ANALYSIS OF CHANGES IN VEGETATION BIOMASS USING MULTITEMPORAL AND MULTISENSOR SATELLITE DATA

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ABSTRACT:

Turkey has always been one of the major agricultural countries in the world. The importance of agriculture is increasing due to the growing of population in Turkey and in the world. Although the importance of agriculture in Turkish economy has been declined relatively in the time with respect to GNP (Gnoss National Product) and export, this issue keeps its importance since the high number of workforce and direct relationship between food resources and agriculture. Turkey can make its place stable among the world countries by defining the potential of harvest. Today, new technologies such as remote sensing and GIS can be used for crop estimation and crop mapping. The analyses of the changes in vegetation biomass over years is also so important and will assist in taking stable decisions for national agricultural policies.

In this study, which was also undergraduate final project, changes in the vegetation biomass at the Lüleburgaz district, Kırklareli, Thrace region in Turkey was analysed using three multitemporal Landsat TM scenes and one Spot XS scene. In the analyses, different vegetation indices for observing the biomass were evaluated with the help of ground truth data. Based on the results obtained, the effectiveness of the use of multitemporal satellite imagery was outlined.

1. INTRODUCTION

The importance of agriculture all around the world is known through the ages. Even the civilisation began with agriculture when first settlements appeared. Parallel to the population growth, needs for living (foods and raw materials) have been increased and force them to show much more care on the issue of agriculture. Besides, the economical dimension also affects its importance. Knowing the amount of the total harvest, the countries can easily determine their needs and also take stable decisions in their agricultural policies. Today, most of the developed countries indicate the importance of agriculture over the economy by taking the resources made surplus by increasing agricultural productivity as a key to economic development (Baker, 1987).

Turkey has the %35 of agricultural lands in a total of its 78 million-hectare area and the climate of the country is a great advantage for agricultural activities. In the year of 2000 the value of the agricultural profit was 9.5 quadrillion TL and in these years the part of agricultural products in export was nearly %50 - %60. Although known as a country that has the potential of being an agricultural country instead of an industrial one, agriculture lost its importance over time (Ministry of Agriculture, 2004). Furthermore, for developing countries like Turkey, facing with powerful countries in the market, to estimate the value of the agricultural products has a vital importance.

As the technology takes part more and more in our lives, space technology gives us the opportunity to observe land and help us to predict very reliable and almost true information about the land use and land cover. These help us to predict about the amount and the quality of the harvest in a higher precision and quicker than terrestrial measurements. The use of remote sensing technologies over agricultural issues and integration with geographic information systems, complex analyses of the state and changes in the vegetation biomass, help the country in increasing the amount and the quality of agricultural products.

In this study, vegetation biomass in Lüleburgaz district, Kırklareli, Thrace region was analysed by using different vegetation indexes and the changes in biomass through 1987 to 2003 years was monitored by multitemporal and multisensor satellite data.

2. STUDY AREA AND DATA USED

Ground truth data was collected from the Türkgeldi State Production Farm, which is in the boundaries of Lüleburgaz district, Kırklareli (41.24 latitude, 27.21 longitude). This farm has a total area of 19.050-decare agricultural usage and a height of 46m above sea level.

Figure 1. The map and Landsat TM image of the study area.

The study area takes 600mm rainfall in average of a year. In this production farm, mostly wheat is the main product and has approximately 3000-ton capacity in a year. In addition, sunflower, corn and canola are the other agricultural products that are aggregated.

In this study, three multi temporal Landsat-TM and one SPOT-XS data sets were used to analyse the vegetation biomass changes over time. The characteristics of satellite data used are shown in the Table 1.

Satellite	Date	Spectral resolution (μm)		Spatial resolution (m)
Landsat TM	11.05.1987	Band 1	0,45 - 0,52	30
		Band 2	0,52 - 0,60	30
		Band 3	0,63 - 0,69	30
	27.05.1993	Band 4	0,76 - 0,90	30
		Band 5	1,55 - 0,75	30
	07.06.2000	Band 6	10,4 - 12,5	120
		Band 7	2,08 - 2,35	30
Spot XS	12.05.2003	Band 1	0.50-0.59	20
		Band 2	0.61-0.68	20
		Band 3	0.79-0.89	20

Table 1. The characteristics of satellite data used.

3. METHODOLOGY

3.1 Vegetation Indexes

In this study, five different types of vegetation indexes, which quantify the concentrations of green leaf vegetation around the globe, were used for biomass analysis. These indexes depend on the reflectance of vegetation, which is very different in near infrared and red bands. Healthy vegetation should absorb the visible light and reflects most of the near infrared light, on the other hand unhealthy vegetation reflects more visible light and less near infrared light. The reflection on visible band is related with the pigments in the leaves of plants but in the near infrared, it depends on the cell structure.

Taking the ratio of near infrared band and red band is the simplest vegetation index. Hence, it is called Simple Ratio (SR) or Ratio Vegetation Index (RVI). SR indicates the amount of vegetation. In the resultant SR image, high values, such as more than 20, show for dense vegetation and low values, which are around the value of 1, show for soil, ice and water. However, it doesn't give information related with topography. It only transmits the spectral information; therefore this also gives an opportunity of having uniform spectral classes after classification.

Another simple vegetation index is the Difference Vegetation Index (DVI), which is also sensitive to the amount of the vegetation. Mathematically, it is in the form of (near infrared band) – (red band). DVI has the ability to distinguish the soil and vegetation but not in shady areas. Hence, DVI doesn't give proper information when the reflected wavelengths are being affected due to topography, atmosphere or shadows.

The more common and known one is the Normalised Difference Vegetation index (NDVI). The algorithm of NDVI is (near infrared band– red band)/(near infrared band + red band). Resulted values change between -1 and +1 regarding to the vegetated area. Such as, if the result is 0,1 or below, it corresponds to an area of rocks; if it is between 0.2 and 0.3, it indicates an area of shrubs or grasslands; if it is between 0.6 and 0.8 it corresponds to an area of tropical rainforests.

Transformed Normalised Difference Vegetation index (TNDVI) is the square root of the NDVI. It has higher coefficient of determination for the same variable and this is the difference between TNDVI and NDVI. The formula of TNDVI has always positive values and the variances of the ratio are proportional to mean values. TNDVI indicates a relation between the amount of green biomass that is found in a pixel. (Senseman et.al. 1996)

Perpendicular vegetation index (PVI) is one of the complex indices that also including soil emissivity factor. It is based on the linear relationship of red and near infrared reflectance from bare soils. This is called the soil line (Figure 2). PVI is the perpendicular distance from the soil line and it is linearly related to the vegetation cover (Sunar and Taberner 1995). PVI uses Gram-Schmidt orthogonalization to figure out the greenness line, which is perpendicular to the soil line and passes through the %100 vegetation cover points. PVI is effective in detecting dry and green vegetation. This is caused by the sensation of red and near infrared combination to the iron oxide absorption that is in many soils. Mainly PVI indicates the vegetative cover, independent from the soil effects.

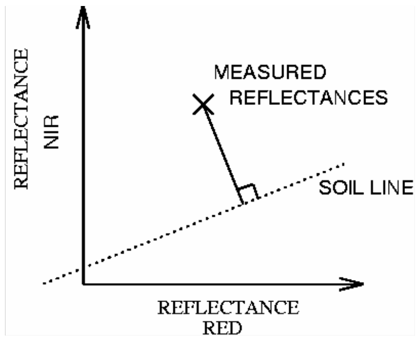

Figure 2. Perpendicular Vegetation Index.

3.2 Geometric Correction

To detect the changes in vegetation biomass all images used must be registered to each other. The 1993 Landsat image was taken as the base image for registering.

Ten GCPs for each year, which were well distributed through the images, were chosen in registration. The number of GCPs and rms errors were outlined in Table 2. Spot XS image (2003) were resembled to 30 m to be analysed together with the other Landsat images. All the registered images were taken as a multitemporal dataset having 455 x 547 pixels.

Base image	Slave image	# of GCPs	rms error
	1987	10	0.5716
1993	2000	10	0.5474
	2003	10	0.4373

Table 2. Number of GCPs used and rms errors.

4. ANALYSIS AND RESULTS

4.1 Analysis of different vegetation indices

In the multitemporal dataset, five different vegetation indexes were performed and analysed as different band combinations by overlying in different RGB layers (Figure 3). As can be seen from the figure, the changes in vegetation biomass through the years were easily observed. In the multitemporal NDVI images, the black colours represent the areas having no vegetation in the years overlaid in RGB. These areas were mostly roads, urban areas and rivers.

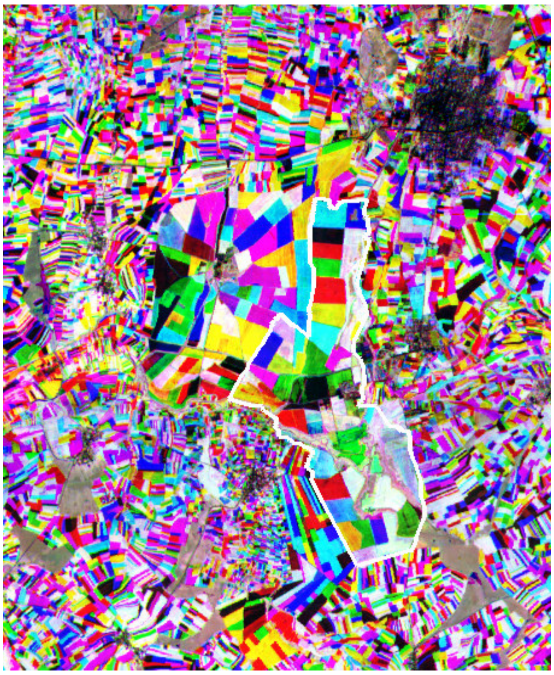

Figure 3. Multitemporal NDVI image
(**R**: 1993 NDVI; **G**: 2003 NDVI; **B**: 1987 NDVI)

For the ancillary information related to the different crops in the area, the 1993 crop plant sketch gathered from the Türkgeldi Production Farm was used.

In this area, there are two main plantation seasons for sunflower and wheat crops in a year. The sunflower crops are generally planted both in April/May or June/July and harvested in June/July or August/September, respectively. On the other hand, the wheat crops are planted in the October/November and harvested in May/June. Because of having same plantation characteristics, barley and wheat crops had nearly the same vegetation index values in the dates of the images acquired (May/June). However, this was the opposite for the sunflower fields. Generally lower values were observed depending on the different plantation time with the others.

As main crops, sunflower (blue colour), wheat (yellow colour) and barley (green colour) were selected and shown as different ROIs (Figure 4). Maximum values of these regions for different vegetation indices were computed for each year and evaluated graphically in Figure 5 through 9.

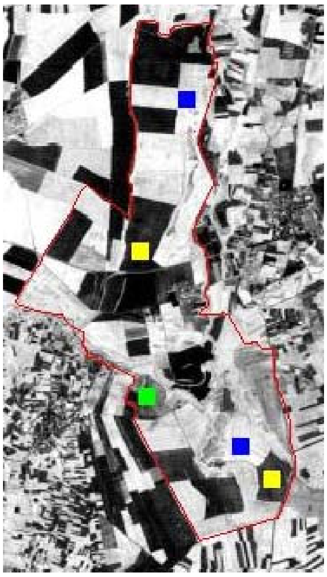

Figure 4. Selected ROIs in the 1993 NDVI image.

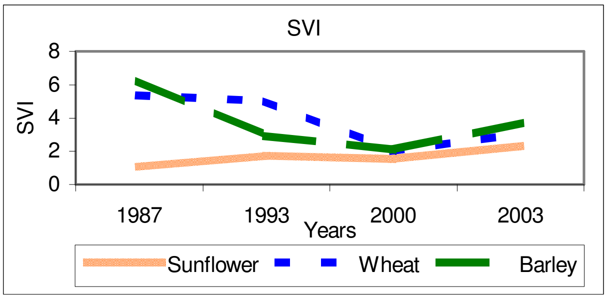

Figure 5. Simple Vegetation Index results.

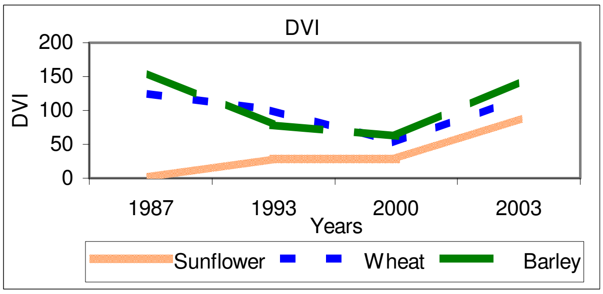

Figure 6. Difference Vegetation Index results.

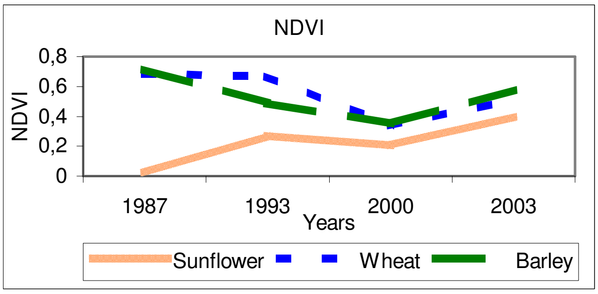

Figure 7. Normalised Vegetation Difference Index results.

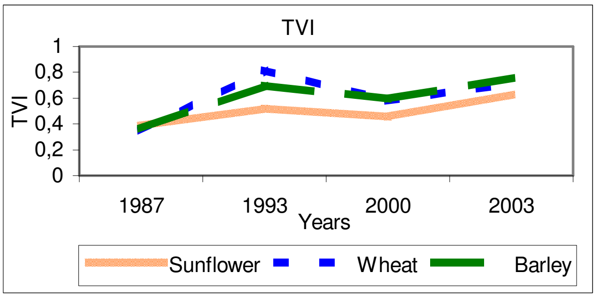

Figure 8. Transformed Vegetation Index results.

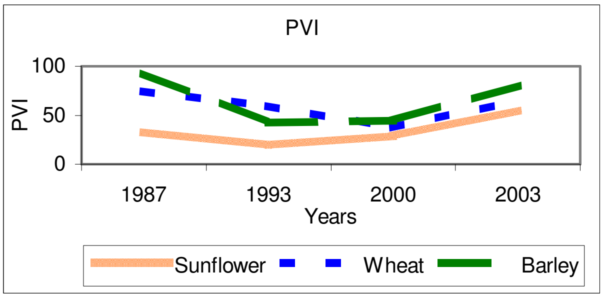

Figure 9. Perpendicular Vegetation Index results.

In all vegetation indexes, it was observed that there was a decrease in the year of 2000. As expressed in many references, the drought effect observed by the precipitation measurements (Figure 10) in a year of 2000 was the main cause (Çaldağ et.al. 2003).

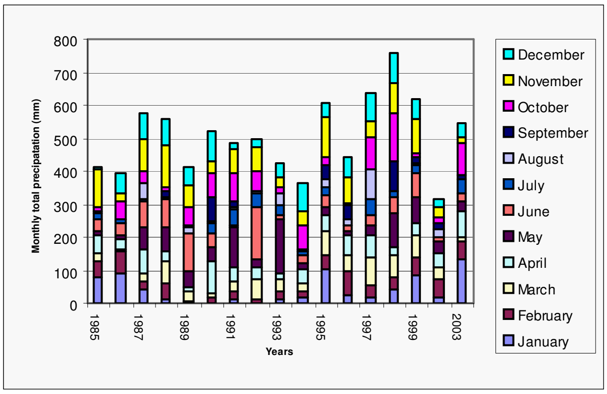

Figure 10. Monthly total precipitation in Kırklareli in between 1985-2003 years.

4.2 Vegetation biomass classification

For this application, only NDVI dataset was chosen. Three training areas representing highly vegetated (mean value greater than 0.7), low vegetated (mean value of 0.4 – 0.0), and non-vegetated (mean value smaller than 0.0) areas were chosen (Figure 11) and the supervised classification method was applied.

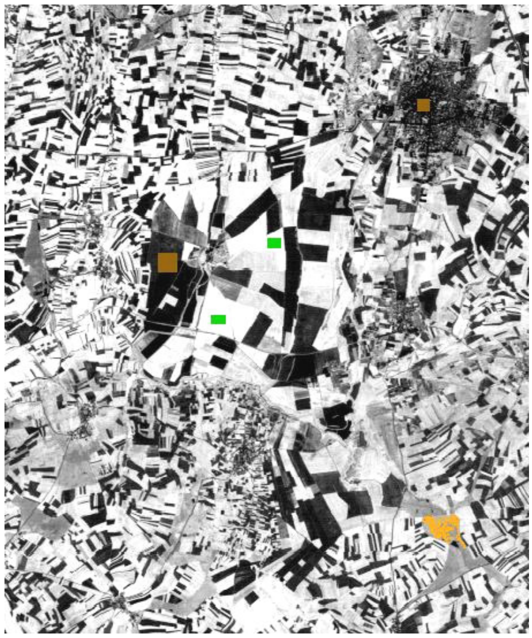

Figure 11. Selected training areas for the supervised classification.

The classification result is given in Figure 12. As can be seen, the green areas represent the highly vegetated areas, brown areas represent the non-vegetated areas and the dark orange areas represent the low-vegetated areas. So this can be concluded that the area is mainly highly vegetated area. The areal extents of each class were also calculated and shown graphically in Figure 35. The effect of drought in year 2000 was also confirmed once more with this figure.

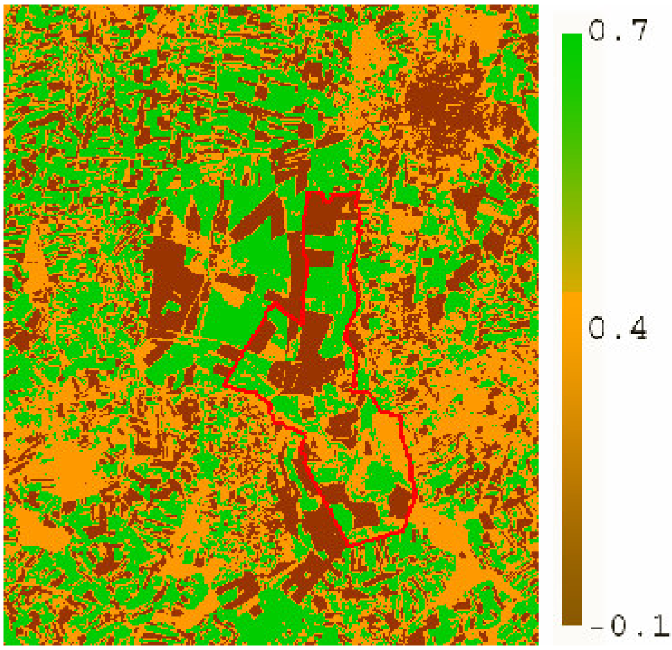

Figure 12. Classified image of 1993 NDVI.

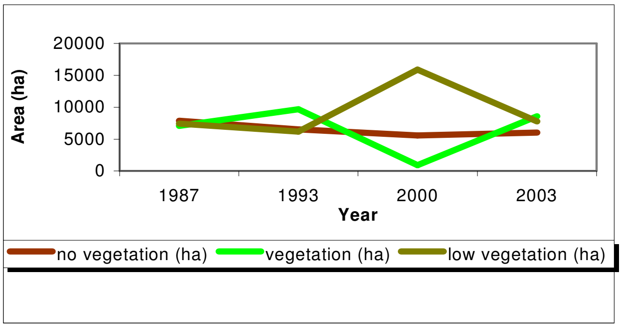

Figure 13. Areal extent of the vegetation through the years.

5. CONCLUSION

The importance of agriculture is not only local or country based but global. As the population rises, the countries have to plan and manage the agricultural resources in a way that there won't be any problems for the future of their countries and worlds. Countries have to take care of their needs and decisions on economy through the knowledge of their agricultural products and the power of these products.

As today's one of the developing countries, Turkey has to be aware of its agricultural products and use them in a more efficient way. Turkey has a potential of being an agricultural country instead of an industrial one, although as the time goes on, this is not taken into consideration enough.

As the use of space and computer technology developed, humankind has a great advantage of produce this much important projects with the help of technology in an easier, more accurate way within less time than other ways. In addition to this with the help of geographical information systems, complex analyses can be also done. As a result all these can have a very effective role in helping the country to increase the amount and the quality of agricultural products.

In this study, the agricultural potential in Lüleburgaz district in Kırklareli, Thrace region, one of the most important region of its agricultural and industrial production over the country' average, was examined by multitemporal remotely sensed data. With different vegetation indexes applied, the changes in biomass were assessed for the years between 1987 and 2003. It was shown that the multitemporal and multisensor satellite data have an great success in biomass analysis.

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