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RESUMO-NOTAS/ABSTRACT-NOTES

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OBSERVAÇÕES/REMARKS

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# TM/LANDSAT-5 DATA TO EVALUATE WHEAT AND BEAN PERCENT SOIL COVER AND LEAF AREA INDEX

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## ABSTRACT

This paper describes the correlations between two crop parameters (green leaf area index and percent soil cover) and eighteen TM/LANDSAT-5 parameters (six bands and twelve band ratios). The TM/LANDSAT-5 data used were the digital numbers extracted from CCT's and corrected for minimizing atmospheric effects. It was used three overpasses during wheat and bean vegetative cycles. The percent soil cover was estimated using 35mm photographs taken perpendicular to the ground. The results showed that the correlation between remote sensing data and crop parameters is dependent on the level of expression of the crop parameter (crop stages). When the crop vegetative parameters are at their maximum expression there are poor correlations with remote sensing data. So, the more significant values of correlations were obtained in the pre-flowering stage. The most useful TM bands were TM4 and TM3, but their usefulness varied in function of the date of overpass, the crop family, and the crop parameter. Ratios were useful in cases where the single bands showed poor correlations, but no single ratio could be identified with good correlation in all situations. Finally, it was concluded that the knowledge of general development condition of crops is necessary in the selection of the most appropriate remote sensing parameter for correlation to the crop parameters considered in this study.

## 1. INTRODUCTION

The application of remote sensing to agricultural related studies is affected by large variations that occur within of agricultural target areas, such as crop species, tillage, development conditions. Crop development monitoring by remote sensing can allow inferences about crop species and conditions at a specific time. Among various parameters of crop development evaluation, percent soil cover and green leaf area index (LAI) are very important from the point of view of crop evaluation via remote sensing.

The difference between plant and soil reflective spectral behavior is very strong. This can be seen during the crop growing cycle where, at the early stage the spectral response comes mainly from the soil and, with time, the vegetation becomes the main part of the upwelling scene radiance.

However, the evolution from typical soil radiometric response to a fully vegetation response varies in function of crop parameters such as row spacing, crop height, and the intrinsic characteristics of the crop, e.g. foliar emission pattern, and foliar distribution and disposition in relation to a plane. The interaction of these parameters will determine the percent soil cover and the green leaf area index which can, through evolutive monitoring, provide information of agricultural interest.

Utilization of remote sensing data to study crop development has been carried out by many authors. Well stablished correlations between green leaf area index and field measured reflectance have been obtained by Ahlrichs and Bauer (1983), Kamat et al. (1983), Daughtry et al. (1985) and Gardner and Blad (1986), among others. Another crop parameter that has been analysed is the percent soil cover. Richardson and Wiegand (1977) working with sorghum obtained significative correlations between percent soil cover and digital values for multispectral scanner (MSS) bands, MSS4 (0.5-0.6μm) and MSS5 (0.6-0.7μm); and poor correlations when MSS6 (0.7-0.8μm) and MSS7 (0.8-1.1μm) were utilized. The inverse was obtained when the crop parameter was the LAI. Daughtry et al. (1980) working with wheat and making field radiometry observed that higher correlations between reflectance and soil cover occurred between emergence and flowering in the visible region of the electromagnetic spectrum. When the vegetative cycle goes on senescence there is a decrease in the correlation between crop parameters and reflectance because there is a decrease of photosynthetically active radiation, which has high correlation with reflectance (Leamer et al., 1978; Aase and Siddoway, 1980). Huete et al. (1985) and Huete (1987) observed good correlations between field reflectance and cotton percent soil cover. Further, they showed that this relation was different in each of the four soils studied and that the higher influence of the soil/crop target occurred when crop covers varies between 20 and 75%.

The utilization of indices obtained by combining two or more TM/LANDSAT bands that produce new values for each pixel has been realized by various authors for many purposes. The more simple indices are the ones obtained by the ratio between two single bands. Since LANDSATs1-3 carried MSS sensors with only four bands (0.5 1.1μm) the literature related to indices largely covers only this portion of the electromagnetic spectrum.

Perry et al. (1984) made an study showing the relationships between various indices constructions. Richardson and Wiegand (1977) point out that, although isolated bands can be well correlated with crop parameters, the utilization of indices allows better consistency for multitemporal comparisons between crop development conditions.

Among the simplest and more utilized indices are the infrared to red ratio (TM4/TM3), and he normalized difference between these two bands (TM4-TM3)/(TM4 + TM3), (Huete et al., 1985). Many authors found good correlations between these indices and percent soil cover and green leaf area index (Gardner and Blad, 1986; Holben et al., 1983; Daughtry et al., 1984). Daughtry et al. (1984) found that the correlation coefficients between vegetation index and crop parameters were higher for percent soil cover than that for green leaf area index.

The objective of this work is to explore the potential correlative of each single TM/LANDSAT-5 band with green leaf area index and percent soil cover; and between these crop parameters and empiric band ratio indices. Furthermore it is analysed the influence of general growing stages of crops on that potential.

## 2. EXPERIMENTAL PROCEDURES

In this work 30 irrigated fields of wheat (15 fields) and beans (15 fields) were selected in northern São Paulo State (Brazil). The crop development at each area was accompained since the early stages. The planting dates were not coincident, and therefore there was a considerable range of percent soil cover, mainly in the early growing season.

Percent soil cover was estimated according to Heilman et al. (1981) and Cihlar et al. (1987), in which a vertical 35 mm photograph is obtained at 2 meters height. Over this photograph, usually in slide format, it is superimposed a millimetric grid and it is evaluated the soil and vegetation contribution on that area. Green leaf area index was measured by junction of leaf planimetry of plants and mean row and plant spacing data. LAI expresses one side leaf area to unit soil area.

TM/LANDSAT-5 data were acquired on three dates, namely P1, P2 and P3 (06/17/86, 07/19/86, and 08/04/86, respectively), where P2 is 32 days after P1 and P3 16 days after P2. The WRS reference to overpasses is 221/74. These data were recorded on CCT's in which an atmospheric minimization was accomplished using deep water bodies to extract minimum digitals values for each TM band (Schowengerdt, 1983).

From these magnetic tapes were extracted four samples of 12 pixels each of digital values over each wheat and bean field. This was repeated for the three overpasses and for TM1, TM2, TM3, TM4, TM5 and TM7/LANDSAT-5 spectral bands. The percent soil cover and green leaf area index were acquired during field works carried out nearly satellite overpasses. Due to the large fields extension, magnetic tapes samples are in greater number and might not match with field samples.

Correlations were attempted with the following ratios: I1=TM2/TM1, I2=TM3/TM2, I3=TM4/TM2, I4=TM5/TM2, I5=TM7/TM2, I6=TM4/TM3, I7=TM5/TM3, I8=TM7/TM3, I9=TM4/TM5, I10=TM4/TM7, I11=TM5/TM7, I12=(TM4-TM3)/(TM4+TM3). From these, there are some largely tested and some proposed to test now, as TM5/TM7.

With percent soil cover, green leaf area index, mean digital value for single bands and empiric simple ratio data it was stablished the correlations between these variables.

## 3. RESULTS AND DISCUSSION

Crop parameters for three overpasses are shown on Table 1. In P1 the percent soil cover presents low values, particulary the fields of beans. In P2, 32 days after P1, percent soil cover was high, and none wheat field showed less than 90% soil cover, but five bean fields showed less than 60% soil cover. In P3, the situation of crop development was characterized by the presence of areas with very different biologic stage, and signals of maturity in some areas were present, making bean leaves to be yellowish and green wheat leaves decreased.

TABLE 1

MEAN ($\bar{x}$), STANDARD DEVIATION ($\sigma$) AND NUMBER OF OBSERVATIONS (n) FOR PERCENT SOIL COVER AND GREEN LEAF AREA INDEX (LAI) FOR BEAN AND WHEAT FIELDS MEASURED SIMULTANEOUSLY TO THREE LANDSAT OVERPASSES

| | | % SOIL COVER | | GREEN LAI | |
|---|---|---|---|---|---|
| | | WHEAT | BEAN | WHEAT | BEAN |
| P1 | $\bar{x}$ | 75.2 | 36.6 | 3.1 | 1.7 |
| | $\sigma$ | 28.6 | 25.7 | 2.2 | 1.8 |
| | n | 12 | 11 | 14 | 12 |
| P2 | $\bar{x}$ | 97.3 | 75.5 | 3.8 | 3.6 |
| | $\sigma$ | 2.2 | 22.5 | 1.6 | 2.8 |
| | n | 13 | 15 | 15 | 15 |
| P3 | $\bar{x}$ | 97.3 | 84.5 | 3.1 | 4.1 |
| | $\sigma$ | 2.1 | 18.1 | 1.5 | 2.2 |
| | n | 15 | 15 | 15 | 14 |

Correlations between percent soil cover and green leaf areas with single bands and band ratios for three overpasses are shown on Table 2. At first glance it can be observed that better correlations between crop parameters and remote sensing parameters were obtained for overpass P1 than for P2 and P3, and also for P3 than for P2. This sequence is similar to the general growing development of the areas, that is, at the time of the P1 passage there was more heterogeneity between the various fields in terms of vegetative development, varying from minimum vegetation cover to maximum cover registered by the large standard deviation (Table 1); during the P2 passage there was more homogeneity in the vegetative stage; and in P3 it was commom the occurrence of reprodutive organs differentiation and senescence signals. So, these results show that early crop stages are more suitable for the stablishment of correlations between remote sensing parameters related to soil/plant area. Daughtry et al. (1980) found similar results.

TABLE 2

CORRELATIONS BETWEEN PERCENT SOIL COVER AND GREEN LEAF AREA INDEX, SINGLE TM BANDS AND BAND RATIOS FOR WHEAT AND BEAN IN THREE OVERPASSES

| | | | TM1 | TM2 | TM3 | TM4 | TM5 | TM7 | I1 | I2 | I3 | I4 | I5 | I6 | I7 | I8 | I9 | I10 | I11 | I12 | %COV | CORRELATIONS IN THE OVERPASS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | WHEAT | COV % | -0,47 | -0.64* | -0.86** | 0.91** | -0.44 | -0.82 | -0.04 | -0.89** | 0.80** | 0.46 | -0.78** | 0.81** | 0.85** | 0.46 | 0.85** | 0.81** | 0.87** | 0.90** | - | 12 |
| | | LAI | -0.51 | -0.68** | -0.62* | 0.80** | -0.20 | -0.55* | -0.01 | -0.61* | 0.87** | 0.69** | -0.46 | 0.80** | 0.79** | 0.49 | 0.77** | 0.81** | 0.81** | 0.69** | 0.78** | 13 |
| | BEAN | COV % | 0.17 | 0.26 | -0.63* | 0.94** | 0.64* | -0.24 | 0.04 | -0.78 | 0.91** | 0.81** | -0.51 | 0.91** | 0.90** | 0.67* | 0.84** | 0.84** | 0.79** | 0.82** | - | 12 |
| | | LAI | 0.33 | 0.32 | -0.59* | 0.89** | 0.58* | -0.21 | -0.07 | -0.71 | 0.85** | 0.65* | -0.54 | 0.89** | 0.84** | 0.58* | 0.84** | 0.84** | 0.76** | 0.74** | 0.91** | 12 |
| P2 | WHEAT | COV % | 0.09 | 0.05 | -0.21 | 0.37 | 0.16 | -0.07 | -0.03 | -0.40 | 0.21 | 0.11 | -0.03 | 0.29 | 0.28 | 0.24 | 0.24 | 0.21 | 0.20 | 0.34 | - | 0 |
| | | LAI | 0.00 | 0.09 | -0.11 | 0.44 | 0.08 | -0.28 | 0.14 | 0.26 | 0.19 | -0.07 | -0.45 | 0.28 | 0.15 | -0.12 | 0.39 | 0.56* | 0.62* | 0.26 | 0.21 | 2 |
| | BEAN | COV % | 0.38 | 0.65** | -0.41 | 0.82** | 0.81** | 0.11 | 0.39 | -0.72** | 0.64* | 0.25 | -0.39 | 0.70** | 0.71** | 0.61* | 0.63* | 0.66** | 0.65** | 0.72** | - | 12 |
| | | LAI | 0.23 | 0.40 | -0.19 | 0.46 | 0.31 | -0.27 | 0.24 | -0.37 | 0.33 | -0.13 | -0.50 | 0.36 | 0.26 | -0.02 | 0.49 | 0.55* | 0.54* | 0.39 | 0.32 | 2 |
| P3 | WHEAT | % COV | 0.15 | 0.03 | -0.13 | 0.53* | 0.23 | -0.08 | -0.24 | -0.26 | 0.36 | 0.32 | -0.15 | 0.30 | 0.27 | 0.09 | 0.28 | 0.37 | 0.49 | 0.40 | - | 1 |
| | | LAI | -0.26 | -0.30 | -0.52* | 0.82** | 0.23 | -0.08 | 0.06 | -0.46 | 0.74** | 0.75** | 0.39 | 0.67** | 0.67** | 0.61* | 0.50 | 0.43 | 0.30 | 0.74** | 0.32 | 8 |
| | BEAN | % COV | -0.50 | -0.33 | -0.75** | 0.55* | -0.15 | -0.83** | 0.14 | -0.65** | 0.45 | 0.24 | -0.45 | 0.50 | 0.49 | 0.23 | 0.66** | 0.63** | 0.66** | 0.72** | - | 8 |
| | | LAI | -0.22 | -0.17 | -0.49 | 0.68** | 0.56* | -0.65** | -0.06 | -0.41 | 0.53 | 0.34 | -0.31 | 0.55* | 0.49 | 0.06 | 0.67** | 0.74** | 0.75** | 0.62** | 0.56* | 8 |
| CORRELATIONS WITH %COV | | | 0 | 2 | 3 | 5 | 2 | 1 | 0 | 3 | 3 | 1 | 1 | 3 | 3 | 2 | 4 | 4 | 4 | 4 | | |
| CORRELATIONS WITH LAI | | | 0 | 0 | 3 | 4 | 2 | 2 | 0 | 1 | 3 | 3 | 0 | 4 | 3 | 2 | 3 | 5 | 5 | 4 | | |

(*) and (**) significant at 5% and 1% level, respectivelly.

When each family (gramineae and leguminosae) is analysed individually, there is a diverse behavior with respect to overpass dates and to analysed crop parameter. It is shown that for bean fields in all overpasses the percent soil cover had significant correlations with many remote sensing parameters. On the other hand, wheat fields showed poor correlations with remote sensing parameters in P2 and in P3 passages. This is due to the fact that wheat presents high soil cover percentages and small variation coefficients at these overpasses (Table 1). This makes that gray level variations in various areas don't have percent soil cover variations correspondence, contrarily to the bean.

In the case of green leaf area index, the precise analysis of results is more complex, not only due to greater difficulty to its real field evaluation as well as the evaluation of the impact of its variation on reflectance when percent soil cover is invariable. To analyse the green leaf area index it is necessary to observe its relationship with percent soil cover. When the correlation between percent soil cover and LAI is high there are various remote sensing parameters that present good correlations with both crop parameters, as ocurred with bean and wheat in P1 and bean in P3. When the correlation between crop parameters are not significant two situations are possible. First, various remote sensing parameters correlate with only one crop parameter (percent soil cover for bean in P2 and LAI wheat in P3). Second, few remote sensing parameters correlate with both crop parameters (wheat in P2). What determines the ocurrence of one case or another is the general condition of the areas with respect to both crop parameters. When there are high percentage of soil cover and LAI few remote sensing parameters correlates with both crop parameters (wheat in P2). When one of the crop parameters is not at its maximum expression in many areas, it can occur that various remote sensing parameters correlate with only one crop parameter.

This interrelationship between LAI and percent soil cover is very important once their bahavior during growing season are different and not necessarily similtaneous. In the early season, after germination, it is a parallelism between them. However, when the vegetation covers completely the soil there is a percent soil cover stabilization (Figure 1). At the end of season, with the senescence process there is again a tendency to a similarity between both crop parameters. The timing of these relations are typical for each crop species and surely affect their evaluations via remote sensing.

The discussion of the remote sensing parameters that show better correlations with the two crop parameters includes not only single bands, but also the band ratios.

The analysis of single bands showed that there is great variations with respect to their correlative potential with crop parameters. From Table2, the following general decreasing classification is obtained with respect to the number of correlations: TM4>TM3>TM5>TM7>TM2>TM1. This sequence can be understood through the knowledge of vegetation and soil spectral behavior. In TM1 and TM2 bands these targets are spectraly similar, which produces a low sensibility In terms of cover differences; the same applies to the green leaf area index. In the infrared region, where is located the TM4, the difference between soil and vegetation reflectance is stronger, and is just where that are more correlations between digital values and the crop parameters. In an intermediate position are the TM3, TM5 and TM7 bands with intermediate correlative potentials.

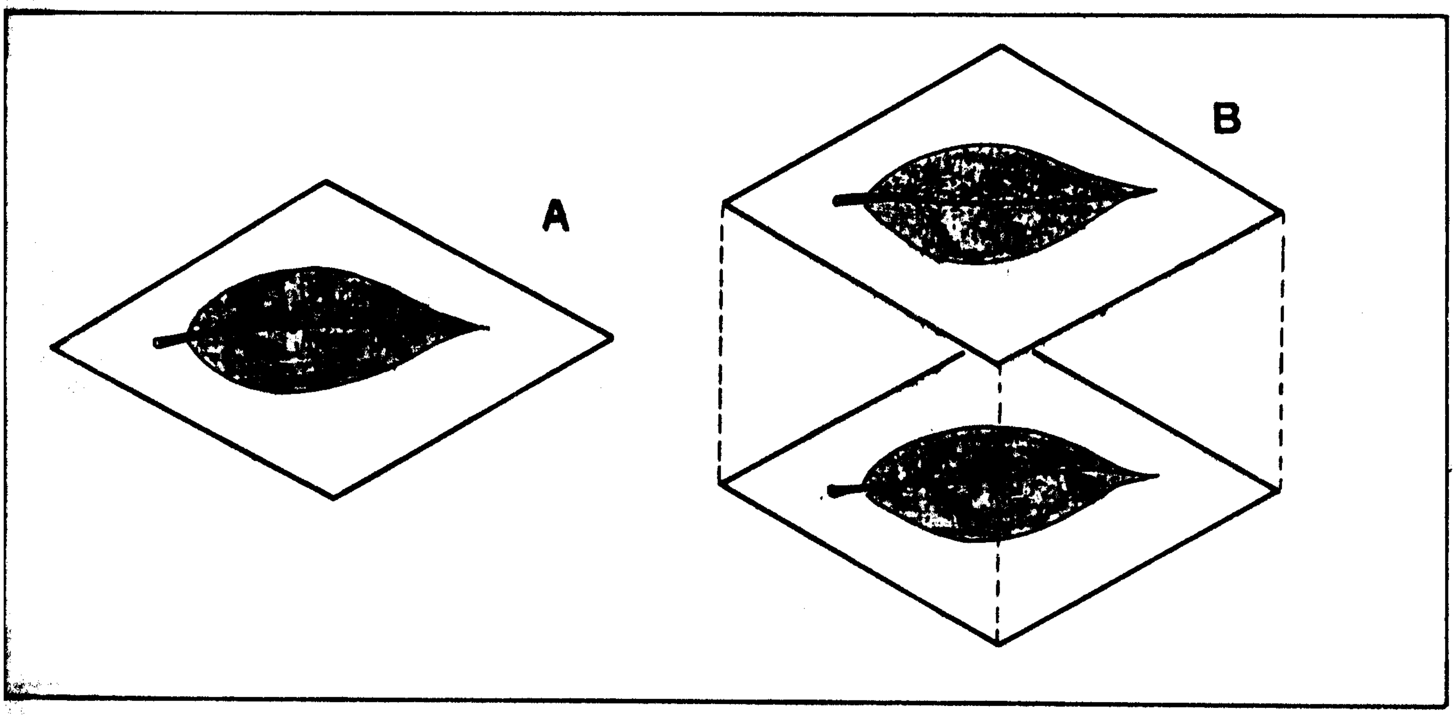


Fig. 1 - In (A) soil cover has perfect correspondence to LAI and in (B) the same percent soil cover corresponds to two LAI units.

An analysis of band ratios showed that the indices with TM4 as a component are those that present greater correlative potentials with crop parameters. These are the cases of I3, I6, I9, I10 and I12. In addition these, it should be noticed the index I11 (TM5/TM7) that presented together with I10 (TM4/TM7) a large number of correlations with crop parameters in the three overpasses. In the more distant spectral bands occur spectral response inversion between vegetation and soil, that is, the soil develops a greater reflectance values than the vegetation. These results indicate the importance of TM5 and TM7 spectral bands to agronomic studies.

Although none of the indices utilized presented better results than TM4, some show similar performance to the TM4 and can be considered satisfactories. In order of decreasing number of correlated ratios are: I10=I11>I12>I6=I9>I7. On the other hand there are ratio indices that have shown low utility in the stablishment of correlations with crop parameters utilized here. These are: I1<I5<I4=I8=I2. These results show the high potential of TM4 spectral band to stablish correlations with crop parameter related to crop vigor or general crop conditions. Furthermore, one observes that band associations in the ratio indices produce better results than isolated bands, mainly if one of which is the TM4.

## 4. SUMMARY

Nevertheless only three satellite overpasses were available, this work showed the importance of the species and the general growing stage of the fields in studies related to green leaf area index and percent soil cover. It was confirmed the higher performance of the TM4 in relation to other TM single bands and to the tested band ratios also. Finally it should be necessary to achieve additional studies that relate TM5 and TM7 to another agronomic parameters.

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