

Features Extraction of Landsat 7 Images Using Tasseled Cap Transformation*

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Abstract: Many of digital processing techniques are used to extract most of the possible information from satellite images, one of these techniques is Tasseled Cap band transformation. This research aims to study the effect of band transformation on the amount and quality of information extracted from Landsat 7 ETM+ images. Multispectral image classification based on raw and Tasseled Cap transformed band were applied. The results showed that the Tasseled Cap give good spectral enhancements and feature extraction which are undistinguishable in raw image, and represent good tool to increase the accuracy of classification.

keywords: Tasseled Cap, Landsat 7, ETM+, Classification.

استخلاص الملامح من صور القمر الصناعي Landsat 7 باستخدام تحويل Tasseled Cap

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المستخلص

العديد من التقنيات الرقمية يتم استخدامها لاستخلاص معظم المعلومات الممكنة من صور الأقمار الصناعية، ومن هذه التقنيات هي تحويلات حزم Tasseled Cap. يهدف البحث لدراسة تأثير تحويلات الحزم الطيفية على كمية ونوعية المعلومات المستخلصة من صور المتحسس ETM+ للقمر الصناعي Landsat 7 الخاص بالمراقبة البيئية.

تم تطبيق تصنيف صور الأقمار الصناعية للصور الخام (الأصلية) وللصور المحولة بطريقة Tasseled Cap، حيث بينت النتائج ان تحويلات Tasseled Cap وفرت تحسينات طيفية واستخرجت معلومات وخصائص أرضية لم تكن واضحة في الصور الخام (الأصلية) حيث ان هذه التحويلات تمثل أداة جيدة لزيادة دقة تصنيف صور الأقمار الصناعية.

الكلمات المفتاحية: Tasseled Cap ، القمر الصناعي Landsat 7 ، المتحسس ETM+ ، تصنيف صور الأقمار الصناعية.

Introduction

In 1976, Kauth and Thomas produced a transformation of the original Landsat MSS data space to a new four dimensional spectral space. It was called the Tasseled Cap or Kauth-Thomas transformation. Tasseled Cap Transformation (TCT) is one of the available methods for enhancing spectral information content of Landsat ETM+ data. It attempts to reduce the amount of data layers (dimensionality) needed for interpretation or analysis by using mathematical equations to transform the

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original bands into new dimensional space. The transformation consists of linear combinations of the four MSS bands to produce a set of four new variables [1]:

$$\left. \begin{aligned} \text{TC1} &= +0.332\text{MSS1} + 0.603\text{MSS2} + 0.675\text{MSS3} + 0.262\text{MSS4} \\ \text{TC2} &= -0.283\text{MSS1} - 0.66\text{MSS2} + 0.577\text{MSS3} + 0.388\text{MSS4} \\ \text{TC3} &= -0.899\text{MSS1} + 0.428\text{MSS2} + 0.076\text{MSS3} - 0.041\text{MSS4} \\ \text{TC4} &= -0.016\text{MSS1} + 0.131\text{MSS2} - 0.452\text{MSS3} + 0.882\text{MSS4} \end{aligned} \right\} \quad (1)$$

Both multi- and hyperspectral data have highly correlated bands. TCT not only compresses several bands into few bands but also decorrelates them by transforming them orthogonally into a new set of axes associated with physical features. Traditionally, three axes were defined: (I) Brightness, (II) Greenness and (III) Wetness. Firstly, a rotation was defined to separate the vegetation from non-vegetated features by maintaining the orthogonal property between I and II components. Then, rotating components II and III orthogonally separated the water from vegetation features. Finally, orthogonal rotation between components I and III was implemented in order to separate water from features of vegetation and non-vegetation [2].

Brightness – the first feature of TCT – is a weighted sum of all the bands and accounts for the most variability in the image. It is typically associated with bare or partially covered soil, natural and man-made features, and variations in topography. Greenness is a measure of the contrast between the NIR band and the visible bands due to the scattering of infrared radiation resulting from the cellular structure of green vegetation and the absorption of visible radiation by plant pigments. Soil reflectance curves (soil signatures) are represented with higher values in ‘Brightness’ while they are expressed in low ‘Greenness’ values. The third component is orthogonal to the first two components and is associated with soil moisture, water and other moist features [3].

There are three planes associated with these features: the plane of soils (Brightness/Wetness space), the transition zone (Greenness/Wetness space) and the plane of vegetation (Brightness/Greenness space). Pre-planting field having bare soil will be analysed best in the plane of soils. After planting, it would shift up through the transition zone towards the plane of vegetation as the crops matured and then would ‘tassel out’ with senescence. All these phases of plots would together form the shape of a ‘tasselled cap’.

Until recently, there were no standards for deriving the orthogonal rotation coefficients due to the pluralistic interpretation of the tasselled cap features [4]. Any number of TCTs may be developed if the choice of aligning these three axes is left to the discretion of a researcher. Since the launch of Landsat 8 in 2013, it was being demanded by researchers working on vegetation how to use TCT for this new sensor in a same way they used it for other sensors.

These new bands are designated as, for example, “TC1”, “for Tasseled Cap band 1”. Although these four new bands do not match directly to observable spectral bands, they do carry specific information concerning agricultural scenes [5]. It can therefore incorporate more information than ratio or modified ratio indices (like most vegetation indices) [6].

TC1 interpreted as brightness, a weighted sum of all four bands. TC2 is designated as greenness, a band that conveys information concerning the abundance and vigor of living vegetation. TC3 depicts yellowness, derived from the contrast between red and green bands. Finally, TC4 is referred to as nonsuch because it cannot be clearly matched to observable land space features and is likely to carry system noise and atmospheric information [5].

The first two bands (TC1 and TC2) usually convey almost the information present in an agricultural scene often 95% or more. Therefore, the essential components of an agricultural landscape are conveyed by a two-dimensional diagram, using TC1 and TC2 as shown in figure (1) [5].

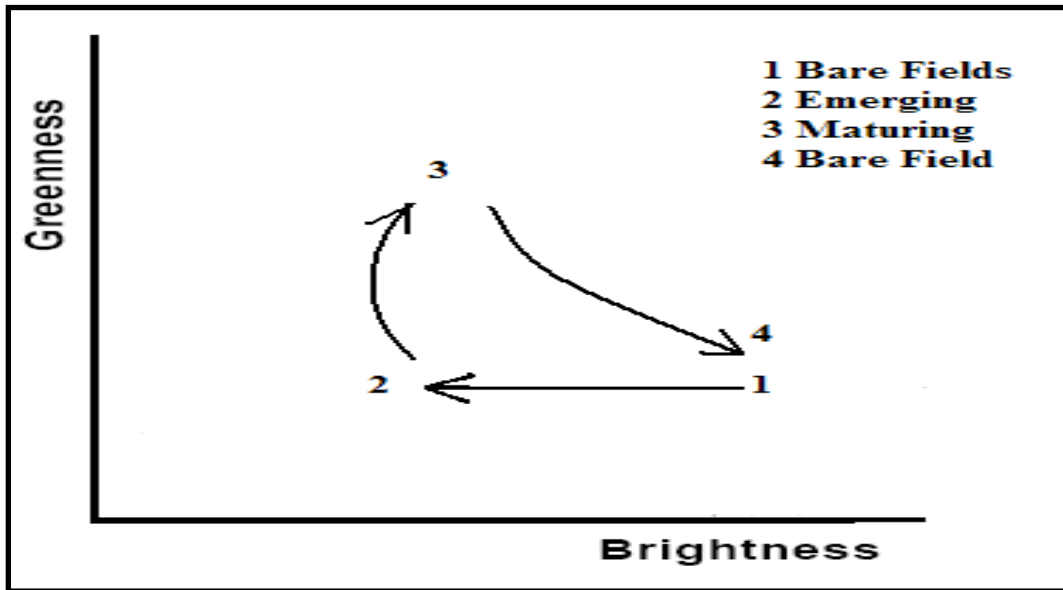


Fig. 1: Seasonal variation of a field is defined by Greenness and Brightness [5]

Figure (1) shows a plot of data which is physically-based on crop growth. The growing cycle of crop started from bare soil, then to green vegetation and then to crop maturation with crops turning yellow. This different stage of vegetation growth has made the data distribution in the two dimensional multispectral space as shown in figure (2) which appear in a shape of cap [7].

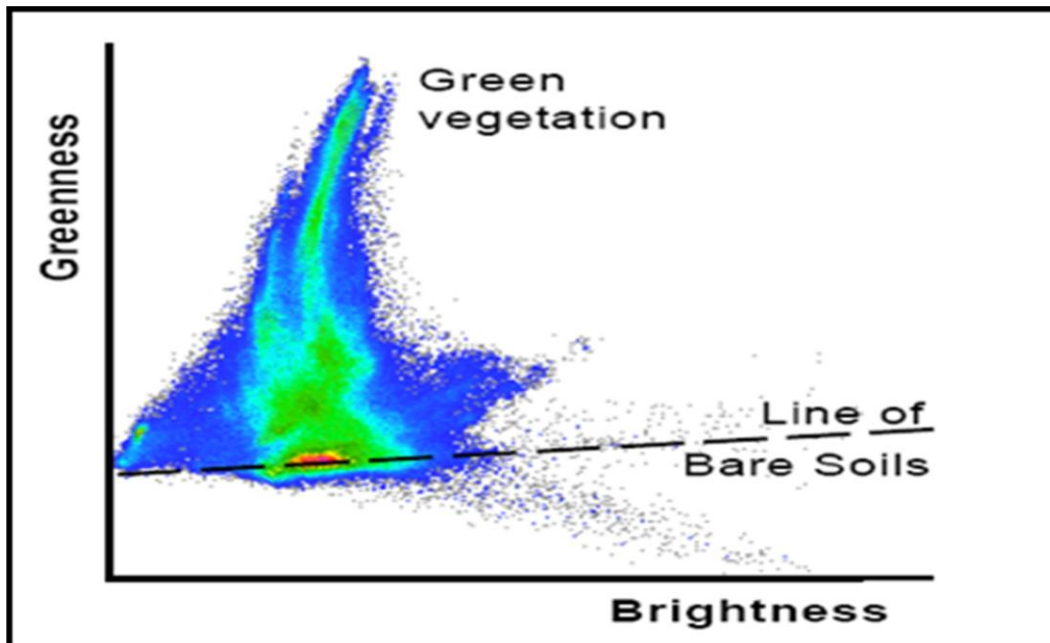


Fig. 2: 2D scatter plot of two Tasseled Cap components [6]

The Tasseled Cap transformation on six non-thermal bands of Landsat TM or ETM+ data can be performed using the following formulas [5]:

$$\begin{aligned}
 \text{Brightness} &= 0.3037(\text{TM1}) + 0.2793(\text{TM2}) + 0.4743(\text{TM3}) \\
 &\quad + 0.5585(\text{TM4}) + 0.5082(\text{TM5}) + 0.1863(\text{TM7}) \\
 \text{Greenness} &= -0.2848(\text{TM1}) - 0.2435(\text{TM2}) - 0.5436(\text{TM3}) \\
 &\quad + 0.7243(\text{TM4}) + 0.0840(\text{TM5}) - 0.1800(\text{TM7}) \\
 \text{Wetness} &= 0.1509(\text{TM1}) + 0.1973(\text{TM2}) + 0.3279(\text{TM3}) \\
 &\quad + 0.3406(\text{TM4}) - 0.7112(\text{TM5}) - 0.4572(\text{TM7})
 \end{aligned} \tag{2}$$

If the greenness and brightness components of a typical scene are plotted perpendicular to one another on a graph to display the distribution of the data in spectral plot, the shape of data plot is look like a cap, so that the name of Tasseled Cap comes from this fact, as shown in figure (2).

Classification

In remote sensing satellite images, data provide the most significant clues about what is on the ground, the spectral data in a scene can be recorded with multispectral images. Each pixel in a multispectral image has spatial coordinates x & y and spectral coordinates λ . It has characterized by its spectral signature, which is determined by the relative reflectance in different wavelength bands. Multispectral classification is a data extraction process that analyzes these spectral signatures then assigns pixels to categories based on similar signatures [8].

There are two broads of classification procedures: supervised classification and unsupervised classification. The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data [9]. Using this method, the analyst has available sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. The most commonly used supervised classification is maximum likelihood classification (MLC), which assumes that each spectral class can be described by a multivariate normal distribution. Therefore, MLC takes advantage of both the mean vectors and the multivariate spreads of each class, and can identify those elongated classes. However, the effectiveness of maximum likelihood classification depends on reasonably accurate estimation of the mean vector m and the covariance matrix for each spectral class data [6]. Another broad of classification is unsupervised classification. It doesn't require human to have the foreknowledge of the classes, and mainly using some clustering algorithm to classify an image data [9].

Data and Method

The study area is Al-Kut city and its neighboring areas. The centre of Al-Kut city is located at latitude $30^{\circ} 30' N$ and longitude $45^{\circ} 49' E$, it is the city in the eastern Iraq, about 100 miles south east of Baghdad. Close to the city lies the Kut Barrage, this distributes river water into irrigation canals. The study was performed using Landsat ETM+ images (six no thermal bands) of study area (path 167, row 38) acquired in 15th September 2002 as shown in figure (3).

**Band 1****Band 2****Band 4****Band 3****Band 7****Band 5****Fig. 3: 6 non thermal ETM+ band images**

Tasseled Cap transformation has been applied on the six non thermal bands of the study area, and then the classification process is applied on the raw bands and on the transformed bands. Supervised and unsupervised have been applied for the classification purpose.

All the basic image processing functions and techniques in this research are done by ENVI (the Environment for Visualizing Images) is a revolutionary image processing system. From its inception, ENVI was designed to address the numerous and specific needs of those who regularly use satellite and aircraft remote sensing data. ENVI provides comprehensive data visualization and analysis for images of any size and any type all from within an innovative and user-friendly environment.

Results and Discussion

Tasseled Cap transformation has been adopted on the six non-thermal ETM+ bands of study area. The production of Tasseled Cap consists of three main indices: brightness, which contains the most information, greenness, which conveys information about living vegetation since it displayed areas with vegetation as the lightest tone (white areas), and wetness which is concern with surface wetness where the river and canals appear as white as shown in figure (4).

Tasseled Cap transformation showed high ability to improve interpretability and extract information from the data which is not readily visible in the raw form of ETM+ data of the study scene.

Unsupervised classification has been performed using the Interactive Self Organizing Data Technique (ISODATA) with five clusters, and has been applied on raw bands and on Tasseled Cap components. This method considered an attempt of preprocessing to the supervised classification, in order to get better understanding about the spatial structure of image data. The results of unsupervised classification show good representation of some classes and merges among the others, figure (5).

A supervised classification method has been adopted on the images using Maximum Likelihood classification. The training samples (region of interests) have been selected and they are based on land cover and terrain. Five different land cover and land use classes were selected including water, vegetation, urban areas, crop lands, and bare lands. The selection of training areas was repeated several times to overcome the cases were some cover material could not be classified accurately and also to avoid as much as possible the overlapping between the classes. The classified images gave a good representation of the scene rather than unsupervised classification images, as shown in figure (6). Table (1) shows statistical parameters of supervised classification.

Conclusion and Recommendation

Tasseled Cap transformation showed high ability to improve interpretability and extract information from the data which is not readily visible in the raw form of ETM+ data of the study scene. The brightness component contains the most information, greenness, which conveys information about living vegetation since it displayed areas with vegetation as the lightest tone (white areas), and wetness which is concern with surface wetness where the river and canals appear as white as shown in figure (4).

The Supervised classification using Maximum Likelihood method gives good representation of the classes with overall accuracies of 87.18%, and 89.26% for raw bands and Tasseled Cap components respectively; this indicated that band transformation techniques increase the accuracy of the classification and extracted the features that are undistinguishable in raw bands, the limitation of this study is the resolution of satellite images bands, so this problem may be solved if we used images of hyperspectral bands for the same study area.

We recommend to use multi-temporal images for the same scene with the same transformation techniques to study the changes in the study area.

Using of Hybrid method for combining between bands and for choosing the type of image for the classification process, where some of topographic detail is discriminate between certain features, this technique may be used in the future works.



Brightness

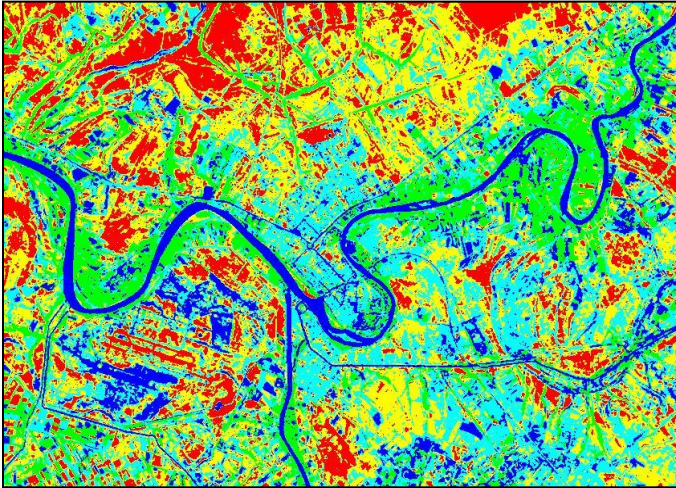


Greenness

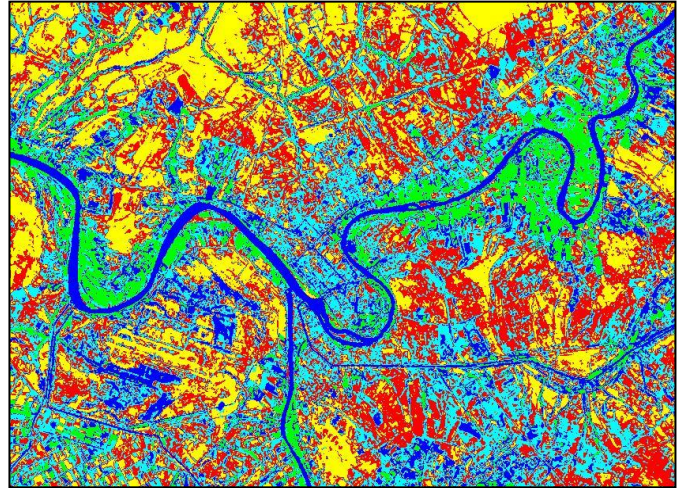


Wetness

Fig. 4: The first three Tasseled Cap transformation components

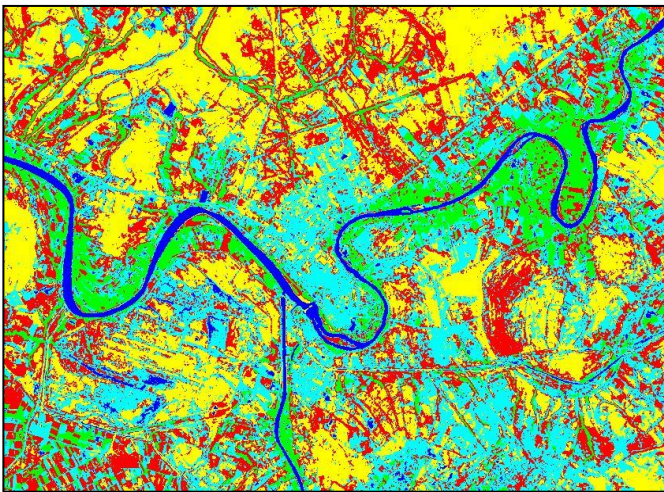


Unsupervised Classification of raw bands

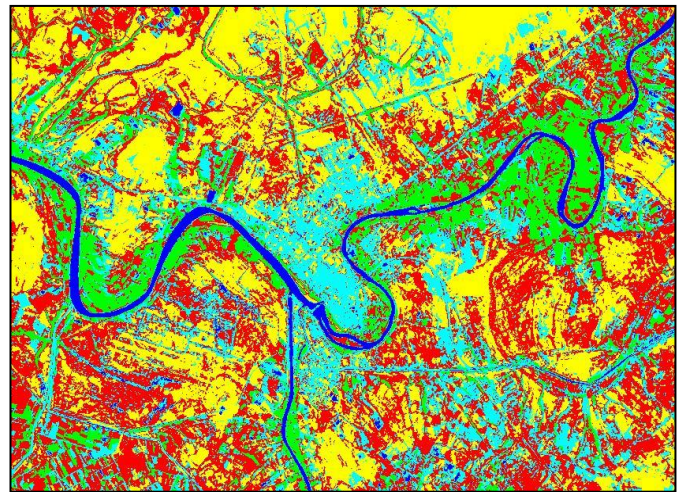


Unsupervised Classification of Tasseled Cap Components

Fig. 5: Unsupervised classification results








Supervised classification of raw bands



Supervised classification of Tasseled Cap components

Fig. 6: Supervised classification results

Table 1: Results of supervised classification

| Classes | | Raw bands | | Tasseled Cap | |
|-----------------|---|-----------------|-------------------------|-----------------|-------------------------|
| Class name | Color | No. of pixels | Area (km ²) | No. of pixels | Area (km ²) |
| Bare lands |  | 148665 | 120.75 | 154114 | 125.17 |
| Urban areas |  | 151521 | 123.07 | 108486 | 88.11 |
| Crop lands |  | 125113 | 101.62 | 161421 | 131.11 |
| Water |  | 20029 | 16.26 | 17700 | 14.37 |
| Vegetations |  | 531136 | 43.15 | 56743 | 46.08 |
| Accuracy | | 87.1812% | | 89.2692% | |

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