

MONITORING IRRIGATION AREAS USING ASTER/TERRA IMAGES: DIYARBAKIR

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ABSTRACT

To transform dry lands into irrigated fields using water resources has a great importance for agricultural development especially in developing countries. In arid and semiarid areas, this transformation needs to take into account the limited water resources available. The monitoring of crop production and irrigation at a regional scale can be based on the use of remotely sensed image data. This study has been done as a part of Kralkizi-Dicle (Tigris) Project. The aim of this project is, to achieve the irrigation of total 23085 ha (4758 ha from PII facility and 18327 ha from PV facility) irrigatable land of central Diyarbakir and Ergani savannas with the accumulated water of Kralkizi and Tigris(Dicle) dams. In this study area, irrigation is supplied by pumping out the water (not with gravity) and has a considerable cost. The cost of electricity for pumping is nearly 850000 USD for a year and financed by the members of DIA (Diyarbakir Irrigation Association) proportional to their size of field. An ASTER/TERRA image has spatial resolution of 15 m in VNIR with 60 km*60 km scene size and has 14 spectral bands (3 VNIR, 6 SWIR, 5 TIR). In this context, this study investigates the feasibility of using ASTER/TERRA images to determine the land-use map and size of irrigated fields.

Key Words: *Remote Sensing, Irrigation areas, ASTER/TERRA, Agriculture, GAP*

INTRODUCTION

The region of Southeastern Anatolia covering nine administrative provinces (Batman, Diyarbakir, Adiyaman, Mardin, Siirt, Gaziantep, Kilis, Sanliurfa and Sirmak) extends over wide plains in the basins of the lower Euphrates and Tigris. The region is called as "Upper Mesopotamia" in history, and also commonly referred as "cradle of civilizations". Southeastern Anatolia is bordering Iraq to the southeast and Syria to the south (Fig. 1). The region covers Turkey's surface area of 9.7% (75358 km²) and has nearly 1.7 million hectares of irrigable land. Turkey is engaged in a large integrated water resources development project in its southeastern region. The Southeastern Anatolia Project (Turkish acronym GAP), involves 22 dams in the upper Euphrates-Tigris Basin, and aims to provide irrigation for 1.7 million hectares of land by 2015. The GAP is not only a water resources development project, but a multi-sector and integrated regional development effort approached in the context of sustainable development. This development program comprises such sectors as irrigation, agriculture, hydraulic energy, forestry, rural and urban infrastructure, health and education.

One of the most important and necessary projects of the GAP, "Kralkizi-Dicle(Tigris) Project is an integrated project involving Kralkizi Dam, Tigris (Dicle) Dam and their irrigation facilities. By courtesy of this project, 54279 ha by gravity and 75880 ha by pumping out the water, total 130159 ha irrigatable plains of Central Diyarbakir, Cinar and Bismil districts are being irrigated, 444 million KWh of electrical energy is being produced and, potable and industrial water of Diyarbakir City is being supplied according to the data provided by Regional Development Administration of Southeastern Anatolia Project. By completion of this project nearly 34000 person will be employed a year.

Remote sensing may be used to map, monitor and estimate the properties of the environmental phenomena. Of the three areas of application, mapping, particularly thematic mapping, is perhaps the most common and may be a prerequisite for the others. Traditionally, classification techniques have been used as the tool for thematic mapping. This applies to mapping through visual as well as digital analysis of remotely sensed data. Thus, for example, classi-

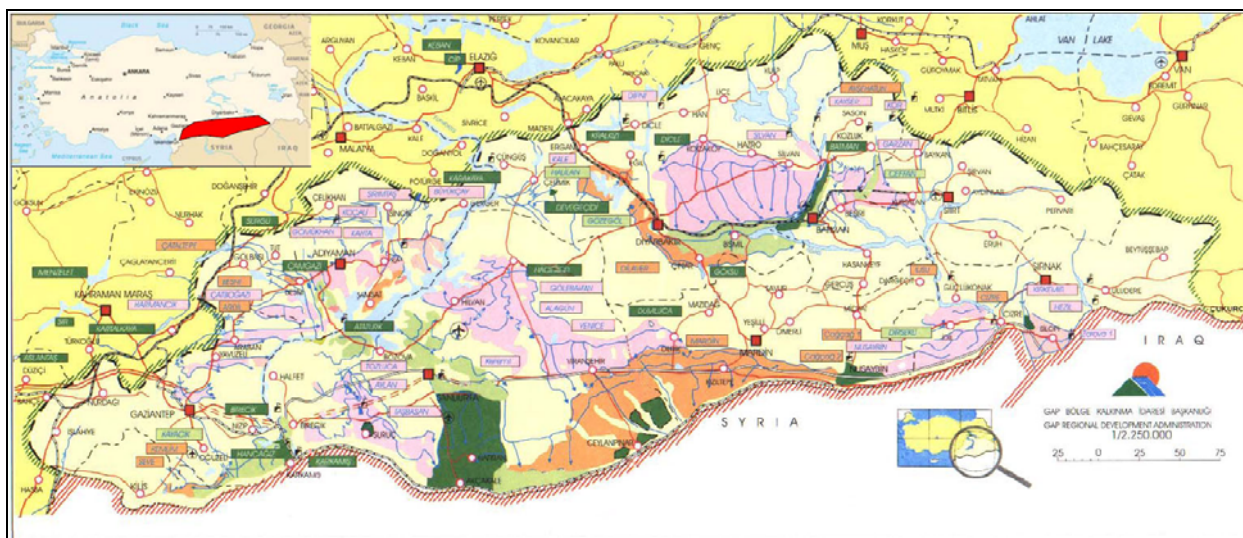


Figure 1. Water Sources Projects in Southeastern Anatolia (GAP).

fication is the basis of mapping through aerial photograph interpretation as well as from computer-based analyses of digital sensor data (Foody, 2000). Remote sensing has been an effective tool for monitoring irrigated lands under a variety of climatic conditions and locations. It provides synoptic and timely coverage of agricultural lands in several spectral regions and archived data allows comparison of images across dates, yielding change over time. To date, a number of studies have used remotely sensed imagery, primarily at high spatial resolutions such as Landsat, to monitor irrigated agriculture. (Ozdogan et al., 2003).

STUDY AREA

Study area is situated in the borders of Diyarbakir, located at the right side of the coast of Tigris Dam between $38^{\circ}08'$ and $38^{\circ}02'$ North and $39^{\circ}55'$ and $40^{\circ}10'$ East (Fig 2). Soil conformation of the study area is brown soils, composed by igneous basalt. The soil is very rich of potassium. Consequently, manure including potassium is not used to increase the agricultural efficiency.

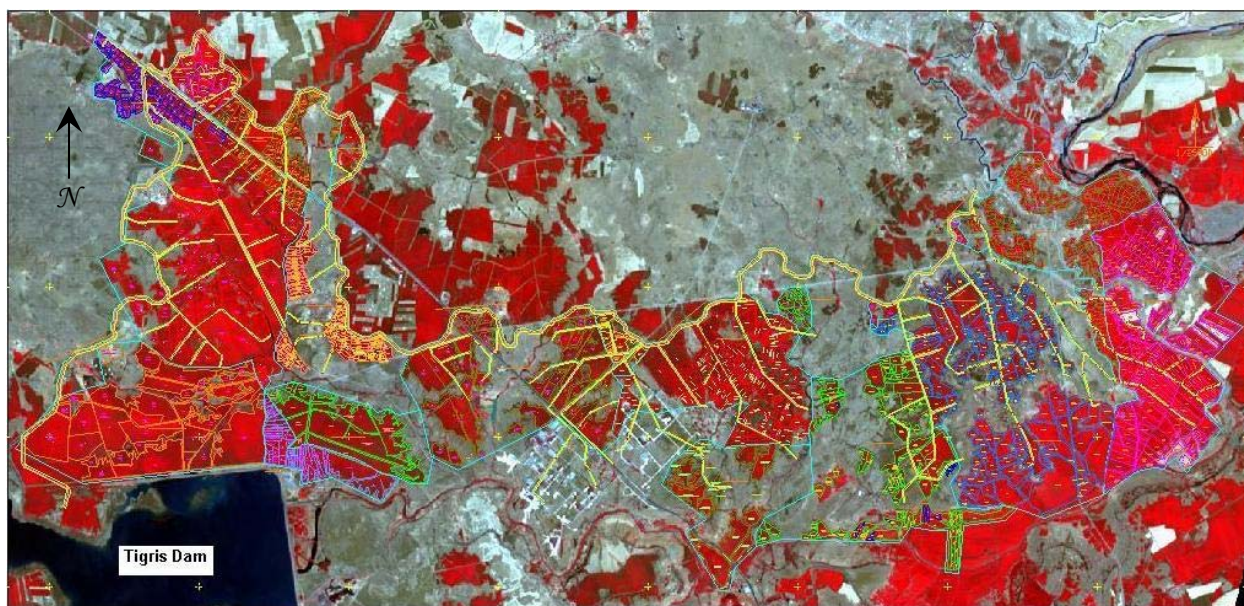


Figure 2. Localization of the Study Area (Irrigation Network on 3-2-1 RGB Combination of ASTER Image 2005).

Topographic structure is not suitable in the study area for ascending the level of ground water except some local areas. So, it can be said that groundwater level is low in the study area. This study has been done as a part of Kralkizi-Dicle (Tigris) Project. The aim of this project is, to achieve the irrigation of total 23085 ha (4758 ha from PII facility and 18327 ha from PV facility) irrigatable land of central Diyarbakir and Ergani savannas with the accumulated water of Kralkizi and Tigris dams.

Totally 23085 ha of the area is irrigated by Kralkizi-Tigris transmission canal, with 107783 m of primary vessel, 413790 m of secondary vessel, 455023 m of maintenance and management way and 3 items of pumping stations(PII, PV and PVII).

MATERIALS AND METHODS

This study has been done as a part of Kralkizi-Dicle (Tigris) Project. The aim of this project is, to achieve the irrigation of total 23085 ha (4758 ha from PII facility and 18327 ha from PV facility) irrigatable land of central Diyarbakir and Ergani savannas with the accumulated water of Kralkizi and Dicle dams. In this study area, irrigation is supplied by pumping out the water (not with gravity) and has a considerable cost. The cost of electricity for pumping is nearly 850000 USD for a year and financed by the members(landowners) of DIA (Diyarbakir Irrigation Association) proportional to their size of field. The purpose of the study presented here is to map the land use of the study area and to designate the illicit use of water where cotton is the primary summer irrigated crop.

In this paper, the area irrigated by PII and PV facilities was studied using ASTER/TERRA satellite images acquired on May and August of 2005 having spatial resolution of 15 m in VNIR with 60 km*60 km scene. In this context, this study investigates the feasibility of using ASTER/TERRA images to determine the land-use map and size of irrigated fields.

ASTER / TERRA

The ASTER (Advanced Spaceborn Thermal Emission and Reflectance Radiometer) is an imaging instrument that is a cooperative effort between NASA and Japan's Ministry of International Trade and Industry. In a sense, ASTER serves as a "zoom lens" for the other instruments aboard TERRA in that it has the highest spatial resolution of any of them. ASTER consists of three separate instrument subsystems, each operating in a different spectral region, using a separate optical system, and built by a different Japanese company. These subsystems are the Visible and Near Infrared (VNIR), the Short Wave Infrared (SWIR) and Thermal Infrared (TIR), respectively (Lillesand and Kiefer, 2000). The superimposed status on model atmosphere of ASTER bands is shown in Fig. 3.

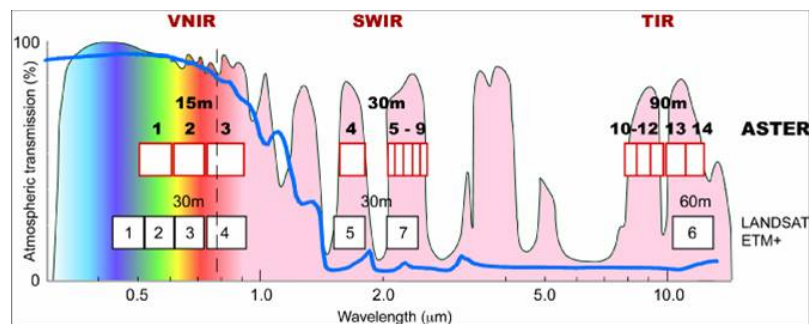


Figure 3. ASTER bands superimposed on model atmosphere [1].

VNIR has 15 m ground resolution with four spectral bands. With all four bands operating (3 nadir and 1 backward (Fig. 4)) the data rate including image data, supplemental information and subsystem engineering data is 62 Mbps [2]. At 3rd and 4th band of VNIR, sensitive to the electro magnetic energy between 0.78-0.86 μm , the instrument has two telescopes; one is nadir looking and the other backward looking (27.7° off-nadir). By courtesy of this feature, the production of DEMs from stereo data be possible with an accuracy between 7 to 50 m. ASTER is able to collect stereoscopic image data along-track. VNIR has cross-track pointing to $\pm 24^\circ$ and, SWIR and TIR has cross-track pointing to $\pm 8.55^\circ$ on either side of the orbit path.

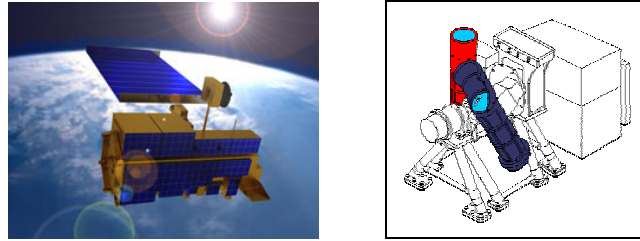


Figure 4. ASTER/TERRA and VNIR Subsystem.

The VNIR subsystem backward looking telescope (red) is of the same design as the nadir telescope and contains only a single silicon charge coupled detector line array and no calibration lamps as it is only used to acquire a stereo pair image. The VNIR subsystem nadir looking telescope (dark blue) is a reflecting-refracting improved Schmidt design. The focal plane of this telescope contains three 5000 silicon charge coupled detector line arrays. The nadir and backward looking telescope pair are used for same orbit stereo imaging and can be rotated as a unit ± 24 degrees to provide extensive cross-track pointing capability. Light from either of two halogen lamps are used periodically for subsystem calibration.

All ASTER bands cover the same 60 km imaging swath with a pointing capability in the cross-track direction to cover ± 116 km from nadir. This means that any point on the globe is accessible at least once every 16 days with full 14 band spectral coverage from the VNIR, SWIR, and TIR. In that the VNIR subsystem has a larger pointing capability, it can collect data up to ± 318 km from nadir, with an average revisit period of 4 days at the equator (Lillesand and Kiefer, 2000).

Table 1. Characteristics of the ASTER Sensor Systems

| Characteristic | Band | Spectral Range (μm) | Swath width (km) | Ground Res. (m) | Quantization (bits) |
|----------------|------|----------------------------------|------------------|-----------------|---------------------|
| <u>VNIR</u> | 1 | 0.54-0.60 | 60 | 15 | 8 |
| | 2 | 0.63-0.69 | | | |
| | 3N | 0.78-0.86 | | | |
| | 3B | 0.78-0.86 | | | |
| <u>SWIR</u> | 4 | 1.60-1.70 | 60 | 30 | 8 |
| | 5 | 2.145-2.185 | | | |
| | 6 | 2.185-2.225 | | | |
| | 7 | 2.235-2.285 | | | |
| | 8 | 2.295-2.365 | | | |
| | 9 | 2.360-2.430 | | | |
| <u>TIR</u> | 10 | 8.125-8.475 | 60 | 90 | 11 |
| | 11 | 8.475-8.825 | | | |
| | 12 | 8.925-9.275 | | | |
| | 13 | 10.25-10.95 | | | |
| | 14 | 10.95-11.65 | | | |

Irrigation Policies

It is estimated that the world's irrigated area is at present in the order of 270 million ha. This is only 17% of the world's total cropped area but accounts for about one third of the world's food harvest. Inadequate water supply is clearly reflected in differences in cropping patterns, intensities and crop development; features which can be conveniently detected and mapped by satellite images. Feasibility studies for improving water distribution can make excellent use of this information (Meijerink and Mannaerts, 2000).

Operation, maintenance and management of irrigation were implemented by Diyarbakir directorship of DSI until 1995. By courtesy of the idea "giving responsibility to the people to operate, maintain and manage the irrigation facilities who are actually taking advantage of using the water", irrigation associations were founded. Since 1995, to achieve the expected benefit from agriculture by irrigation, management of the facilities constructed by government was given to DIA (Diyarbakir Irrigation Association) over the area of Kralkizi-Tigris Project.

According to the data of Directorate General of Press and Information [3]; more than a half of total cotton harvest is fulfilled from 12 provinces in South and Southeast Anatolia in Turkey (Table 3). Turkish Government gives financial support to the farmers producing cotton, proportional to the size of their cultivated area with cotton. At year 1999, Ministry of Agriculture made a land-use map using remotely sensed satellite images. This land-use map showed that the well intention of the Government was abused by some of the landowners. The difference of the data between 1998(exaggerated) and 1999(real) is shown in Table 2. For the year 2006 this financial support is 348 YTL(~246 USD) for per tons.

Table 2. Difference between the Real and Exaggerated Cotton Production

| | 1998 | 1999 |
|--------------------------------|-------------|-------------|
| Cultivated area(ha) | 683.000 | 443.000 |
| Cotton production(tons) | 2.000.000 | 1.300.000 |
| Financial support(USD) | 206.000.000 | 136.000.000 |

Table 3. The Amounts of Cotton Cultivation Areas, Production and Efficiency in Turkey in 2001/2002 Period [4]

| Regions 2001/2002 | Cultivation Area (1000ha) | Production (1000 ton) | Efficiency (Kg/ha) |
|------------------------------|----------------------------------|------------------------------|-------------------------------|
| Southeast Anatolia | 297 | 411 | 1,387 |
| Aegean Region | 235 | 290 | 1,235 |
| Çukurova | 151 | 206 | 1,365 |
| Antalya | 11 | 14 | 1,330 |
| TOTAL | 693 | 922 | 1,330 |

Geometric Registration and Classification of Images of Study Area

Two ASTER/TERRA images were obtained for this study. Unfortunately, the first satellite image acquired on May 2005 couldn't make it possible to collect information from it. Because, the development of the crops, especially cotton, was not much enough to be monitored by an ASTER/TERRA image having resolution of 15 m. It was observed that the acquirement date of the second image (August 2005) was appropriate to eventuate the purpose of this study. Especially cotton showed considerably good development to be monitored by a 15 m resolutioned sensor. Ground validation was realized at the date of acquirement for August image.

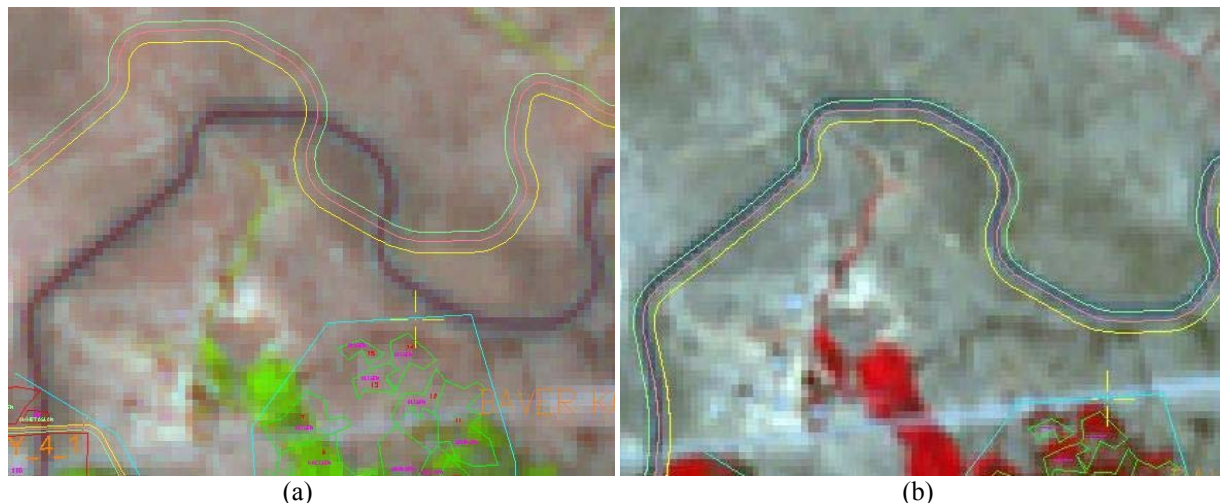


Figure 5. (a) 4-3-2 **R G B** Comb. of Original Image (b) 3-2-1 **R G B** Comb. of Geometrically Corrected Image.

The satellite images used in this study were Level 3A01 images. Users get level 3A01 images in geometrically corrected form. According to Watanabe (2003), Level 3A01 images are orthographic images generated from relative DEM (4A01) data, and are free from geographical distortions due to elevation differences. However, when

compared with 1/25000 scaled maps of the study area; important shift was observed between the map and satellite image (Fig. 5). Because of this, images were rectified again. During the rectification process, 1/25000 scaled vector maps were used. Affine transformation method was used for rectification. Rectification process covered the accuracy expectations (<0.5 pixel).

The images were thematically classified (supervised classification) using maximum likelihood method with the assistance of an agricultural engineer, who knows the features of the study area very well, working in DSI Diyarbakir Directorship and commissioned in management of Tigris Dam. Classification process was fulfilled in the Remote Sensing and GIS Laboratory of Yildiz Technical University.

Overall class performance was nearly %100. One of the reasons of this result is specialties of the satellite image chosen for this study. ASTER/TERRA is delineated as a “super spectral” satellite by most of the remote sensing experts. The considerably large spectral range, 15 m of ground resolution and satisfactory size of the swath width (60 km) of ASTER/TERRA makes it very useful for these studies. The second reason of this high classification performance is the structure of the study area. Cotton was very dominant in the study area (20800 ha). Classification results are shown in Fig. 6. Green shows cotton cultivated area, blue shows the water bodies and open water vessels, and yellow shows blank lands, roads and etc.

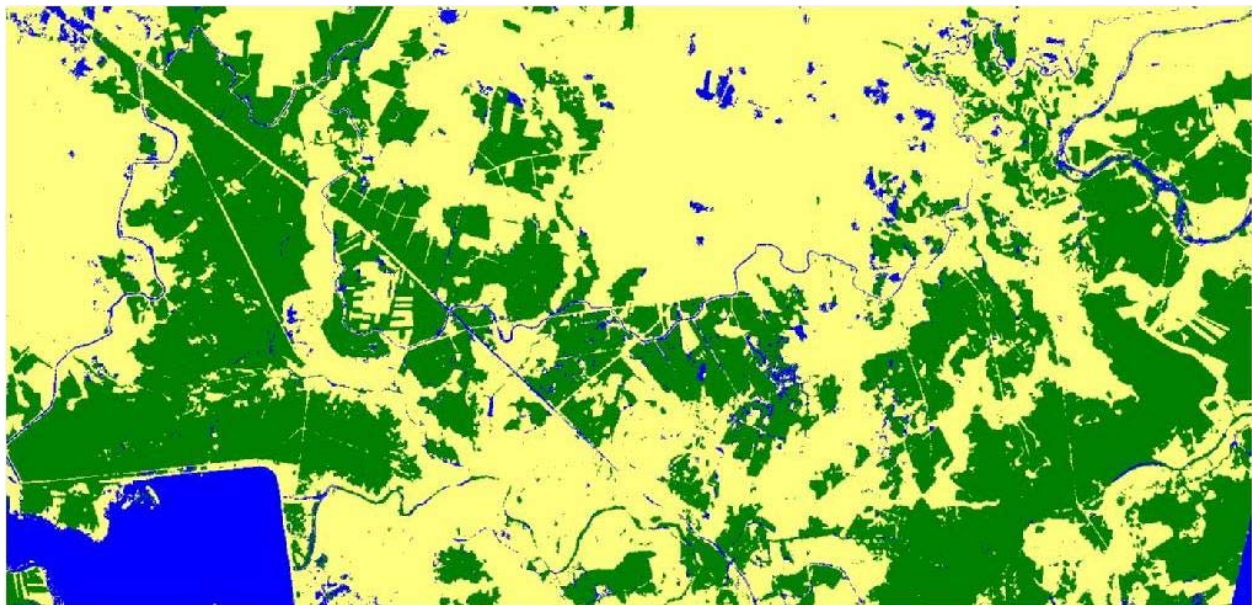


Figure 6. The Classification Map of Study Area.

The details of the classification results are shown in Table 4.

Table 4. Classification results

| Class | Number of Samples | Percent % | Area (hectares) |
|--------------------|-------------------|-----------|-----------------|
| Cotton | 344042 | 37,2 | 7740,945 |
| Water | 62110 | 6,7 | 1397,476 |
| Blank Lands | 518977 | 56,1 | 11676,98 |
| Total | 925129 | 100.0 | 20815,4 |

CONCLUSION

Until this study eventuated, DIA made contractors do ground surveys using conventional mapping techniques for this purpose. Besides this technique is very time consuming and exhausting, it is also expensive. Turkish Government gives financial support to the farmers producing cotton, proportional to the size of their cultivated area with cotton. At the same time, landowners have to pay the water cost proportional to the size of their irrigated area. Irrigation by pumping out the water is very expensive and has to be reflected to the landowners fairly.

The results of this study were announced to the farmers by DSI Diyarbakir Directorship and DIA (Diyarbakir Irrigation Association). Although this study being a straightforward application of remote sensing; because of it's low cost, being easily implemented, and having deterrent effect against illicit use of water, generated constructive results. Although remote sensing can easily be used very effectively, the authorities dealing with water are not aware enough about this technology. Unfortunately they don't have enough technical experts.

ASTER/TERRA satellite images are very capable in mapping land-use, land-cover studies. But authors recommend to the readers to use Level 1B image, instead of using Level 3A01 image, and geometrically correct the image by themselves.

ACKNOWLEDGEMENT

The authors wish to thank Principal of DSI Diyarbakir Directorship Mr.Nihat Üstündağ and Agricultural Engineer Mr. Salih Sarı for their support and their keen interest.

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