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Coastal Water Quality Monitoring in Cyprus using Satellite Remote Sensing

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Abstract

Knowledge of the current ecological state is of vital importance for coastal zone management. Due to the optical complexity of coastal waters compared to the open ocean, more sophisticated instruments and algorithms are needed to derive relevant variables. Satellite remote sensing allows the spatial and temporal assessment of various physical, biological and ecological parameters of water bodies on global and regional scales. Indeed, this project presents the methodology and results obtained by using satellite remote sensing for assessing quality spatial and temporal variations in the coastline of Paphos and Limassol District areas in Cyprus. In-situ spectraradiometric measurements have been collected to retrieve the surface reflectance of the coastal waters so as to validate our proposed methodology. Time series Landsat-5/7 TM/ETM+ images have been used. Such coastal water quality assessment can assist the Blue-Flag Programme in these areas.

Keywords: coastal water quality, remote sensing, Landsat TM/ETM+, spectroradiometer

1. INTRODUCTION

Methods currently used to monitor water quality across the landscape consist of in situ measurements or collection of water samples for analysis in the laboratory. Such techniques, while are considered accurate for a sampling point in time and space, however are time consuming and expensive and do not give the synoptic views of the landscape necessary to allow management decisions that can effectively control or improve water quality. Not only is the water sampling time and labor consuming, but the required number of samples would also practically hinder such implementation. An integration of remote sensing technique and seawater sampling is therefore more appealing and worth pursuing. Using remote sensing data to assess the quality of water bodies has proven to be successful not only in inland waters but to coastal water areas as shown by several other conducted studies [1, 2, 3, 4, and 5]. The main objective of this study is to use firstly Landsat TM/ETM data to evaluate the potential of using such remotely sensed digital data, to extract information that help in the monitoring system for Cyprus coastal water quality. A Landsat TM scene covers most of the Island [6] so an entire image covers all the beaches that are included in the Blue-Flag Programme. Initially this study is set to assist for alerting the local authorities in the case where 'increase' of reflectance values are occurred during the summer period in which Blue-Flag programme is running.

2. MATERIALS AND METHODS

2.1 Satellite Imagery

The availability of cloud free images for operational projects is very important and depends on the geographical position and the prevailing weather conditions for the area of interest. Countries such as Greece and Cyprus are characterised by good weather conditions and the availability of cloud-free images. This is important when using satellite remote sensing in multi-temporal studies of those areas. The availability of cloud-free images in the Mediterranean and especially in Greece and Cyprus increases the potential of using satellite remote sensing techniques for those areas [6].

2.2 Pre-processing of satellite imagery

Remotely sensed data are subjected to preliminary corrections upon their download to the ground receiving stations. Next, pre-processing is needed. Pre-processing refers to those operations that are proceeding to the main analysis, and include *geometric* and *radiometric corrections* (mainly sensor calibration and atmospheric correction). [7]

Geometric correction: In this case, geometric correction was carried out using standard techniques with ground control points (GCP's). Well-defined features such as road intersections, airport runway intersections, bends in rivers and corners of inland water bodies were chosen as GCP's. All images were ortho-rectified to a Universal Transverse Mercator grid using the nearest neighbour resampling method. Geometric correction was carried out using standard techniques with ground control points and a first order polynomial fit.

Sensor Calibration: In the case where the user needs to compare images acquired at different times or from different sensors or if remotely sensed data are to be used to determine reflectance values, digital numbers (DN) must be converted to radiance or reflectance. Calibration in units of radiance or reflectance is an important processing step before atmospheric correction can be applied. Indeed, the three raw satellite images were converted into units of radiance and finally to at-satellite reflectance using calibration values given by the image provider.

Atmospheric Correction: Indeed, the darkest pixel atmospheric correction technique was also applied in the two Landsat TM/ETM+ satellite images. The darkest pixel (histogram minimum) was subtracted from each band [8].

2.3 Study Area

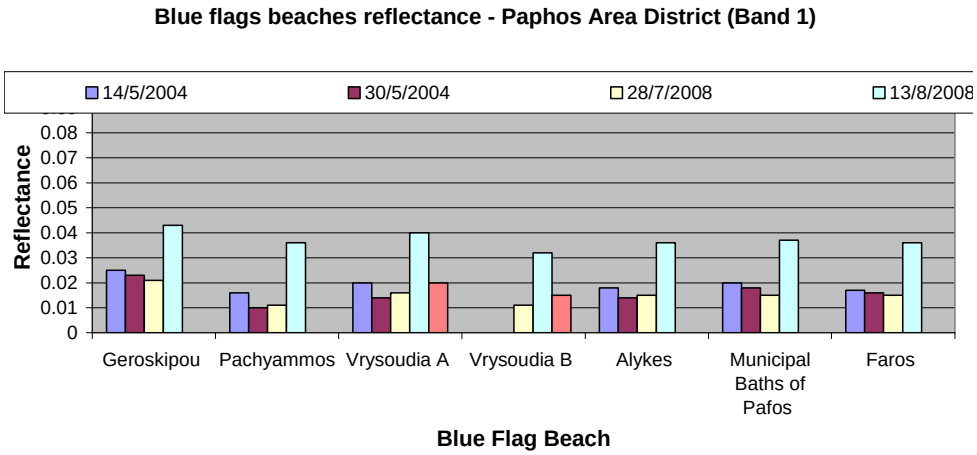
The project concentrates to the investigation of coastal water quality in all the beaches in the Cyprus region that included in the programme of the blue-flags. Figure 1 shows all the beaches in the coastal areas of Paphos and Limassol that are currently included in the Blue-Flags programme.

Figure 1. Blue flag beaches in the coastal area of (a) Limassol and (b) Paphos

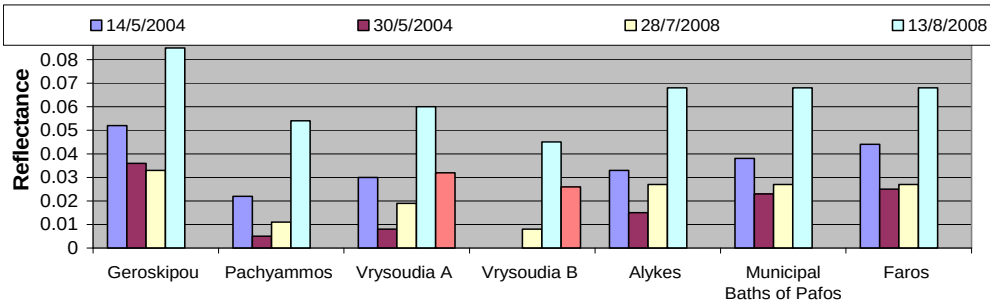
Figure 2. In-situ spectroradiometric measurements using the GER1500 field spectroradiometer and fibre-optic probe (13/8/2008, Paphos)

3. RESULTS

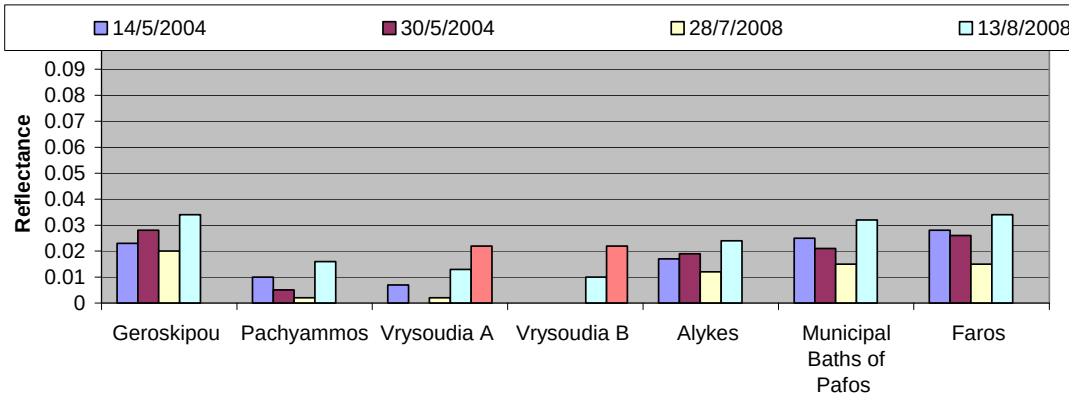
The determined average reflectance values after the removal of atmospheric effects in Landsat TM/ETM+ bands 1, 2, 3, 4 are shown in Figure 3 for Paphos and Limassol beaches. It has been found from previous studies that turbidity can be related with Landsat TM band 3 reflectances (after atmospheric correction). Indeed, looking through the results presented at Figure 4 for Paphos coastal areas the in-band 3 reflectance values ranged from 0.3 % to 3.4 % and for Limassol areas ranged from 0.2 up to 4.5 %. This means that there are no alerts for possible coastal water pollution or scenarios of high turbidity values. For the image acquired on the 13th of August 2008, there is evidence from our spectro-radiometric measurements acquired in-situ using the GER1500 field spectro-radiometer at Yeroskipou coastal area (Figure 2), that our retrieved reflectance values found after atmospheric correction are within the values found from the images.



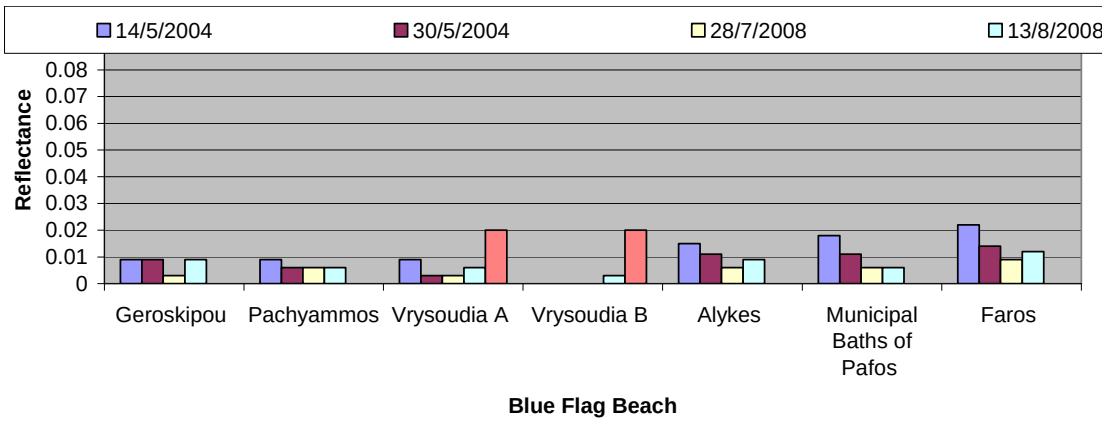
Blue flags beaches reflectance - Paphos Area District (Band 2)



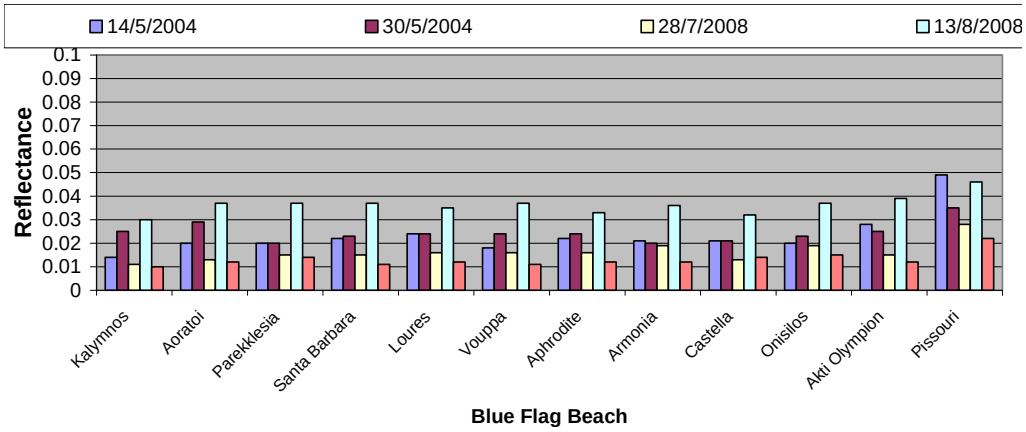
Blue flags beaches reflectance - Paphos Area District (Band 3)



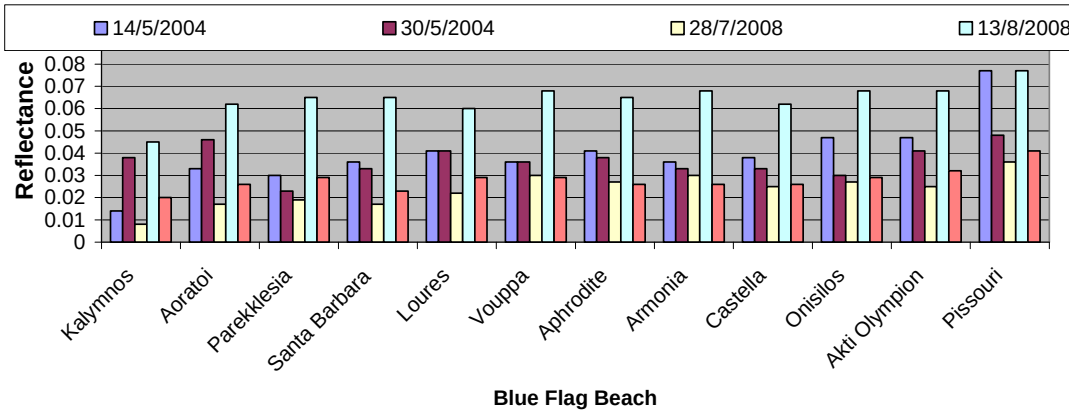
Blue flags beaches reflectance - Paphos Area District (Band 4)



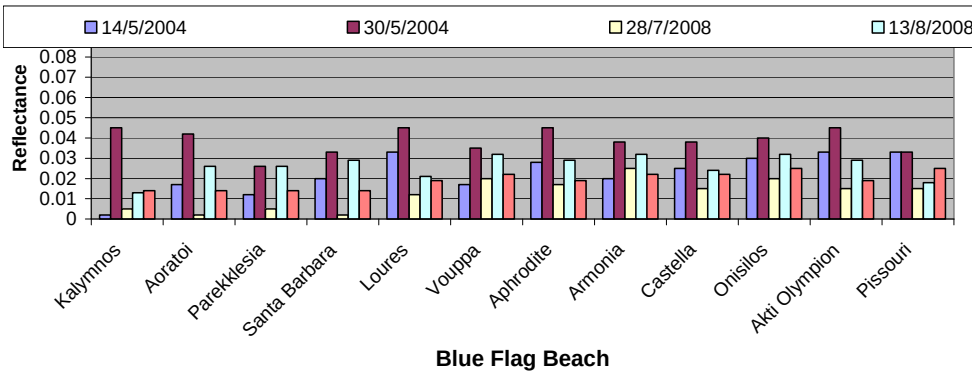
Blue flags beaches reflectance - Limassol Area District (Band 1)



Blue flags beaches reflectance - Limassol Area District (Band 2)



Blue flags beaches reflectance - Limassol Area District (Band 3)



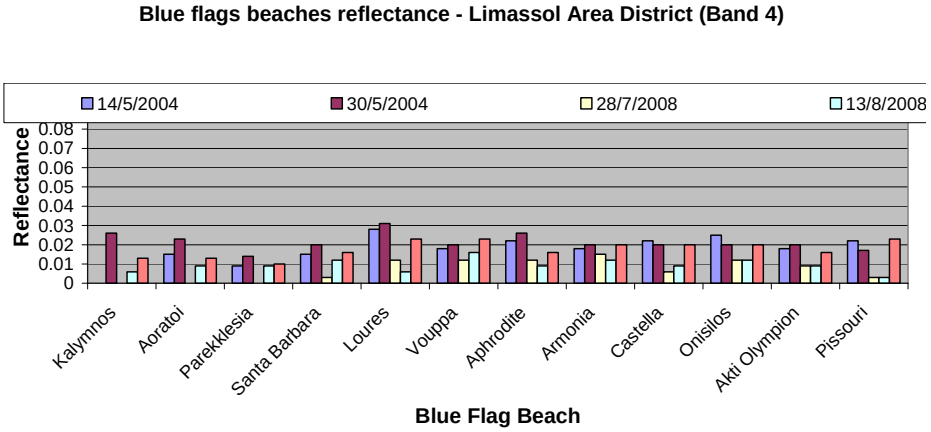


Figure 3. Reflectance after atmospheric correction in Landsat TM/ETM bands 1, 2, 3, and 4 for Paphos and Limassol coastal areas.

4. CONCLUSIONS

Satellite remote sensing information has been found to be useful for monitoring and qualitative evaluation of the coastal water quality conditions in beaches in the coastal areas of Cyprus. Spectro-radiometric in-situ measurements and water sampling (e.g. E-coli, turbidity, temperature etc) during the satellite overpass using Landsat and ASTER images are planned to be undertaken during the forthcoming summer period. This will permit the most effective and reliable assessment of the coastal water quality in coastal areas in Cyprus.

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