Assessing the information content of Landsat-5 Thematic Mapper data for mapping and characterizing fire scars

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ABSTRACT: A classical problem in multispectral satellite sensor data is the choice of the most effective three-channel color composites for enhancing certain characteristics of the scene, as for instance fire scars. Giving a paradigm, there are 210 unique ways to present in a three dimensional color space (i.e. RGB) the seven available spectral channels of Landsat-5 Thematic Mapper data (Sheffield, 1985). In literature, they have been proposed and used different methods to account for spectral information content assessment among and within satellite sensors, including visual comparison of various RGB color composites, consideration of the total variance within each band, principal component analysis, separability measurements, as for instance Transformed Divergence (TD) and Jefferies-Matusita distance (JM). However, there is no any systematic work concerning the spectral in-formation content of Landsat-5 TM data in respect to burned land discrimination and characterization. Following the literature review in the general topic of information content assessment, as well as the associated literature on spectral properties of burned areas, we try to systematically characterize and quantify the information content carrying on the Landsat-5 TM data. For the discrimination of the burned areas, emphasis is given on the maximization of their spectral discrimination against other land cover types, while minimizing at the same time their within spectral variability. For the characterization of the burned areas, emphasis is given on the maximization of the spectral variability found within the burned areas. Under this perspective we discuss the information contained in each spectral band and we present the best three-channel color composites. Using all land cover types the grouping of the spectral channels is a follows. There are two distinct groups consisting of TM1 and the rest. The second division is between TM5 and the rest, while the third one is between TM4 and the rest followed by TM7. These channels contain the most useful information for general land cover discrimination. It is interesting to mention that Koutsias and Karteris (2000) found that the best three channel color composite consists of TM7, TM4 and TM1.

1 INTRODUCTION - BACKGROUND

A classical problem in multispectral satellite sensor data is the choice of the most effective three-channel color composites for enhancing certain characteristics of the scene, as for instance fire scars. Giving a paradigm, there are 210 unique ways to present in a three dimensional color space (i.e. RGB) the seven available spectral channels of Landsat-5 Thematic Mapper data (Sheffield 1985). In literature, they have been proposed and used different methods to account for spectral information content assessment among and within satellite sensors (Chavez et al. 1982, Price 1984, Benson and DeGloria 1985, Sheffield 1985, Chavez and Bowell 1988, Mausel et al. 1990, Dwivedi and Rao 1992). Occasionally, visual comparison of various RGB color composites can be used, however, deciding the best possible combination visually is relatively difficult, subjective and time-consuming (Dwivedi and Rao 1992).

One of the methods is to choose those channels with the largest sum of squared principal axes, which account for the largest total variance. However, the consideration of the total variance, as a measure for the information content of three-channel composites, is problematic. Instead, Sheffield (1985) proposed the use of the ellipsoid of maximum volume. This approach discourages selecting spectral channels with high correlation. He concluded that the TM4, TM5 and TM1 RGB color composite consistently ranked high regardless of image location. Since eye is most sensitive to green followed by red and blue part of electromagnetic spectrum, he associated the spectral channel with the maximum variance to the green, the channel with the second largest variance to the red and the channel with the smallest variance to the blue color plane (Sheffield 1985).

Dwivedi & Rao (1992) used the Optimum Index Factor (Chavez et al. 1982) to assess the best three-channel color composites of Landsat TM data for delineating salt-affected area. The Optimum Index Factor (OIF) is based on the variance and the correlation values among the spectral channels that compose the three channel color composite. Specifically, the OIF value is computed by dividing the sum of the standard deviations of each of the three spectral channels by the sum of the absolute value of the correlation coefficients of the three spectral channels taken by two at a time. They found that TM1, TM3 and TM5 composite was the best in terms of the information content without, however, denoting that any specific correspondence of each of the three spectral channels to a specific color plane is important (Dwivedi and Rao 1992).

Principal component analysis has been evolved for assessing the information content of multispectral satellite data, particularly, when different satellite sensors are considered (Chavez and Bowell 1988). Comparing the spectral information content of Landsat TM and SPOT data at three different sites, Chavez & Bowell (1988) applied principal component analysis and used the percent of variance mapped to each principal component to identify the dimensions of the original multispectral satellite data. They found that 99% of the original Landsat-5 TM data in an agricultural site was mapped at the first three components denoting a three-dimensional original data set, while 99% of the variance of the SPOT data was mapped at the first two components denoting a two-dimensional original data set.

The problem of optimum band selection has been handled by the use of separability measurements, as for instance Transformed Divergence (TD) and Jeffreys-Matusita Distance (JM). Mausel et al. (1990) found that TD and JM separability indices were very good predictors of classification accuracy. In their study, both of these indices identified that the 3, 4, 7, and 8 channels, out of a two-date multispectral video data, would yield the most accurate classification results. They, also, found that the correlation coefficients between the classification results and the separability indices were very high.

Spectral characterization of fire scars is very popular research objective among scientists (Chuvieco and Congalton 1988a, Pereira and Setzer 1993, Koutsias and Karteris 2000, Trigg and Flasse 2001, Chuvieco et al. 2002, Pereira 2003). However, there is no any systematic work concerning the spectral information content of Landsat-5 TM data in respect to burned land discrimination and characterization. Following the literature review in the general topic of information content assessment, as well as the associated literature on spectral properties of burned areas, we try to systematically characterize and quantify the information content carrying on the Landsat-5 TM data. For the discrimination of the burned areas, emphasis is given on the maximization of their spectral discrimination against other land cover types, while minimizing at the same time their within spectral variability. For the characterization of the burned areas, emphasis is given on the maximization of the spectral variability found within the burned areas. Under this perspective we discuss the information contained in each spectral band and we present the best three-channel color composites.

2 MATERIALS AND METHODS

2.1 *Study Area*

In August 2006 a large fire occurred in Chalkidiki, Greece. This was the study area for the assessment of the information content of Landsat-5 Thematic Mapper data for mapping and characterizing fire scars. For this purpose, a Landsat-5 Thematic Mapper image was acquired just a few days after the fire and constituted the basic source of information.

The study area belongs to Mediterranean type climate, while the vegetation in the area is composed mainly of conifers and shrubs. In detail, the bioclimate is characterized as semi-arid, with high temperatures and low relative humidity during the fire season. As a result, the forested land is composed by pines, and various Mediterranean shrubs (Maquis), that are well adapted in such climatic conditions.

2.2 *Methods*

Cluster analysis was applied to hierarchically cluster the spectral channels using the complete linkage method based on the squared Euclidean distance criteria, a method that works properly with Thematic Mapper data. The use of the Euclidean distance is not recommended since it assumes orthogonal axes, which is not valid in Thematic Mapper data because of the high correlation among spectral channels (Chuvieco and Congalton 1988b). The cluster analysis has been successfully applied by Chuvieco and Congalton (1988b) to improve the selection of training statistics in classifying remotely sensed data, by merging training statistics derived from supervised and unsupervised techniques.

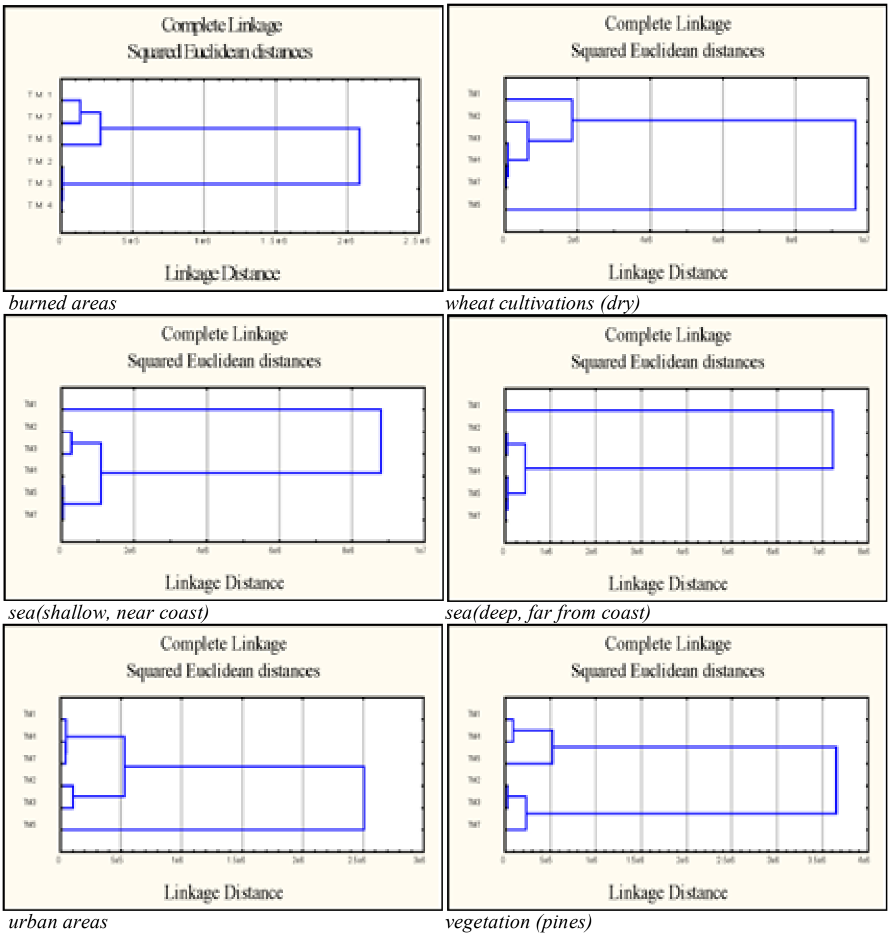
The cluster analysis has been applied using a sample of some of the most important and representative land cover types that of the area.

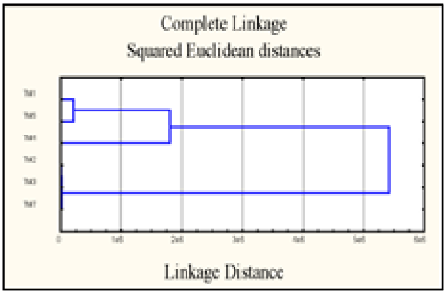
3 RESULTS AND DISCUSSION

Figure 1 shows the dendrograms resulting from the cluster analysis taking into account basic land cover types found in the satellite imagery. Each graph shows the similarity of the spectral channels for each land cover. For example, the spectral information of the Landsat-5 Thematic Mapper channels creates two distinct groups; the first composed of TM1, TM7 and TM5 and the second composed of TM2, TM3 and TM4. The first group also is consisted of two distinct sub-groups TM5 alone and TM1 and TM7. Each land cover presents a unique pattern concerning the similarity of the spectral channels.

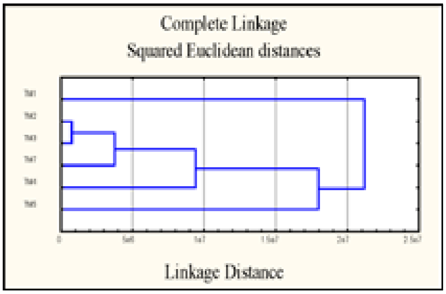
Using all land cover types the grouping of the spectral channels is a follows. There are two distinct groups consisting of TM1 and the rest. The second division is between TM5 and the rest, while the third one is between TM4 and the rest followed by TM7. These channels contain the most useful information for general land cover discrimination. It is interesting to mention that Koutsias and Karteris (2000) found that the best three channel color composite consists of TM7, TM4 and TM1.

Figure 1 Cluster analysis of spectral channels of Landsat-5 Thematic Mapper data.





vegetation (cultivations)



all categories

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