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14. Abstract/Notes *Nowadays, there is an increasing amount of data processing techniques for image enhancement, e.g. high-pass filtering, low-pass filtering, Laplacian filtering. More recently, a new approach to produce topographic enhanced images was presented as an alternative technique to extract the topographic modulation component from digital data. The enhancement process is based on the fact that the pixel contains two types of information: (1) reflectance variation due to the target; (2) reflectance variation due to the topography. In order to enhance the signal variation due to topography, the technique recommends to extract from original LANDSAT data the component resulting from target reflectance. Considering that the role of topographic modulation over the pixel information will vary with solar incidence angle, the results of this technique of digital processing will differ from one season to another, mainly in highly dissected topography. In this context, the main purpose of this study is to evaluate the effects of solar incidence angle over topographic modulation technique. To accomplish this study, two sets of MSS/LANDSAT data, with solar elevation angles varying from 22^o to 41^o, were selected to implement the digital processing at the Image-100 System. A secondary watershed (Rio Bocaina) draining into Rio Paraíba do Sul (São Paulo State) was selected as a test site. The results showed that the technique used was more appropriate to MSS data acquired under higher sun elevation angles. Topographic modulation components applied to low sun elevation angles lessens rather than enhances topography.*

15. Remarks
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THE EFFECTS OF SOLAR INCIDENCE ANGLE OVER DIGITAL PROCESSING OF LANDSAT DATA*

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ABSTRACT

Nowadays, there is an increasing amount of data processing techniques for image enhancement, e.g. high-pass filtering, low-pass filtering, Laplacian filtering. The main objectives of these techniques are to accentuate the data characteristic mainly for visual display. Feature extraction techniques are another visual approach to enhance discriminating features. More recently, a new approach to produce topographic enhanced images was presented as an alternative technique to extract the topographic modulation component from any digital data. According to its authors,this technique is a completely closed system employing only the image data. The enhancement process is based on the fact that the pixel contains two types of information: (1) reflectance variation due to the target; (2) reflectance variation due to the topography. In order to enhance the signal variation due to topography, the technique recommends to extract from original LANDSAT data the component resulting from target reflectance. Considering that the role of topographic modulation over the pixel information will vary with solar incidence angle, the results of this technique of digital processing will differ from one season to another, mainly in highly dissected topography. In this context, the main purpose of this study is to evaluate the effects of solar incidence angle over topographic modulation technique. To accomplish this study, two sets of MSS/LANDSAT data, with solar elevation angles varying from 22^o to 41^o, were selected to implement the digital processing at the Image-100 System. A secondary watershed (Rio Bocaina) draining into Rio Paraíba do Sul (São Paulo State) was selected as a test site, mainly because it presents a highly dissected topography. The resulting enhanced images were compared taking into account the degree of accuracy of river valleys, scarps and geomorphic boundaries. The results showed that the technique used was more appropriate to MSS data acquired under higher sun elevation angles. Low sun elevation increases the variance of each cluster in such a way that the average brightness doesn't represent its albedo properties. Topographic modulation components applied to low sun elevation angles lessens rather than enhances topography. The results indicated that the technique produces better results when applied to channels 4 and 5 and that sun elevation aspects must be carefully checked before selecting the type of digital processing to be applied to the data.

1. INTRODUCTION

The role of LANDSAT (MSS and RBV) data for geomorphological studies is receiving increased attention, mainly as a tool for acquiring topographic information. In this context, the seek for new topographic enhancement techniques is an important task for both geologists and geomorphologists.

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Considering that previous work (Gardner and Miller, 1977; Miller, 1978; Kitcho, 1979; Kowalik, 1981; Novo, 1982) had already demonstrated that scene illumination geometry (solar elevation and azimuth) is an important source of variation in the degree of topographic enhancement on MSS/LANDSAT data, the present study aims to evaluate the effects of solar angles over topographic modulation technique suggested by Eliason et al. (1981).

As one could expect, it was not possible to follow strictly the approach developed by Eliason et al. (1981), and it was taken in account in the final technique evaluation.

2. EXTRACTION OF TOPOGRAPHIC INFORMATION FROM MSS/LANDSAT IMAGERY

According to Eliason et al. (1981), the main advantage of the technique is that topographic enhancement is accomplished in a completely closed system employing only the image data.

Those authors considered that the MSS/LANDSAT pixel contains two types of information: (1) reflectance variation due to the target; (2) reflectance variation due to topography. If someone succeeds in extracting from digital data the brightness component related to target reflectance, a topographic enhanced image can be easily obtained. For that, the authors assumed that: (1) topographic modulation is independent of materials properties and wavelength; (2) photometric function is independent of wavelength.

According to those authors, the image brightness distribution within an image can be expressed as follows:

$$B(x,y,\lambda) = R(x,y,\lambda) * M_T(T(x,y),\ \phi(\alpha,i,E)) + H_{(\lambda)}$$

where:

$B(x,y,\lambda)$ = Brightness distribution in each MSS band.

$R(x,y,\lambda)$ = Brightness of the scene as a function of wavelength, λ, assuming a flat surface.

M_T = Modulation of the brightness due to topography; it is a function of topography $(T(x,y))$, and the photometric function $\phi(\alpha,i,E)$.

H_λ = Additive atmospheric scattering.

After correction for additive atmospheric effect, the brightness distribution can be expressed as follows:

$$B = R * M_T$$

A gray level distribution representing only the topographic modulation of the brightness (M_T) can be obtained (Eliason et al., 1981) by rationing brightness distribution in each channel (B), by the brightness derived from surface reflectivity (R).

According to Eliason et al. (1981), color information in the four LANDSAT bands could be reduced into three independent ratios which, theoretically, would have only spectral information about target reflectivity.

Using ratio variables, the authors accomplished an unsupervised clustering technique to obtain R values for each channel. The average brightness of each cluster in band(i) was taken as predicted brightness of all pixels within the class, assuming that slopes were simmetrically distributed in relation to the illumination source.

Finally, by rationing Brightness values (B) by the R values, Eliason et al. (1981) obtained the M_T image for MSS band 5, where topography was expressively enhanced.

In the present work, it will be demonstrated that although the method developed by Eliason et al. (1981) presents high performance for MSS imagery taken at high elevation angle, and covering low relief areas, it is possibly not the best approach for MSS/LANDSAT data taken at low solar angles.

Material and Methodology.

Two sets of MSS/LANDSAT data referring to the ORBIT 150, ROW 28 (Table 1), available as computer compatible tape, were used to accomplish this study.

The dates of the MSS/LANDSAT data were selected considering the need of contrasting illumination conditions over the scene, as the main objective of the study was to evaluate scene illumination geometry over digital topographic enhancement.

A secondary watershed (Rio Bocaína) draining into Paraíba do Sul River (São Paulo State) was selected as test site (Figure 1), mainly because it presents a highly dissected topography.

The digital processing was performed by using Image-100 system (General Electric, 1975), according to the following procedures (Figure 2).

Considering that the technique for extraction of topographic information from multispectral images (Eliason et al., 1981) was originally implemented in a microcomputer, some adaptations were accomplished to implement it on Image-100 system. These differences, however, do not modify the basic approach suggested by the authors.

Steps 1 to 3 in Figure 2 are routine procedures on Image-100 system. The step 4 and the following represent the necessary operations to perform the digital topographic enhancement.

As automatic co-registration is not available at IMAGE-100 system yet, temporal data were co-registered by superposing images taken in the different date. It was possible by storing two MSS/LANDSAT bands from each date in the four out of the five channels available in the IMAGE-100 system. It permits to display LANDSAT data of different overpasses at the same time and, by changing one set in relation to the other, to obtain the best adjustment between the images.

Correction for atmospheric effects was performed according to the methodology suggested by Robinove et al. (1981). Considering that shadowing slopes or deep and clear water bodies shouldn't present any response to MSS sensors, they were used as training area in order to identify the lowest gray level related to them. In this way, the lowest density number registered on MSS band 7 (which is supposed to present the lowest scattering level) was used as training sample to classify the other MSS bands. The average gray level of the alarmed area in the remaining bands was then obtained and subtracted from the original data.

Band ratio variables were then obtained by using Ratio 2 Program, which must be fed with gain and offset values, heuristically determined. Although Eliason et al. (1981) had used besides ratio 6/5 (which best distinguishes between major material groups), a composite ratio to summarize information from ratios 5/4 and 7/6, in the present work only ratios 4/5 and 6/5 were applied. These ratios were used as it was thought to be the most suitable for a region of homogeneous vegetation cover (grassland).

Band ratios were then used to implement an unsupervised classification using 2-channel system which allows to separate all pixels in K clusters, according to their digital number (Dutra et al., 1982). That classification system requires a reduction of the dynamic range from 256 to 64 digital number. The process of dynamic range reduction uses the compression option, which consists in substituting few populated DN for the next most similar gray level among the 64 DN more frequent in the scene.

To implement the unsupervised classification, training samples were selected. By means of those samples, gray level distribution is defined and the most populated cells are used as initial center to implement K-Means algorithm (Dutra et al., 1982).

The classification results were then used to calculate the average brightness for each cluster using Single-cell option. GERCOR program further allowed to assign the average brightness value to each pixel within each cluster and MSS band.

The resulting (R) images were then stored for posterior use. By using the programs Video Disk I/O, Video Exchange and Ratio 2, (M_T) image could be obtained. For that each original channel (Bi) was rationed by the average brightness image (Ri) in order to obtain the (M_T) image.

The same procedure was performed for both sets of LANDSAT data.

Results

Thte resulting topographically enhanced images were analysed so as to as certain their capability of showing new aspects of topographic relief. This analysis demonstrated that the enhancement effects are variable, either debasing or improving image quality for topographic studies.

Enhanced image referring to high sun elevation angle (01/31/1978) presented better results in bands 5 and 6, whereas for that acquired at low elevation angle, only channels 4 and 5 presented good results for geomorphological mapping.

The comparison between Figures 3 and 4 allows to verify that topographic modulation technique applied to image taken at high solar elevation enhanced Ribeirão Piquete Flood Plain (1), Paraíba River channel (2), and the hilly dissection pattern (3) due to the elimination of tonal variation related to ground cover.

In Figure 3 Ribeirão Piquete Flood Plain can not be well defined because land use spectral characteristics almost delete the smooth feature of this type of gemorphological unit. This smoothness however is enhanced on Figure 5 as an effect of extracting albedo information from the original data set, and leaving only topographic information.

The evaluation of the modulation technique performance for LANDSAT data acquired at low solar elevation, demonstrated that there is a strong difference between channels. As the gray level variance increases within each cluster from channel 4 to channel 7, due to illumination geometry, topographic modulation image (M_T) quality decreases.

The comparison between Figures 5 and 6 allows to verify that there is not a significant increase in the amount of topographic information after digital processing. On the contrary, it can be noted that the amount of noise has increased considerably. As it has been mentioned by Eliason et al. (1981), the signal to noise ratio is poor when the sun angle is low. So, after extracting albedo/color information from original data, noise rather than topography is enhanced.

Although those are preliminary results, the following observations can be made:

1 - Topographic modulation technique seems to be more suitable to MSS bands 4 and 5, where tonal variation is related to material reflectivity.

2 - Illumination geometry affects significantly the technique performance.

Eliason et al. (1981) have already pointed out the fact of confusing local albedo variation with topographically induced brightness in areas where topographic effect is large. As low elevation angle increases the topographic effect (Kowalik, 1981), the discrimination between different types of material in images taken at low sun angles is much more difficult. To minimize this problem, the authors suggested to divide the area of the classified image into sections. According to them, box size of 100 by 100 pixels proved successfull for their study, and this approach will be a next task in the present study.

Another possible explanation of the failure of this technique for low solar elevation images is related to the fact that, although the clusters are defined over multispectral ratios which reduce topographic effect, Eliason et al. (1981) derives the average brightness by summing the brightness value of image points in band(i)(representing a cluster). As the average brightness is a function of the scatter of brightness values within a cluster, and considering that low elevation angles increase the scattering of tonal distribution on the image, there is a decrease in the probability that average brightness can represent a good estimate of scene brightness in each cluster.

So, the assumptions made by Eliason et al. (1981) are good for a region where topography presents little variation and for images taken at high sun elevation angles, since in these cases gray level variance within each cluster is smaller.

Variation coefficient of the brightness value proved to be greater for image taken at low solar angle, mainly when band 7 was considered, showing that in this band topographic control of brightness is much more effective.

3. CONCLUSION

In face of the results, one can conclude that Ri values, according to Eliason et al!s approach (1981), are suitable to represent brightness values of different surface material in the image taken at 41^{o} of solar elevation. The variance within each cluster is higher for image acquired at low sun angle, from what can be concluded that average brightness doesn't represent correctly the albedo and color properties of the surface material. As the variance increases from channel 4 to 7, the scene quality under digital processing decreases, since the success of the technique is based on a faithfully classification of spectral albedo information from the image.

The results showed that much more effort must be endeavored in testing the technique under different illumination geometry and topography. Even so, one can conclude that there is a temporal subjection of the enhancement performance. Topographic modulation applied to low elevation angle image damages rather than enhances topographic features.

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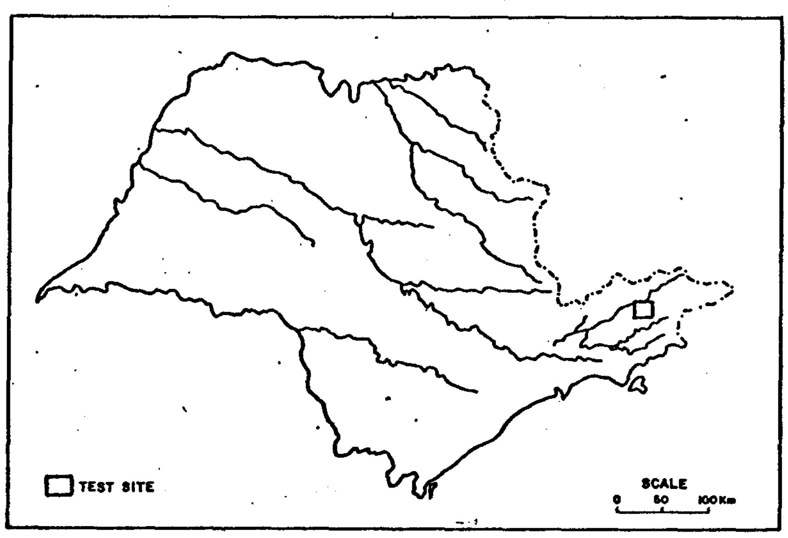

Figure 1. Test Site

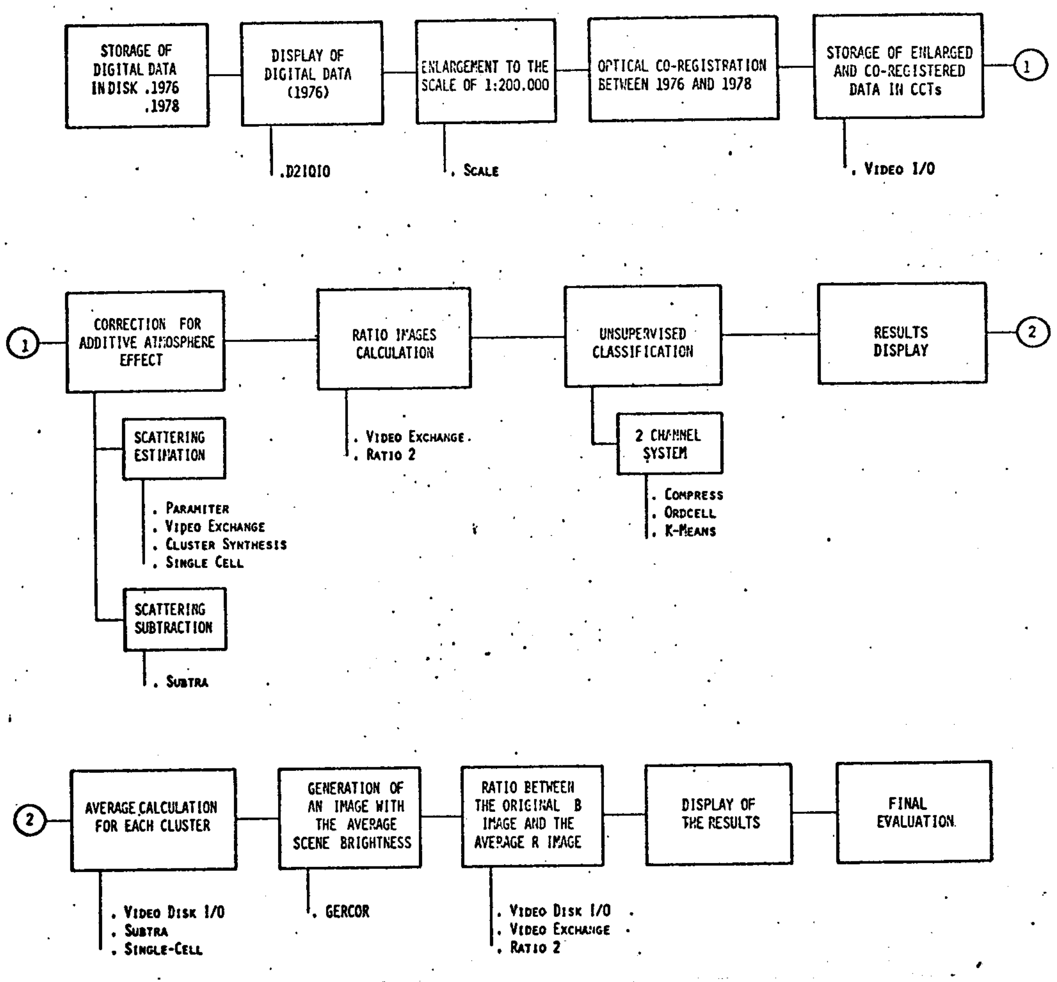

Figure 2. Flux Diagram

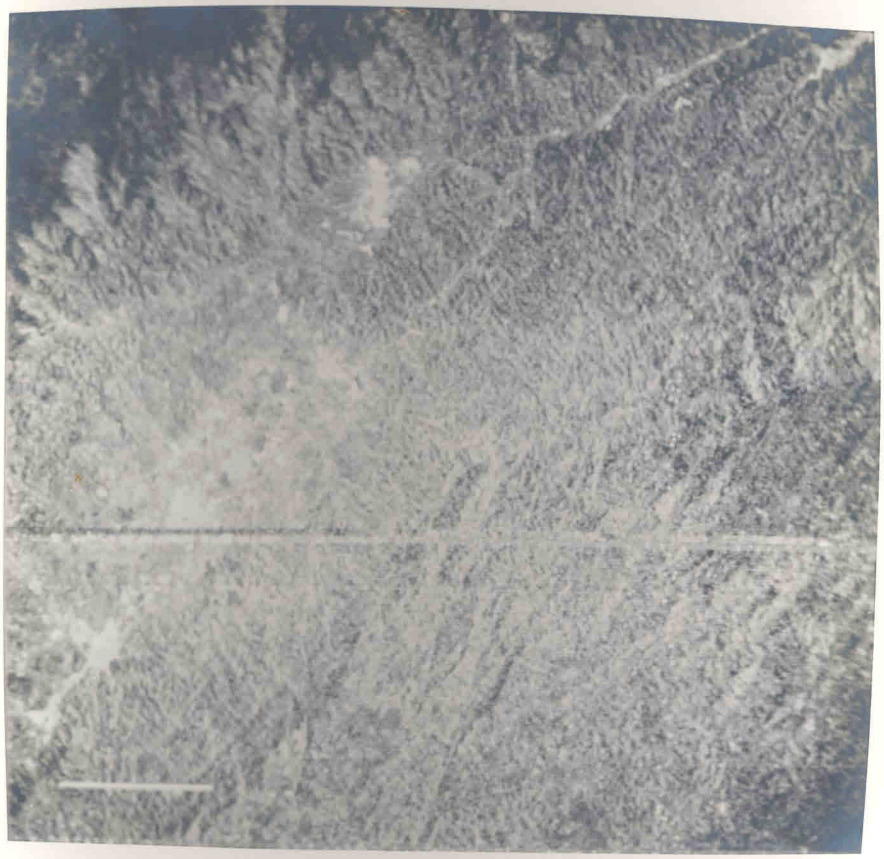

Figure 3. Portion of LANDSAT Scene Acquired in 31/01/78. Band 5 with correction for Additive Atmospheric Effects (High Solar Elevation - 41°).

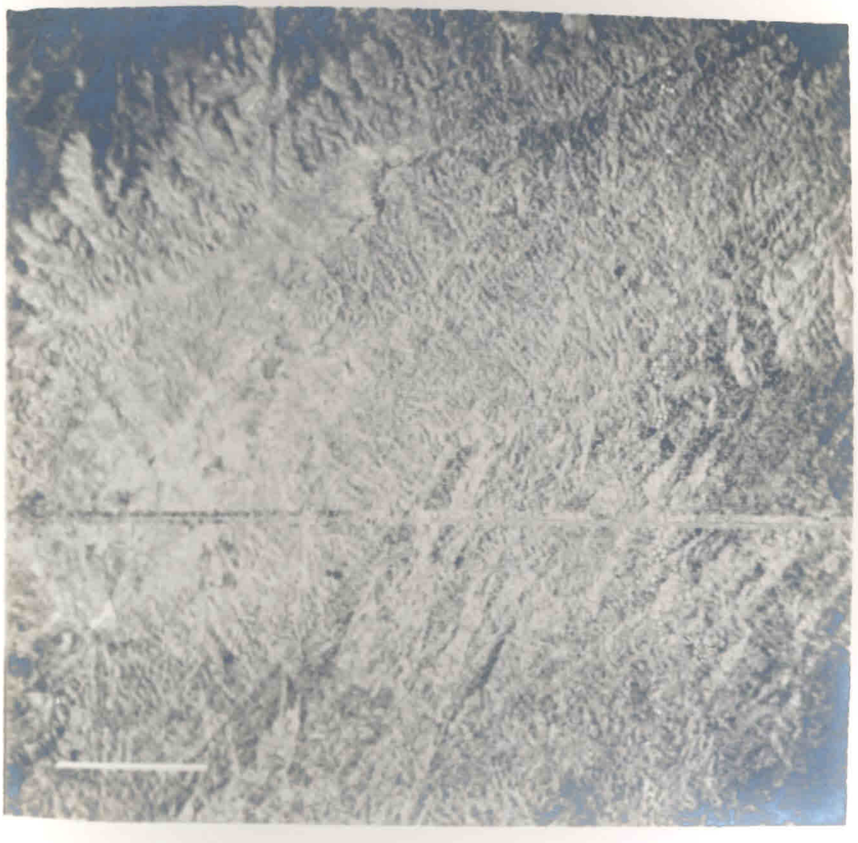

Figure 4. Image displaying M_T, which is supposed to have its tonal variation related with slope. (High Solar Elevation - 41°).

Figure 5. Portion of LANDSAT scene acquired in 25/06/1976. Band 5 with correction for Additive Atmospheric Effects. (Low Solar Elevation - 22^{O}).

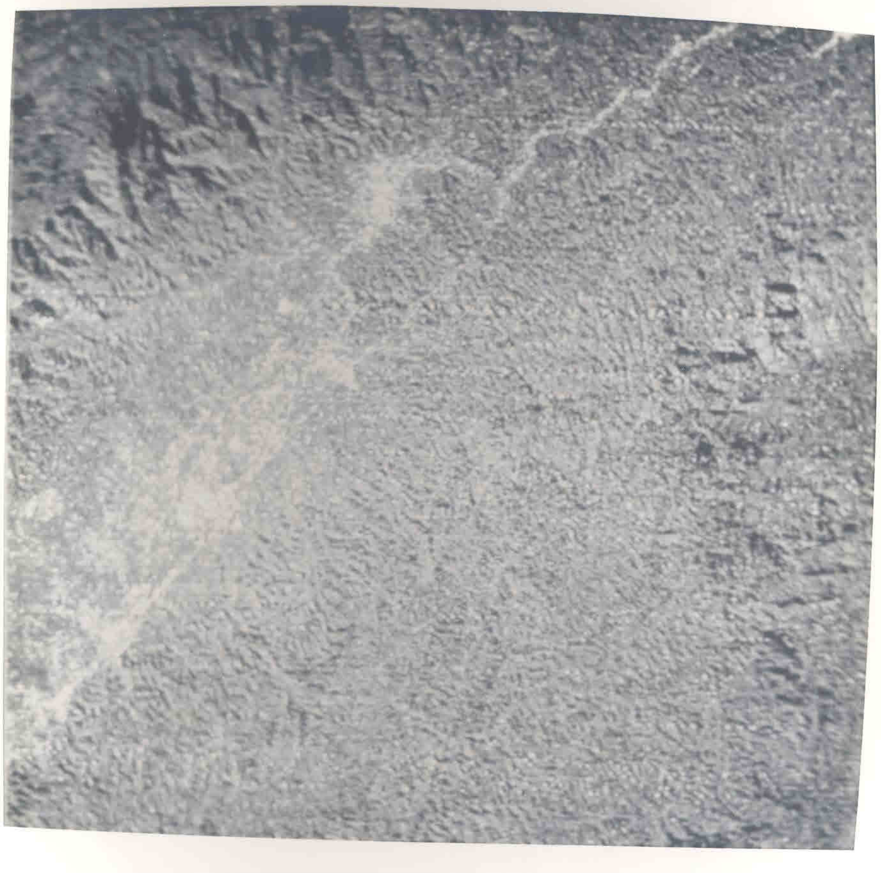

Figure 6. Image displaying M_T, which is supposed to have its tonal variation related with slope. (Low Solar Elevation - 22^{O}).

Table I. LANDSAT Data Available for the study.

SOLAR POSITION / DATE	SOLAR ELEVATION	SOLAR AZIMUTH
25/06/1976	22^{o}	49^{o}
31/01/1978	41^{o}	93^{o}