N O T I C E

80-10146
CR-163164

XVIII RASSEGNA INTERNAZIONALE ELETTRONICA NUCLEARE ED AEROSPAZIALE

Roma, 7-16 Marzo 1980

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(E80-10146) GREEN AND SOIL BRIGHTNESS INDICATORS OBTAINED THROUGH A LANDSAT DATA TRANSFORMATION PROCEDURE (Telespazio) 11 p HC A02/MF A01 CSCL 14E N80-26733 Unclas G3/43 00146

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XX Convegno sullo Spazio

11-13 Marzo 1980

ROMA

PALAZZO DEI CONGRESSI - EUR

Segreteria: VIA CRESCENZIO, 9 - TELEFONI 65.69.343-4-5

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SUMMARY

This work describes a linear transformation method of Landsat images which permits to isolate, in a given biophase, the green development and the bare soil conditions in terms of light and dark.

The method starts from previous works of Kauth and Thomas (1976) on this subject and, in particular, on the hypothesis of the Landsat data structure in the signals space. These data are enough spectrally correlated, so that almost all of them lie on a V-shaped pattern of a plane in the four dimensional bands space. Greenstuff and bare soil tend to lie along the different V arms.

Using properly some factor analysis techniques, it is possible to rotate this space and to obtain images correlated to these indicators.

This paper discusses also some experimental results.

INTRODUCTION

Landsat agricultural data assume a particular form in the signals space, which has suggested the study of some visual models, physically interpretable.

A particular interest for this form can be found in the signals factorial space, for the invariance, in this space, of certain parameters.

Starting from the observation of this signals structure and the works of Kauth and Thomas (1976), it has been possible to develop an algorithm for determining green and soil brightness indicators, in normalized observation conditions.

LANDSAT DATA STRUCTURE

GENERAL CONSIDERATIONS

As it is known, the Landsat data structure of an agricultural scene has approximately a form of a flattened triangular region, in the cartesian space of spectral bands pair (refer to Kauth + Thomas, 1976).

The compactness and the thickness of this region depend mainly on the haze conditions and on the spectral bands used.

In relation to the haze conditions, the effect of increasing haze on MSS signals implies a reduction in the available signal contrast (i.e. in the dynamic range encompassed by the data) and a shifting of most signals toward brighter levels.

This fact generates both a progressive increasing of the data structure compactness and its shift from a very clear atmospheric conditions to a dense haze concentration. When the haze becomes dense enough to reduce the signal contrast to zero, the triangular region becomes one point (refer to Lambeck, 1977).

Concerning the spectral bands used, the triangular region has a little thickness when two bands are correlated, i.e. when the data lie near the diagonal of the relevant space.

If one assumes that band 4 is correlated to band 5 and band 6 is correlated to band 7, than almost all the data lie on a plane (band 5 vs. band 6) in the 4-dimensional space (refer again to Kauth + Thomas, 1976).

V-SHAPED PATTERN

Two axes of the triangular region have particular importance for agricultural problems, i.e. the soil brightness axis and the green development axis.

These axes form a V-shaped pattern in which both ground truth information and different experiences (refer for instance to Kauth + Thomas, 1976, and Kauth + Richardson, 1977) have shown that soil brightness tend to lie along the "V" arm vs. band 5 (dark scene elements, as water and other, lie at its apex), whereas green vegetation lies along the "V" arm vs. band 6. The healthy green vegetation lies at the top of this arm.

PHYSICAL INTERPRETATION

The physical reasons of this structure may be sought in the plane of bands 5 vs. 6 (refer to Kauth + Richardson, 1977).

Band 5 is centered in the chlorophyll absorption band of green vegetation around 0.65 μm, whereas band 6 is centered on the cellulose reflectance peak of green vegetation around 0.75 μm.

The green vegetation signal is small in band 5 and large in band 6. If one considers the life of the crop, it appears that the crop starts its growth on the axis of soils (refer to Suits, 1972). As it grows, the composite reflectance of soil and crop increases the band 6 value for the presence of the cellulose in the plant. The composite reflectance of band 5 decreases for the chlorophyll absorption. Hence, the radiance typical of green plants can be found at the top of the "V" arm vs. band 6.

SOILS REFLECTANCE DISTRIBUTION

The above considerations on Landsat data structure permit to define a soils reflectance subspace. The limits of this subspace are determined by soils reflectance planes of spectral bands pair.

Assuming the hypothesis of bands correlation, it is possible to demonstrate that the first two principal components of the data distribution define a plane containing most part of the data variance (refer again to Lambeck, 1977).

Figure 1 (a) gives an idea of this soils reflectance subspace, showing in particular the triangular regions of the bands 5 vs. 6 and of the two principal components.

Figure 1 (b) gives instead a visual description of the normalized reflectance space. This space has a "diagonal" along which the normalized reflectances of all bands are equal. The main characteristics of this space are:

- the mean reflectance of soils lies near the diagonal;
- the largest principal component is situated nearly parallel to this diagonal (refer again to Kauth + Thomas, 1976).

Figure 2 shows the difference between the best K-plane of signals space projected onto the first two principal components and onto the first two factors rotated by varimax criterion (refer also to Zandonella, 1978).

In the first case the best K-plane of projection is situated within the bands 6 vs. 5 and the green development axis is almost parallel (i.e. correlated) to the 2-nd component.

In the second case the best K-plane of projection is instead situated within the bands 5 vs. 7 and the soil brightness axis is almost parallel to the 2-nd component.

PROCEDURE FOR DETERMINING
GREEN AND SOIL BRIGHTNESS
INDICATORS

Consider the V-shaped patterns of the principal spectral component planes and the rotated spectral factor planes.

Assume that:

a. The V-shaped patterns change only along the principal direction of these planes, in function of the observation conditions (i.e. viewing and illumination geometry, amount of haze, amount of H_2O vapor, amount of cirrus cloud and height distribution of these in the atmosphere, etc.) (refer to Kauth + Thomas, 1976).
b. A factorial axis is representative of the nearest V-arm if this is parallel (i.e. correlated) to the same factor (refer to Bertier + Donio, 1970).

In relation to these hypothesis and considering the correlation between 2-nd component and green axis, 2-nd rotated factor and soil brightness axis, for obtaining images correlated to these indicators it is sufficient to increase the contrast variance of these factorial axes, in normalized observation conditions.

The procedure, shown in Figure 3, consists of the following steps:

Step 1

Normalize the soils reflectance space.

Step 2

Compute the first two factors rotated (by the varimax criterion) or not, for obtaining images correlated to green or soils brightness indicatois, respectively.

Step 3

Rotation of the soils reflectance factorial space by the ratio factor loading/ associated factor lenght (this length represents the portion of the contrast variance).

Step 4

Compute the first unnormalized factorial axis, i.e. using mean and variance of the origin soils reflectance space.

APPLICATION OF THE PROCEDURE TO A TEST AREA

A test area situated at North-East of Bracciano Lake has been selected.
From ground truth information 11 classes have been identified.
The Landsat data have been compressed by a supervised classification method: the Sebestyen quadratic classifier (refer to Sebestyen, 1962).
Figure 4(a) shows the one sigma dispersion ellipses of different classes projected onto the first two principal components.
The classes centers form a V-shaped pattern. At the apex of this pattern are situated water and other dark scene classes, along the righthand arm of the "V" are bare soil fields whereas green classes are along the lefthand.
Figures 5 and 6 show the images projected onto 1-st and 2-nd component, respectively. Notice in Figure 6 the low information quantity due to the low contrast variance. The dark scene elements correspond to woodland classes.
Figures 4(b) and 4(c) show the one sigma dispersionellipses of the classes projected ontothe first two factors, respectively, rotated or not by varimax criterion.
Also in these cases the classes centers form a V-shaped pattern. At the apex of this pattern are situated light scene elements, i.e. water and other, because the best K-planes of projection are band 4 vs. band 7 for the greenstuff and band 6 vs. band 4 for the soil brightness. Refer also to Figure 3.
In Figure 4(b) the healthy green classes lie at the top of the green axis, i.e. vs. dark scene.
Figure 7 shows the greenstuff image, having the above mentioned characteristics.
Similar considerations can be made for the brightness. In fact, in Figure 4(c) the dark scene elements are referred to brighter soils classes.
Figure 8 show the soil brightness image.

CONCLUSIONS

The described method for obtaining, in a given biophase, the green development and soils brightness indicators, is based on the analysis of Landsat data structure in the factorial signals space.
Considering the width and the redundancy in the information of Landsat bands, this paper intends also to indicate that the solution of agricultural problems may be achieved by the analysis of data structure in a pictorial/geometric sense.

REFERENCES

Bertier P., Donio J.
"Programmes de structuration des données"
SEMA - Rapport de recherche N. 52,1970.

Kauth R.J., and Richardson W.
"Procedure B: A Multisegment Training Selection and Proportion Estimation Pro cedure for Processing Landsat Agricultural Data".
NASA CR-ERIM 122700-31-F, November 1977.

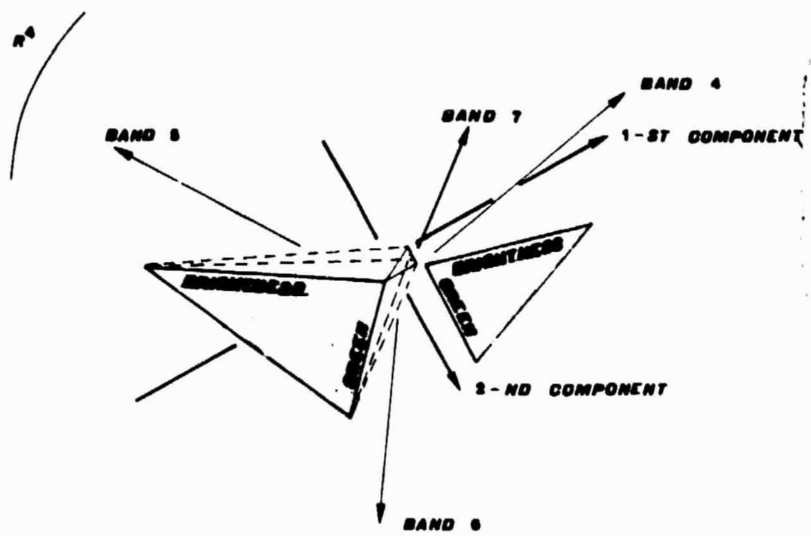
Kauth R.J., and Thomas G.S.
"Proceeding of Symposium on Machine Processing of Remotely Sensed Data".
Purdue University, W. Lafayette, Indiana, 1976.

Lambeck P.F.
"Signature Extension Processing for Landsat MSS Data".
NASA CR-ERIM 122700-32-F, November 1977.

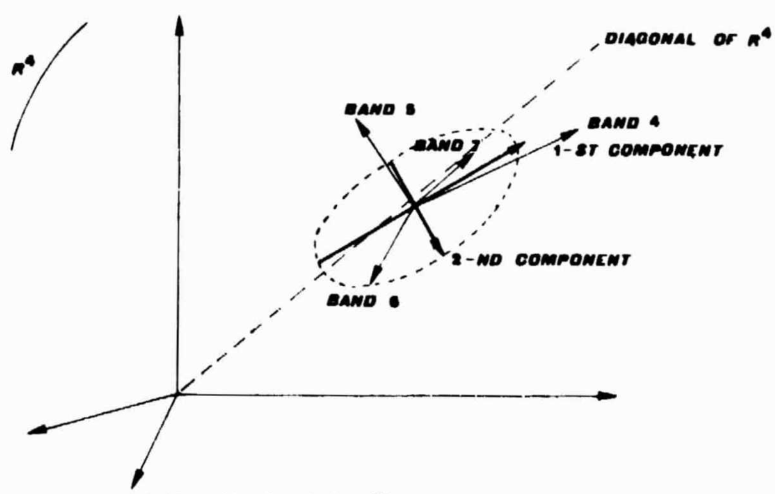
Sebestyen G.S.
"Decision Making Process in Pattern Recognition".
The McMillan Company, 1962.

Suits G.H.
"The Calculation of the Directional Reflectance of a Vegetative Canopy".
Remote Sensing of Environment, Vol. 2, 1972.

Zandonella A.
"Alcuni Metodi Fattoriali Utilizzati come Trasformate Lineari di Immagini Lan dsat".
Primo Congresso Naz. sul Telerilevamento delle Risorse Terrestri organized by S.I.T.E., September 1978.



a) Unnormalized soils reflectance subspace. The limits of this subspace are determined by soils reflectance planes. The best K-plane of projection onto 1st and 2nd component is situated within the cartesian space of bands 5 and 6.



b) Normalized soils reflectance space.

FIGURE 1 - Concept of soils reflectance distribution in a 4-dimensions space spanned by the 4 Landsat MSS channels.

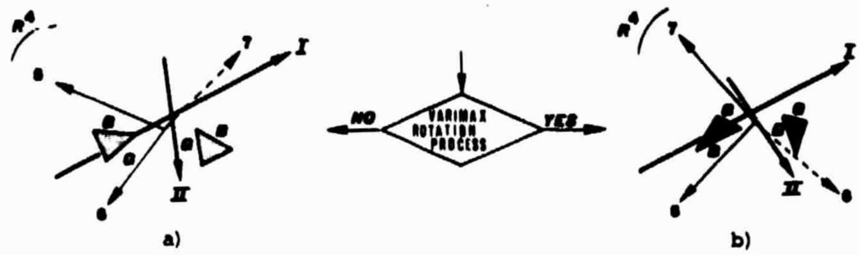
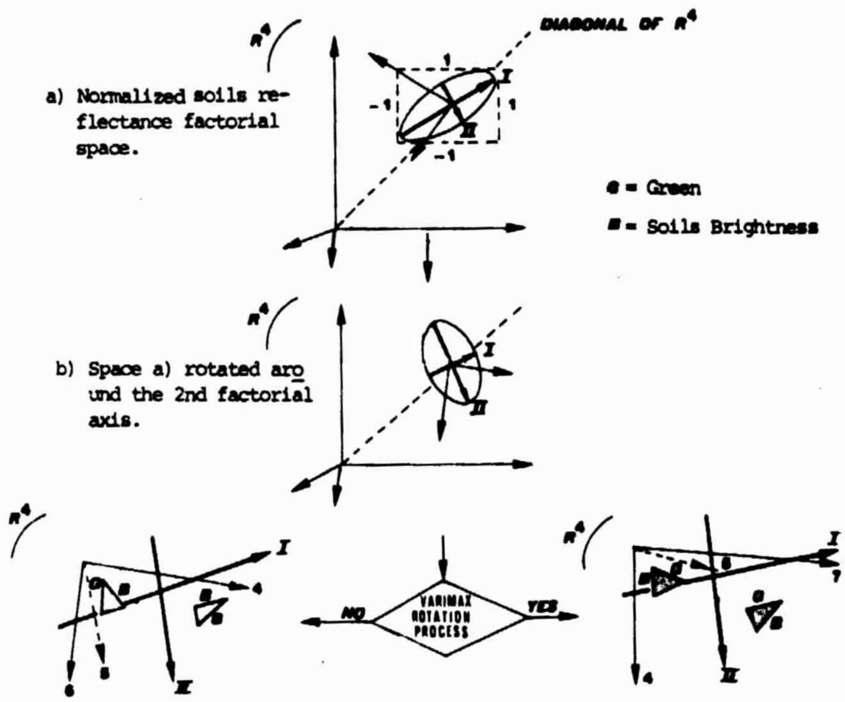


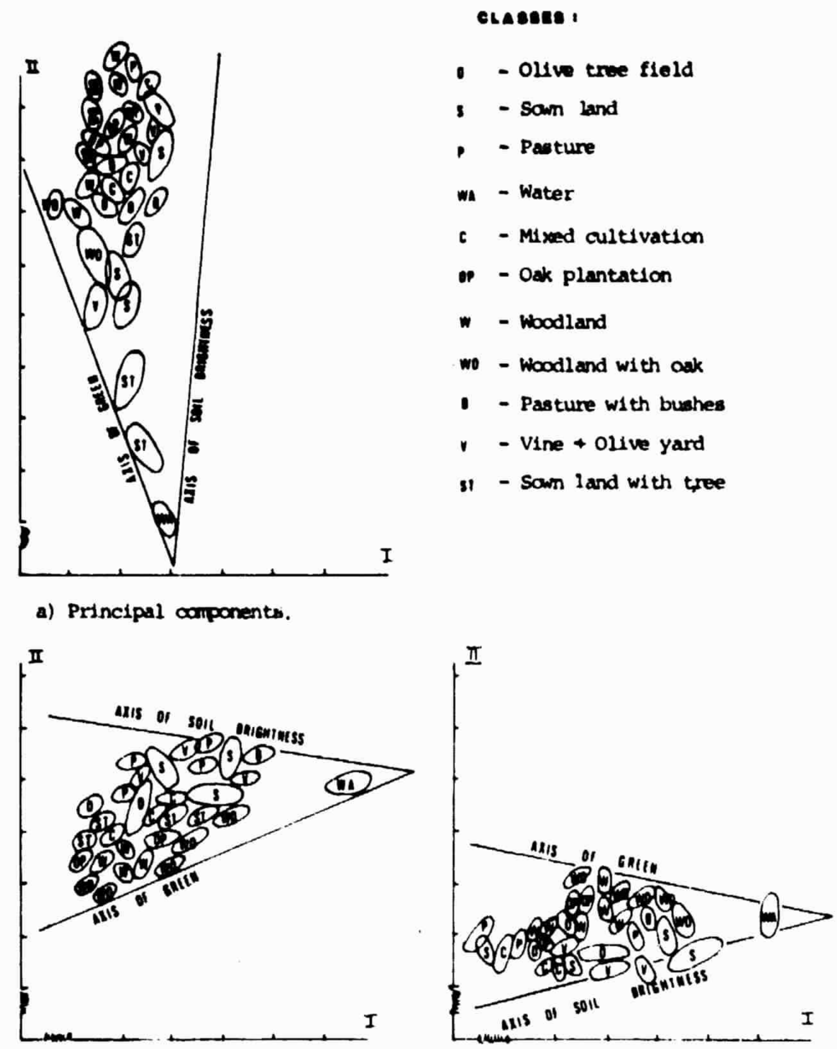
FIGURE 2 - Projection of the best soils reflectance K-plane onto:
a) first two principal components,
b) first two factors rotated by varimax criterion.



c) Axis of soils brightness projected onto 1st unnormalized factor.

d) Axis of green projected onto 1st unnormalized factor.

FIGURE 3- Scheme of the procedure for obtaining images correlated to green and/or soils brightness indicators.



a) Principal components.

b) Factors rotated by the varimax criterion.

c) Factors not rotated.

FIGURE 4 - Plot on first two factors of one sigma dispersion ellipses of different classes.

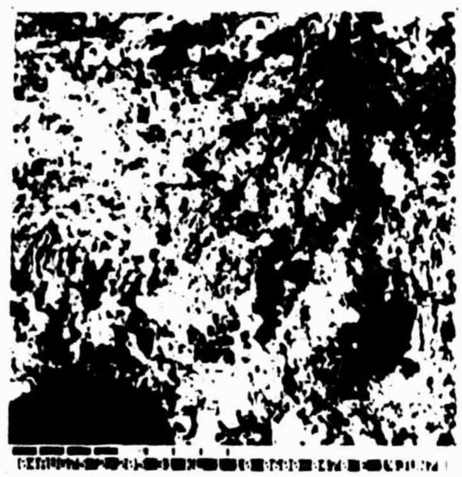


FIGURE 5 - Image projected onto the first principal component.

FIGURE 6 - Image projected onto the second principal component.

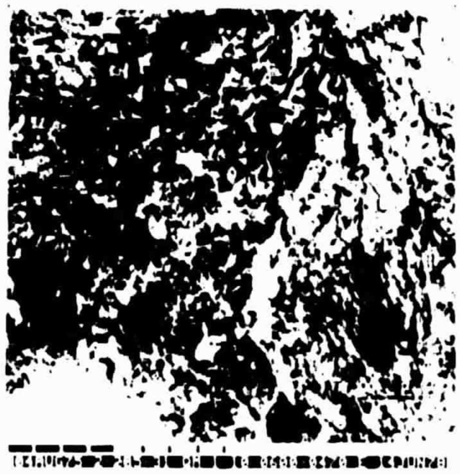


FIGURE 7 - Greenstuff image.

FIGURE 8 - Soil brightness image.