LAND COVER CHANGE IN THREE SELECTED AREAS UNDER DIRECT INFLUENCE OF THE "EGNATIA" HIGHWAY, IN GREECE.

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ABSTRACT:

The Egnatia highway, a modern closed motorway 670 kilometres long, is one of the largest road construction projects in Europe, running across Northern Greece. In order to record and analyze the spatial and environmental effects that inevitably the Egnatia highway has caused to its surroundings, the need for effective and efficient integration of land cover dynamic information is becoming more and more essential. Facing this need, this project aims at the analysis of multi-temporal spaceborne images for the detection of land cover changes in selected areas under direct influence of the Egnatia highway. This is accomplished with the estimation of two specific impact indicators, in order to assess the interaction between the Egnatia road axis and the developmental procedure and physical planning in its impact area. The first indicator monitors the pressure for land use changes that have occurred over the decade 1998-2007, and the second monitors the changes in residential areas for the same period of time. The data used are for the base year 1998: three multispectral orthoimages SPOT, with spatial analysis 20 m, and for the check year 2007: three synthetic images IKONOS, with spatial analysis 1 m. The images mentioned above depict the region of three junctions of "Egnatia" highway. With the intention to estimate the indicators mentioned above, a change detection method is applied and thematic maps are produced, portraying land use variations for the areas of interest.

1. INTRODUCTION

In Roman Times, one of the most important roads leading to the capital Rome was the Via Egnatia, an overseas extension of the Via Traiana. The Via Egnatia was built between 146 and 120 B.C., initially following the traces of an older, pre-Roman road running from the Adriatic to the Aegean Sea. The Romans initially used the road for military purposes, but as it became more widely used it rapidly developed into the main road from the Adriatic to the Black Sea, competing with the traditional sea route from Italy across the Isthmus to the North Aegean and into the Black Sea. (www.egnatiaodos.gr)

Nowadays, Egnatia highway continues its fundamental role in Greece and broadly in the Mediterranean as well as in Balkans, because, when the construction will be finished, it will be a collector route for the Balkan and South-eastern European transport system. Pan-European Corridors IV (Berlin - Sofia - Thessaloniki), IX (Helsinki - Alexandroupolis) and X (Vienna - Belgrade - Thessaloniki) all end at the Egnatia highway.

Figure 1. The Egnatia highway (red color) and its vertical axes (yellow color), in Greece

The importance of the construction project, as well as the large scale of the investment, large part of which emanates from the European Union, leads to additional actions, in order to provide updated and reliable information about the highway's spatial impact and the situation of the areas influenced by the construction and operation of the road and its vertical axes.

In this project this is achieved through the estimation of two indicators concerning aspects of the project impact, such as the spatial planning pressures and changes in land uses. More specifically, the first indicator monitors the pressure for land use changes that have occurred over the decade 1998-2007. This has to do with the changes from rural to non-rural land use as a result of pressures expected at specific areas along the motorway, estimating: (a) the rate of change of agricultural land (cultivated areas) into urban land, (b) the change of natural areas into urban land, and (c) the change of natural areas into agricultural land.

The second indicator has to do with the changes in residential areas for the same period of time. Here is estimated the rate of change of the urban's land density, based on three categories: continuous, linear and discontinuous urban land.

2. DATA

The satellite data used are three multispectral orthoimages from SPOT, with spatial analysis 20 m and three synthetic images IKONOS, with spatial analysis 1 m. The images mentioned above depict the area of three junctions of "Egnatia" highway, in Thessaloniki, in Komotini and in Ioannina. Three corresponding DTMs (Digital Terrain Models) with grid size of

25 meters are also used, as well as the established borders of the Greek Settlements in vector format.

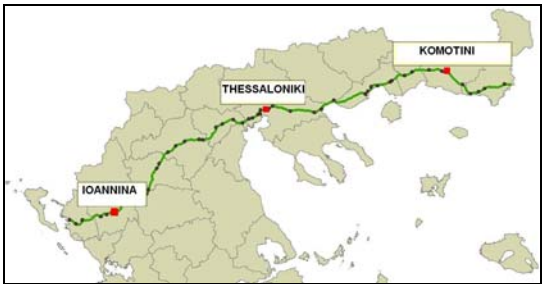

Figure 2. The study areas

For the development of this project, the software used is the Erdas Imagine 9.0 and the ArcGIS 9.2.

3. PROSSESING OF SATTELITE IMAGE DATA

The initial part of the project includes the selection of the 5x5 km areas, for determining the areas in which the indicators are to be estimated. The areas of interest are selected from both the SPOT and IKONOS images. Since the SPOT images for the base year 1998 are already orthorectified the following procedure is the orthorectification of the check year's IKONOS images.

3.1 Orthorectification of IKONOS images

Remotely sensed image data gathered by a satellite are distorted by both the curvature of the Earth and by the sensor being used. Rectification is the process of geometrically correcting an image so that it can be represented on a planar surface, conform to other images, and have the integrity of a map. Orthorectification is a form of rectification that additionally corrects the terrain displacement and can be used only if there is a DEM available for the study area.

For the orthorectification of the IKONOS images, the following input data are used: (a) the RFMs, that accompanied the three satellite images (b) three Corresponding DTMs with grid size 25m (c) and the available reference ground control points.

3.1.1 The Rational Functions Model (RFM): The geometric model, taking into account the geometry of the acquisition and by recovering the distortions that exist, describes the relation between the sensor and one ground reference system. In this project the geometric model being used is the Rational Functions Model (RFM).

The Rational Functions Model transforms the image pixel coordinates through the ratios of polynomial of ground coordinates with the following relations:

$$x = \frac{P1(X,Y,Z)}{P2(X,Y,Z)} \quad (1)$$

$$y = \frac{P3(X,Y,Z)}{P4(X,Y,Z)} \quad (2)$$

$$\begin{aligned} P(X,Y,Z) = {} & a_1 + a_2 \cdot X + a_3 \cdot Y + a_4 \cdot Z + a_5 \cdot X \cdot Y + a_6 \cdot X \cdot Z \\ & + a_7 \cdot Y \cdot Z + a_8 \cdot X^2 + a_9 \cdot Y^2 + a_{10} \cdot Z^2 + a_{11} \cdot X \cdot Y \cdot Z + a_{12} \cdot X^3 + a_{13} \cdot X \cdot Y^2 \\ & + a_{14} \cdot X \cdot Z^2 + a_{15} \cdot X^2 \cdot Y + a_{16} Y^3 + a_{17} \cdot Y \cdot Z^2 + a_{18} X^2 Z + a_{19} \cdot Y^2 \cdot Z \\ & + a_{20} \cdot Z^3 \end{aligned} \quad (3)$$

where X, Y, Z = normalized coordinate values of object points in ground space
α_{ij} = Rational Functions Coefficients
x,y = normalized line (row) and sample (column) index of pixels in image space

3.1.2 The DTM (Digital Terrain Model): In the orthorectification process, distortions arising from the topographic relief are eliminated with the use Digital Terrain Models. Relief displacement is corrected with a process that takes each pixel of a DTM and finds the equivalent position in the satellite image. As it is mentioned above, in this project, three DTMs of the areas of interest are used, with grid size 25m.

Finally a Resampling method is performed. Most geometric transformations lead to pixels that do not coincide with the original image. Resampling is the process of calculating the intensity of the new pixels with one method of interpolation. The method used here is The Nearest Neighbour Interpolation.

3.2 Results

The following table shows the results from the orthorectification process:

	IOANNINA	THESSALONIKI	KOMOTINI
RMS Error (pixel)	1.1209	1.0219	0.898

Table 3. The RMS errors of the IKONOS orthoimages

The accuracy assessment of the produced orthoimages that follows, show that the orthoimages are adequate for the estimation of the two indicators.

4. CLASSIFICATION OF THE ORTHOIMAGES

Image data are often used to create thematic maps through multispectral classification. Classification is the process of defining the image pixels into various classes, representing the different types of land cover and uses. These classes represent groups of pixels that have the same spectral values.

With the intention to estimate the two indicators about the spatial planning pressures and changes in land uses that occur in three selected areas of Egnatia Highway, three basic classes are determined; the classes of ***urban, agricultural*** and ***natural*** land. With the maximum-likelihood supervised classification that is performed, all the pixels of the initial SPOT, as well as of the IKONOS orthoimages are to be inscribed in these three classes. It has to be mentioned that each class has several sub-categories that might appear in the orthoimages. For example, the class "urban land" can be consisted of the sub-classes of "roads", "buildings", "buildings with pottery roof" etc.

4.1 Classification of SPOT orthoimages

After the definition of the three basic classes and their sub-classes, specific training sites on the images are located in order to identify the classes. The resulting training sites are areas representing each known land cover category that appear fairly homogeneous on the image (as determined by similarity in tone or color within shapes delineating the category).

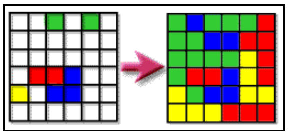

Figure 4. The supervised classification: training sites (left) and the classified image (right). (www.nrcan.gc.ca)

By locating the proper training sites of each class, the classification is realised according to fuzzy logic, which contributes to better results.

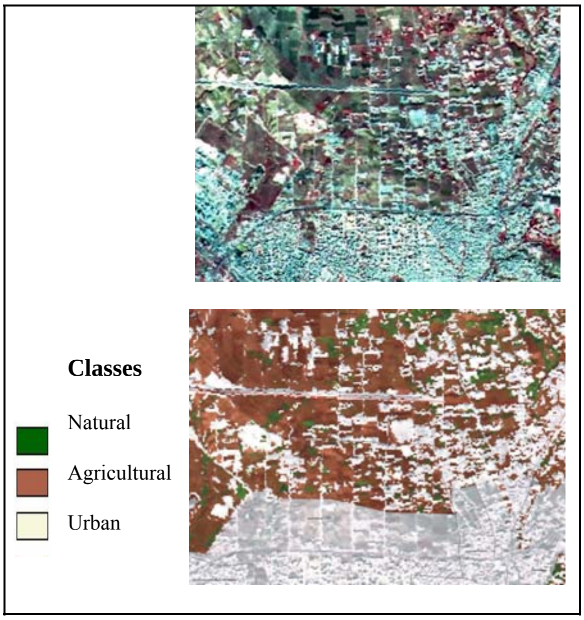

Figure 5. SPOT orthoimage (up) from Thessaloniki and the corresponding classified (down) into three basic classes.

4.2 Classification of IKONOS orthoimages

The same procedure is followed for the classification of the IKONOS orthoimages. It should be noticed that due to the high spatial resolution the classification leads to better and more accurate results.

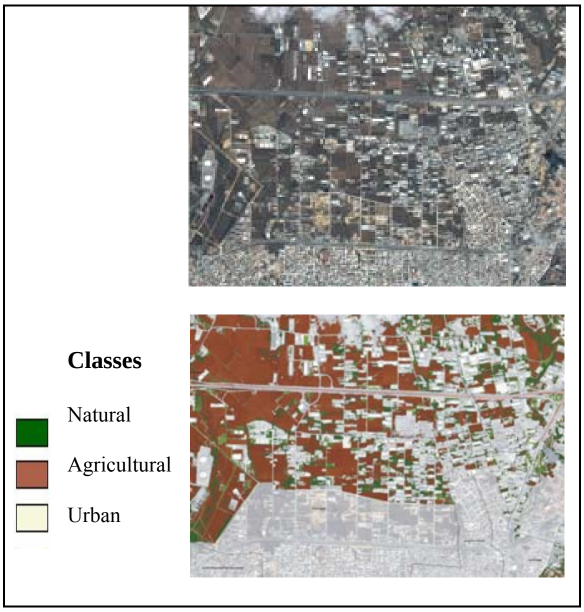

Figure 6. IKONOS orthoimage (up) from Thessaloniki and the corresponding classified (down) into three basic classes.

4.3 Accuracy Assessment

With the accuracy assessment the classified image is compared to geographical data that are assumed to be true. A set of reference pixels, that is selected randomly, is used to compare the classified data, and the error matrix, the accuracy report and the Kappa coefficient are calculated. Finally, the overall accuracy and the Kappa coefficient, determine the degree of success of the procedure. The results are presented in Tables 7 and 8.

	IOANNINA	THESSALONIKI	KOMOTINI
Overall Accuracy	93.75%	91.67%	95.00%
Kappa Coefficient	92.04%	90.00%	93.75%

Table 7. The accuracy totals and the kappa statistics for the SPOT classified orthoimages

	IOANNINA	THESSALONIKI	KOMOTINI
Overall Accuracy	91.00%	85.71%	91.07%
Kappa Coefficient	90.18%	84.00%	89.84%

Table 8. The accuracy totals and the kappa statistics for the IKONOS classified orthoimages

A classified image is considered to be accurate and close to ground data, when the value of overall accuracy is >75% and the Kappa Coefficient >65%. Consequently, the classifications of both SPOT and IKONOS orthoimages are considered to be accurate and adequate to continue for the change detection process.

5. CHANGE DETECTION- ESTIMATION OF TWO INDICATORS REGARDING TO LAND USE CHANGES

Due to natural and anthropogenic activities the earth land changes, and this change plays vital role in the social and economic development of one area. In case of Egnatia highway, considering the large scale of the construction project and the impact that already has and will have in the future, the need to exploit the highway's contribution to the development and cohesion of its impact area, is becoming more and more essential. To achieve this task in this study, the estimation of two indicators regarding to land use changes over the decade 1998-2007 is carried out, with change detection methods.

The change detection issue is one of the most interesting applications of Remote Sensing and numerous methods have been proposed by the scientists over the decades. The post classification comparison method is selected to perform land cover change detection in this study.

5.1 The indicators

As it is mentioned above, two indicators are estimated in order to assess the interaction between the Egnatia highway and the developmental procedure and physical planning in its impact area:

- **a)** The first indicator monitors the pressure for land use changes that have occurred over the decade 1998-2007 by estimating the change from rural to non-rural land use.
- **b)** The second indicator estimates the rate of change of the urban's land density, based on three categories: continuous, linear and discontinuous urban land.

5.2 The change detection procedure

The first step, in order to assess the two indicators, is to transform the classified images from raster format into vector format in order to introduce the images into the ArcGIS environment and to proceed in further processing.

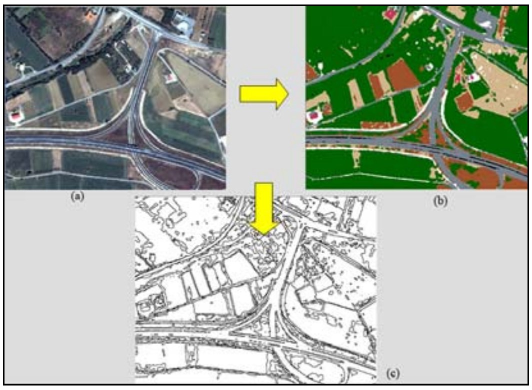

Figure 9. Raster to vector: The initial orthoimage (a), the corresponding classified image (b) and the produced vector image (c).

The shapefiles derived from the vector images, represent each class from the classification process. This enables to identify the areas that have been changed over the decade 1998-2007 by executing an intersection between the shapefiles of the SPOT vector images with the corresponding shapefiles of the IKONOS vector images.

5.2.1 The first indicator: The first indicator estimates (a) the rate of change of agricultural land (cultivated areas) into urban land, (b) the change of natural areas into urban land, and (c) the change of natural areas into agricultural land. This is accomplished with the intersection between the shapefiles that are shown in the following table:

Intersection		Final product
The shape file "agricultural land" from the SPOT vector image (Base year 1998) with the shape file "Urban land" from the IKONOS vector image (Check year 2007)	→	Areas that changed from agricultural into urban land
The shape file "Natural areas" from the SPOT vector image (Base year 1998) with the shape file "Urban land" from the IKONOS vector image (Check year 2007)	→	Areas that changed from natural into urban land
The shape file "Natural areas" from the SPOT vector image (Base year 1998) with the shape file "agricultural land" from the IKONOS vector image (Check year 2007)	→	Areas that changed from natural into agricultural land

Table 10. The intersections for the first indicator

The areas that result from the above intersections depict the land use changes that have occurred over the decade 1998-2007 in the selected areas. The following table presents the percentage of change that is also calculated.

	IOANNINA	THESSALONIKI	KOMOTINI
	percentage of change		
Natural areas& Agricultural land	-3.53%	-19.49%	-1.33%
Urban land	+12.20%	+21.79%	+8.22%

Table 11. The percentage of land use change in the study areas.

As it can be concluded from the above table, all the areas have an increase of urban land and simultaneously a degrease of natural and agricultural land over the past decade.

5.2.2 The second indicator: The second indicator estimates the rate of change of the urban's land density. Before performing the intersections for this indicator, it is necessary to determine the areas of continuous, linear and discontinuous urban land.

Therefore, the continuous land is determined as the urban land that is located inside the areas of the established borders of the Greek settlements of the study areas, the linear is defined as the urban land located in a buffer zone of 500m along the basic road axis of the study areas, and finally the discontinuous land is defined as the urban land that is located in areas that do not belong either at linear nor at continuous urban land. After the appropriate intersections between the shape files of these three categories of urban land, result the areas that depict the change of urban land, and the percentages of change that are calculated for the study areas are presented in the table that follows.

	IOANNINA	THESSALONIKI	KOMOTINI
	percentage of change		
Linear urban land	+30,27%	+23,25%	+3,84%
Continuous Urban land	+13,27%	+18,29%	+19,54%
Discontinuous Urban land	+10,86%	+58,74%	+60,03%

Table 12. The percentage of urban land change in the study areas.

After the estimation of the indicators and the calculations of the percentage of change in land uses and in urban's land density, follows the production of thematic maps portraying the land use variations.

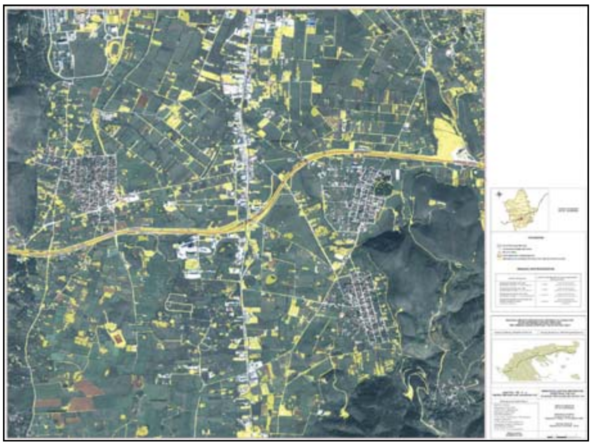

Figure 13. Thematic map of Ioannina, presenting the areas that have changed from agricultural and natural land to urban land (yellow color)

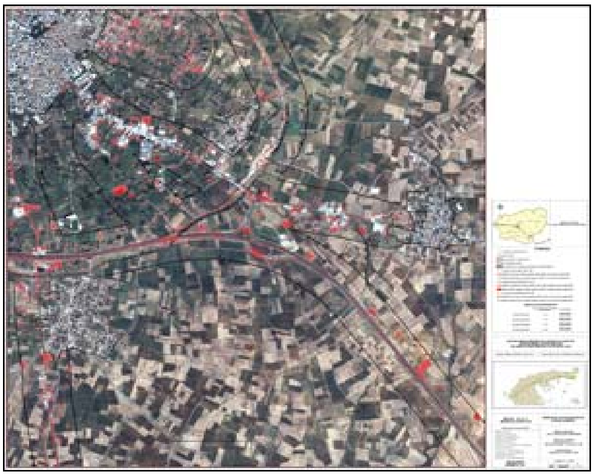

Figure 14. Thematic map of Komotini, presenting the areas that have changed from discontinuous to linear urban land (red color)

6. CONCLUSIONS

This project, with the intention to detect land use changes over the decade 1998-2007 in three selected areas under direct influence of Egnatia highway, focuses on a change detection method based on post-classification comparison and the estimation of two indicators. The images being used are for the base year three multispectral SPOT images, with spatial analysis 20m and for the check year three IKONOS images with spatial analysis 1m.

The classification process leads to very satisfactory results varying from 85% to 95% for the overall accuracy and from 84% to 94% for the Kappa coefficient. The change detection method that follows gives detailed "from-to" information that can be extracted from the classification maps. Another advantage of this method is the fact that the classification map for the next base year is already complete (Jensen 1996). Nevertheless, due to the low spatial analysis of base year's images, it is quite complex to identify and compare same areas. Hence, the change detection results unavoidably carry errors from the misidentifications between the compared images.

The results for the first indicator show that the bigger increase of urban land is located in the area of Thessaloniki. Significant areas of agricultural and natural land were converted into urban land. In detail, in this area the urban land is increased by 22%. In Komotini and Ioannina, the urban land is increased by 12% and 8% respectively.

The second indicator shows that the major change in continuous urban land is measured in Komotini (19.5%) and in Thessaloniki (18.3%). Ioannina presents the higher increase (30.27%) of the linear urban land. The increase of linear urban land along the Egnatia highway in Thessaloniki is significant (23%), while in Komotini it is extremely low (3.8%). Finally the discontinuous urban land has its bigger increase at Komotini while the smaller is located at Ioannina.

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