Development of Methodology for the Optimization of Classification Accuracy of Landsat TM/ETM+ Imagery in a Catchment Area in Cyprus

Dimitrios D. Alexakis[1], Diofantos G. Hadjimitsis[1], Athos Agapiou[1], Adrianos Retalis[2] and Christiana Papoutsa[1]
[1]*Cyprus University of Technology, Department of Civil Enginnering and Geomatics, Limassol, Cyprus; dimitrios.alexakis@cut.ac.cy*
[2]*National Observatory of Athens, Athens, Greece*

Abstract. One of the important tools for detection and quantification of land cover changes across catchment areas is the classification of multispectral satellite imagery. Several techniques have been reported to improve classification results in terms of land use discrimination and accuracy of resulting classes. The aim of this study is to improve classification results of multispectral satellite imagery for supporting flood risk assessment analysis in a catchment area in Cyprus. Moreover, this paper describes the results obtained by integrating remote sensing techniques such as classification analysis and contemporary statistical analysis like maximum entropy for detecting urbanization activities in a catchment area in Cyprus. The final results were incorporated in an integrated flood risk management model. This study aims to test different material samples in the Yialias region in order to examine: a) their spectral behaviour under different precipitation rates and b) to introduce an alternative methodology to optimize the classification results derived from single satellite imagery with the combined use of satellite, spectroradiometric and precipitation data. This hypothesis was tested against Landsat derived reflectance values and validated with in-situ reflectance observations with the use of high spectral resolution spectroradiometers. In this way, this study aspires to highlight the potential of medium resolution satellite images such as those of Landsat TM / ETM+ for LULC studies under certain circumstances in the broader Eastern Mediterranean region.

Keywords. Land use, classification, remote sensing, Cyprus.

1. Introduction

One of the important tools for detection and quantification of land cover changes across catchment areas is the classification of multispectral satellite imagery. Such results are very important for hydrological analysis and flood scenarios.

Several techniques have been reported to improve classification results in terms of land use discrimination and accuracy of resulting classes [1]. However, the multispectral images acquired from different satellite sensors suffer from serious problems and errors, such as radiometric distortions, areas with low illumination, physical changes of the environment, etc.

During the last years many studies have proved that the accuracy of classification of remote sensing imagery does not increase by improving the applied algorithms. This is due to the fact that classification is mainly depended from the physical and chemical parameters of the ground objects [2].

This study aims to test different material samples in the Yialias region (central Cyprus) in order to examine: a) their spectral behaviour under different precipitation rates and b) to introduce an alternative methodology to optimize the classification results derived from single satellite imagery with the combined use of satellite, spectroradiometric and precipitation data.

2. Study area and data

2.1. Laboratory spectroradiometric measurements

Located in the central part of the island of Cyprus the Yialias basin extends to an area of 110 km^2 (Figure 1). The island of Cyprus is located in the North-Eastern most corner of the Mediterranean Sea and, therefore, has a typical Eastern Mediterranean climate: the combined temperature–rainfall regime is characterized by cool-to-mild wet winters and warm-to-hot dry summers [3].

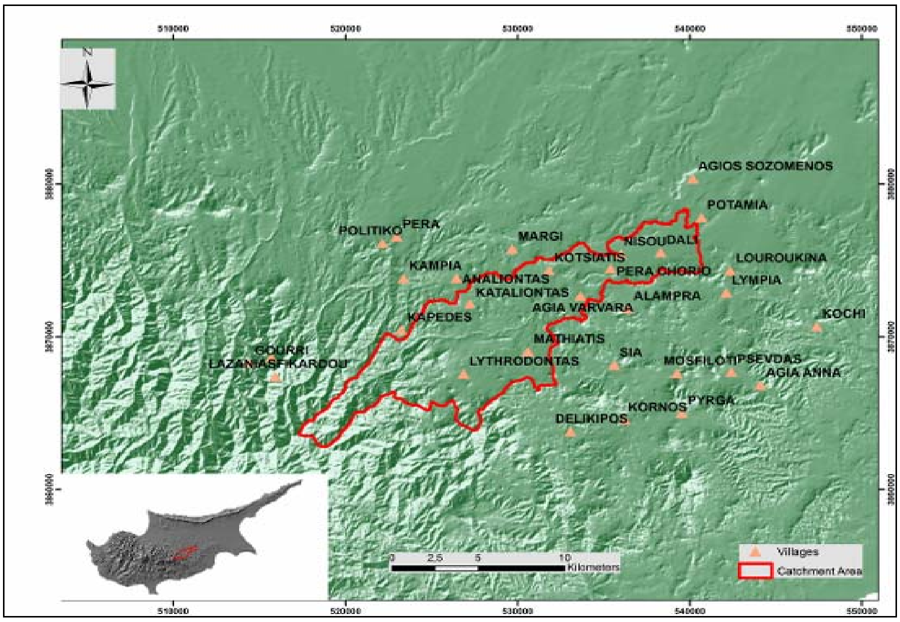

Figure 1: The study area.

2.2. Ground samples

According to some preliminary classification results [4] spectral mixing between urban areas and specific geological formations were observed. Thus, samples of regolith and construction material were collected and tested for their spectral response under different conditions of humidity with the use of spectroradiometer in the premises of the Remote Sensing and Geomatics Laboratory of Cyprus University of Technology.

2.3. Satellite and precipitation data

For the purposes of the study, the above tools and data were incorporated:

- Four Landsat TM/ ETM+ multispectral images of medium resolution (30x30 m^2 pixel size).
- Precipitation data obtained from the Meteorological Service of Cyprus (Pera Chorio Meteorological Station). All these data were compared with the satellite imagery data. The acquired images were selected a day after the record of substantial scaling amount of precipitation from the Pera-Chorio Metereological Station.
- Data derived from spectroradiometric field campaigns. For this reason the GER 1500 spectroradiometer was used. This instrument can record electromagnetic radiation between 350 nm up to 1050 nm.

3. Measurements

3.1. Laboratory spectroradiometric measurements

For the purposes of this study five different targets from the Yialias watershed basin were selected and their corresponding samples were collected. These were three samples (by the name A, B, C with different percentage of chalk content, collected from three different places of the catchment area) of marl-chalk outcrops from three different areas within the watershed (the B sample was a little more whitish than the others), a sample of tile and a sample of construction material (roof house). The first three samples represent regolith and the other two urban fabric materials. At the next stage all the samples were used in order to extract their spectral signatures in the premises of the Laboratory of Remote Sensing and Geomatics of Cyprus University of Technology - CUT (Figure 2). For that purpose, ten measurements were carried out consecutively for each different sample and a final mean measurement, corresponded to Landsat TM / ETM+ bands was extracted from each of them.

In order to search the different spectral response of each sample under different moisture conditions, all samples were sunk in water in a step-by-step process and measured for the rate of their humidity with the use of a soil moisture meter.

The specific hand-held instrument used in this study could measure moisture values from 0 to 50% within an accuracy of 0.1%. The final under investigation regolith samples were divided in four different categories according to their level of humidity: 0% (dry sample); 25%; 50%; > 50%. Concerning tile and roof specimens the results were divided to “dry” or “humid” categories due to the difficulty to measure the scaling levels of humidity in those kinds of materials.

Based on the results of the scatter - plots it was proved that in the case of dry samples there is a strong spectral confusion between the chalk A response and the urban fabric (roof and tile) materials. The “moisture” scatter plot (humidity > 50%) highlights the different spectral response between artificial materials (roof and tile) and natural materials (chalk A, B, C). In this plot, the spectral difference between different samples is increased and two major clusters are created with complete contrary spectral response (Increase of chalk A spectral response and substantial decrease of tile and house roof (constructed by clay and cement consecutively) spectral response) (Figure 3).

The results highlighted once again the different spectral response of materials under different humidity levels. Specifically, reflectance values of chalk samples (samples A and C) tend to be separated from those of urban samples (tile and roof) as humidity increases.

Figure 2: Collection of soil data (left). Spectroradiometric measurements of material samples at the premises of the Remote Sensing and Geomatics Laboratory of CUT (right).

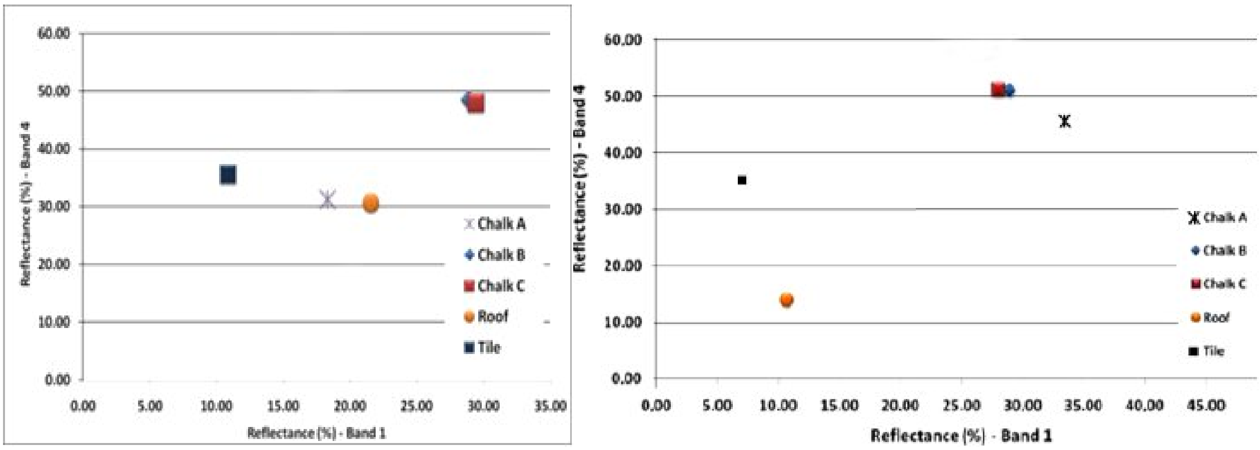

Figure 3: Scatter-plots of the different targets examined in this study for Band 1 – Band 4(humidity 0%) (left) and Band 1 - Band 4 of Landsat (humidity > 50%) (right).

3.2. Satellite imagery data

After the application of all the necessary pre-processing steps, spectral signature profiles were extracted for all the different materials during different acquisition dates of satellite images (Figure 4). The results of the scatter plots denoted the scaling optimization of spectral separability of satellite imagery data from 0 to 23.7 mm of precipitation. Specifically, concerning 0 mm precipitation case, a spectral confusion was indicated between the “urban” targets (roof and tile) and chalk A and C targets. This conflict was outreached gradually as the precipitation level increased. The samples started to have different spectral behaviour, with the chalk samples (except chalk B) standing gradually away from the “urban” samples cluster in the scatter-plot. It is important to mention the quite different spectral response of chalk C sample in satellite images compared to its response in the laboratory specimens. This problem was occurred due to the medium spatial resolution of Landsat images (30 m pixel size) that increases the highly common mixing pixel phenomenon.

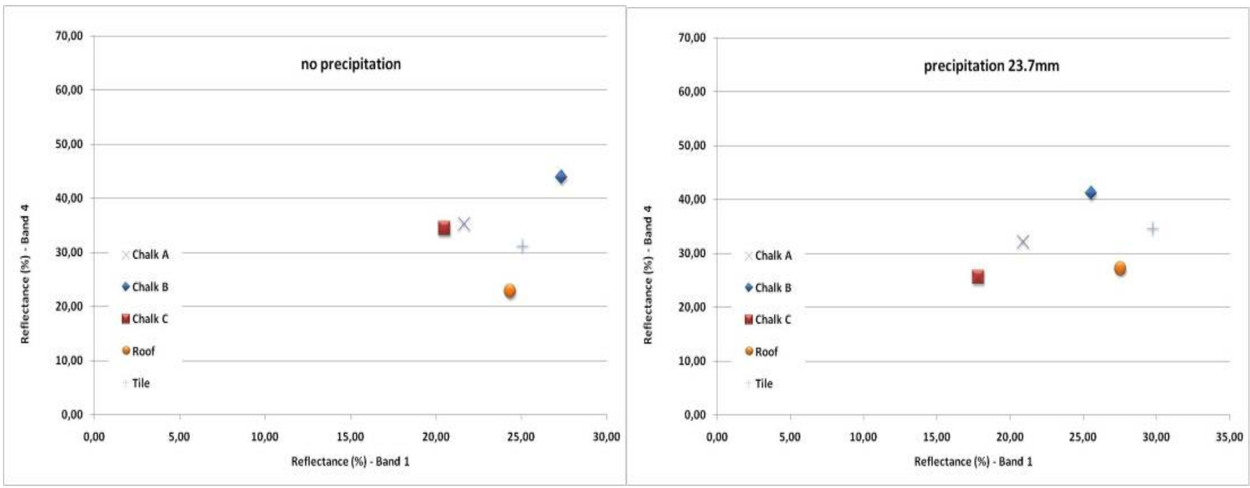

Figure 4: Scatter-plots of the different targets examined in this study for Band 1 – Band 4 (left) and Band 3 - Band 4 of Landsat (right).

4. Results and verification

The results from the laboratory and satellite imagery analysis methods highlighted the different spectral response of materials to different levels of humidity. For the direct comparison of the classification accuracy between images, where different levels of precipitation have been recorded, two Landsat TM/ETM+ images acquired at 02 June 2005 (0 mm precipitation - A) and 23 July 2009 (23.7 mm precipitation - B) were classified and compared (Figure 5). Both unsupervised (ISODATA) and supervised classification algorithms (ML) were used. Initially, the ISODATA classification technique was applied to both images with 95% convergence threshold. The following 5 classes were used for both the supervised and unsupervised algorithms: 1) urban Fabric, 2) marl - chalk formations 3) vegetation 4) bare soil and 5) forest. The same classes were created for the supervised technique in both images as well. Concerning the results of unsupervised algorithm for both dry and humid acquisition days they can be described as poor and cannot be evaluated (K< 60%). On the other hand, the application of supervised algorithm to "rainy" image was effective, providing good accuracy results ($K = 0.75$). The product of "dry" image was substantially better than that of unsupervised case but not accurate enough in order to be considered as credential.

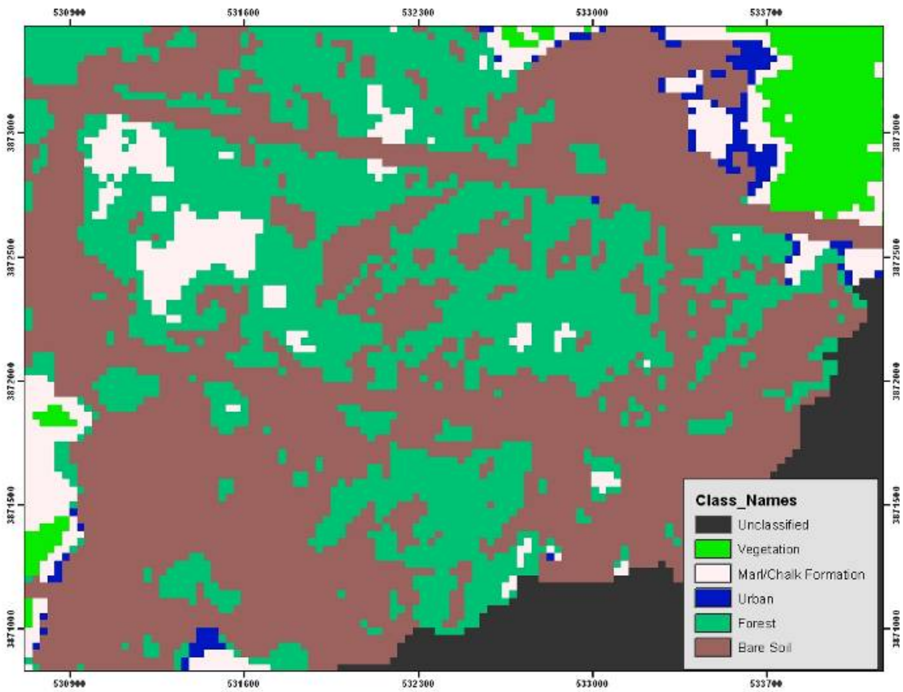

Figure 5: Detail of the "rainy" satellite image after the application of supervised classification algorithm.

5. Conclusions

The results denoted the importance of imagery acquisition date for optimization of classification results. Specifically, the overall accuracy of classification product was substantially increased (more than 30% for supervised classification), especially for urban and marl/chalk areas, during days where high precipitation measurements were recorded in the broader study area. The results were established either by laboratory or by satellite imagery analysis.

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