TM/LANDSAT IMAGES FOR PEDOLOGICAL SURVEY UNDER BRAZILIAN NORTHEAST SEMI-ARID CONDITIONS

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ISPRS COMMISSION VII
PAPER N..0247

ABSTRACT

Orbital Remote Sensing techniques are not widely used in studies related to pedology in Brazilian semi-arid regions. This research tried to evaluate TM/Landsat images contribution in the segmentation / identification of different soil classes from one 15 Km x 15 Km study area located in the southeast region of Ceará state, Brazil. Digital processing (3-D synthetic images) and visual analysis were carried out, considering the following photopedologic elements: relief, drainage, photographic texture, land use and photographic tonality. Most photopedological informative bands were TM5 and TM4 and best band compositions was TM345, where vertic character was clearly visible. Additionally synthetic 3-D images enhanced relief and physiographic aspects.

KEY WORDS: Soil Mapping, Semi-arid Regions, Photopedology, 3-D Images, Image Interpretation

INTRODUCTION

The possibility of using orbital images for soil survey is based on the fact that the soils are composed by profiles (internal characteristics) and, in the same way, by the surface landscape (external characteristics) (MONTOYA, 1983). Thus, landscape features and appearance, visible in remote sensing images, are expected to exhibit soil internal characteristics.

The recognition (interpretation) of the soil unities from orbital images is done consequently from great surface patterns, mainly relief, drainage, photographic texture, tonality (spectral reflectance), vegetation type and land-use (GOOSEN, 1968; VALERIO FILHO et al., 1981; VETORAZZI, 1988). Besides, auxiliary data, which can include the parent material (geology) and the geomorphology, must be regarded.

In a country said to have "continental" territorial dimensions, as in Brazil, there is a great lack of thematic informations on intermediate levels of detailing. This is clear in the case of the "Pedology" theme on the brazilian semi-arid region, which has only one exploration/recognition survey at a scale of 1:600.000 (BRAZIL, 1973) and another exploration survey at a scale of 1:1.000.000 (BRAZIL, 1981).

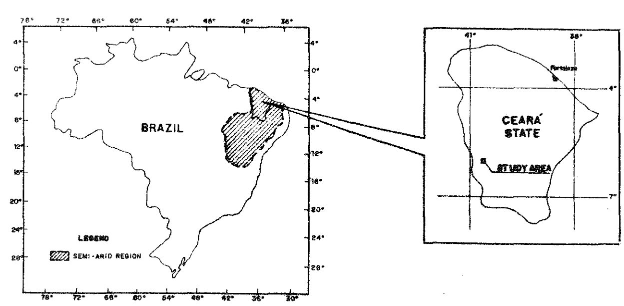
Remote sensing orbital images technique is still unused nowadays on soil survey studies about the brazilian semi-arid region, which corresponds to 11% of the territory (Figure 1). This also occurs to the majority of the semi-arid regions of the World.

It is found, so, that adequate methodology of photopedological interpretation may produce results of great informational potentiality.

The objectives of this study were: (a) to develop the extraction of pedological information from orbital multispectral images; (b) to verify what are the pedological important informations for semi-arid areas that one can extract from orbital images; and (c) to evaluate the pedologic detail level given by the images.

TEST SITE

The chosen area is placed in the southwest of the state of Ceará, in the northeast region of Brazil, between the $6^{o}00$'S and the $6^{o}15$'S paralells and the $40^{o}30$'W the $40^{o}45$'W meridians (Figure 1).



Brazilian semi-arid Region

Figure 1 - Brazilian semi-arid region (a) and test site location (b).

As related by SUDEC (1981), test site is geologically composed of: (1) Cenozoic, represented by alluviums displaced in narrow bands along the rivers; (2) Paleozoic, represented by granitoids and biotite gneiss.

The relief is fundamentally smooth with soft slopes and hill forms. Granitoid rocks perform occasional points of higher altitudes

The climate type, according to Koppen classification, is Bswh, in other words, hot and semi-arid wheather, with insufficient and irregular precipitation (SUDEC, 1981).

Test site original vegetation was represented by Forests (Deciduous Forests) and by semi-arid shrubland ("Caatinga").

MATERIALS AND IMPLEMENTS

For the development of the study, analogical products from TM/Landsat-5 sensor were used in the form of individual band and color composition images at 1:50.000 and 1:100.000 scales, from the 218/64 orbit/point (WRS) of 08-26-90. Also used for this study were the Parambu/1:50.000 topographic map

(SUDENE, 1985) and the soil survey maps: (a) Exploration/Recognition survey at scale of 1:600.000 (BRAZIL, 1973); (b) Exploration survey at scale of 1:1.000.000 (BRASIL, 1981); and (c) Semidetailed Recognition at scale of 1:50.000 (SUDEC, 1981).

The digital processing part of the study required the use of SITIM/SGI (ENGESPAÇO, 1990 a,b), which has algorithms specially designed for treating remote sensing image data (SITIM unity) and a Geographical Information System (SGI unity), based on 16 or 32 bit PC microcomputers (ERTHAL et al., 1988).

METHODOLOGY

In a first step, digital TM/Landsat-5 data from 08-26-90 were matched with a topographic map (SUDENE, 1985), and then enhancing was done through "contrast enlarging" (ENGESPAÇO, 1990 a,b); afterwards, one digital composition image, made out of three TM bands, was codified to allow the transfer to the SGI unity.

In the second step, the aim was the obtention of tridimensional synthetic images of the test site. Thus, contour lines from topographic map (SUDENE, 1985) were digitalized, resulting on the DEM (Digital Elevation Model) of the area. The test site DEM and codified image were then matched by superposition.

The third step consisted on visual interpretation of the various TM/Landsat photographic products that were available (individual bands and band compositions, in the 1:50.000 and 1:100.000 scales). The following photopedological elements were used for this interpretation: relief, drainage, photographic texture, land use and photographic tonality (soil spectral reflectance), according to proposition from GOOSEN (1968), VALERIO FILHO et al., (1981) and VETORAZZI (1988). These photopedological elements are features and informations easily taken from photographic products and, despite of being surface features, they are related with soil types in a studied image. I.e., this work is done based on the assumption that exists a "soil type x landscape aspects" relation. The final product of this step is the Photopedological Model of the test site, where there is a number of subdivisions (soil unities) resulting from the photointerpretation according to the above mentioned photoelements.

In the last step, the following points were analysed for the semi-arid region: (a) the photopedological contribution of the TM/Landsat images; (b) the contribution of the employed photopedological elements; and (c) the detail improvement achieved with orbital images.

RESULTS AND DISCUSSIONS

TM/Landsat images and photopedological elements contribution

Table 1 presents the evaluation of the contribution potential of the different TM bands and compositions employed in this study.

TABLE 1 - TM DIFFERENT BANDS/COMPOSITIONS CONTRIBUTION TO THE ANALYSIS OF PHOTOPEDOLOGICAL INTERPRETATION ELEMENTS

BANDS/COMPOSITIONS	SCALE	RELIEF	DRAINAGE	PHOTOGRAPHIC TEXTURE.	PHOTOGRAPHIC TONALITY.	LAND USE
TM-1	1:50.000	B	VB	VB	B	B
TM-2	1:50.000	B	VB	B	B	R
TM-3	1:50.000	R	B	R	R	VG
TM-4	1:50.000	R	G	G/R	R	G/R
TM-5	1:50.000	G	G/R	G	R	G
TM-7	1:50.000	R	R	G	R	G
TM-235	1:50.000	B	VB	R	G	B
TM-345	1:50.000	R	G	G/R	G	R
TM-234	1:100.000	G/R	B	G/R	G	VG
3-D	-	VG	R	R	NO	NO

Where:
VG = Very good
G = Good
R = Regular
B = Bad
VB = Very bad
NO = Not observed

Table 2 presents information related to the separability of each pair of soil type (indicating the probability of distinguishing them placed one baside the other, through TM image) and, for each pair of soils, the relative importance of each photopedological element.

TABLE 2 - RELATIVE CONTRIBUTIONS OF THE PHOTOPEDOLOGICAL ELEMENTS AND SEPARABILITY BETWEEN PAIRS OF SOIL TYPES

SOIL TYPES (pairs)	SEPARABILITY	RELATIVE CONTRIBUTIONS FROM THE ELEMENTS
P x B	very low	relief, drainage, texture
P x N	not separable	-.-
P x V	high	tonality
P x N	not separable	-.-
B x V	high	tonality
B x L	medium	relief, drainage, texture, land-use
N x V	high	tonality
N x L	medium	relief, drainage, texture
V x L	high	tonality, relief, drainage, texture
A x ANY	high	tonality

Where:
P= deep soil with B textural horizon ("Podzolics") ;
B= shallow soils with B textural horizon ("Non-Calcic Brown);
N= soils with B textural horizon and Na saturation between 6% and 15% ("Planosol");
V= (highly montmorillonitic soils) ("Vertisol");
A= Low developed soils ("Alluvial soils");
L= Low developed soils ("Litholic soils").

To maximize pedological information extraction from photographic images, easy identification of the terrestrial surface elements (which are related to the soil types), as relief and drainage, is required.

From Table 1, it can be said that the best TM bands to extract informations about the main pedological photointerpretation elements, under brazilian semi-arid conditions, were, firstly, TM5 and, following, TM4 and the TM345 composition.

The wider water - courses (all temporary) show sandy river beds (alluviums) with high TM4 reflectances, contrasting with adjacent areas. However, the riverside vegetation is green in August (when the images used here were acquired), what enhances the water-courses in false-color compositions (like TM234 composition). Thus, it's possible to identify the continuity of these rivers with these compositions.

Considering TM4 band only, those rivers appear enhanced, since high reflectance of the sandy river beds occurs together with the also higt reflectance (in this band) of the riverside vegetation. Where adjacent areas covered with schrub ("caatinga") vegetation exhibit low TM4 reflectance (dark gray), the rivers appear in a high contrast.

Minor water-courses are better observed on band TM5, because the "Caatinga" vegetation appears brighter in this band, allowing a more clear observation of the relief. On band TM4, "caatinga" areas have dark gray levels, so minor water-courses cannot be observed. There is an additional complexity factor in this area due to the land-use which is intense and consisted of a large number of small agricultural areas. These areas (bare soils, generally) appear very bright in TM4 images, decreasing the contrast between water-courses and adjacent areas.

The photographic texture, as photopedological element, is highly related with the terrain surface roughness. It can be stated that photographic texture and relief show high correlation. On areas free of land-use, the photographic texture is clear and of easy extraction, and is given by illuminated and shadowed portions of the surface (areas facing east and west, respectively) alternatively.

When occurring agricultural activities, bare soil areas show high reflectances and so the sense of photographic texture is lost, what may be considered one of the difficulties for the obtainment of the photopedological model.

In general, TM4, TM5, TM7 bands and the TM345 and TM234 compositions gave the best photopedological contributions. TM1 and TM2 bands gave no additional contribution to the informations extracted from the other TM images.

When used as photopedological element, photographic tonality is practically the soil spectral reflectance. It is known that soil spectral reflectance is related mainly to variables as: organic matter (content, form and stage of decomposition), moisture, parent material, mineralogy type, surface conditions, granulometric composition, iron oxide and others (STONER and BAUMGARDNER, 1980).

Among these variables, some decrease soil reflectance (for example, increasing organic matter content) while others increase it (for example, increasing sand content). Since all soil reflectance variables occur together, the resulting reflectance will be determined by the integration of all these variables.

The bluish features in vertic soils occurring in the TM compositions were remarkable in the test site. Montmorillonitic clays probably retain moisture and organic matter, determining so the bluish appearance observed on vertic soils.

In the test site area generally occurs soils origined from granites and gneisses with a very bright tonality (and with high reflectance in most of the TM bands).

In this area, the surface coverage is mainly composed of farmlands and "Caatinga"/deciduous vegetation (SUDEC, 1981), what means that in the dry period of the year the leaves fall or dry. Since the radiometric sign that reaches the sensor is a soil/vegetation sign composition, the role of the superficial conditions on the interpretability of the studied photopedological elements turns out to be evident.

Thus, the low contrast between water-courses and adjacent areas and the relatively intense farming turned the extraction of some of the main photopedological elements from the TM image a difficult job. It is important to record here the relief sensation caused on the images by the drainage net dissection. Bare soil areas resulted from land-use interrupt the drainage visibility, causing difficulties to the physiographic analysis, based on relief + drainage + texture.

Analysing table 2 and the photopedological model (not presented here), it is verified that "Podzolics"and " Non - Calcic Brown" and "Planosols" can not be distinguished through any photopedological element, in this semiarid area with its crystalline rocks.

The photopedological elements considered for these three soil classes are quite similar, in addition to the low contrast, mentioned above, that made very diffuses the limits of these soil unities in the images.

The selection of an image acquired during the rainy period of the year probably may result in an increase in the interpretability of the photopedological elements, for these soil classes.

Concerning to the alluvial soils, they can be considered the most easily distinguishable soil when one photointerpreter uses TM images. Usually occurring along temporary river beds, they are sandy soils and reflect much more than any adjacent target, appearing practically white in all TM band images.

For the discrimination of the Litholic soils in relation to any of the studied soil classes, the elements relief, drainage and photographic texture were practically enough (Table 2). These soils occur generally on rough relief areas, thus with denser drainage and rougher texture, as compared to the "Podzolics" soils and "Non-Calcic-Brown ", for example. Due to the relief roughness in the areas where these soils occur, land-use is absent,without the contrast decrease effect caused by agricultural bare soil.

The TM images scales were 1:50.000 and 1:100.000.In the first case, there was a loss of detailing particularly related to the drainage, due to perception of individual pixels, mainly in individual TMbands. At the scale of 1:100.000, although visualization of great surface patterns was easier, there was a sensation of loss in general details of the image. Probably, an image at a scale of 1:75.000, an intermediary scale between the two scales used in this work would be the best for studies concerning to soil surveys and sattelite imaging.

In relation to the potentials of image digital processing, an effort was done aiming the obtention of synthetic 3-D images for further evaluation of their contribution to the pedological information extraction from the images.

The use of the synthetic 3-D images aimed to help the visualization of the terrain physiography,once the orbital images do not offer the stereoscopic character, available in aerial photographs.

Analysing these 3-D images, it is found that the visualization of the great relief patterns is actually improved because of the perspective views available this way. (N-S, L-W, S-N and W-L, all not presented here). However, of remark is the difficulty in representing spatially the interpretations made in the 3-D image to a 2-D basis, the dimension we used to work with in this research.

The utility of the 3-D image is then restricted to an analysis paralell to TM image, as a safe source of detailed information related to the relief.

Anyway, it is opportune to remark the necessity of further testings of other kinds of compositions, scales and image digital processing and enhancing techniques, what could bring much more fundamental information.

TM/Landsat Images and Pedologic Detailing Level

Regarding to the brasilian pedologic carthography available nowadays, there is already soil maps about the entirenational territory, but the scales and the detailing level is quite coarse (for Ceara State, for exemple, there are: Exploration/Recognition survey at a scale of 1:600.000, BRASIL, 1973 and Exploration survey at a scale of 1.1.000.000, BRASIL, 1981). In some limited areas in Ceara state, there is more detailed surveys (for exemple, SUDEC, 1981), where is localized the test site of this study.

It would be of great utility if orbital images taken over large territorial areas could contribute to improve the detailing of old pedologic surveys.

Comparing the informations obtained from the TM/Landsat image interpretation (photopedological model) to those found in the invailable surveys (BRAZIL, 1973, BRAZIL, 1981), it was observed that the map detailing is much coarser than the model, in which "Vertisols" and Litholic and Alluvial soils occur with good precision (as compared to the Semidetailed Recognition SUDEC,1981,the ground truth in this work). In addition the carthographic precision performed by the model is much better.

CONCLUSIONS

From the materials and from the methodology utilized in this study, it was possible to state the following conclusions.

The most pedologically informative bands were the TM4 and TM5, that showed better the relief freatures and the water-courses; minor water-courses are better showed by TM5 band; great water-courses can be easily observed through TM4, but the TM3, TM5 and TM7 bands also resulted in a good identificability.

TM345 (blue, green and red filters, respectively) scale 1:50.000 was the best composition, offering good visibility of texture and relief and drainage features. This composition showed good performance for soils with vertic character.

The TM234 (blue, green and red filters, respectively) scaled 1:100.000 looses photopedological potential in an area of crystalline rocks, under semi-arid environmental conditions and intense farming like the site, because it remarks exactly the land-use feature, oppose to other photopedological elements.

The most informative photopedological elements were the relief, the drainage and the photographic texture. The land-use element, which has a good information content for special cases, made difficult the interpretability of the main soil classes in the test site. The photographic tonality was of great utility for the identification of areas of vertic soils. The above mentioned elements weren't enough to allow distinction between the "Podzolics","Brown" "Planosols" soils. The alluvial soils were the most easily distinguishable, for their high contrast with other targets in the TM images.

As concerning to the digital processing, the synthetic 3-D images were considered of great importance to enhance features related in special to relief and to physiography, which have large informative potential in photopedology. However, it was difficult to compare the 3-D with the 2-D images,because of the 3-D photographs' perspective. Nevertheless, it was not possible to evaluate the actual vertical enhancing of the 3-D images, therefore the correlation between the synthetic and the real relief was not observed.

The TM/Landsat orbital images show potential of detailing of the existent pedologic surveys in Brazil today (basically, the Radambrazil project and the SNLCS survey) and probably in other semi-arid lands of world.

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