D. Rokos, V. Karathanassi

Lab. of Remote Sensing
Dept. of Rural and Surveying Engineering
9 Heroon Polytechniou, Zographos 157780
Tel. 30-1-7722593, Fax 30-1-7722594

e-mail rslab@survey.ntua.gr, karathan@survey.ntua.gr

Development of an Integrated Remote Sensing and GIS methodology for the protection of forest environment

Abstract

The impact of human activities increasingly threatens forests and forest areas. In Portugal for example, plots of pine forest are cleared after a fire and eucalyptus is illegally planted instead, for commercial reasons, while in Greece, roads and houses are constructed in forests and forest areas, most of them illegally, without any official permission for the decharacterisation of the approved Land Use of these areas.
For this reason, each country protects forest environment with a set of Laws, Presidential Decrees, Ministerial Decisions and administration rules. But law application is not as evident as it seems. It requires multidimensional quantitative and qualitative spatial information on two main issues. The first refers to the identification of the conditioned areas where a legal rule is applied. The second refers to the determination of the areas where there is an infringement of that rule.
In this paper, a methodology is developed aiming at the support of the application of the Greek Forest Law 998/1979 Articles 2 & 3, 71 and 45. Articles 2 and 3 refer to the characterisation of an area as a forest, article 71 prohibits the construction of buildings in forests and forest areas, and article 45 prohibits any intervention in forests and forest areas. The proposed methodology is applied on the study area of Penteli, Attica, Greece which constitutes the invaluable forest environment of Athens agglomeration.
The conditioned areas, which are forests and forest areas, result from the photo-interpretation of aerial ortho-images based on aerial photographs of 1937 and the compilation of the information produced, with the Approved City Plan maps of Attica, Greece. The potential illegal areas, which are houses in forests and forest areas, result from the application of image processing methods and techniques on KVR 1000 remotely sensed images, captured in 1992.
Both information levels, managed in a GIS environment, produce a useful tool for the application of the aforementioned law on the study area and for a short period of two years after 1992. The case study results prove the effectiveness of such a Spatial Information Management System as an important tool in environmental law application.

1 Introduction

According to the Greek Forest Law analysis,[1] seven different causes of deforestation have

[1] Articles 2,3 of Law 998/1979, Art.1,2 of Legislation Decree of 17.11.1927, Council of State 3414/1978, Art. 45 par.1 of Law 998/1979, Council of State 1516/1993, Art. 71 of Law 998/1979, Art.45 par.1 of Law 998/19979, Art.60 Leg. Decree 86/1969, Art. 57 of Law 998/1979, Art. 45 par 3 of Law 998/1979, Art. 117 of the Greek Constitution, Art. 41 of Law 998/1979, Art. 21 of Law 431/1968, Council of State Decisions 1009/87 and 4884/1987.

been identified and made subject to detailed regulation. These are: land-use planning and extension of city plans; fencing of private forests and forest areas; illegal building in forests and forest areas; fragmentation of forests and forest areas; quarries; reforestation of burnt forests and forest areas; and building associations.

Maps could efficiently support environmental law enforcement. Each one of the causes of deforestation could be mapped. Infringements of the law concerning a specific deforestation category could be identified and depicted on a map showing the forests and forest areas of an area, as they are defined by the Greek Forest Law.

In this study, the map concerning potential illegal building in forests and forest areas in the municipalities of Old and New Penteli, Attica, Greece, was chosen to be produced. According to the spatial requirements of the objects to be mapped, the scale of the produced map should be 1:5000. On this map, the areas characterised as forests or forest areas according to Art 2 and 3 of Law 998/1979 and the buildings on these areas should be indicated. The interpretation of Articles 71, 45 of Law 998/1979, is to prove the legal or illegal character of these buildings.

For this purpose, the forests and forest areas identified by photo interpretation of aerial ortho-images based on aerial photographs of 1937, according to the relevant law requirements[2], were digitised and input in the GIS. This information, after being compiled with the information included in the Maps of the Approved City Plan of Attica valid since 1985[3] led to the production of the layer of the forests and forest areas of the proposed map. A more recent relevant map of the Approved City Plan of Attica was not available.

The potential breach areas layer resulted from the image processing methods and techniques applied on the KVR image, captured in 1992. This image was the most recent satellite image of the test site which meets the image processing spatial requirements of the application. Thus, the produced map refers to 1992 data. Other background information such as the road network, the drainage network, etc. was selected from the respective topographical map (scale 1:5000) and overlaid on the map.

2. Description of the map produced and the relevant GIS database.

2.1 Test site description and map characteristics

The forest area of the municipalities of Old and New Penteli is an "ideal" site for illegal housing due to its proximity to the Athens urban agglomeration and its natural beauty. The final product of the integrated Remote Sensing and GIS proposed methodology for the above test site is a *Housing Detection Map in Forest Environment (1992).* This map is going to help the application of laws / decrees/ rules regarding legal and illegal building in the test site forests and forest areas. The map indicates the potential illegal buildings within the forests and forest areas of the test site, and is practically the overlay of the potential illegal buildings layer over the forests and forest areas layer.

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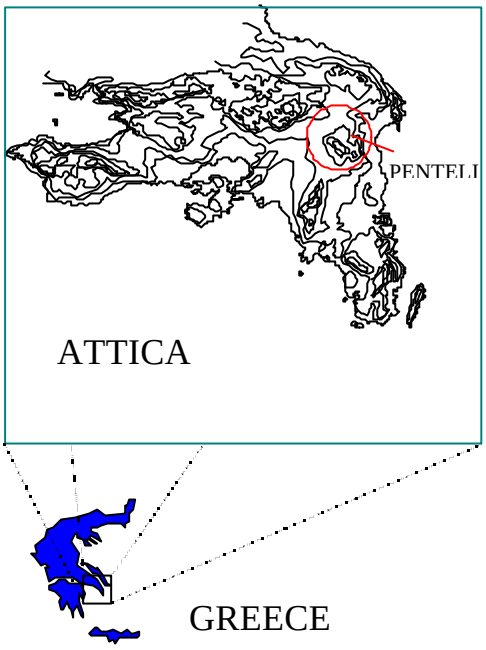
2 Art. 11,12 and 13 of Law 998/1979 and Presidential Decree 1141/1980, introduce the use of the first aerial photographs of the country (dated in 1937 for the Attica) in order for an area to be characterised as forest.

3 According to the Law, areas are included in the Approved City Plan after the application of the respective Presidential Decrees.



Map technical characteristics:

The reference system of the map is the Hellenic Geodetic Reference System (EGSA87), with the following parameters:

Projection:	Transverse Mercator
Spheroid:	GRS80
Units:	Metres
Central scale:	0.9996
Central Meridian:	24°
Origin Latitude:	0°
False East:	500,000
False North:	0

The reference and visualisation scales are 1:5,000 with a positional accuracy of approximately 3 meters.

The background data of the final map consists of the following layers:

- The iso-contours (digitised from the 1:5,000 topographic maps).
- The road network of the forests and forest areas (digitised from the geometrically corrected 1992 KVR image and the 1:25,000 topographic maps).
- The forest roads (digitised from the 1992 KVR image).
- The drainage network (digitised from the 1:25,000 topographic maps).
- The boundaries of the municipalities of Old and New Penteli.
- The annotation layer.

2.2 Other relevant information that could be included in the GIS database

The proposed GIS database could include more layers, which are not used in the map production. For example:

- The classification results of multispectral remotely sensed images, which indicate areas of the test site covered by forests and bushes in the more recent years, and could be used to identify and monitor changes on these areas. In our case, the classification results of the SPOT multispectral image captured in 1992 are included in the database.

- The buildings detected by image processing methods and techniques in years other than the one selected for the map production, for monitoring purposes. In our case, the buildings detected by image processing methods and techniques in 1988 are also included in the GIS database.

The first layer presents the land use status of the test site in 1992. Although according to legal requirements an area is characterised as forest or forest area if its forest character is pronounced in the earliest air – photos available (dated from 1937 for the case of Attica), the preservation of this character till 1992 is strong evidence. Consequently, if the area surrounding a building detected in 1992, is classified as shrubs or pines in the classification applied on the SPOT 1992 image, this helps the judge to draw conclusions.

The second layer pronounces the existence or not of a building in 1988. This helps to determine the period when a potential breach has taken place.

3. Description of the methodology

3.1 Production of the map layer depicting the forests and forest areas

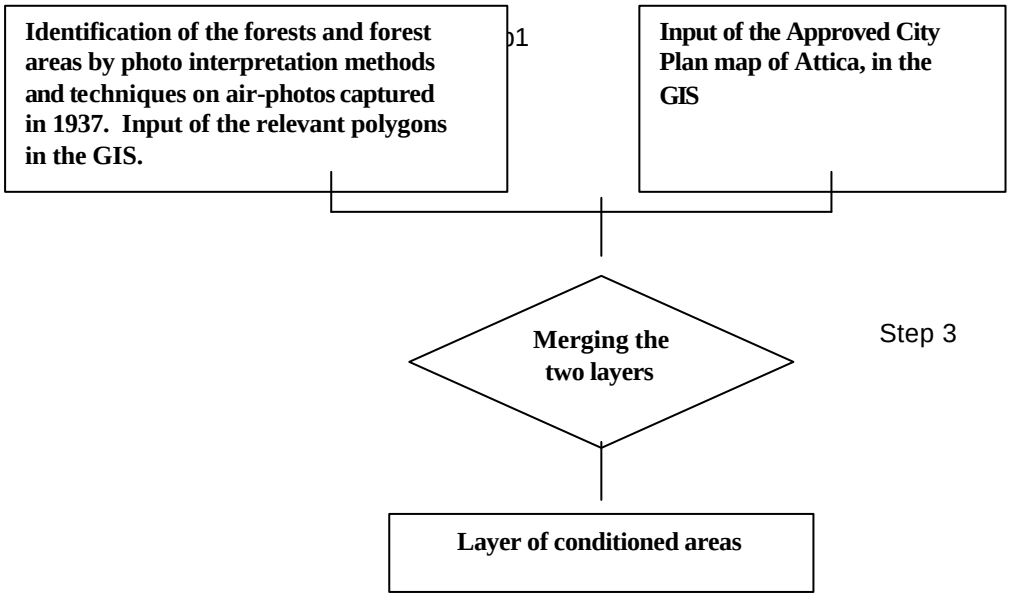
For the production of the layer depicting the forests and forest areas, the cross-reference of the map which shows areas included in the Approved City Plan of Attica, and the relevant information concerning the land use / cover of the test site in 1937, was necessary.

The methodology for the production of this layer is outlined in the following three steps:

- Application of photo-interpretation methods and techniques on ortho -photos based on aerial photographs captured in 1937, for the identification of forests and forest areas in this year, according to Law 998/79 requirements. Digitization and input in the GIS of the polygons showing forests and forest areas in 1937. These ortho-photos were produced by the Hellenic Ministry of Agriculture at scale 1:5000.
- Digitization and input in the GIS of the maps, which depict areas included in the Approved City Plan of Attica, since 1985. These maps, produced by the Ministry of Environment, Physical Planning and Public Works at scale 1:25000, have the 1:25000 topographic maps as background data.
- Merging of the aforementioned information. All areas that are not included in the Approved City Plan since 1985 and have been characterized as forests or forest area in 1937, were considered as forests and forest areas.

The ArcInfo 7.2.1 and ArcView V3.1 software was used for the application of the above methodology.

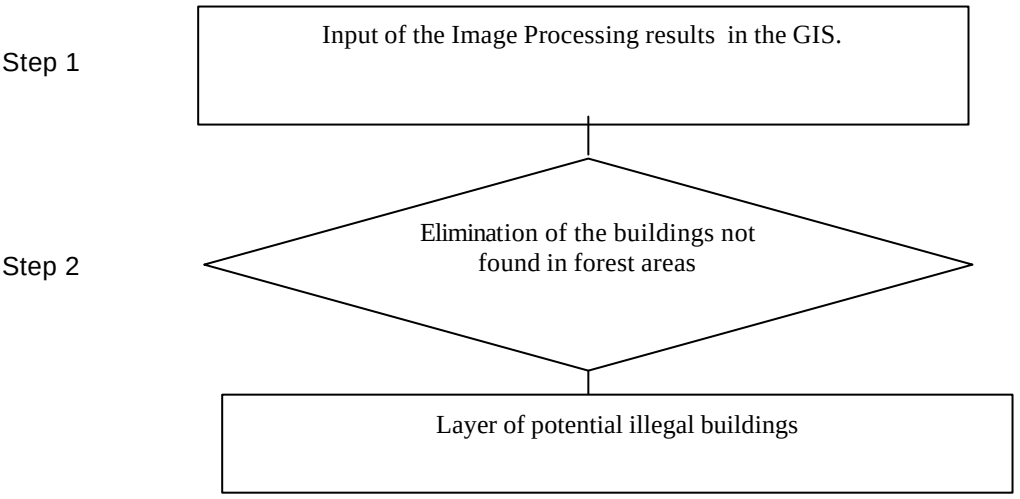
Flow diagram



3.2. Production of the potential illegal buildings map layer

On the potential illegal buildings layer, buildings in forests and forest areas have to be shown for the test site. This layer has resulted from the image processing methods and techniques applied on the KVR image captured in 1992. The texture analysis product has been input in the ArcView environment as a raster layer. Buildings indicated in this layer, which are not found in the forests and forest areas, were eliminated.
Buildings resulting from image processing methods and techniques are not well indicated by their edges and are slightly confused with rock and road patterns. Quality control actions regarding the thematic information of this layer have been performed during the Image Processing implementation. Spatial accuracy of this layer depends on the accuracy of the geometric correction, which is 1.5 pixel (approximately three metres). Buildings have been identified with an accuracy of 92%.

Flow diagram



4. Conclusions. Evaluation of the map potential and limitations

Although buildings depiction resulting from Image Processing methods and techniques are not well indicated by their edges and slightly confused with rock and road patterns, the produced map serves as a useful tool. It indicates with an adequate accuracy, areas where in situ controls and interpretation of relevant air-photos are required. The end-user has to perform the above controls and interpretations for the presence of buildings in the specific areas to be certainly proved. The necessity of such a procedure arises from the lack of convenient earth observation data of very high resolution (e.g. IKONOS I) for our application. The class of buildings detected by image processing methods presents an error in the range of 8%, which means that some entities belonging in other land use classes, such as roads and rocks, may be indicated as buildings in the proposed map.
Now that the IKONOS satellite has been launched and its data with improved spatial/spectral characteristics are to be available, the performance of image processing methods and techniques is expected to be improved drastically. This could be the subject of further research.

Acknowledgements

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