The Tasseled Cap Transformation for the IKONOS Satellite and its Utility

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## Introduction

Remotely sensed imagery plays an important role in landscape ecology with a several different applications. However, there is a broad spectrum of data available that varies by spatial resolution (pixel size and extent), spectral resolution, and temporal resolution. In addition to this variation in sensors there are a variety of data transformation and manipulation techniques that can be used to enhance the interpretability of imagery. It is important to understand what data is best suited for the desired application, or to put it differently, what applications are appropriate for the data (Frohn 1998).

The research outlined in this paper is undertaken as an attempt to understand the appropriate applications of the Tasseled Cap transformation for the IKONOS satellite. When the IKONOS satellite was launched in 1999 it was the highest spatial resolution satellite sensor with 4m multi-spectral and 1m panchromatic band resolution. This high resolution imagery promised to make smaller targets discernable. IKONOS captures four bands of radiance, Blue, Green Red and Near-Infrared (GeoEye 2006).

The Tasseled Cap transformation is a spectral transformation that decorrelates data (pixel values, especially in the visible spectra, are often redundant) and organizes data into a feature space rather than spectral space. It is a standardized principal components analysis that allows transformed images to be compared to each other (unlike PCA, which is image dependent) (Crist et al, 1984 & 1986). Crist and Kauth found that band 1 captured brightness values, band 2 greenness (or vegetation), and band 3 wetness (or moisture content). Band four was labeled Nonesuch, and the rest of the bands were noise (Crist and Cicone 1984).

The Tasseled Cap Transformation was developed for use with data from the Landsat TM sensor and coefficients have been calculated for subsequent Lansat sensors. In 2003 Space Imaging (the company that operates IKONOS) published a paper outlining the derivation of Tasseled Cap coefficients for the sensor (Horne 2003). It is important to note that these two sensors differ in their spectral resolution. The IKONOS spectral resolution is much smaller than the Landsat satellite which captures an additional 4 bands of data through the shortwave infrared and thermal infrared.

For the IKONOS satellites transformation bands 1 and 2 capture the same features, however, since the IKONOS sensor lacks the shortwave infrared bands captured by the Landsat satellite, band 3 does not capture wetness. In Horne’s paper establishing the transformation parameters the features captured by band 3 were not described (Horne 2003) and it has not been subsequently described. Since IKONOS’ Tasseled Cap transformation is based on a more spectrally limited dataset than Landsat’s, what has been learned about Landsat’s transformation is not directly transferable. Therefore, my purposes here are to take the first investigative steps at examine what characteristics it has that would be useful for researchers interested in ecological or natural resource applications.

To do this, transformed and un-transformed images were classified using unsupervised classification to test if the transformation improved classification accuracy. Additionally, the greenness band was compared to 4 vegetation indices to determine what the nature of the data in the greenness band is.

## Methods

### Data

Initially 3 images were obtained from the Muskegon River watershed in Northern Michigan. The images were captured in September of 2002. One of the images was discarded due to cloud cover in the images. The Haymarsh image is dominate by a patchwork of forest and agricultural fields (both bare soil and vegetated) and the Houghton image is dominated by wetlands.

Additionally a Muskegon River watershed LULC layer was obtained from RSGIS. This dataset was digitized from 1998 aerial photography and classified according to the MIRIS classification system, level 2. This data was reclassified to a level 1 and the grassland and agriculture classes were combined resulting in 5 classes: water, urban, grassland/agriculture, forest and wetlands. This vector dataset was then converted to raster, with the same pixel size(4m) as the IKONOS data. Because of the temporal difference between the satellite data and the imagery that the LULC layer was digitized from an initial inspection of the two layers was conducted and it was determined that no significant change had occurred between the dates of the imagery. This dataset was used as truth for the purposes of this research.

### Classification

The Tasseled Cap transformation was performed on the two images in Erdas Imagine software using coefficients from Horne, 2003. These two images and the original two images were classified using Imagine's unsupervised classification that uses ISODATA, an iterative, self ordering classification algorithm that groups pixels solely on pixel values. The algorithm was instructed to cluster pixels in to 20 groups and to continue iterating until 98% of the pixels did not change clusters. These clusters were then grouped into 5 classes: water, urban, forest, grassland/agriculture, and wetlands.

The Hawth's Analysis Tools plug-in for ArcGIS 9.2 was used to create 6 rasters with 500 random pixels selected for each study area (Haymarsh and Houghton). A model was then created in Imagine to compare the pixel values of the 500 randomly selected pixels of the ground truth to the 4 classified images. That produced three sets of accuracy assessments data for each image. Confusion matrices were created and k-hat statistics and users and producers accuracy were calculated.

### Vegetation Indices

Simple ratio (SR), Differenced Vegetation Index(DVI), Normalized Difference Vegetation Index(NDVI) and Soil Adjusted Vegetation Index(SAVI) were calculated for each image( figure 1). Then a correlation was conducted to compare each of the indices to the greenness band of the transformed images.

Figure 1: Vegetation Index formulas used. Source: Johansen and Phinn 2006.
SR = NID/RED
DVI = NIR-RED
NDVI = (NIR – RED) / (NIR + RED)
SAVI = (NIR – RED (1 + L) / (NIR + RED + L)      L = .5

## Results

**Classification**

K-hat statistics and producer and user errors were calculated for each of the images (tables 1-5) to compare the accuracy of each of the classification attempts.

Table 1: Individual and average K-hat values.

| | 1 | 2 | 3 | Avg. |
|---|---|---|---|---|
| Haymarsh Un-transformed | 46.7 | 48.7 | 53.6 | 49.7 |
| Haymarsh Transformed | 41.8 | 43.9 | 47.7 | 44.5 |
| Houghton Un-transformed | 54 | 45.5 | 43.9 | 47.8 |
| Houghton Transformed | 45.4 | 45.9 | 45.6 | 45.6 |

Tables 2-4: Average producer and user errors of three runs for each image.

Table 2. Haymarsh Un-transformed

| Producer | User |
|---|---|
| 70.4 | 22.8 |
| 0.0 | 0.0 |
| 77.8 | 63.0 |
| 70.2 | 86.8 |
| 1.1 | 38.2 |

Table 3. Haymarsh Transformed

| Producer | User |
|---|---|
| 72.1 | 17.8 |
| 0.0 | 0.0 |
| 78.5 | 40.5 |
| 62.6 | 87.8 |
| 27.8 | 36.6 |

Table 4. Houghton Un-transformed

| Producer | User |
|---|---|
| 84.7 | 85.9 |
| 20.4 | 43.2 |
| 26.3 | 12.3 |
| 68.5 | 81.4 |
| 66.4 | 53.6 |

Table 5. Houghton Transformed

| Producer | User |
|---|---|
| 84.0 | 85.6 |
| 16.8 | 45.7 |
| 13.7 | 9.35 |
| 76.1 | 74.5 |
| 56.5 | 51.1 |

The k-hat values were low for all images classified. This was expected since unsupervised classification is known to be poor for high resolution imagery (Jensen 2004). This is because the algorithm relies solely on pixel values and doesn't not take and spatial factors into consideration. A forest canopy is not characterized by a single pixel value however, but instead a combination of shadows, leaves, branches, squirrels, etc. High resolution imagery makes smaller objects discernable but it also captures all of the variability is a given land use or land cover. This problem can be seen in the high number of forest pixels classified as water (because of shadows).

An additional problem in classification is the grassland/agriculture class. This class is characterized by two major pixel groups that have very different spectral signatures: vegetated cover, and bare soil. The bare-soil pixels were responsible for the misclassification if urban pixels since another known problem with pixel based classification algorithms in the confusion of bare soil and impermeable surfaces. In fact, it was not possible to classify any of the ISODATA clusters as urban in both Haymarsh images because of the inability of the algorithm to distinguish between bare mineral soil and urban covers.

**Vegetation Indices**

The r-squared values that were computed for the Haymarsh image Tasseled Cap band 2 are as follows: SR: .567, DVI: .920, NDVI: .993, SAVI: .920.

The r-squared values that were computed for the Houghton image Tasseled Cap band 2 are as follows: SR: .491, DVI: .825, NDVI: .987, SAVI: .826.

The vegetation indices used here each describe the amount of vegetation in different ways. The general spectral signature of vegetation is characterized by a low value in the red since green vegetation absorbs red wavelengths and a high NIR value since the internal structure of leaves reflects NIR wavelengths and multiple layers of leaves amplify this reflectance (Lillesand 2004). Different indices describe this relationship differently in an attempt to account for other factors that may affect the reflectance. The SR and DVI are inferior indices to the NDVI since their values can be affected by things like image brightness. The SAVI index includes a correction factor that attempts to eliminate the effects of red wavelengths reflected off of soil in areas partially covered with vegetation. The very strong correlation (.987 and .993) between NDVI and Band 2 indicates that the Greenness band is capturing differences in vegetation well.

One important finding is that the r-squared value for the Houghton image is almost identical to the Haymarsh image for NDVI but lower by about .1 for the other values. Visual comparison of the two images shows that while the Haymarsh image is dominated by thick forests and agricultural fields the Houghton image is dominated by wetlands. Most of the vegetated areas appear to be mixed pixels characterized by sparse forests and patchy wetlands. This indicates that the greenness band performs similarly to the NDVI metric in response to a variety of different situations.

# Discussion

**Classification**
Since only three replicates were done it is not possible yet to compare the two methods statistically. However, these initial results indicate that further research would not be productive. Average k-hat values for the transformed images were slightly lower than classification for the untransformed images. Additionally, there is no indication that the Tasseled Cap transformation increases image interpretability for the ISODATA algorithm for any individual class since producer and user errors are similar between images although, again, no testing has been done to determine if there is a statistically significant difference between the classification performances.

**Vegetation Indices**
The very strong correlation between the Tasseled Cap band 2 and NDVI indicate that the Tasseled Cap transformation would be a useful tool when comparing multiple images from multiple dates, such as in change analysis, since its values are not data dependent. There are currently differing opinions in the literature on calculating LAI from different vegetation indices (Chen et al 2002, Colombo et al 2003). Band 2 of the Tasseled Cap has not been used in this work yet, but the strong positive correlation with the standard vegetation indices indicates that it is worth looking at in these experiments.

Overall, The IKONOS Tasseled Cap transformation has been demonstrated to be useful for some applications; however it does not improve the performance of classification algorithms. Further experimentation with band 2 should be pursued as well as an in depth examination of the information contained in band 3, which is still undescribed.

## Literature Cited


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