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SHORT COMMUNICATION

A TM Tasseled Cap Equivalent Transformation for Reflectance Factor Data*

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A transformation of TM waveband reflectance factor data is presented which produces features analogous to TM Tasseled Cap brightness, greenness, and wetness. The approach to adjusting the transformation matrix to other types of reflectance factor data (different instrument or band response) is described in general terms.

Introduction

The Tasseled Cap transformations of Landsat MSS (Kauth and Thomas, 1976) and TM (Crist and Cicone, 1984a,b) data provided a mechanism for data volume reduction and enhanced data interpretability by emphasizing the structures in the spectral data which arise as a result of particular physical characteristics of scene classes. The basic concepts underlying these transformations are discussed by Crist and Kauth (1985). Because the expression of the data structures is influenced by sensor calibration and detector response, the transformations are sensor-dependent; i.e., the transformation matrix for MSS data cannot be applied successfully to TM data. Similarly, the transformation matrix for actual TM signal count data cannot be directly applied to reflectance factor data, even if those reflectance factor data are collected or combined in bands equivalent to those of the TM.

Scientific investigations related to the use of satellite remotely sensed data for monitoring vegetation often include use of ground level (truck-mounted or hand-held) spectrometer data to supplement data from the spaceborne sensor. Such data can be collected under more controlled conditions, allowing detailed analysis of the physical characteristics of the entities being observed as well as their spectral response.

This paper presents a transformation by which one type of reflectance factor data may be converted to TM Tasseled Cap equivalent features. Others have used a "Tasseled-Cap-like" approach to defining dataset-specific transformations for reflectance data (e.g., Jackson, 1983). Some of the differences between such approaches and the Tasseled Cap transformations of MSS and TM data are discussed specifically by Crist and Cicone (1984b) and can be inferred from Crist and Kauth (1985). The transformation presented here is intended to provide features which relate as directly as possible to the corresponding TM Tasseled Cap features. Such a direct relationship allows

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researchers whose end goal is to better understand and use TM data to move more easily between actual satellite data and ground-measured data, thus facilitating application of the results of field experiments to actual Landsat TM data.

This paper is not intended to provide a full explanation of the basic Tasseled Cap concepts or of the particular characteristics of the MSS or TM Tasseled Cap transformations, since these have been provided elsewhere (Crist and Kauth, 1985; Kauth and Thomas, 1976; Crist and Cicone, 1984a, b). Instead, a basic familiarity with at least the TM Tasseled Cap transformation is assumed.

Approach

The data set used in deriving the transformation consists of field spectrometer reflectance factor measurements (sampled at 10-nm increments from 400- to 2400-nm) of a diverse mix of crops and soils, obtained from the Laboratory for Applications of Remote Sensing (LARS) (Biehl et al., 1982). These are the same data which were used in the TM simulation and analysis of Crist and Cicone (1984a), and are described in greater detail in that paper. TM band reflectance factor values were derived by computing weighted averages of the measured reflectance factors, using as weights the prelaunch composite detector response functions of the Landsat-4 Thematic Mapper. The procedure for obtaining the transformation, which in general terms involves selective rotation and viewing of particular known scene classes in the six-dimensional spectral space, is also described in Crist and Cicone (1984a).

Results and Discussion

Table 1 contains the transformation coefficients derived by this analysis. The results of the transformation are illustrated for the entire data set in Figs. 1–3, and for selected sample groups in Figs. 4–6. Note that in all cases a subscript R is used as a reminder that the features are reflectance factor equivalent features and not the actual TM Tasseled Cap features.

In evaluating the results of the transformations, one should keep in mind that the reflectance spectra used here are identical to those used in the simulation of Landsat TM signal counts which comprised the data set from which the first TM Tasseled Cap transformation was derived (Crist and Cicone, 1984a). Comparison of Figs. 1–3 to the overall data distributions of Crist and Cicone (1984a, b) demonstrates at least a general correspondence. Similarly, comparison of the transformation matrix in Table 1 to those of the previous works shows that the basic characteristics of the resultant features are similar (i.e.,

TABLE 1 TM Tasseled Cap Equivalent Transformation Matrix for Band Reflectance Factor Data[a]

Feature	TM 1	TM 2	TM 3	TM 4	TM 5	TM 7
Brightness_R	0.2043	0.4158	0.5524	0.5741	0.3124	0.2303
Greenness_R	− 0.1603	− 0.2819	− 0.4934	0.7940	− 0.0002	− 0.1446
Wetness_R	0.0315	0.2021	0.3102	0.1594	− 0.6806	− 0.6109
Fourth_R[a]	− 0.2117	− 0.0284	0.1302	− 0.1007	0.6529	− 0.7078
Fifth_R[a]	− 0.8669	− 0.1835	0.3856	0.0408	− 0.1132	0.2272
Sixth_R[a]	0.3677	− 0.8200	0.4354	0.0518	− 0.0066	− 0.0104

[a] See text for cautions concerning fourth through sixth features.

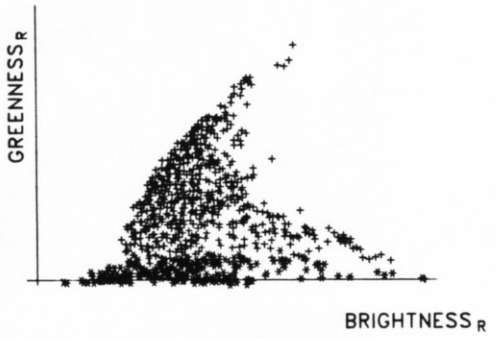

FIGURE 1. Reflectance factor TM Tasseled Cap plane of vegetation. All data: (+) vegetation data; (*) bare soil data.

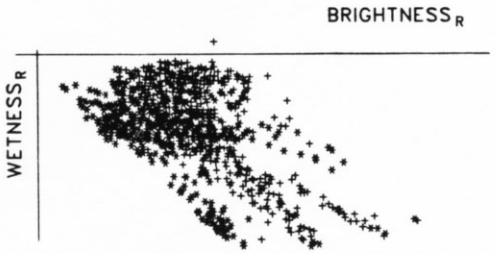

FIGURE 2. Reflectance factor TM Tasseled Cap plane of soils. All data: (+) vegetation data; (*) bare soil data.

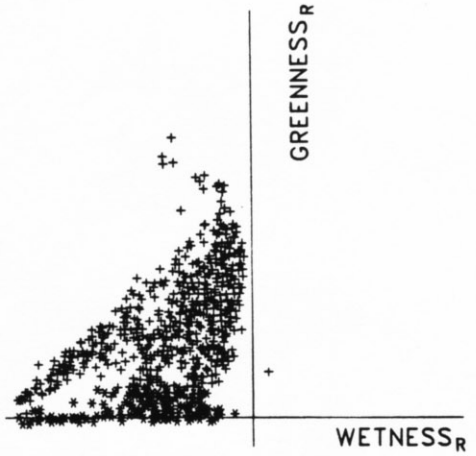

FIGURE 3. Reflectance factor TM Tasseled Cap transition zone. All data: (+) vegetation data; (*) bare soil data.

the same bands exert the key influences and the primary contrasts represented by the features are the same). The differences which do occur between the transformation matrices can likely be attributed to the effects of solar irradiance, atmospheric interference, and TM sensor calibration.

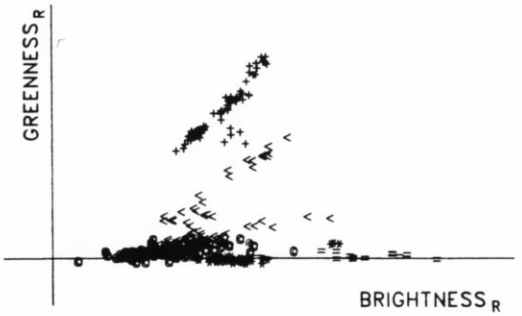

FIGURE 4. Reflectance factor TM Tasseled Cap plane of vegetation. Sample data: (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

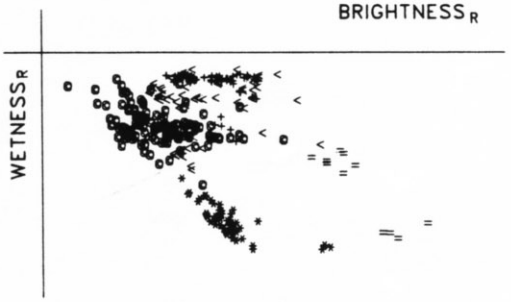

FIGURE 5. Reflectance factor TM Tasseled Cap plane of soils. Sample data: (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

Further evidence of the transformations' correspondence can be found by comparing the data distributions in Figs. 4–6 to those in Figs. 7–9. The two sets of figures are based on the same spectra, selected from the larger group to represent particular scene classes, but the data in the first set (Figs. 4–6) have been converted to TM inband reflectances and transformed via the reflectance factor TM Tasseled Cap transformation (Table 1), while the data in the second set have been used to simulate TM signal counts and then transformed in the manner of

FIGURE 6. Reflectance factor TM Tasseled Cap transition zone. Sample data: (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

Crist and Cicone (1984a). Here again, comparison indicates a high degree of similarity in the transformation results. Each of the narrowly defined scene classes occupies a similar position in the two transformed feature spaces, and the relative positions of scene classes are likewise similar between the two sets of figures. The one noticeable difference occurs between Figs. 5 and 8, which provide what is termed the Plane of Soils view (Crist and Cicone, 1984b). The soils data are aligned somewhat differently with respect to the vegetation samples and the coordinate axes (particularly the Wetness direction). While the reason for this difference is not entirely understood, it should be kept in mind when evaluating transformed reflectance factor data and comparing results to actual TM data behavior.

The transformation presented in this paper is, as pointed out by the above example, comparable but not identical to the TM Tasseled Cap transformation of actual TM data. One ought not to assume, using this transformation any more than simply using in-band reflectance factors, that the spectral behavior of scene classes measured on the ground will be exactly duplicated in space-borne sensor data. Whether using reflectance factors or transformed features, ground-based results should be taken as indicators, and should always be confirmed in actual sensor data.

Crist and Cicone (1984a,b) describe the physical significance of the TM Tasseled Cap features, and note that the

FIGURE 7. TM Tasseled Cap plane of vegetation. Sample data (based on simulated TM signal counts): (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

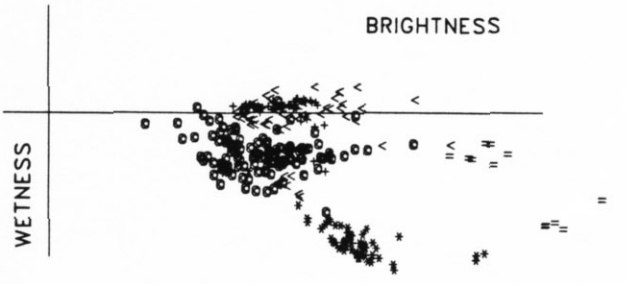

FIGURE 8. TM Tasseled Cap plane of soils. Sample data (based on simulated TM signal counts): (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

fourth–sixth features of the transformation have as yet no known physical association. Because of this, there can be no assurance that the fourth–sixth features of this reflectance factor TM Tasseled Cap Transformation correspond to the same features in the simulated or actual signal count data transformations. Thus, while the entire matrix is included in Table 1, only the brightness$_R$, greenness$_R$, and wetness$_R$ features should be assumed to respond in the same manner as the analogous features of the previous transformations. No conclusions should be drawn, with respect to actual data response, based on reflectance factor data response in the fourth–sixth features.

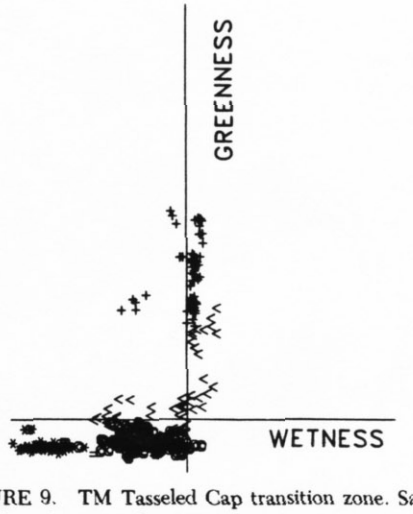

FIGURE 9. TM Tasseled Cap transition zone. Sample data (based on simulated TM signal counts): (+) green vegetation, full cover; (<) brown vegetation, nearly full cover; (@) field capacity soils (lab-measured); (*) bare field soils; (=) quarry sand (field-measured).

Extending the Transformation

The reflectance factor TM Tasseled Cap transformation presented here is based on spectrometer data integrated over the prelaunch composite detector response functions of the Landsat-4 Thematic Mapper, and should not be routinely applied to reflectance factor data derived from some other source (e.g., a multiband radiometer) or integrated over different detector response functions (e.g., Landsat-5 TM). It is expected that the results obtained with this matrix for other reflectance factor data would be very nearly correct, depending, of course, on how greatly the instrument response differs from that used in this study. However, the results should be checked before proceeding with any analysis of the transformed data. The procedure for checking the transformation results, and adjusting the transformation if necessary, is outlined in general terms below.

First, the transformation matrix in Table 1 should be applied to the data. Viewing plots such as those in Figs. 1–3, taking into account the data structures described in Crist and Cicone (1984a,b), and comparing results to the figures in this and the previous papers, should give a first indication of the accuracy of the transformed results for the particular data in question. Plotting known samples from the entire data set, as in Figs. 4–6, will give an even better measure of the transformation accuracy. If adjustment is indicated, it can be accomplished by applying three-dimensional rotations to the data (and the transformation matrix) such that the proper data alignments are achieved (again, for a more complete discussion of what "proper data alignments" are, see Crist and Cicone, 1984a,b). Because all the features of the transformation are orthogonal, rotations applied to a subset of features will not affect the other features, or the interrelationships between the rotated subset and the other features.

Conclusion

The reflectance factor TM Tasseled Cap transformation described here can be applied directly to many sets of reflectance factor data, and further provides a base from which similar transformations can be derived for other types of reflectance factor data. The resultant brightness$_R$, greenness$_R$, and wetness$_R$ features, though not identical to the actual data TM Tasseled Cap features, are analogous to TM Tasseled Cap brightness, greenness, and wetness, and thus facilitate the application of knowledge gained through analysis of ground-based reflectance factor data to satellite-based signal count data.

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