# Monitoring and Prediction of Land Cover Changes in the Island of Corfu in Greece

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**Abstract.** Land cover change detection has been one of the most important applications of remote sensing since the first launch of Landsat satellite in 1972. The use of satellite remote sensing allows to monitor land cover changes, to make predictions and even to prevent future evolutions. It also helps using the natural resources in good effect, identifying new resources and protecting the existing ones from natural or human interference. This study examines the land cover changes in the island of Corfu in Greece for nearly 20 years. Two Landsat satellite images, dated back to 1990 and 2000, are used and a land cover change prediction is made for the future. The main analysis of this work involves a change detection modelling of the potentials through multi-layer perceptron neural network classification and a dynamic change prediction process, by means of Markov chain analysis. In order to estimate the prediction accuracy, the predicted image of 2007 is compared to the classified Landsat image of the same year. It is noticed that the urban sprawl and the economical development through tourism, is an indicator of land cover change detection, whereas the forestry and the natural environment to a large extent is preserved for the last 20 years and so does for nearly the next decade.

**Keywords.** Environmental monitoring, urban sprawl, neural network classification, Markov change detection.

## 1. Introduction

Land use/land cover change detection and prediction through the use of satellite imagery, one of the most significant applications of remote sensing, contribute significantly to the detection, monitoring and prediction of the changes of natural environment over the years or to be made in the future [1], [2]. Therefore, it offers great potential not only to the management of the natural environment but also to the management of the social and economical consequences to the human environment [3]. Some of the methodologies for such applications can be categorized as: delineation of changes, multivariate temporal resolution in feature space, image rationing and subtraction, image regression, post-classification comparison and multi-temporal linear data transformation [4], [5].

This study examines the land cover changes in the island of Corfu in Greece using two Landsat satellite images and a third Landsat image to test the land cover change prediction. More particularly, it involves a change detection modelling of the potentials through multilayer perceptron neural network classification and a dynamic change prediction process, by means of Markov chain analysis. Markov theory has been successfully used in remote sensing to assess and predict anthropogenic or natural changes of the environment. The Markov models have the property to some extent, to reduce the spatial heterogeneity of classified images [6]. The spatial heterogeneity affects negatively the transition matrix (a probability transition matrix from one land cover to another, at two separate time intervals) [6]. Provided that images with relatively low heterogeneity are available, can this yield to better accuracy to the probability transition matrix.

Two Landsat satellite images dated back to 1990 and 2000 have been used to assess the land cover changes over the years for the island of Corfu. In order to estimate the prediction accuracy, the predicted image of 2007 is compared to a classified Landsat satellite image of the same year. It is noticed that the urban sprawl and the economical development through tourism, indicates specific land cover changes, whereas the forestry and the natural environment areas, to a large extent, are preserved for the last 20 years and so does for the next decade.

## 2. Study area

The island of Corfu, located at the west coast of Greece, is the second largest island in the Ionian Sea (Figure 1). Corfu is characterized by a mild Mediterranean climate, rich in vegetation compared to the other Greek islands. Hot and dry summers along with winter rain create lush vegetation dominated by over two million olive trees which constitutes its main cultivation. However, a large part of the economy of the island is due to the tourism during the summer season.

Figure 1: The study area of the island of Corfu highlighted in the map of Greece.

## 3. Materials and methods

For this study, two Landsat TM satellite imagery of 1990 and 2000, available at no cost by the Global Visualization Viewer of the United States Geological Survey [7], have been used to assess the land cover changes and a third image of 2007 to predict future evolutions for the island of Corfu in Greece. The pre-processing steps involved the radiometric corrections of the satellite imagery using the Chavez’s COST model [8] and the geometric corrections using the linear affine transformation between the two images, by means of ground control points. The root mean square (rms) error was nearly 15m, about half of the pixel size of the Landsat imagery, accurate enough for the mean scale of 1:50.000. Therefore, the two images were referenced to a common coordinate system, the Hellenic Geodetic Reference System 1987 (HGRS 87).

Spectral signatures have been created from polygons extracted from the Landsat images of 1990 and 2000 for each land cover class, according to the generalized Environment Agency CORINE land cover maps of 1990 and 2000 for the island of Corfu [9]. The CORINE land cover maps have been generalized to 8 classes leading to eight spectral signatures in the study area (urban, mixed land cover, olive grove-forest, barren land, wetlands, sea, vineyards and salinas).

Two of the most used classification techniques were tested in order to choose the one with the optimal results. These were the maximum likelihood classification and the neural networks classification.

The prior probabilities, with which each class can occur, are proportional to the percentage area occupied in the corresponding CORINE Land Cover for the Corfu island for the same year. The application of maximum likelihood classification gave an accuracy level of 79,3% according to the CORINE Land Cover thematic map of the same period of time.

Nevertheless, the differences between nonparametric, such as neural network (NN) and parametric, such as maximum-likelihood classifiers led to the application of the neural network classification for the Corfu island.

The distribution free neural network classifiers have some advantages over the classical statistical methods, such as the ability to learn complex patterns and to be generalized in noisy environments [10].

One of the most used neural network models is the multi-layer perceptron (MLP) used in the back-propagation (BP) learning algorithm. Multilayer perceptrons (MLP) have one or more hidden layers of neurons between the input and output layers [11]. Completely interconnected successive layers of each neuron are weighted in order to define the influence of each connection. The input to each neuron in the next layer is the sum of all its incoming connection weights multiplied by their connecting input neural activation value [12].

During the training process, each feature vector associated with every pixel is fed into the input layer and the receiving node, sums the weights from all nodes to which it is connected in the preceding layer. Proper weights are defined both for the connection between the input and hidden layer, and between the hidden and the output layer for the classification of the unknown pixels [13]. The achieved accuracy according to the Corine Land Cover thematic map of the same period of time, was 84,1% after the neural network classification for the island of Corfu.

According to the previous outputs, the NN classification results were used compared to those of the maximum likelihood classification.

For the prediction of the land cover changes for the year 2007, the Markov chain analysis has been implemented. This process describes that the state of a system is determined knowing its previous state and the probability of transitioning from each state to each other state. In order to estimate the transitions from one class to another, a probability transition matrix has been used. This square matrix dimensioned with the land cover classes calculates for each land cover the probability of its existence after a number of iterations corresponding to the periods of time existing between the last and the predicted land cover map. The probability values of this matrix of the estimated change into a different land cover class in the later image, are calculated by the ratio of the pixels that correspond to this land cover in the later image (after a number of iterations), to the number of the corresponding pixels in the earlier image. The thematic output of the Markov chain analysis is a probability image for each land cover that exists both in the earlier and the later image. Each pixel in the final predicted image is being assigned to the probability that belongs to this land cover, expressed by this image.

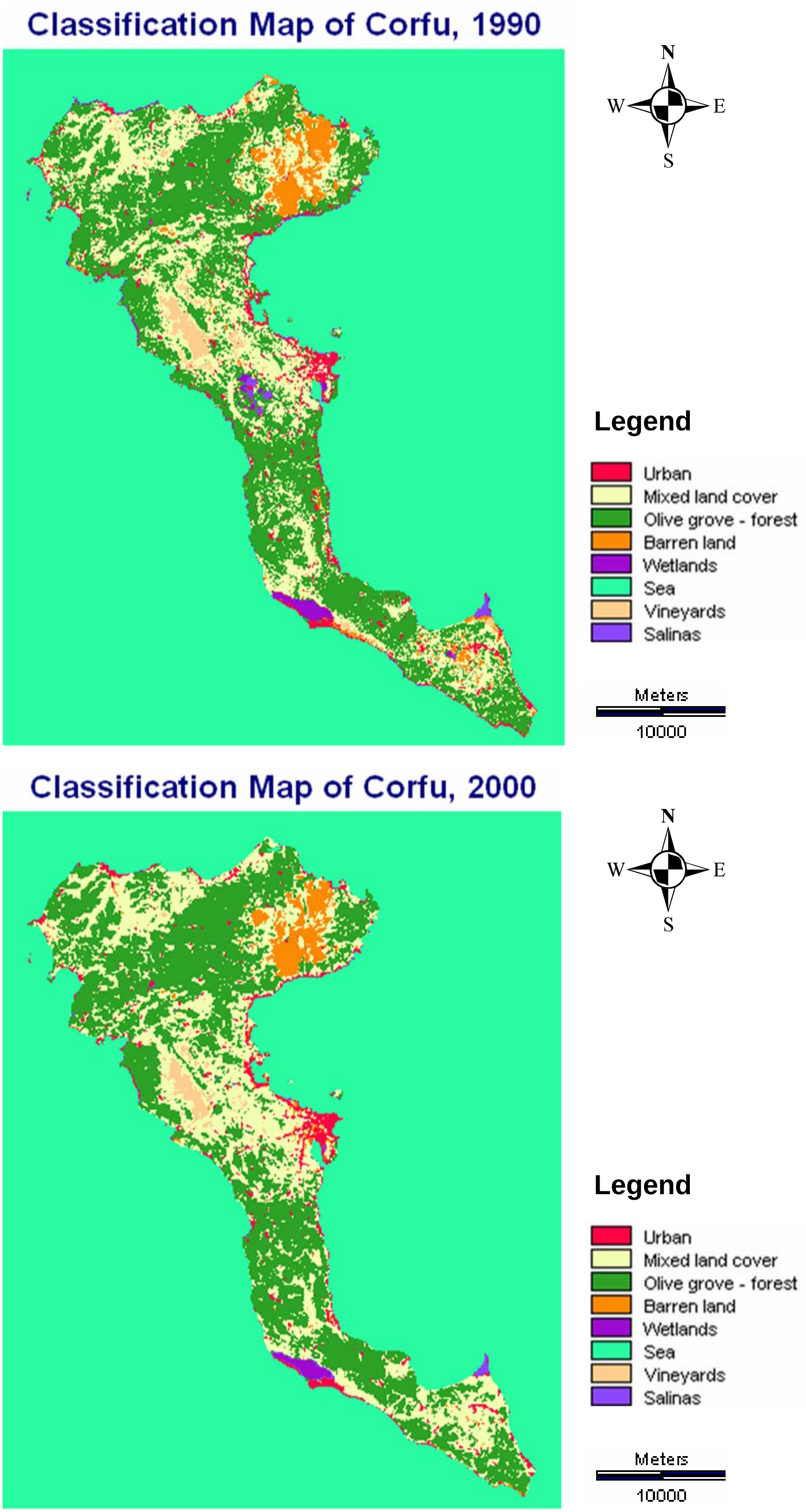


Figure 2: The neural network classification maps of 1990 (top) and 2000 (bottom) for the island of Corfu.

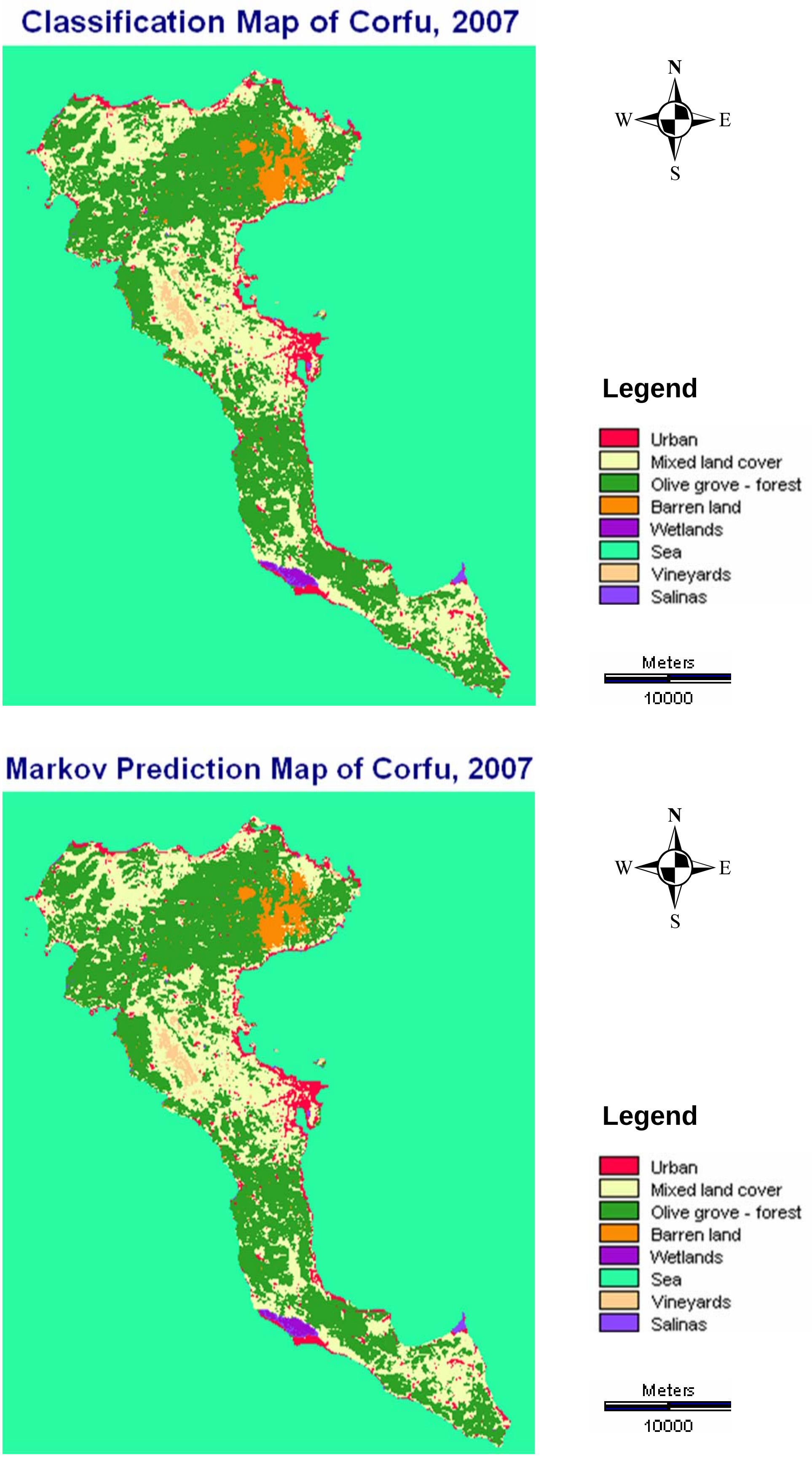


Figure 3: Comparison between the NN classified image of 2007 (top) and the image of prediction (bottom) for the same year.

## 4. Results

An assessment of the agreement of the classified images with those of CORINE land cover maps for the years 1990 and 2000 has been made using the Kappa Index of Agreement. The output values of 0.54 and 0.51 corresponding to 1990 and 2000, shows that there have been land cover changes in the study area. More particularly, the classification maps of 1990 to 2000 (Figure 2) shows that the urban environment, the olive grove-forest, the mixed land cover and the salinas are very dynamic land covers. A considerable amount of wetlands seem to deplete and comparatively a smaller mount of vineyards. The predicted image of 2007 has been validated against a classified Landsat satellite image of the same year (Figure 3). The application of the Markov chain method overestimates the extended land cover changes of olive groves and forests towards the barren land. The urban areas, the vineyards and the wetlands have been accurately predicted with no significant changes. The validation shows the quality between the predicted land use maps in relation to a map of reality. This is expressed by running a 3-way cross-tabulation between the later land cover map (classified image of 2000), the predicted land cover map of 2007 after the Markov chain detection method and a map of reality (classified image of 2007) with an accuracy level of about 80%.

## 5. Conclusions

Land cover change detection and prediction in the island of Corfu through Markov chain analysis yield to fairly good results. However, this methodology reduces the spatial heterogeneity of classified images, which has a negative effect on the probability transition matrix from one land cover to another, at two separate time intervals. The assessment of the agreement of the classified images with those of CORINE land cover maps for the years 1990 and 2000 has been made using the Kappa Index of Agreement which reveals the land cover changes. The urban environment, the olive grove-forest, the mixed land cover and the salinas are very dynamic land covers, whereas a considerable amount of wetlands seem to deplete and comparatively a smaller amount of vineyards. The image of prediction through the Markov chain analysis overestimates the extended land cover changes of olive groves and forests toward the barren land. The urban areas, the vineyards and the wetlands have been accurately predicted with no significant changes.

This methodology is employed to investigate the use of transition probabilities through Markov chain analysis in the modeling processes of the land cover change detection and prediction. Future research should include the experimentation of other spatially explicit models to better understand the land cover dynamics of this area.

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## References

[1] Jensen, J. R., 2006. *Remote Sensing of the Environment: An Earth Resource Perspective.* Prentice Hall, 608 pp.

[2] Moysiadis, A., 2011. The contribution of space technologies to environmental monitoring, *International Society for Photogrammetry and Remote Sensing (ISPRS) Student Consortium Newsletter*, 5, (3), p.4.

[3] Detsis, V., Ntasiopoulou G., Chalkias C. and Efthimiou G., 2010. Recent insular Mediterranean landscape evolution: a case study on Syros, Greece, *Landscape Research*, 35, (3), pp. 361–381.

[4] Singh, A., 1989. Digital change detection techniques using remotely sensed data, *International Journal of Remote Sensing*, 10 (6), 989-1003.

[5] Perakis, K., 1999. Régression linéaire régionalisée appliquée à l'étude des changements d'occupation du sol dans le département de Magnésie (Grèce centrale) durant la dernière décennie, *Photointerprétation, images aériennes et spatiales,* 37 (99), pp. 37-45.

[6] Perakis, K., 2011. Temporal changes and land cover prediction in the prefecture of Magnesia using Markov chains and cellular automata, *Aeichoros*, No 16 pp. 124-141.

[7] Global Visualisation Viewer, 2011. Available from: http://glovis.usgs.gov [Accessed 12 December 2011].

[8] Chavez, P. S., 1996. Image-based atmospheric corrections – revisited and improved", Photogrammetric Engineering and Remote Sensing, 62 (9), pp. 1025-1036.

[9] Corine Land Cover. 2011. Available from: http://www.eea.europa.eu/publications/COR0-landcover [Accessed 10 December 2011].

[10] Ji, C. Y., 2000. Land-use classification of remotely sensed data using Kohonen self-organizing feature map neural networks, *Photogrammetric Engineering & Remote Sensing*, 66, (12), pp. 1451-1460.

[11] Mustapha, M. R., Lim, H. S. and M. Z. Mat Jafri, 2010. Comparison of neural network and maximum likelihood approaches in image classification. *Journal of Applied Sciences*, 10: pp. 2847-2854.

[12] Tedesco, M., Pulliainen, J., Takala, M., Hallikainen, M. and Pampaloni, P., 2004. Artificial neural network based techniques for the retrieval of SWE and snow depth from SSM/I data. *Remote Sensing of the Environment*, 90: pp. 76-85.

[13] Idrisi Taiga Tutorial, 2009, J. Ronald Eastman, Clark Labs, Clark University.