in the region; 51% in winter; 21% in spring; 8% in summer and 20% in fall were recorded. In the region, where the average temperature is 16.9°C, the lowest average of 11°C has been calculated in January and the highest has been in July as 43.6°C. The relative humidity average ranges between 50-76%[5].

In the study, LANDSAT-7 ETM satellite images, which were captured in May and July 2001, were used. Reflection values of soil and plant were determined in four different band of electromagnetic spectrum by using a Hand held radiometer (exotech 100BX model) that had equal sensing limits with the sensing devices of the satellite LANDSAT-7 ETM.

A $BaSO_4$ coated white plate was used to calibrate the value displays of radiometer. In addition GPS devices and topographic maps scaled 1/25.000 were used in marking the test areas and other purposes in the field. The color of the soil was determined by Munsell color chart[6]. In processing the satellite images the Image Analyst (Intergraph) and Microstation (Bentley) software were used.

Base maps covering the study region and test areas were prepared by using scanned standard topographic maps scaled 1/25.000. These base maps were used in rectifying the satellite images taken separately in May and August 2001 by LANDSAT-7 ETM examining the image taken in May, 10 test areas were selected, later they were confirmed during surface surveys and marked on the base map. An attention was paid on selecting the test areas that should be on the fertile soils of Fluvents soil subgroup which are widely observed among the flat lands of the area. In order to complete radiometric measuring and to do it in a constant atmospheric condition test areas were selected within a short range of distance.

Pixel in satellite images, depending on the resolution, has an average reflection value of 30x30 m of a land piece together with the soil and plants upon. Therefore, to be able to correlate satellite images with radiometric values of the surface, the soil coverage ratios and reflection values at certain times were measured and finally an average pixel reflection value (mixel) was obtained. Reflections of the energy that has a wavelength within visible part and near infrared part (1, 2, 3 and 4 bands of the spectrum) of electromagnetic spectrum.

Field works aiming radiometric measurements were carried out seven times (as 20-d periods) every 20 days. In order to determine land coverage ratios eight additional field surveys including the extra measuring on June 27th were realized. Measurements were taken five times for each test area and their average was considered as the result value for the area.

Since the solar energy is affected considerably by the atmospheric corridor, measurements were taken either on the same day or on a different date, show deviations even if the elements are the same. Radiometric measurements were taken at different solar energy intensities need correction factor in order to be correlated accurately. To do so a correction factor was worked out by using reflection values of a white plate coated with $BaSO_4$. Between 09:30 and 10:30, which is known as the best reading time, 42 reflection values of $BaSO_4$ board were taken and the average of which was determined as "constant" value. At times when soil and plant values were being measured an initial $BaSO_4$ plate reflection value was taken and deviation between this measurement and the "constant" which had been determined earlier was accepted as the "correction factor". Reflection values of the soil and plants, taken during the field works and their coverage ratios in one pixel were taken in to consideration therefore, "mixel" values were calculated shown below:

$$M = [(Rs)Fs]+[(Rc)Fc)]$$

Corrected cotton reading: $R_c = C+(C.k)$

Corrected soil reading: $R_s = S+(S.k)$

$BaSO_4$ plate "correction factor": $k = \frac{(B - \Delta b)}{B}$

Mixel value: M

Constant from $BaSO_4$ board readings: Δb

Field reading of cotton plant: C

Field reading of soil: S

Field reading of $BaSO_4$ plate: B

Cover range of plant (%): Fc

Cover range of soil (%): Fs

Atmospheric, radiometric and geometric corrections of satellite images were done. Test areas were marked on the satellite images using Microstation software. All digital data was determined on 1, 2, 3 and 4 bands of satellite image for all pixels that cover the test area and average values for each test areas were correlated with radiometric results.

RESULTS

Soils in the study area were examined and parameters for effective factors on reflection were determined. Surface soil horizon was classified as Ochric epipedon with light color. They have sandy-loam soil structure with weak-medium granular structure. Their water holding capacities are low so that they can easily dry up. Soil color readings were taken in both dry and humid conditions of the lands and determined as; (10YR 6/4) and (10YR 3/4).

The most important factor for the cotton plants to be distinguished in satellite images is its surface cover ratio. In order to determine the soil coverage development, empty spaces between the plant rows in the cotton fields and the green tissue above the surface were measured in three different parts of each test area and this was carried out all through April-September, the growing period of cotton plants. Later averages of readings were taken for each different period to determine the changes in coverage ratios by the time during the growth. During the first three measurement readings displayed a moderate coverage increase but between 3rd and 5th measurements a vast increase in coverage ratio was observed. While there was no increase between 5th to 7th measurements a decrease was observed starting from the 7th measurement. Accordingly, it was determined that the cotton would start to be slightly visible by July 10th in satellite images but between July 31st and September 19th it would be visible clearly. Since it started drying up after September 19th it would gradually lose its visibility (Fig. 1).

Soil reflection values were dominant because the cotton seedlings were still small in 3rd measurement on June 24th 2001. At this phase mixel values resembled soil reflection values (Fig. 2). In fourth measurement on July 7th, 2001 figures showed that parallel to the growth, the soil coverage of the cotton expanded and its reflection values exceeded soil reflection values and average pixel reflection values (Fig.3).

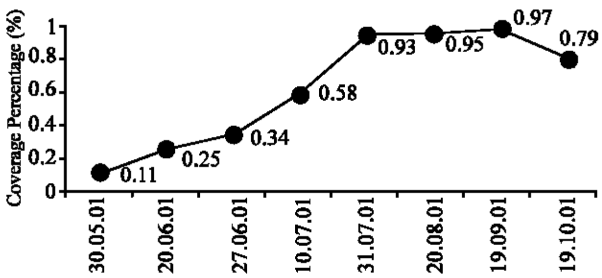

Fig. 1: Coverage ratios of cotton calculated during the growth

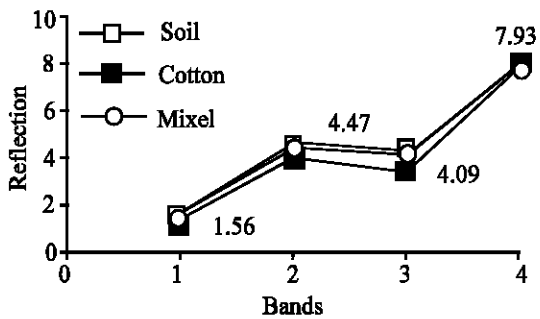

Fig. 2: Soil, cotton and average pixel reflection values of test area nr. 10 on June 27th 2001

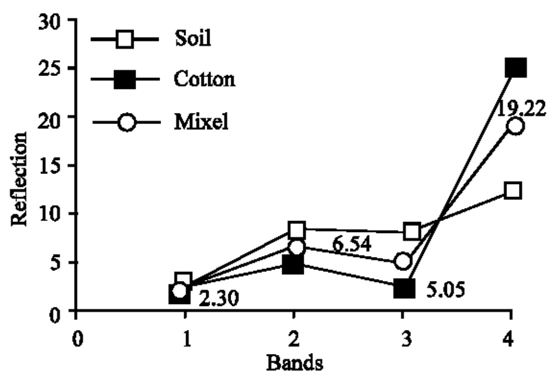

Fig. 3: Soil, cotton and average pixel reflection values of test area nr. 10 on July 07th 2001

The following coverage ratio readings taken on August 20th, 2000 was at the time when the cotton plants was fully grown causing the soil to be covered almost completely by the green leafs of the cotton. At this phase reflection value of cotton was well over soil reflection value and average pixel reflection value (Fig. 4).

During the growth of cotton plant, among the radiometric measurements (seven times) the most significant changes were detected in the reflection values of energy having near-infrared wavelength (4th band). Reflection values of band 4 started to display a rapid increase on June 27th but were followed by decrease in September. Highest values of bands 1, 2 and 3 were measured at the beginning when soil reflection was

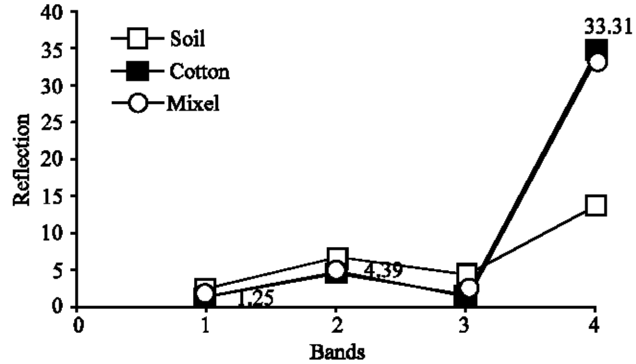

Fig. 4: Soil, cotton and average pixel reflection values of test area nr. 10 on August 20th 2001

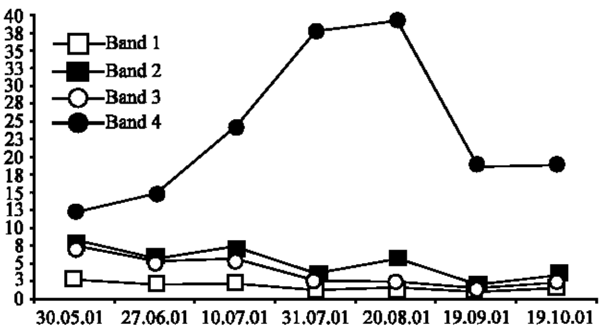

Fig. 5: Radiometric readings on bands 1, 2, 3 and 4 during the growth of cotton

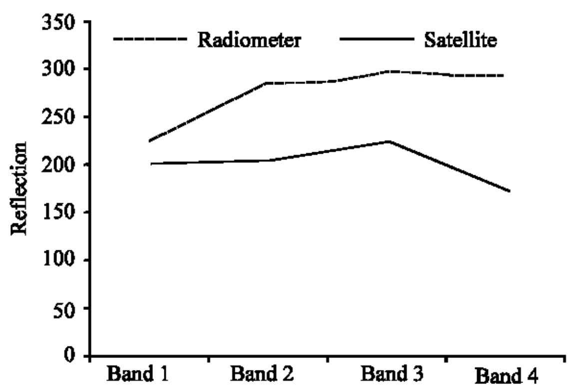

Fig. 6: Correlation between radiometric readings and reflection values of Landsat satellite image of May

effective but in the following periods these values gradually decreased (Fig. 5).

However, the natural humidity of the soils in April-May period and following irrigations caused soil to increase its absorbing capacity, therefore reflection values were measured low. It was observed that the humidity of the soil was also a factor which affects the digital range within which cotton plant can be detected.

In order to have a correlation between the radiometric readings taken during field surveys and digital pixel number optic satellite images, global coordinates of each

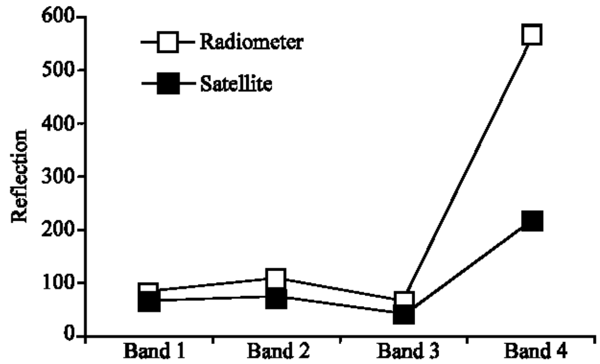

Fig. 7: Correlation between radiometric readings and reflection values of LANDSAT satellite image of July 2001

Table 1: Average reflection values of the pixels covering test areas in Landsat 7 ETM satellite image taken in August 2001

	Bands			
Test areas	1	2	3	4
1	81	94	58	217
2	81	85	50	211
3	100	94	64	185
4	81	94	50	189
5	85	85	54	183
6	85	85	46	214
7	77	82	48	223
8	77	88	50	228
9	93	88	49	210
10	97	88	54	189
Mean	85.70	88.30	52.30	204.85

test area's borders were determined by using GPS devices in the field and those coordinates were marked on Landsat satellite image. Atmospheric and radiometric corrections of LANDSAT 7 ETM satellite images that belonged to May-July period. Digital numbers of pixels covering each test area were determined on bands 1, 2, 3 and 4 and their averages were taken (Table 1). These digital numbers were correlated with mixel values that had been determined at the end of radiometric measurement. Between digital numbers of cotton fields in the Landsat images of August when the soil coverage ratio of the plant was highest and surface measurements taken at the same period showed significant parallelisms.

A negative relation (-0.55) was detected between Digital Numbers of pixels of satellite image taken in May 2001 and radiometric surface readings, but as a result of correlations between the July image and radiometric readings, a significant linear relationship (0.97) was determined (Fig. 6 and 7).

DISCUSSION

The most important factor in determining the distribution of cotton is the percentage of soil coverage of the plant. Being able to record near-infrared energy dominantly which is the most reflected energy by the vegetation, is directly related to the plant having dense leaves being densely planted and the growth ratio of the plant. For this reason the surface coverage ratio of cotton was observed from April to October. Coverage ratios starting at 1-4% in April were observed to have increased up to 4-6% in May; 34% in June; 58% in July and 95% in August. Therefore, since the cotton seedlings were small in first reading period surface covering ratios were low and accordingly reflection values were less than soil reflection values and pixel reflection values. In second reading period, parallel to the growth and the increase in soil coverage ratio, the plant's reflection values exceed the soil and pixel reflection values.

As a result of full growth and accordingly almost full coverage of the soil, it was determined that reflection values of the plant were well over the reflection values of the soil and pixel. Radiometric measurements that were taken during the field surveys were done within 1, 2, 3 and 4 bands wave-lengths of the satellite sensing devices of Landsat 5 TM.

Frequent changes in reflection values depending on the soil coverage ratios and characteristics of the plants were observed during the measurements from May 10 to September 19. The highest reflection values on bands 1, 2 and 3 were measured in surface surveys on May 30th and June 20th. The lowest reflection values on bands 1, 2 and 3 measured on September 19. While the highest band 4 reflection value reading was on August 18th, the lowest band 4 reflection values which was directly related to soil coverage percentage of the plant, was measured on May 30th.

It was determined that the highest reflections cotton plant were recorded between July 31st and August while the coverage ratio was also high. Mixel values and pixel values that constitute the test areas in Landsat 7 ETM satellite images were correlated and possible relations were searched. While considerable negative (-0.55) relation was observed between May image and radiometric readings, a very important linear (positive) relation (0.97) between July image and radiometric readings was detected following the correlations. In spectroradiometric measurements the highest readings has always occurred on band 4. The highest 4th band measurement (39.2) was taken on August 20th and the lowest was measured (12.09) on May 30th which was the first reading. However, the highest readings for bands 1, 2, 3 were recorded on May 30th and the lowest ones were on August 20th.

It was determined that the best period for the cotton plant to be easily identified in satellite images using remote sensing technique is July-August period for Aegean region.

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