A Case Study of Developing An Olive Tree Database For Turkey

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Abstract

This study was conducted to develop an olive tree registration database using geographic information systems (GIS) and remote sensing technology. It also provides information on the methodology used for the database development for the candidate country during its accession process to the European Union. Since olive farming has a great importance to the Turkish economy, an olive registration database supported by GIS and compatible with the Integrated Administrative Control System (IACS) is needed for adaptation to the European Commission Common Agricultural Policy. In this study, cadastral maps and satellite images were used to count olive trees using the OLICOUNT software developed by the Joint Research Center of the European Commission in order to develop an olive tree database. According to the analysis of the counting results for the test sites with 2,291 trees, overall omission error was 11.1 percent and commission error was 2.94 percent. These results indicate that the determination of olive trees by OLICOUNT within the area of interest has 90.37 percent accuracy that makes the method reasonably reliable.

Introduction

Olive (*Olea europaea*) is produced in 39 countries all over the world with an area of over 8,093 hectares. The quantity of world olive production is about 15.5 million tons. Over 85 percent of this production is obtained from five Mediterranean countries including Spain, Italy, Greece, Turkey, and Tunisia. If olive production is assessed in coverage of the EU, percentages of olive production are 27 percent for Spain, 20 percent for Italy, 16 percent for Greece, and 11 percent for Turkey in 2002 (Bartolini and Petrucelli, 2002).

Olive crop provides raw material for the table olive and olive oil sub-sectors. Nearly 400,000 families, who are generally small family enterprises, are involved in the olive production sector in Turkey. Their annual olive export value is approximately 250 million USD. For these reasons, it has considerable contribution to the Turkish economy (DPT, 2000).

To support farmers, the Ministry of Agriculture and Rural Affairs (MARA) of Turkey has initiated a new subsidy scheme called "Direct Income Payment and Farmers Registration System" on 21 June 2001. The Farmers Registration System is based on the farmer's declarations and cadastral information. The type of information recorded in the database includes cadastral information, size of the agricultural areas, type of production, and information about farmers' identity, etc. Declarations by the farmers make reference to the cadastral parcels, and recently, the following methods have been applied in order to validate the farmers' declarations:

- If there are cadastral maps, the farmer's declarations are controlled by a random selection of declarations to confirm present agricultural activity and title deed registration.
- If the cadastral maps are not available, the farmer declarations are controlled by field surveys done by a technical committee.

Currently, there are no operational remote sensing and geographic information systems at Ministry of Agriculture of Turkey for controlling and validating farmers' declarations compliance with the Common Agricultural Policy of European Union. It should be highlighted that all Candidate Countries, like Turkey, have to adapt their olive production legislation throughout accession process to the EU. The OLIGIS is a part of the acquis communautaire to be adopted in the framework of the accession process. The purpose of Olive GIS (OLIGIS) is gathering reliable and objective information on the number of olive trees, and the olive growing areas in which the farmers were lodged. With the regulation of 2366/98 of the European Commission, the use of OLIGIS system has been mandatory for the member states.

As a result, in accordance with MARS and Central and Eastern European Countries (PECO: Pays d'Europe Central et Orientale) (MARS PECO) project and European Commission Acquis announced on 23 June 2003 that this project be initiated in 2003. In this context, the project which aims to determine olive growing areas and to develop an olive database by counting trees in Balikesir province was launched by Department of Geographic Information Systems and Remote Sensing at the Central Research Institute for Field Crops with the collaboration of European Commission Joint Research Center to initiate the full implementation of the Integrated Administration and Control System (IACS) in Turkey in March 2004.

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Background

In response to a requirement to identify all the olive trees in Europe, the Joint Research Centre (JRC) of the European Commission has initiated a project to study methods of computer-assisted tree identification from digital orthophotos. In this frame, JRC designed an automatic counting tool called OLICOUNT that counts and locates olive trees on VHR images. Recently, there is a strong interest in locating tree crowns by applying different algorithms on high spatial resolution images. A kind of segmentation method has been developed to determine tree crowns using edge detection and differential geometry which produces results similar to visual interpretation (Brandtberg and Walter, 1998). Wang *et al.*, (2004) have used aerial photos to identify treetops and crown extent. After using edge detection to mask out the background, trees are labeled and modeled through radiometry and geometry parameters. Counting the number of trees and delineating tree crowns by means of this automatic method yield results similar to manual delineation. Three different methods, one of them uses templates and the others use region growing, were tested for tree crown detection by Erikson and Olofsson (2005). It was concluded that all the methods have around 80 percent detection accuracy and that large trees are easier to detect. Similarly, two methods, visual delineation and computer-aided automatic classification, were applied to establish the relationship between field measured stem volume and tree attributes such as tree crown area and tree shadow in a sparse Crimean juniper forest, using pan-sharpened high-resolution satellite imagery (Ozdemir, 2007). It is found that stem volume is correlated with both shadow area and crown area. So it is concluded that stem volume can be estimated from high-resolution satellite imagery, facilitating data collection for "open forest" inventories.

Objectives

In this study, the OLICOUNT software which was designed for the semi-automatic counting of olive trees on panchromatic digital VHR imagery or aerial photography was used. It is an effective tool to implement such a project, which was carried out in the county of Burhaniye with the specific objective of implementing a computer-based registration system of olive growers.
The objectives of this study were as follows:

- To gather reliable and objective information on olive trees and olive growing areas at the study site.
- To have an operational tool for the management and the control of the subsidies applications.
- To control of the existing farmers' declarations with remote sensing in a specific region.

Study Area

The Aegean and Marmara regions have the most appropriate agro-climatic conditions for olive growing in the country. These two regions were accounted for 86.6 percent olive production in Turkey (Anonymous, 2001). Burhaniye County of Balikesir Province was selected as a study area for this project because it is located at the cross borders of the Marmara and Aegean regions suitable for large olive production and high quality olive oil (Figure 1). The study area is moderately sloping and characterized by hilly terrain especially when far from the coast. Olive groves are spread out from the coast throughout the hills. Olive production is a mono-cultural activity in this region. In flat areas, farming is diversified with vegetables and field crops. On the other hand, hilly land is mostly dedicated to shrubs and olive trees. Generally, they are old olive groves, and "Ayvalik" is the dominant olive variety with high oil content.

Olive groves cover 38 percent of county area which is approximately 298 km^2. The number of farmers dealing with olive production in the area is approximately 5,400. According to the county agricultural statistics, the size of olive groves and the number of olive producers are summarized in Table 1 (County statistics, unpublished data, 2003). Even though the entire county consisting of 27 villages was selected as a project area, only 16 villages were available to implement OLIGIS due to some drawbacks such as lack of cadastral maps neither in hardcopy or digital format, inconsistent or missing projection system for existing cadastral maps, and uncompleted cadastre work for relevant villages. Two of the sixteen villages were selected as control sites: Hisar and Dutluca (Figure 2). The purpose of the control sites is to assess accuracy of automatic counting done by OLICOUNT. A more detailed explanation of control sites will be given in the Data section.

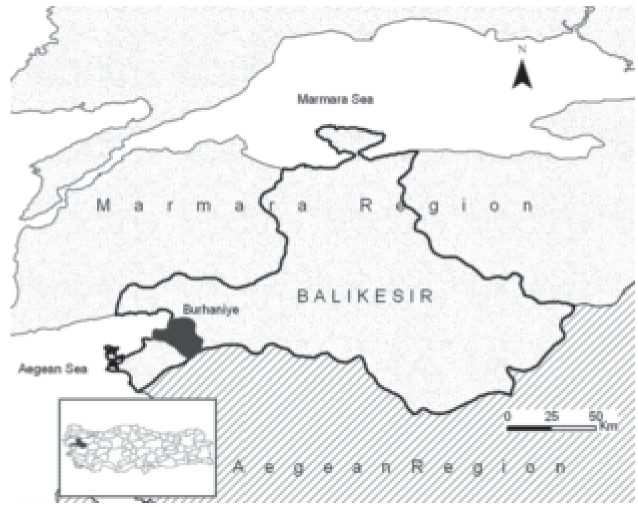

Figure 1. Study area: Burhaniye County in the Turkish Province of Balikesir.

Materials

Cadastral Data and Farmer Registration Database

The Turkish cadastral system is based on a hierarchical coding structure that is consistent throughout the country. This system includes two unique numbers, the ADA number (block number) and the parcel number, that can be used as spatial reference elements in a Geographic Information System (GIS). Physical blocks such as roads, channels, etc.

TABLE 1. OLIVE STATISTICS OF STUDY AREA (COUNTY STATISTICS, 2003)

Size of olive parcels (ha)	Number of farmers	Total area (ha)	Proportion (%)
0 – 1	2530	1262.6	11.1
1.1 – 2	1274	1844.4	16.1
2.1– 5	1175	3616.9	31.6
5.1 – 20	434	3590.5	31.4
20.1 <	30	1123.6	9.8
TOTAL	5443	11438	100

Figure 2. Location of two villages from where the control sites are selected.

play a major role to differentiate the ADAs (blocks of parcels) whose numbers are the unique for a village or town.

Parcel numbers are assigned continuously in ADA without duplication. As a result, ADA and parcel numbers constitute a unique feature for implementation of Olive GIS (OLIGIS) developed by the European Union (EU) in order to identify and locate all olive parcels (OP) and olive trees (OT) of the producers who have lodged at least one crop declaration and one aid application during the season. OLIGIS has two items: an alphanumeric database that includes the farmers' declarations and a geographic database that consists of cadastral maps and olive tree locations.

All cadastral data consist of hard copy, cadastral maps with the following scales: 1:500, 1:1000, 1:2500 and 1:5000. One drawback for the cadastral data is lack of completed cadastre parcel maps neither in hardcopy or in digital format throughout the country. It is an ongoing process to complete cadastre data. As a result, only completed cadastre data were obtained from local cadastre government office and then scanned to produce digital cadastre parcels that were used in the GIS. A total of 671 cadastre sheets were gathered, and 379 of them covering 16 villages were digitized and registered to the Universal Transverse Mercator (UTM) coordinate system. It should be noted that those cadastral maps do not have land owner information, but include ADA, parcel numbers, and parcel size. Information about land ownership is available only in the farmer registration database which also has attribute of ADA/parcel number. This unique information was used to establish a relationship between cadastre parcels data and the farmer registration database. From the perspective of OLICOUNT, being a tree counter software, the farmer registration data is not a well-designed database at the time of this project, because farmer registration data does not have tree number information, which makes the applicability of controlling farmer declarations difficult. There are also inconsistencies between the two databases such as un-matched ADA/parcel number and some missing data or erroneous data entering as farmer ID, name, parcel number, etc.

Topographic Data

For orthorectification of the satellite imagery, a digital elevation model is required. In this study for the purpose of orthorectification, a digital elevation model produced from Shuttle Radar Topography Mission (SRTM) was used. SRTM data is the most complete digital topographic database of the Earth. It is available for the public's use at a pixel spacing of approximately 90 meters.

Topographic data was also used for selection of two villages representing different topography from where control parcels were selected. It's assumed that one of villages, Hisarkoy, represents hilly sites, while the other, Dutluca, represents relatively flat sites.

Satellite Data

Even though OLICOUNT is designed to count olive trees on the basis of aerial photos, very high resolution satellite or airborne images can be used for the same purpose. Satellite imagery with very high spatial resolution such as Ikonos or QuickBird can be acquired easily from image vendors for a specific time and location which is useful for such studies. For this study, to determine the appropriate date for image acquisition, crop phenology, climatological and meteorological conditions, and farming practices (such as soil plowing times) were considered. These factors are important for discriminating target objects from the other features on the image. As grass cover reflectance makes the detection of olive trees difficult, plowed soil is preferable for image acquisition timing. Soil plowing is usually conducted during May in the region, so it was decided that images could be obtained during clear weather conditions after May. The study area is covered by four QuickBird scenes acquired on 13 June 2004, which were the highest resolution imagery commercially available. The imagery is four-band (blue, green, red, and near-infrared) imagery with 60 cm spatial resolution in panchromatic mode and 2.5 meter spatial resolution in multispectral mode. In this study, panchromatic QuickBird image was used.

Methodology

The methodology required to fulfill defined objectives is based on simply locating declared olive grove parcels in the study area, performing semi-automatic counting of trees using OLICOUNT, verify some of the results with the field survey, and building up an olive database. A flow chart methodology is presented in Figure 3. The boxes in Figure 3 represent data sources or results of processes which are shown as ellipsoids within the same figure as well. More detailed explanations of tasks in flow chart follow.

Olive Counting Algorithm Approach

This method is a tree-identification algorithm which is coded in C++ and integrated into a standard GIS application environment (ArcView®) (Kay *et al.*, 1998; Masson *et al.*, 2004). The algorithm is based on a set of following input parameters which define the shape and radiometry (grey level): (a) The minimum and maximum grey values ("thresholds") in the image which distinguish tree from background, (b) the diameter range of the tree, (c) the aspect ratio of the tree crown, and (d) the density range within each tree "envelope" (i.e., the bounding rectangle). This is a measure of the size of holes in the tree crown relative to the overall tree area. OLICOUNT consists of an ArcView® Project file and two DLL's (OTCount and OTValues) which perform olive tree recognition on raster panchromatic image with 8-bit grey levels and evaluate certain parameters defined above from the trees identified manually by the operator on a computer screen. In order to identify trees in OLICOUNT, at least one TIFF image needed and vector data

Figure 3. Flow chart of the methodology used in the study.

(polygon shapefile) containing at least one parcel. The operator has to select a field which uniquely identifies individual parcels. Upon loading of a selected parcel theme, fields are automatically added to store the total count of trees for that parcel. The user can work on parcels with OLICOUNT performing clipping of trees or adding new trees within the bounding rectangle within the TIFF image according to whether they are inside or outside of the selected parcel. Each tree (point) is tagged with the parcel identifier to which it belongs and stored in a database which can be set up for the region being studied. The count of the number of trees identified in each parcel is also stored as an attribute of the parcel polygons, allowing checks against the number of trees declared by the farmer or the number identified by ground survey.

Data Preparation

Cadastral parcels were produced in shapefile format from scanned and rectified cadastral maps. These digital parcels were appended to each other based on names of villages to make separate village parcel sets. The attributes of the parcels were then recorded manually into the database in accordance with the cadastral maps. Other necessary fields of attributes such as the farmer name and citizen number are acquired from the MARA Farmers Registry System database using relational query.

Vector data produced from cadastre sheets have some misregistration problems when overlaid onto ortho-imagery due to scaling problems between the raster and the vector data. To implement OLIGIS successfully, it is necessary to have good matching vector data with the borders of parcels and to have imagery data in plain TIFF format because the OLICOUNT works only with panchromatic data in TIFF. To meet these requirements, the vector data need to be adjusted manually to the parcel borders on as shown on the ortho-imagery. So, the process of "overlay and spatial adjustment" was inserted into the flow chart. To convert ortho-imagery into TIFF raster data, Xnview software was used.

For VHR images, it is necessary to orthorectify the imagery for getting a acceptable geometric accuracy and the ability to approximate the image representation to a real world surface so that determination of the trees' locations, parcel measurements, and boundary matching on imagery can be done at a high level of accuracy.

DEM derived from the Shuttle Radar Topography Mission (SRTM) data were used for orthorectification and yielded satisfactory results with an RMSE of less than 2.5 m on check points. A field survey for collecting ground control points (GCPs), used in orthorectification was conducted by project team in 2004.

Twenty GCPs were recorded by DGPS receivers. For the orthorectification process, nine ground control points (GCP) and three local reference points were used, while there were 11 checkpoints used for the RMSE calculation. Producing digital ortho-images from the VHR satellite imagery requires that an acceptable RMSE should be less than 2.5 m for the DEM height accuracy, and less than the tolerance of geometric accuracy of image horizontal accuracy (EC, 2003a).

Implementation of OLIGIS

The OLIGIS system is implemented to locate only olive parcels declared by the producers as olive groves, i.e., to identify and count olive trees on these parcels to test the applicability of the system for Turkey conditions. The system was also used to develop a reliable olive database. For the purpose of the project, OLICOUNT method developed and provided by JRC was used for the semi-automatic counting of olive trees in the area of interest.

As stated in Data section, Olive trees on declared parcels within the border of 10 villages were located and then counted and finally were recorded into ArcGIS® database with OLICOUNT software to develop an olive database. The results of tree counting is discussed in Results and Discussion section. The establishment of the database will be extended to the remaining villages by a local organization of the Ministry (Agricultural Directorate of Burhaniye County) in the near future.

Control Sites

For this project, two control sites (villages) having different topographic pattern, Hisar and Dutluca, were selected (Figure 2).The selection of control sites was made by stratified, random sampling method among the villages whose cadastres were completed. Dutluca village is located 7.5 km northeast of Burhaniye town on the border of neighboring county, Havran, another important olive growing region. According to the county agricultural statistics of Local Agricultural Office, there are 139 farmers engaged agricultural activity on 217 ha of land in Burhaniye. Olive groves are the main plant on the agricultural parcels. The other control site, Hisar village is located near Burhaniye town. This site is relatively hilly and has more diverse land-use such as shrubs and pine forest on the south, and some arable lands on the west. The county's local statistics which is based on farmers' declarations in 2003 show that 182 ha of land are used for agricultural production.

Field Survey

Field surveys were conducted in two villages (Hisar and Dutluca) according to the suggestions by the Olive Research Institute and Agricultural Directorate of Burhaniye County in February 2005 because these two villages are the representatives of other places in which olive production is the main agricultural practice and had complete cadastral parcel maps. The total number of the parcels including residential areas for the Dutluca village was 1,531. Of these parcels, 247 were declared by farmers. For the Hisar village, 546 parcels were declared agriculture from a total of 1,872 parcels. Satellite images were visually inspected for selection and categorization of these parcels based on the position, shape, and condition of olive trees. These parcels were categorized into four groups; regular, irregular, young tree, and mixed tree parcels (Figure 4). Five parcels for each category totaling of 20 parcels for each village were selected as control sites. Selection of parcels' locations representing four categories for both villages is based on criteria of their accessibility (mostly) and size. It is recommended that 10 percent of the declared parcels should be visited for ground-truthing (EC, 2004). In our case, because of time and budget limitations, this recommendation could not be accomplished. A total of 40 sites that make approximately 5 percent of the declared parcels were planned to visit, but due to the geographic conditions, two parcels were deleted from the visiting list. As a result, only 38 parcels were available for ground-truthing and used for accuracy assessment. For each parcel, a detailed field survey was conducted to determine agricultural practices, counting results, crop type, and morphological characteristics of sub-sampled trees. All these data were recorded in sheets in which a parcel sketch of satellite image was previously drawn. The sub-sampled trees were also marked on these sketches having a scale of 1:1000 with the information of trunk perimeter, crown diameter, and tree height. The spatial location of the trees were recorded using a hand held GPS device and were uploaded into ArcGIS® to create GIS point data in the UTM coordinate system.

Results and Discussion

To test the accuracy of tree counting achieved for the study area; the field visit results which are called "ground data" are used to evaluate the OLICOUNT results. The greatness of discrepancy called "bias" between the results of semi-automatic counting and field visit counting shows the overall accuracy of counting results. When computing the accuracy, two statistical terms are involved in evaluation process which are the omission and commission errors. The omission error expresses the number of the trees that are exist in the field but not determined by OLICOUNT software. On the other hand, the commission error is the number of trees that are not present in the field but identified by OLICOUNT software.

Even though bias shows the overall accuracy of counting results, the spatial location of trees on the ground should also be taken into the consideration. The statistical discrepancy between field visit counts and OLICOUNT results is given in Figure 5. This figure shows statistical summary of bias attributes; the X axis represents bias values, and the Y axis represents the number of parcels having bias values. It could be concluded from Figure 5 that the mean bias is 1.4 with the standard deviation of 9.3. The accuracy assessment test was carried out for 38 parcels selected from the two villages (Table 2). To evaluate positions of trees, a two-meter buffer zone in diameter was created around tree identified during field survey. If a tree falls inside the buffer zone, it is considered to be counted by both field survey and OLICOUNT (FS_OLI), which then be used for the calculation of omission and commission errors. According to the analysis of the count results for the test sites with 2,291 trees, the overall omission error was 11.1 percent, and the commission error was 2.94 percent.

As can be seen in Table 2, some omission and commission errors have zero values. If the trees are identified both by OLICOUNT and the field survey, the omission error becomes zero. Inversely, if the trees are neither identified

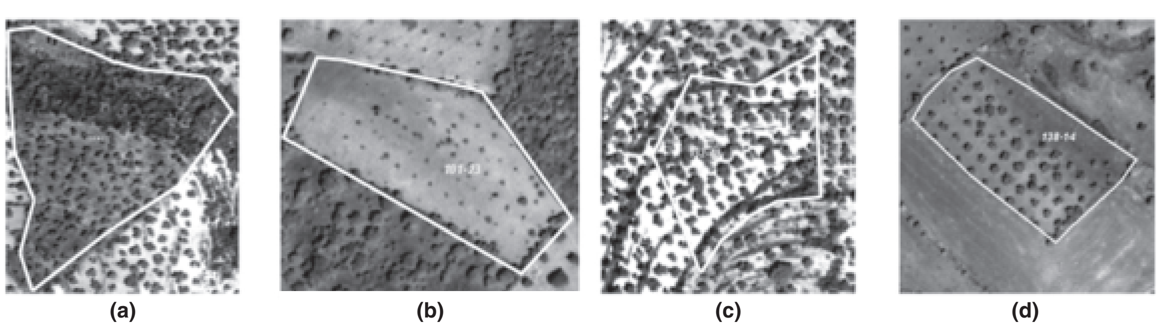

Figure 4. Categorized parcels visually distinguished in satellite images: (a) mixed parcel, (b) young tree parcel, (c) irregular parcel, and (d) regular parcel.

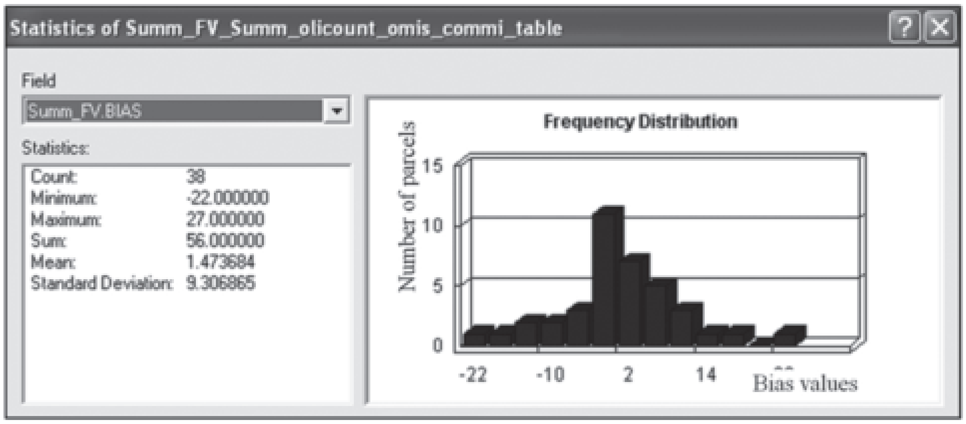

Figure 5. The statistical discrepancy between field visit counts and OLICOUNT results.

by OLICOUNT nor by the field survey, the commission errors have zero values. The highest omission and commission errors were found in two parcels with parcel IDs 114–84 and 117–65 (Figure 6). We can infer that this error may come from mixed plantation of olive trees with other trees at the parcel boundary. In addition, irregular plantation, joint crowns, young plants, and badly maintained parcels may cause these errors increase. If we look at the first three parcels having lowest commission and omission errors which are zero, it can be seen that those errors occur for one young tree and two regular parcel categories, and vice versa, the highest omission and commission errors can be seen in one irregular and two mixed parcel category (Table 2). These results support the assumption given upper sentence that OLICOUNT may produce high error for mixed and irregular parcel categories, but less for regular and young tree parcels. The reason for errors of irregular parcel category is assumed to be coming from the neighboring trees' crowns which are joined each other creating one big crown. For the mixed parcels, the reason for algorithm produced omission and commission errors is possibly due to the morphological and spectral characteristics of the trees in parcels that are not OLICOUNT distinctive. OLICOUNT does not aim to classify tree species, but count trees when performing OLICOUNT; it is assumed that all trees are olive species since the region is dominantly covered by olive groves. Only after field visit, tree species in test parcels were identified. So the accuracy test was performed in terms of tree species. In test parcels, nine different tree classes are encountered according to crop nomenclature stated in MARS PAC (Politique Agricole Commune) Technical Document, 2003 (EC, 2003b).

The number of olive trees on the test parcels was 2,076 from a total of 2,291 trees. The omission and commission errors for the olive trees were found to be 9.63 percent and 6.6 percent, respectively. This explains that 200 olive trees were never identified by OLICOUNT, and 164 olive trees absent in the field were wrongly identified by the program. For all tree classes, omission and commission errors are given in Table 3.

There has been strong interest of using remote sensing to recognize individual trees automatically in forestry applications (Gougeon, 1995; Brandtberg and Walter, 1998). Several models have been developed by researchers who discussed their practicability. Those models including the template matching, the segmentation supported by fuzzy rules, and the segmentation supported by Brownian motion are explained and compared by Erikson and Olofsson (2005). In the template matching method, a library of three-dimensional model trees is used to determine tree positions in the digital image. The highest correlation between tree positions and three templates indicates probable trees. Segmentation supported by the fuzzy rules method is based on region growing. Using a set of rules, a region is grown from a seed point. Segmentation by Brownian motion method is also based on region growing. In this method, a seed point actually belongs to a tree crown. That is why the number of seed points should be equal to the number of tree crowns in the image. Accuracy of detecting tree crowns using these three methods is as 82.3 percent, 79.9 percent, and 95.1 percent, respectively (Erikson and Olofsson, 2005).

In another study, three different automatic counting methods were used for counting olive trees and citrus trees that are namely: OLICOUNT (applied in this study), Morphological Image Analysis, and CRISP software (developed by Centre for Remote Sensing and Processing of the National University of Singapore) (Masson *et al.*, 2004). They found that OLICOUNT has good accuracy in large and homogenous groves, but in heterogeneous or in young groves has poor accuracy.

The other applied counting method, Morphological Image Analysis, is based on regional minima, since each crown usually has regional minima. This method uses mathematical morphology and analyses shape and spatial arrangements of pixel groups. CRISP is based on a tree counting method developed by Brandtberg and Walter (1998) and was originally designed for counting palm oil trees, but modified later for counting citrus trees. To detect edge pixels of each crown and form a model for intensity profile, CRISP uses intensity gradients and differential geometry for designating edge and curvature. They concluded that CRISP and OLICOUNT yield similar results on citrus trees. Morphological Image Analysis and OLICOUNT are alike in terms of omission rate, but the commission rate of Morphological Image Analysis is higher than OLICOUNT which should be improved.

In conclusion, there is a strong interest of the European Commission for identifying and positioning fruit trees for subsidy management activities in the frame of CAP (Common Agricultural Policy). Turkey as a candidate country should also perform these task during the harmonization process. By carrying out this study, we found that OLICOUNT works well on homogenous and large parcels, but does not work relatively well in small and heterogeneous parcels such as

Table 2. Omission and Commission Errors of the Control Parcels

Parcel type	Parcel Id	Percent__Bias	Fv	Oli	Omission Count	Commission Count	Om (%)	Com (%)
Y.tree	101–23	0.19	94	76	18	0	19.1	0.0
Regular	102–139	0.22	27	21	6	0	22.2	0.0
Y.tree	102–18	0.06	66	62	8	4	12.1	6.5
Y.tree	102–4	0.06	52	49	3	0	5.8	0.0
Mixed	102–47	0.36	33	21	12	0	36.4	0.0
Y.tree	102–94	0.00	93	93	0	0	0.0	0.0
Y.tree	109–26	−0.02	59	60	1	2	1.7	3.3
Regular	109–27	0.11	18	16	2	0	11.1	0.0
Regular	109–60	0.00	50	50	0	0	0.0	0.0
Regular	110–39	0.03	32	31	2	1	6.3	3.2
Regular	111–117	0.20	40	32	6	2	15.0	6.3
Y.tree	111–27	−0.06	107	113	2	8	1.9	7.1
Irregular	112–103	0.08	103	95	14	6	13.6	6.3
Y.tree	112–28	−0.17	81	95	1	15	1.2	15.8
Mixed	112–68	0.27	45	33	16	4	35.6	12.1
Irregular	112–70	−0.31	39	51	1	13	2.6	25.5
Irregular	112–86	−0.02	43	44	1	2	2.3	4.5
Irregular	114–15	0.00	86	86	11	11	12.8	12.8
Y.tree	114–25	0.08	80	74	18	12	22.5	16.2
Regular	114–69	0.01	112	111	7	6	6.3	5.4
Number	Parcel Id	Percent__Bias	Fv	Oli	Omission Count	Commission Count	Om	Com
Y.tree	114–75	0.05	58	55	11	8	19.0	14.5
Irregular	114–84	−0.36	14	19	4	9	28.6	47.4
Mixed	117–2	−0.42	53	75	0	22	0.0	29.3
Mixed	117–52	−0.08	73	79	4	10	5.5	12.7
Irregular	117–58	−0.35	46	62	2	18	4.3	29.0
Mixed	117–65	−0.08	24	26	7	9	29.2	34.6
Irregular	120–5	−0.33	24	32	0	8	0.0	25.0
Irregular	120–9	−0.27	30	38	3	11	10.0	28.9
Mixed	121–19	0.04	122	117	10	5	8.2	4.3
Irregular	131–1	0.19	26	21	4	1	15.4	4.8
Mixed	132–29	0.17	86	71	16	1	18.6	1.4
Irregular	132–40	0.25	106	79	28	1	26.4	1.3
Regular	138–14	0.12	76	67	10	1	13.2	1.5
Regular	138–4	−0.01	79	80	3	4	3.8	5.0
Y.tree	139–25	0.07	151	140	21	10	13.9	7.1
Mixed	140–122	0.00	7	7	0	0	0.0	0.0
Regular	141–18	0.00	27	27	0	0	0.0	0.0
Regular	146–16	0.07	30	28	2	0	6.7	0.0

FV: Trees counted during the field survey
OLI: Trees counted by OLICOUNT
OMISSION COUNT: Trees counted during the field survey but not counted by OLICOUNT
COMMISSION COUNT: Trees counted by OLICOUNT but not counted during the field survey
OM : Omission Error
COM: Commission Error

mixed plantations and irregular plantations. We also believe that this software reduces manual photo-interpretation and fieldwork. A very detailed database has been developed by using this software and much information on parcel and trees has been recorded in the OLIGIS such as position, age, number of the trees, and parcel location. This information can be used for subsidy management, agricultural planning, and agricultural policy making activities.

Conclusions and Recommendations

This study has proven that implementation of OLIGIS database that is a requirement for accession and being a member state of the EU can be achieved properly, if some drawbacks are removed. It seems that the main problems in this study most likely associated with the following:

Data Related Problems

- Incomplete cadastral parcels across the country, old cadastral maps not suitable for the study, and lack of metadata for those maps.
- Insufficient Farmer Registration Database for the aim of this project since it does not have the information about tree counts on a parcel basis.
- Inconsistencies between cadastre records and Farmer Registration Database.
- Missing and faulty records in both databases stated above.

Implementation of OLICOUNT Related Problems

- Highly scattered and fragmented agricultural structures.
- Traditional growing of olive trees instead of intensive production (irregular plantation and badly maintained parcels).

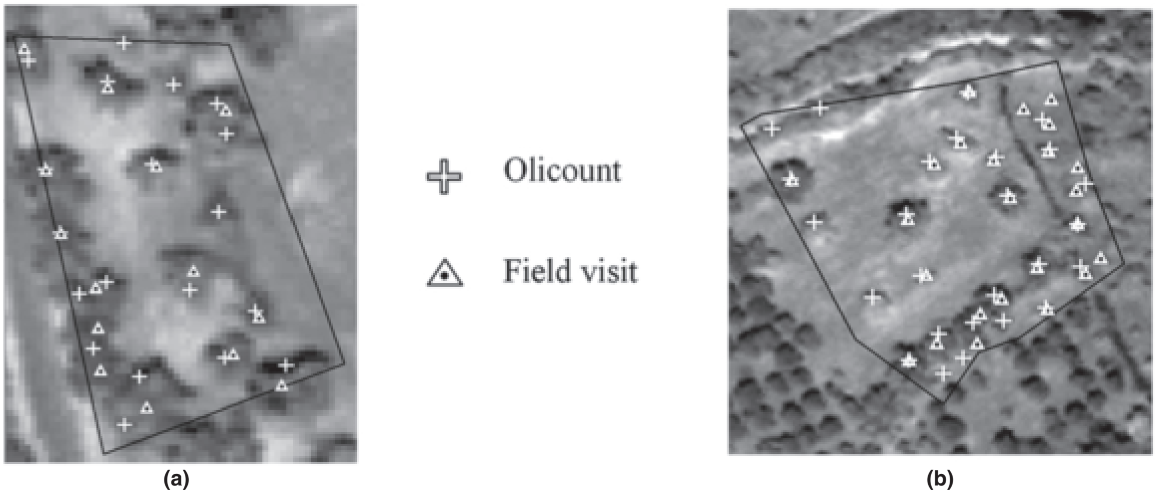

Figure 6. Display of tree locations resulted from field survey and OLICOUNT operation: (a) 114–84 parcel, and (b) 117–65 parcel.

- Mixed plantation of olive trees with other trees especially almond, apricot, and fig trees at the parcel boundaries.

This initial study showed that the determination of olive trees by OLICOUNT within the area of interest had the accuracy of 90.37 percent, and the semi-automatic counting of the olive trees by OLICOUNT identified the trees with a 6.6 percent error. The degree of these errors may have resulted in various sources such as data preparation process (scanning and digitizing of cadastral maps), orthorectification of image (even though GPS measurements for the GCPs has proven to be satisfactory, but coarse 90 m interval DEM data was used), and counting errors (manual editing by adding and deleting trees). Joined crowns, shadows, and young plants cause some counting errors during the application of the software for counting process. Nevertheless, it provides promise for correctly counting the number of olive trees compared to standard photo interpretation methods.

Overall, OLICOUNT facilitates development of a GIS database including tree coordinates and counting of olive trees. Since, registration of each olive tree is a requirement for European Commission Common Agricultural Policy, OLICOUNT has been used operationally in Italy, France, and other EU member countries, and with this study it is demonstrated that OLICOUNT can be used to handle this work in Turkey. In addition to this, having information about the country's resources is useful for agricultural planning, subsidy management, and control activities.

Table 3. Omission and Commission Errors by Tree Classes

Tree classes	Number of Trees counted	Omission error (%)	Commission error (%)
ALMOND	137	21.8	0.8
APRICOT	6	16.6	11.3
FIG	25	40	0.4
OAK	6	16.6	0
OLIVE	2076	9.63	6.6
OTHER (fruitful) FRUIT	31	32.2	0.4
OTHER TREE (fruitless)	6	0	0
PISTACHIO	3	0	0
PLUM	1	0	0.1

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