A RULE-BASED APPROACH FOR MAPPING AND MONITORING OF LAND COVER CHANGES IN LESVOS (E. GREECE), WITH EMPHASIS IN DEFORESTATION AND OLIVE GROVES ABANDONMENT

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EXTENDED ABSTRACT

This research focuses on the assessment of land cover changes that have taken place in Lesvos island during a 25-years span (1975-1999), using a rule-based approach combined with Remote Sensing and Geographical Information Systems (GIS) techniques. The detection of multitemporal land cover changes is significant, as these changes may trigger or indicate the cause of many environmental problems.

Three satellite images, a Landsat MSS scene (1975), a Landsat 5 TM scene (1990) and a Landsat 5 TM scene (1999), were employed for identifying land cover changes. The study area was initially divided into five relatively homogeneous zones, depending on surficial and geomorphological characteristics, and the type of vegetation/land cover that dominated each area. Each zone was individually classified with the maximum likelihood classifier using *a priori* class probabilities, in order to achieve better classification results and higher accuracies. Additional data were derived from aerial photographs (1960 and 1995) and Quickbird data (2001). Detailed photo-interpretation (on the above-mentioned data) aided by a Digital Elevation Model (DEM), and the three classified images within each zone, led to the generation of a subset of rules for the post-processing of the classified images and the detection and correction of erroneously classified pixels of specific land cover classes.

The application presented here has focused on:

a) The mapping of land cover using Landsat images and the analysis of the information regarding change detection during the 25 years span (1975-1999).

b) The integration of Remote Sensing imagery with other ancillary GIS data such as a DEM, other land cover maps and field measurements, using a rule-based approach, which led to a more accurate identification, assessment and mapping of land cover changes.

The land cover changes observed during the last three decades are considerable, even though the island is far from the mainland and without any intense tourist growth. The human pressure to the natural environment is manifested through the rapid expansion of the urban areas, fires, deforestation of pine forests, the expansion of cultivations into natural vegetation zones and overgrazing mostly in semi-mountainous or mountainous areas. On the other hand, the abandonment of the olive groves and other crops in inaccessible or mountainous areas has been observed.

The above framework has proved to be a promising and practical approach in order to quantify, understand, conceptualize and better present the dynamics of land cover changes and their implications to local environments and sustainable development.

Keywords: rule-based approach, land cover changes, remote sensing, GIS, Lesvos.

1. INTRODUCTION

Multi-temporal and multi-spectral satellite data have demonstrated significant potential in detecting modifications and in monitoring and quantifying abrupt and rapid changes occurring on the Earth's surface [8, 9, 11, 13]. However, change detection based on satellite data is a difficult task to perform and aerial photography analysis and interpretation is still a widely used tool for mapping and monitoring land use/cover changes [14]. Nevertheless, the advantages that satellite data offer combined with recent advances in satellite technologies and image analysis techniques have further enhanced the potential of satellite imagery and satellite data currently constitute the primary data source in the detection of changes in land use/cover [1, 4]. At the same time, increasing emphasis is being given to the use of Geographic Information Systems (GIS) in classifications using ancillary GIS data [7, 10, 12].

This research focuses on the assessment of land cover changes that have taken place in Lesvos island during a 25-years span (1975-1999), using a rule-based approach combined with Remote Sensing and GIS techniques.

The application presented here has aimed in:

a) The mapping of land cover using three Landsat images and the analysis of the information regarding change detection during the 25-year span (1975-1999).

b) The integration of Remote Sensing imagery with other ancillary GIS data such as a DEM, other thematic maps and field measurements, using a rule-based approach, which led to a more accurate identification and mapping of land cover changes.

The above framework has proved to be a promising and practical approach in order to quantify, understand, conceptualize and better present the dynamics of land cover changes and their implications to local environments and sustainable development. It is therefore suggested that the presented methodological framework can be used as a useful tool at national or regional level, towards improved management of land cover.

2. DESCRIPTION OF THE STUDY AREA

The study area is the island of Lesvos (North Aegean - Eastern Greece) (Figure 1). It was selected due to the fact that the island's ecosystems are faced with disturbance as a result of limited available natural resources, insularity, and the development of monocultures in the agricultural sector [6]. At the same time, Lesvos has limited prospects for development other than that of tourism.

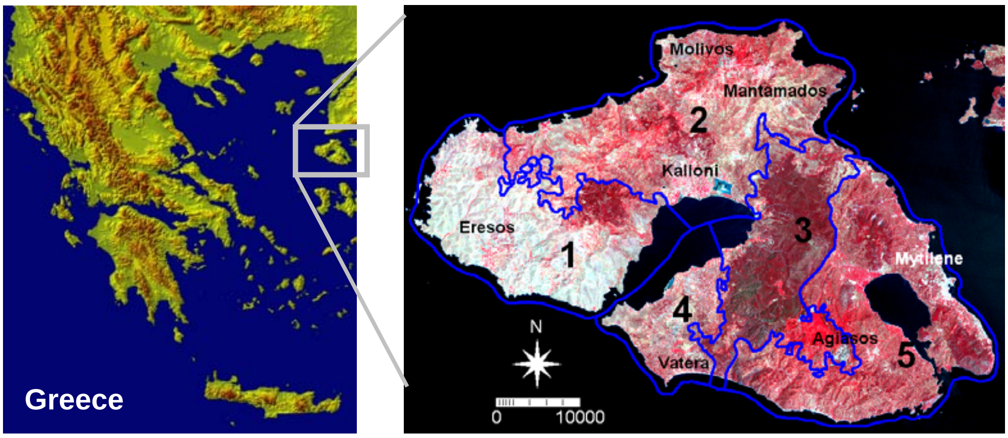

Figure 1: Landsat-5 TM image illustrating the study area

Extensive fields of olive groves and mixed natural and agricultural landscapes characterize the island, while the main income of the local population comes from the agricultural and stock-farmer activities. Many socioeconomic processes that have taken place, together with physiographical properties, have played a significant role in the formation of the natural and agricultural land cover, and are responsible for the alterations of the landscape. Consequently, in the last three decades the island has experienced considerable land cover changes despite being far from the mainland and without intense tourist growth.

The systematic observation and detection of land cover changes has therefore become very important for financial and environmental reasons. These changes are mostly due to human activities and interventions in the urban, agricultural and natural environment, which are manifesting in many ways, such as the rapid expansion of the urban shell, fires, the vegetation degradation and deforestation, the penetration of cultivations into natural vegetation zones, land abandonment and the appearance of serious erosion phenomena and desertification. In addition to these factors, the slow but stable shift to tourism-related activities has important implications for the economy and this in turn leads to the increase of urban land and a more complicated coexistence with agriculture.

3. DATA AND METHODOLOGY

Three satellite images, a Landsat MSS scene (July 1975, 4 bands, pixel size 59m), a Landsat 5 TM scene (July 1990, 7 bands, pixel size: 30m) and a Landsat 5 TM scene (July 1999, 7 bands, pixel size: 30m), were employed for identifying land cover changes in the island of Lesvos. The three scenes were referenced to a common projection (EGSA'87). The study area was initially divided into five relatively homogeneous zones, depending on surficial characteristics and the type of vegetation/land cover that dominated each area (Figure 1).

The **first zone** includes the western part of the island where serious erosion phenomena and desertification occur (Eresos and Sigri villages – 429km^2). The vegetation of garrigue and bare land cover almost 75% of this zone. Live-stock farming activities and the mild tourist growth sustain the local economy, due to the infertile and unproductive soils met in this area. The **second zone** comprises a completely different landscape (NW part – Molivos and Petra villages - 560km^2), where olive trees and arable crops dominate. The **third zone** contains the main pine forest and the only broadleaved forest (chestnut trees) of the island (310km^2 - central part). A large portion of the third zone is covered by natural vegetation (almost 90%). The **fourth** zone comprises mostly of olive trees and arable crops (approximately 80%). It includes a part of the southern island (167km^2 - Polichnitos village and saltworks) where elevation is low. The **fifth** zone includes the city of Mytilene and an extensive area of olive trees, which occupy nearly 80% of this zone. It is located in the east and south-east part of the island (508km^2) where a considerable urban growth is observed, due to the internal migration, the mild tourist growth and the construction of the University of Aegean campus facilities.

Each zone was individually classified with the maximum likelihood classifier using *a priori* class probabilities and some randomly selected samples for each land cover class.

Additional data were derived from aerial photographs at a scale of 1:40.000 (1960 and 1995) and Quickbird data (2001), which were orthorectified for this purpose. Additionally a DEM of the study area was acquired (30m resolution).

Despite the well designed sampling framework, the produced thematic maps of land cover alone were not suitable for change detection. For the year 1975, the poor spatial and spectral resolution of Landsat MSS produced classifications of low accuracies (58%). The rule-based approach used was combined with manual editing which allowed us to produce classified images with accuracies of 90% for the 1975 image. This approach can also improve accuracies of Landsat TM classified products (1990-1999), which are low (50-55%), too. The lower accuracies of Landsat TM are owed mainly to the higher spectral confusion among three classes, namely olive trees, maquis and garrigue that cover a large part of the island (approximately 75%).

3.1. Rule-based enhancement of both classified images

After the division of the island in relatively homogeneous zones, post classification processing for both images took place in three stages, in order to improve the classification accuracy of the images using ancillary data and rules.
In the **first stage**, correction initially focused on errors that were due to the terrain complexity. A simple but effective approach was undertaken at this stage. The hillshade surface was derived using the DEM based on the Sun angle values. Erroneously classified areas were identified with interpretation of aerial photos using a mask of hillshade values lower than 160 in order to correct the classified "maquis" pixels to "olive cultivations". In the **second stage**, a correction for urban areas was applied. This process was based on a mask generated using a polygon layer of current urban coverage for each date. Pixels being classified as "garrigue" vegetation or "bare land" and that fell within the masked area were reclassified as "urban". Also, all pixels erroneously classified as "urban areas" were reclassified to "bare land".
Furthermore, this stage involved the use of DEM for vegetation zoning. Detailed photo-interpretation (on aerial orthophotos and Quickbird data) aided by the DEM, and the classified images within each zone, led to the generation of a subset of rules for the detection and correction of erroneously classified pixels:

Zone 1: broadleaved forest reclassified to maquis (similar spectral signatures)
over 500m olive trees reclassified as garrigue
Zone 2: broadleaved forest reclassified to maquis (similar spectral signatures)
over 600m olive trees reclassified as maquis
over 150m or slope>15%, other crops reclassified as bare land
Zone 3: over 350m olive trees reclassified as maquis
Zone 4: broadleaved forest reclassified to maquis (similar spectral signatures)
over 280m olive trees reclassified as garrigue
Zone 5: under 450m broadleaved forest reclassified to olive trees
over 600m olive trees reclassified as maquis
Zones 1-5: over 510m urban areas reclassified as bare land
Zones 1, 2, 5: slope>38%, urban areas reclassified as bare land

Additional corrections to the classes of natural vegetation, olive cultivations, other crops, marsh and saltworks were applied based on the interpretation of aerial orthophotographs and Quickbird imagery, and manual editing. Also, the main "other crops" and all the marshes and saltworks were digitized, and overlaid to the classified map. Similar overlays were made in specific areas for olive trees and natural vegetation.
The **third stage** involved change detection mapping, identification of erroneous changes using knowledge-based rules (e.g. changes that are impossible to happen in the time span studied) and correction of the classified images focusing on the areas where erroneous changes occurred [5]. This stage was aimed in the comparison of multi-temporal changes and the identification of false changes based on a set of rules summarized in Table 1. The false changes were re-examined with the help of orthorectified aerial photographs and Quickbird imagery, and the classified images were revised. Finally, scattered "changed" pixels were also removed from the "change" maps as they most probably identified erroneous changes due to random errors.

3.2. Accuracy assessment of the produced land cover maps

In order to evaluate the classified maps before and after their post classification processing established accuracy assessment procedures were employed [2, 3]. Ground truth data were provided by the interpretation of aerial photographs for the classified map of 1975 and the map of 1990, and Quickbird imagery for the map of 1999. Also, selected field checks were carried out in order to estimate the accuracy of the classification results (for the 1999 map).

Table 1: Possible and false land cover changes.

1975 (from)	**1999 (to)**	
other crops	olive trees	possible
other crops	garrigue	possible
other crops	maquis	possible
maquis	olive trees	possible - re-examined
maquis	garrigue	possible - re-examined
maquis	pine forest	possible
water	all classes except water	false
urban areas	all classes except urban areas	false
olive trees	garrigue	false
olive trees	bare land	false
olive trees	other crops	possible - re-examined
olive trees	maquis	possible - re-examined
garrigue	olive trees	possible
garrigue	pine forest	possible
garrigue	bare land	possible – re-examined
pine forest	olive trees	possible – re-examined
pine forest	garrigue	possible
pine forest	maquis	possible

4. RESULTS

Three thematic maps of high accuracy were produced (Figure 2, 3, 4) for the identification of land cover changes (59m resolution). The total accuracy in all land cover maps was considerably improved (1975: from 58% to 90%, 1990: from 56% to 91%, 1999: from 53% to 90%). Also, the individual producer's and user's accuracies were improved.
The rate of changes for each land cover varies between the two periods (1975-1990 and 1990-1999). Two thematic maps (1975-1999) were overlaid and cross-tabulated in order to detect and map land cover changes. The area covered by each land cover class is shown in Table 2. The more significant changes that have taken place in Lesvos are shown in Figure 5.

Table 2: Statistical data of land cover changes.

Land cover	**Area (%) 1975**	**Area (%) 1990**	**Area (%) 1999**
Bare land	1.4	1.6	1.3
Broadleaved forest	0.9	1.2	1.1
Maquis	5.1	7.3	11.6
Marsh	0.4	0.3	0.3
Olive trees	42.8	44.9	41.1
Other crops	6.6	4.2	4.2
Garrigue	26.8	23.8	22.6
Pine forest	15.2	15.1	16.1
Saltworks	0.1	0.2	0.2
Urban areas	0.7	1.4	1.5

Human pressure manifested through certain practices, in the study area, led to a considerable modification of the landscape, which is presented below:

A) Although the change in the distribution of pine forest is uneven, an increase of total area of pine forest is recorded. Four main pine forests exist in the island. The larger forest is located in the central part of Lesvos (zone 3), where the regeneration of pine forest seems to prevail and the newly forested areas are larger than the areas that were burned or replaced by crops. The second forest is in the west part of the island (near Parakoila village) and appears to increase its area, suffering less human pressure. The last two forests, in zone 5 (near Komi village and Kratigos area), experience high pressures until today, and their extent are being reduced.

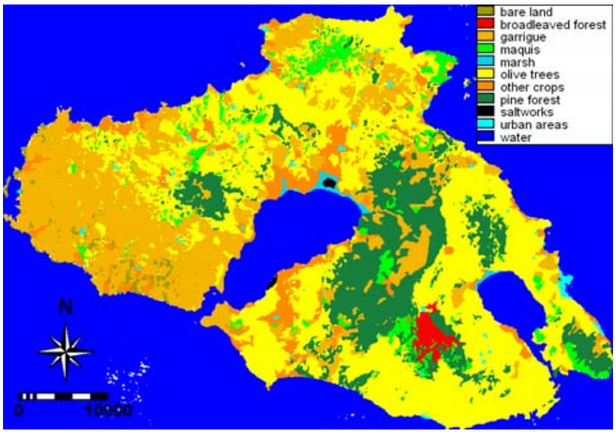

Figure 2: Land cover map produced from LANDSAT MSS image classification (1975).

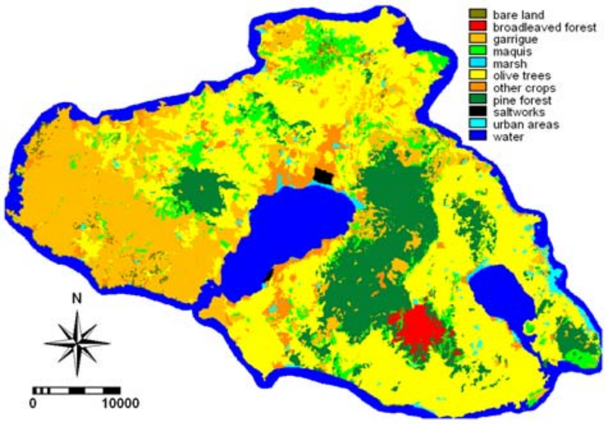

Figure 3: Land cover map produced from LANDSAT-5 TM image classification (1990).

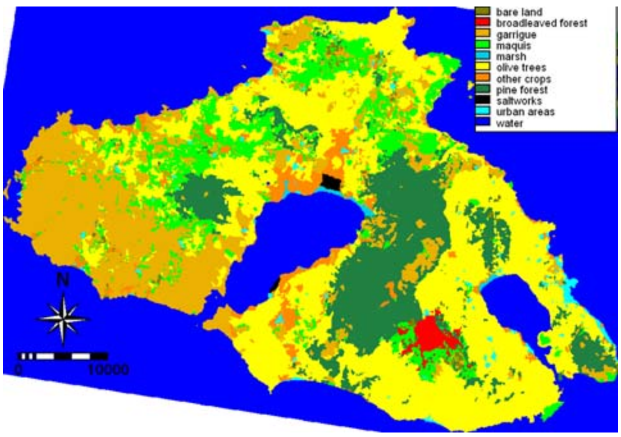

Figure 4: Land cover map produced from LANDSAT-5 TM image classification (1999).

B) The olive trees sprawl was observed mainly in coastal and plain areas, while the abandonment of olive trees occurred primarily in mountainous and semi-mountainous areas. The increase of olive groves was observed to have taken place at the expense of natural vegetation (mostly garrigue and maquis rather than pine forest) and other crops (arable cultivations). On the other hand, several sites were detected where the abandonment of olive trees was succeeded by maquis vegetation.

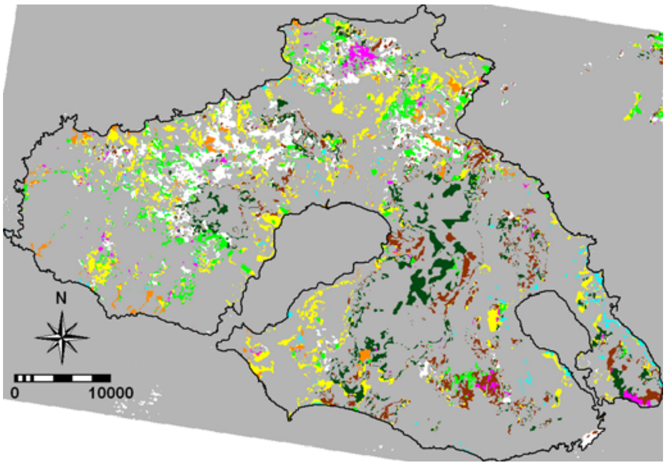

Figure 5: Land cover changes (1975-1999). Gray: no change, Cyan: urban expansion, Orange: other crops decrease, Yellow: olive groves expansion, White: olive groves abandonment, Dark Green: regeneration of pine, Dark Brown: deforestation of pine, Green: maquis vegetation increase, Magenta: degradation of bush vegetation.

C) An expansion of maquis vegetation in the north and north-west parts of the island (replacing olive trees) was observed. However, distinguishing these two land cover types by manual photo-interpretation (using aerial photographs and Quickbird imagery) was not entirely successful due to texture similarities. Moreover, field verification of olive groves abandonment in all these areas is proved to be very difficult as well, due to problematic site accessibility (absence or ill maintained road network). In these particular areas, more work will be carried out in order to discriminate maquis vegetation from olive groves based on field work, auxiliary data and enrichment of the knowledge base with new rules.
D) A considerable urban expansion can be observed, mainly in the coastal plain, tourist areas and the larger villages. This expansion is recorded in the perimeter of the existed urban areas.
E) A notable decrease of other crops (mainly arable crops) was observed in many sites. In a few cases, an increase of arable crops, mainly near to coastal villages and plain areas, was recorded, reducing the rate of total decrease of other crops.

5. DISCUSSION-CONCLUSIONS

Using Landsat imagery, the identification of important land cover types was difficult to perform. Land cover types that are similar in their appearance and spatial distribution on the landscape, are very difficult to identify with imagery of relatively poor spectral and spatial resolution. For instance, olive trees are demonstrated a similar spectral response to the maquis vegetation. Bare land and low vegetation (garrigue) are also difficult to discriminate using Landsat imagery due to their homogeneous and smooth appearance.
The results confirm that change detection using satellite data alone is a difficult task with many inaccuracies. Manual interpretation and rules based on ancillary data are unavoidable in mapping these landscapes. The rule-based approach gave us the ability to improve upon the accuracy of land cover maps. The overall accuracy of the results is satisfactory. However, improvements on the accuracy are needed for specific land cover

types that exhibit similar textures and spectral signatures (maquis - olive groves, garrigue - bare land). These areas have already been identified in this research and additional work is in progress.

The land cover changes detected during the time span 1975-1999 are considerable. The intense relief of the island, in conjunction with human interventions, is related directly with land cover changes. The complexity of the relief is a limiting factor for the agriculture, and often results in the abandonment of olive cultivations. Most changes in the olive cultivations were on high slopes and altitudes. On the other hand, a deforestation of specific areas was detected due to the human pressure.

The production of three land cover thematic maps, at a scale of 1:150.000, in a region which is characterized by the absence of accurate old or recently updated maps (the existent Corine maps cannot fulfill the user needs as they are not so accurate and frequently updated), is a significant contribution to appropriate management of land use and the conservation and protection of natural environment. These thematic maps can be used as a reference base, in the future, on a similar study of change detection.

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