ABANDONED SETTLEMENTS DETECTION USING VERY HIGH RESOLUTION SATELLITE IMAGES: A CASE STUDY OF GÖKÇEADA (IMBROS) ISLAND, TURKEY

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Abstract: The aim of this study is focused on the detection and recognition of structural remains of the abandoned village of Vounaritsia in Gökçeada (Imbros) island, Turkey. For this purpose, a pan-sharpened QuickBird image has been used dated on 18/08/2004. Two different processing methods have been applied, the Principal Component Analysis and the Tasseled Cap Transformation. By examining the products of the two methods, we conclude that mainly the first principal component analysis image from the four components of the analysis and the brightness image of the TCT show excellent results in detection and recognition of the structural remains (masonry remains) and enhanced by applying an edge enhance filter.

Περίληψη*:* Σκοπός της συγκεκριμένης εργασίας είναι η ανίχνευση και αναγνώριση των ερείπιων του εγκαταλελειμένου χωριού Βουναρίτσια που βρίσκεται στην Ίμβρο (Τουρκία). Για αυτό τον λόγο, χρησιμοποιήθηκε μία πανγχρωματική εικόνα του δορυφόρου QuickBird, της οποίας η λήψη έγινε στις 18/08/2004. Χρησιμοποιήθηκαν δύο μέθοδοι επεξεργασίας, εκείνη των κύριων συνιστωσών και του μετασχηματισμού Kauth-Thomas. Εξετάζοντας τα παραγόμενα ποϊόντα των δύο μεθόδων, καταλήγουμε στο συμπέρασμα ότι η πρώτη κύρια συνιστώσα από τις τέσσερις και η εικόνα της φωτεινότητας που παράχθηκε από τον μετασχηματισμό Kauth-Thomas, δείχνουν πολύ ωραία αποτελέσματα όσον αφορά την ανίχνευση και αναγνώριση των ερείπιων (τοίχοι των κτιρίων) τα οποία βελτιώθηκαν ακόμη περισσότερο εφαρμόζοντας το φίλτρο βελτίωσης των ακμών.

Keywords: QuickBird, PCA, TCT, detection, masonry remains, Gökçeada island
Λέξεις κλειδιά: QuickBird, Ανάλυση Κυρίων Συνιστωσών, μετασχηματισμός Kauth-Thomas, ανίχνευση, ερείπια, Ίμβρος

1. Introduction

Gökçeada (Imbros) island (Turkey) is located on the north Aegean Sea just at the exit of the Dardanelles (Figure 1). During the last four decades several transformation processes as well as strong economic and socio-structural changes took place, affecting the natural and anthropogenic environment. The island was primarily inhabited by ethnic Greeks from ancient times through to approximately the middle of the twentieth century. Data dating from 1922 taken under Greek rule and 1927 taken under Turkish rule showed a strong majority of Greek inhabitants on Imbros had a strong presence on the island.

The present study concerns the detection of abandoned settlement of Vounaritsia after the exodus of the population in early 1960's, using very high resolution (VHR) satellite images and advanced processing methods. The case study is located in the south-eastern part of the island and specifically in between the Tuzla Lake and the new settlement of Eselek on a small hill (Figure 1). The south-eastern area of the island presents a smooth anaglyph with an average altitude of 100 meters (Koral et al., 2008).

It is mostly an agricultural area that produces fruit and vegetables. Between 1964 and 1984, almost all the usable land on Imbros had been expropriated, for inadequate compensation, for an army camp, a minimum-security prison, reforestation projects, a dam project, and a national park. The Vounaritsia village had been used for seasonal residence, for people coming from long distance to the local working area (agricultural fields).

Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.

Figure 1. Location map

2. Image data, methodology and processing

For the current investigation a Pan-sharpened QuickBird image (4 bands) has been used acquired on August 18th 2004 at 09:05 UTC time. In order to highlight the abandoned settlements, we used two techniques. The first one was the Principal Component Analysis and the second one the Tasseled Cap Transformation (TCT). In Table 1 the main characteristics of the QuickBird satellite are shown.

The Principal Components Analysis (PCA) is a statistic technique of many variables, which chooses non-correlated linear compositions of variables in such a way that each output principal component shows the minimum variance. In this study standardized PC transformations were carried out using 4 bands (3 visible and a reflected infrared band). The analysis of eigenvalues and eigenvectors, in combination with the principal components interpretation, allow us to choose the component images which are suitable in order to recognize abandoned settlements.

The TCT technique is a linear affine transformation based on the convention of given input channel dataset in a new dataset of composite values. The TCT is performed on a pixel basis to enhance the underlying structure of the image by using weight sums of the input channels.

Table 1. Main characteristics of the sensors on board the QuickBird Satellite

Parameter	Panchromatic imagery	Multispectral imagery (4 bands)
Spectral range(s)	0.45 - 0.90 μm, grayscale	0.45-0.52, 0.52-0.60, 0.63-0.69, 0.76-0.90 μm
Spatial resolution, IFOV	0.61-0.72 m (GSD), 1.37 μrad	2.4-2.6 m (GSD), 5.47 μrad
Swath width, FOV	16.5 km (450 km altitude), 2.12°	
Camera	Pushbroom array (11 bit pixels)	Pushbroom arrays (11 bits x 4)
Detector array	27,000 pixels	6,700 pixels x 4
S/C body pointing capability	±30° (along-track/cross-track) providing a ±544 km wide field of regard (FOV) in the cross-track direction	
Pointing accuracy	≤ 0.5 mrad absolute per axis	
Geolocation of data	≤15 m (3 σ) after ground processing	
Imaging modes	Snapshot: 16.5 km x 16.5 km (single scene) Stripmap mode: 16.5 km x 225 km Area (mosaic patterns): 32 km x 32 km (typically) Stereo: 16.5 km x 16.5 km typically; in along-track direction (single pass)	
Data quantization	11 bits	
Data size/ PAN scene	8 Gbit (uncompressed), 1.5 Gbit (compressed)	

Then, the data set has been processed by applying the Principal Components Analysis (PCA), which is a multivariate statistical technique. PCA chooses non-correlated linear compositions (eigenvectors) of variables in such a way that each output principal component (linear composition)

Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.

shows the minimum variance. These variables in the multispectral images are related to the spectral response of various surface characteristics. One of the important features of PCA is that it produces totally uncorrelated images, thereby removing redundancy in the original data sets (Mather, 1998).

In this study standardized PC transformations were carried out using 4 bands and the analysis of eigenvalues and eigenvectors as well the visual interpretation has assisted us to clarify the contribution to the task of each pc image.

Next, the Pan-sharpened QuickBird bands were processed to obtain the so-called Tasseled Cap Features (TC). The TCs, also known as Kauth-Thomas Transforms, are utilized for enhancing spectral information content of satellite data (Crist et al., 1986).

The TCT is performed on a pixel basis to enhance the underlying structure of the image by using weight sums of the input channels.

In this case, three composite variables tasseled cap transformed bands have been generated. TCT- band1, which is the weighted sum of all spectral bands and can be considered as the overall brightness of the surface, TCT-band2, which measures the contrast between the VIS bands and NIR bands and it's similar to vegetation index and TCT-band3, which can be interpreted as a measure of soil and moisture.

The transformation depends on the considered sensor. The original TCs firstly were derived (Kauth et al., 1976) for the four bands of the Landsat MSS sensor. Later, the TC transformation was extended to the Landsat TM (Crist et al., 2002), ETM and IKONOS sensor (Horne, 2003). As far as QuickBird satellite is concerned, the coefficients to compute the TCs for this study were taken from (Yarbrough et al., 2005). The TCT coefficients for QuickBird DN 11-bit data derived using the Gram-Schmidt Orthogonalization Process are showing in Table 2:

Table 2. The TCT coefficients for QuickBird

Brightness	Greeness	Wetness	Forth Band
0.319	-0.121	0.652	0.677
0.542	-0.331	0.375	-0.675
0.490	-0.517	-0.639	0.292
0.604	0.780	-0.163	0.011

where the column eigenvectors of the matrix represent the coefficients for each spectral band.

The resulting TCs covering the study area were combined as False Colour Composite (FCC), where Brightness, Greenness and Wetness are respectively displayed as Red, Green and Blue.

Finally, spatial enhancement of the produced images was obtained by applying high pass filtering.

3. Results

It was expected that the TCT bands should provide improved results in order to detect the abandoned settlements.

Whereas, unsatisfactory results were obtained from TCT bands (wetness, greenness and the fourth), the first TCT band (brightness) tends to capture meaningful information to highlight the abandoned village. The first component obtained from both the TCTs is a weighted sum of all bands in the direction of principal variation in soil reflectance, thus including more soil reflectance or brightness information (Figure 4a). The second TCT band, was not able to extract meaningful features of any interest. This was widely expected being that these TCT bands are the greenness axis, which tends to describe the spectral contrast (mainly emphasized in the NIR band) between the bare soil and areas covered by vegetation. Such a contrast was merely present in study area, which was scarcely vegetated when the satellite image were acquired.

The wetness product (Figure 4c) was expected to enhance the no-humid features that are generally characterized by pixels of a higher brightness digital numbers. The building materials, mostly rubble stones, tend to reduce soil humidity content; thus, increasing the spectral values compared to the surrounding area. In practice though, the wetness product did not appear to be capable of clearly distinguishing variability in the soil moisture content. Finally, the greenness and fourth product did not provide any interesting results.

Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.

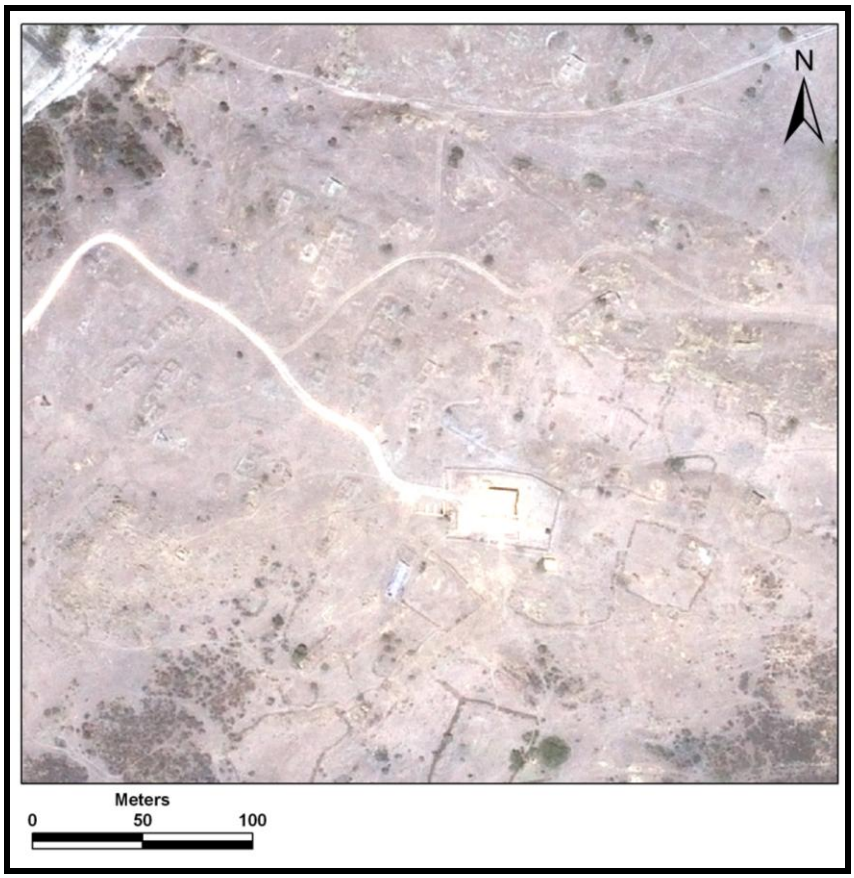

Figure 2. The QuickBird image of the study area

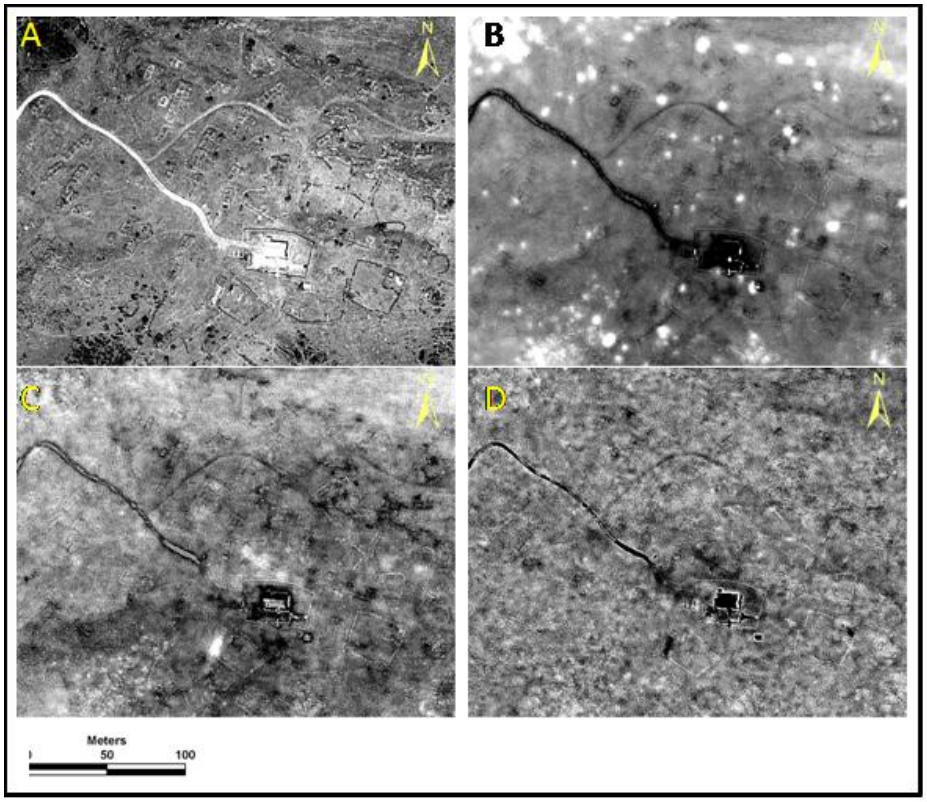

Figure 3. The Principal Component Analysis. A) PCA-1, B) PCA-2, C) PCA-3, D) PCA-4

Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.

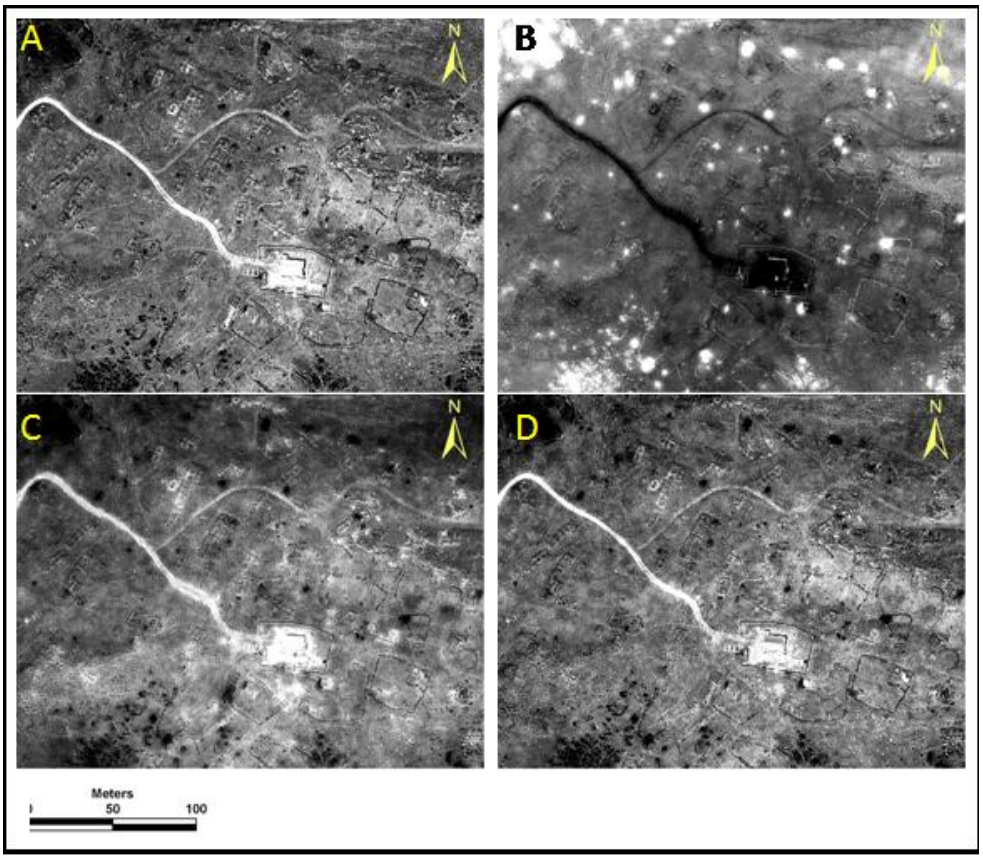

Figure 4. The tasseled cap transformation. A) brightness, B) greenness, C) wetness and D) fourth component

The application of PCA to the four QuickBird spectral images provides a new set of four uncorrelated components. Principal Component Analysis provided the best results in its component 1. Components 2,3,4 are characterized by poor information or noisy content especially the fourth component.

In conclusion, the first principal component and the brightness product provide us with similar level of information concerning the old settlement of Vounaritsia making feasible to identify the area of the old village.

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Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.

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Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ.