E82-10292

CR-169335

SECRETARIA DE PLANEJAMENTO DA PRESIDÊNCIA DA REPÚBLICA

CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO

(E82-10292) EVALUATION OF SPATIAL FILTERING ON THE ACCURACY OF WHEAT AREA ESTIMATE (Instituto de Pesquisas Espaciais, Sao Jose) 10 p HC A02/MF A01 CSCL 02C

N82-33792

Unclas
G3/43 00292

INSTITUTO DE PESQUISAS ESPACIAIS

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1. Publication Nº	2. Version	3. Date	5. Distribution
INPE-2431-PRE/135		*June, 1982*	☐ Internal ☒ External ☐ Restricted
4. Origin *DSR*	Program *RECAF*		

6. Key words - selected by the author(s)
SPATIAL FILTERING
AREA ESTIMATION ACCURACY
LANDSAT DATA

7. U.D.C.: *63:31:621.376.5*

8. Title *INPE-2431-PRE/135*	10. Nº of pages: *09*
EVALUATION OF SPATIAL FILTERING ON THE ACCURACY OF WHEAT AREA ESTIMATE	11. Last page: *08*
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14. Abstract/Notes

A 3 X 3 pixel spatial filter for post-classification was used for wheat classification to evaluate the effects of this procedure on the accuracy of area estimation using LANDSAT digital data obtained from a single pass. Quantitative analyses were carried out in five test sites (≃ 40 km² each) and t tests showed that filtering with threshold values (2,2) significantly decreased errors of commission and omission. In area estimation filtering improved the overestimate of 4.5% to 2.7% and the root-mean-square error decreased from 126.18 ha to 107.02 ha. Extrapolating the same procedure of automatic classification using spatial filtering for post-classification to the whole study area, the accuracy in area estimate was improved from the over-estimate of 10.9% to 9.7%. This study concludes that when a single pass LANDSAT data is used for crop identification and area estimation the post-classification procedure using a spatial filter provides a more accurate area estimate by reducing classification errors.

15. Remarks *Presented at the Sixteenth International Symposium on Remote Sensing of Environment, Buenos Aires, Argentina, June 2-9, 1982.*

EVALUATION OF SPATIAL FILTERING ON THE ACCURACY OF WHEAT AREA ESTIMATE*

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ABSTRACT

The objective of this study was to select the optimal combination of threshold values for the 3x3 pixel spatial filtering for post-classification implanted in Image-100 system of INPE and to evaluate the effects of this procedure on the accuracy of wheat area which was estimated by Image-100 system using a hybrid classifier and LANDSAT digital data obtained from a single pass. An area of 800 km² in Cruz Alta which is one of the most important municipals for wheat production in southern Brazil, was selected for this study. Different threshold combinations: (1,2), (2,1), (2,2), (2,3), (3,2), (3,4) and (3,5) were employed in the spatial class filtering for the whole study area after wheat was classified. Alphanumeric theme prints of classification results with and without employing spatial filtering were compared using aerial photographic mosaic as "ground information". The combination of (2,2) was then selected as the best threshold values in spatial filtering and was applied to five test sites (≈ 40 km² each) with different wheat densities for a quantitative evaluation of the accuracies of wheat area estimates. T tests showed that filtering with threshold values (2,2) significantly decreased errors of commission and omission, also, the accuracy in area estimate was improved from the over estimate of 4.5% to 2.7% and the root-mean-square error decreased from 126.18 ha to 107.02 ha. Extrapolating the same procedure of automatic classification using spatial filtering for post-classification to the whole study area, the accuracy in area estimate was improved from the overestimate of 10.9% to 9.7%. This study concludes that when a single pass LANDSAT data is used for crop identification and area estimation the post-classification procedure using a spatial filter provides a more accurate area estimate by reducing classification errors.

1. INTRODUCTION

The ideal LANDSAT pass for wheat identification and area estimate is in the late September or in the beginning of October when this crop is at yellow-ripe stage in southern Brazil. However, these months coincide with the initial of the rainy season, thus, cloud-cover is a serious problem for image analysis. LANDSAT data prior to the yellowing stage may also be used for area estimation purpose; nevertheless , a less accurate estimate is obtained, since a large commission error is expected due to the similar spectral responses among wheat, pastureland and fallow fields. The objetive of this study was to verify whether improved classification results and a more accurate estimate of crop area might be obtained through post-classification using spatial class filtering when only LANDSAT digital data of a single pass were available for analysis.

2. STUDY AREA AND DATA ACQUISITION

Cruz Alta is one of the major municipals for wheat production in Rio Grande do Sul State, Brazil. The geographic location of this municipal is around 28°35'S and 53°45'W. An area in Cruz Alta (approximately 20 x 40 km²), which represents the wheat plantation of the state, was selected for this study (Figure 1). In this region, depending on climatic conditions, wheat may be planted in April or May and be harvested in October or November.

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Aircraft data acquisition

On September 2, 1979, INPE's (Instituto de Pesquisas Espaciais) aircraft Bandeirante was flown over the study area using a RC-10 photogrammetric camera and color infrared (CIR) aerial photographs of medium scale (1:20,000) with 30% sidelapping and overlapping were taken. Aerial photographs were later interpreted visually according to a predetermined legend. The photointerpretation results were then used as "ground information" to assess the computer-aided classification performance of Image-100 system.

LANDSAT data acquisition

The ideal LANDSAT pass for wheat identification and area estimation is in the late of September or in the beginning of October when wheat is matured and presents a golden-yellowish color, different from the surrounding crops (predominantly pastureland) which are still green (Chen et al, 1981). However, LANDSAT data on September 22, 1979 was with 100% cloud cover, thus LANDSAT CCT's on September 4th when most of wheat plantations were at heading/flowering stage, were used for this study.

3. METHODS

For wheat classification, the unsupervised clustering algorithm (K-means) was first employed to separate homogeneous spectral classes; these spectral classes were then transformed to informational classes and training areas for each informational class were located on the image monitor of Image-100 system using the electronic cursor. The spectral information of those training areas were used to derive training statistics required by MAXVER which is a supervised classifier based on the Gaussian maximum-likelihood decision rule (Velasco et al, 1978). This hybrid procedure of using clustering to assist the selection of training areas which were later used in a supervised classification was called M-2 procedure (Lima et al, 1982). For *homogeneisation* of classification results, a post-classification procedure named UNITOT was used.

UNITOT is a three-by-three pixel spatial class filter implanted in INPE's Image-100 system (Dutra, 1982). There are two threshold values which should be predetermined by the analyst. The first threshold value, T_1, is the number of times the analyst wants the central pixel to be considered in calculation of class frequency. After calculation of the frequency for all the classes in the 3x3 pixel matrix the highest class frequency will compared to a second threshold value T_2 which is arbitrarily assigned by the analyst. If the T_2 value is smaller than the highest class frequency then the class of the central pixel will be substituted by the class which has the highest class frequency. If the T_2 value is larger than the highest frequency then the class of the central pixel remains unchanged. The best combination of T_1 and T_2 to be used in spatial filtering should improve classification performance by diminishing classification errors. To select the optimal threshold values for this study the following combinations of (T_1, T_2) were tested, they were (1,2), (2,1), (2,2), (2,3), (3,2), (3,4) and (3,5).

Analysis procedure

In order to work at the scale of 1:100,000 on the image monitor the study area was divided into two square subareas (A and B) of approx. 20x20 km² each. Analysis procedure was carried out similarly for both areas. Once the subarea was delimited, wheat was classified using the M-2 procedure as mentioned above, afterwards, spatial filtering (UNITOT) using different combinations of threshold values were applied and alphanumeric print out (1:20,000) of the classified wheat, with and without using spatial filtering, were obtained. Each alphanumeric printout was overlaid on the aerial photographic mosaic; on a light table, and a visual comparison was made observing the commission and omission errors presented on the print-out. After comparing all the print-outs with aerial photographic mosaic the best combination of threshold value was selected.

In order to evaluate quantitatively the effects of spatial class filtering using the best threshold values on the classification results, five test sites (≈ 40 km² each) with different wheat densities were selected from the study area. A point-by-point comparison of alphanumeric print-out of each test site to its corresponding aerial photographic mosaic provided data for statistical analyses. Paired t-tests were applied to the percentages of correct classification (CC), error of commission (EC) and the estimated wheat areas obtained by using and without using the spatial filtering. Correct classification, commission error, omission error and relative difference are defined as below:

$$\text{correct classification (CC \%)} = \frac{\text{nº of wheat pixels which were classified correctly}}{\text{area-transformed pixel nº of wheat from aerial photographs.}} \times 100\%$$

$$\text{commission error (CE \%)} = \frac{\text{nº of non-wheat pixels which were erroneously classified as wheat}}{\text{nº of wheat pixels classified by Image-100 system}} \times 100\%$$

$$\text{omission error (OE \%)} = 1 - \text{CC\%}$$

$$\text{relative difference (RD \%)} = \left(\frac{\text{estimated wheat area by Image-100 system}}{\text{estimated wheat area from aerial photographs}} - 1\right) \times 100\%$$

4. RESULTS AND DISCUSSION

Figure 2 shows the classification results of subarea A using procedure M-2. Even though M-2 was selected as the best procedure for wheat classification (Lima et al, 1982) there were some confusion among the classes of wheat, pastureland and sparse arboreal vegetation. This might be explained by the fact the LANDSAT data were gathered at the time when wheat was in heading/flowering stage, consequently perfect separation could not be obtained due to the similarity between spectral responses of wheat and pastureland. It was noted that in most of the cases the sparse arboreal vegetation which was misclassified as wheat possessed a understore of vigorous grass which might contribute to the spectral similarity to wheat.

Quantitative comparisons of alphanumeric print outs to aerial photographic mosaic showed that the application of spatial class filtering with the combination of threshold values (2,2) gave better classification results. This improvement can be observed by comparing Figure 2 and 3. Quantitative comparisons were performed using data of Table 1 and 2 which were obtained after classification with and whithout the application of UNITOT, combination (2,2), for five test areas. T tests showed that the application of UNITOT (2,2) increased significantly (α = 0.05) the percentage of correct classification and decreased significantly (α = 0.01) the error of commission. Comparing area estimates obtained by using of without using UNITOT to that of the aerial photographs no statistical difference was found. However, with the applying of UNITOT after classification the root-mean-square error of area estimates for these five areas decreased from 126.18 ha to 107.02 ha. The relative difference in area of these five test sites decreased from an overestimate of

4.5%, when no spatial class filtering was used, to +2.7% when UNITOT with threshold values (2,2) was applied in analysis procedure. Applying UNITOT (2,2) to the whole study area an improvement in area estimation was observed, i.e. RD of +10.9% obtained by classification whithout the application of spatial class filtering was decreased to +9.7%. Even though the improvements in area estimate were not pronounced the better classification accuracy caused by a higher correct classification and a smaller error of commission when spatial class filtering was employed made this post-classification worthwhile.

5. CONCLUSIONS

When multitemporal LANDSAT digital data are not available for crop identification studies the classification errors caused by the similarities of spectral responses among classes on a single-pass LANDSAT data may be diminished by the application of spatial class filtering with optimal threshold values in post-classification. The improvements in crop classification results using spatial class filtering for post-classification are contributed by a higher percentage of correct classification, a smaller error of commission and a more accurate estimate in area.

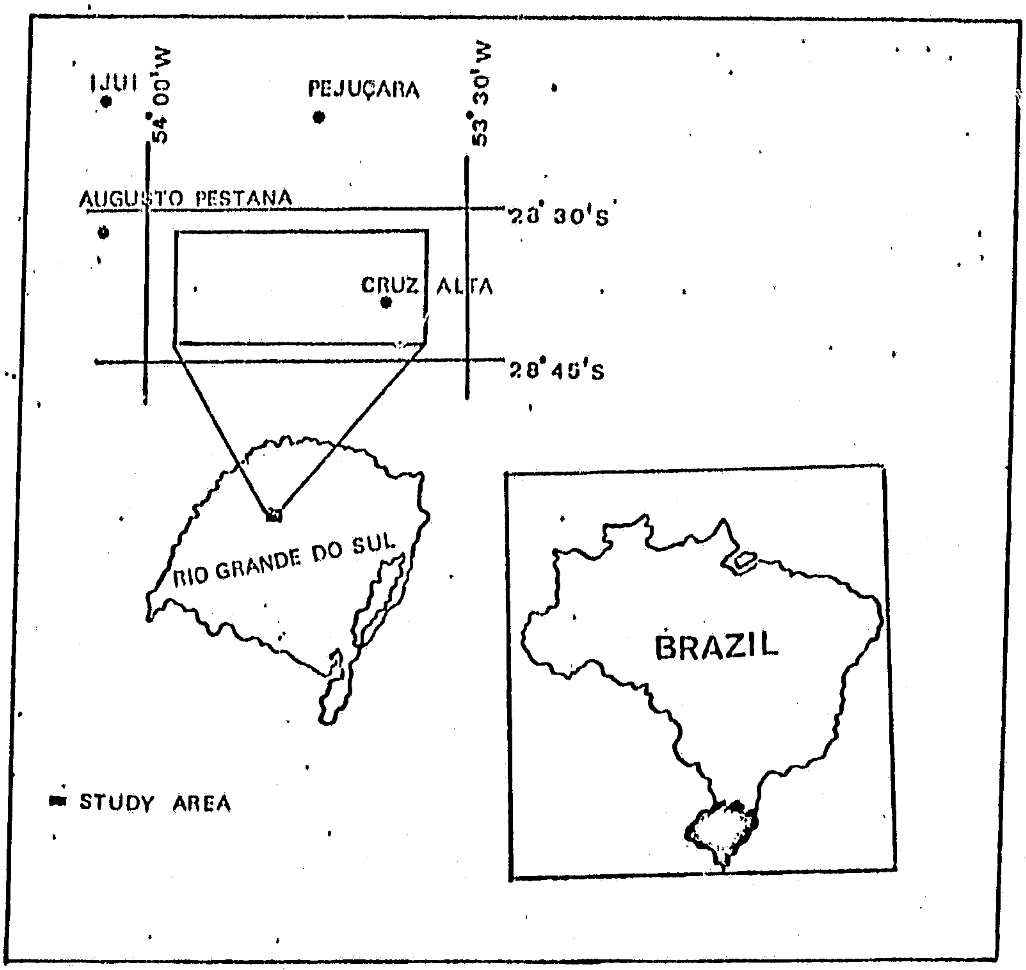

Fig. 1 - Location of study area.

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Fig. 2 - Result of wheat classification without using UNITOT (2,2) in subarea A.

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Fig. 3 - Result of wheat classification using UNITOT (2,2) in subarea A.

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Table I. Estimated wheat area based on aircraft and LANDSAT data for five test sites

TEST SITE	WHEAT DENSITY (%)	ESTIMATED WHEAT AREA (ha)		
		AERIAL PHOTOGRAPHS	LANDSAT CCTs	
			WITHOUT SPATIAL FILTERING	SPATIAL FILTERING WITH UNITOT (2,2)
1	56.69	2331.77	2290.26 (-1.78)*	2286.98 (-1.92)
2	46.13	1897.60	1906.26 (+0.45)	1852.51 (-2.38)
3	39.28	1615.72	1999.77 (+0.51)	1600.79 (-0.92)
4	22.87	971.05	1481.95 (+23.55)	1137.96 (+17.18)
5	31.15	1322.50	8502.32 (+12.05)	1481.06 (+11.99)
TOTAL	-	8138.64	8502.32 (+4.46)	8359.30 (+2.7)
RMSE	-	-	126.18	107.02

* Percentage of relative difference (RD%)

Table II. Wheat classification accuracies resulted by using and without using UNITOT (2,2) in five test sites

TEST SITE	CORRECT CLASSIFICATION (CC%)		COMMISSION ERROR (CE%)	
	WITHOUT SPATIAL FILTERING	SPATIAL FILTERING WITH UNITOT (2,2)	WITHOUT SPATIAL FILTERING	SPATIAL FILTERING WITH UNITOT (2,2)
1	83.75	86.05	14.73	12.26
2	82.83	83.93	17.54	14.67
3	77.51	78.93	22.89	20.33
4	88.41	89.08	28.45	23.98
5	87.85	88.30	21.60	21.15

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