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Paper A 22

CROP SPECIES RECOGNITION AND MENSURATION IN THE SACRAMENTO VALLEY

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ABSTRACT

An earlier paper, presented at the 28 September meeting at Goddard, dealt with agricultural recognition maps of a portion of the "San Francisco" frame (1003-18175). The recognition maps were generated by applying multispectral pattern recognition techniques to ERTS-MSS digital taped data. The earlier results have been improved and extended as a result of field studies to check the accuracy of the original recognition. The goal of the second recognition map prepared from these data was to delineate various crop species in a portion of the Sacramento Valley, and at the same time to determine how accurately each could be classified and measured from ERTS-1 data.

The new recognition map, a new and concise display of the old map, and classification and mensuration accuracy data will be presented and discussed. The mensuration accuracy, in particular, is affected by the presence of an edge effect one resolution wide surrounding nearly all fields. Points on the edge are misclassified because they contain a mixture of e.g., crop and bare soil. Using a processing technique to estimate the proportions of unresolved objects in this edge region, a much improved mensuration capability will be demonstrated.

1. INTRODUCTION

Shortly after the launch of the ERTS satellite, the Environmental Research Institute of Michigan (then Willow Run Laboratories of the University of Michigan) obtained digital tapes of the "San Francisco" ERTS frame, designated 1003-18175. The request for these tapes was made

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EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

so that existing multispectral data analysis software could be tested on ERTS data. To verify the software performance, it was decided to generate a recognition map of a portion of the data. The area selected for analysis was northwest of Sacramento. This 375 sq mi area of intensive, irrigated agriculture was classified into eight categories. The identity of these categories was later verified by ground visits to the site and to Bureau of Reclamation offices.

The initial maps produced were discussed at the Goddard symposium of 29 September, 1972 and have been further analysed by the ERIM staff (Refs. 1, 2). While the original maps were good and accurate classifications of the data, two questions remained.

1. It was clear that conventional digital computer page printer displays of ERTS data were cumbersome because of the large quantity of data displayed. While the use of computer page printer data for initial analysis was acceptable, could a more concise display be found for the final classified results?

2. While several economically important crops were classified in the first effort, there were several "salad" categories (categories consisting of several crop species). While this was unavoidable in the first map because of lack of ground information, could a crop species map be generated given training sets for the important crop species in the area?

Because the answers to these questions were felt to be significant to the ERTS data analysis in general, processing of this data set was pursued.

2. CONCISE DISPLAY OF ERTS DATA

ERTS data are delivered in digital tape and film form. For many ERIM analyses, digital tape data are processed for wide area surveys. The concise display of such processed results is clearly important. A conventional page printer display of all the data in one ERTS frame covers a 27 ft x 24 ft area!! While the utility of computer page printer outputs for initial analysis is acceptable, some more concise display of final processed outputs is essential if these processed outputs are to be accepted by users.

Two solutions to the problem exist. First, at ERIM we have good 70 mm filmstrip printers developed for producing aircraft scanner imagery. Through the development of digital to analog (D/A) conversion facilities, we are now able to produce high resolution images of ERTS raw data or processed results on the same printers used for printing aircraft multispectral data. Data from each digital tape of ERTS data may be printed separately and results mosaiced to provide a 9" x 9" display quite comparable to a typical 9" x 9" transparency from Goddard.

Second, we have obtained through the courtesy of Data Corporation, Dayton, Ohio, a color coded recognition map of the Sacramento data presented at the earlier Goddard meeting. This is shown in Figure 1. (Unfortunately, the black and white figure cannot do justice to the vivid colors present in the original). This display was produced from digital tape using a special display device developed by Data Corporation. While the cost of the device was too high for us to buy a printer,Data Corporation agreed to make maps at a reasonable price for us. Display sizes up to 40" x 60" are available, and the basic resolution element size is 1/72". The device directs different colored inks at paper to produce an effective color display.

3. CROP SPECIES RECOGNITION AND MENSURATION

After obtaining ground information from the Sacramento Valley area, we were convinced that our first map was an accurate map of agricultural categories in the area. However, we wanted to determine whether the economically important species could be recognized in such an agricultural area. Also we wished to determine how accurately crop acreages could be determined from ERTS data.

First, we attempted to classify the crops of the area using training sets selected from fields of different crop species as determined from ground information. The results, shown only for the area for which ground information was readily available, are shown in Figure 2.

We determined that crop species could be discriminated on the basis of signatures. The criterion was the probability of misclassification computed from the signature information. Typical probabilities of misclassification are shown in Table 1 below. We were unable to discriminate between wheat and barley stubble because the wheat had been harvested and was stubble at the time. Also, tomatoes and sugar beets could not be discriminated, probably because both have dark green foliage and were relatively immature at the time of ERTS coverage.

The probabilities of misclassification are useful for defining separable classes but do not tell the whole story because of the limited training set areas used to calculate these probabilities. So to further test the ability to classify crops, we made a recognition map. (See Figure 2). The signatures for the recognition map were derived from three fields of each class of vegetation.

TABLE I

SELECTED PROBABILITIES OF MISCLASSIFICATION FOR SACRAMENTO VALLEY CROP SPECIES

CATEGORIES	PROBABILITY OF MISCLASSIFICATION
Stubble-Wheat*	0.204
Tomatoes-Sugarbeets*	0.157
Melons-Sugarbeets	0.075
Milo-Sudan	0.059
Tomatoes-Sudan	0.038
Corn-Orchard	0.032
Corn-Milo	0.032
Tomatoes-Melons	0.030

*Combined in Recognition Map

3.1 Analysis of the Recognition Map

We analysed the recognition map of Figure 2 to determine the classification accuracy of the various crops on a per field basis.

Rice was well recognized. Of 30 rice fields (other than the training set) examined, all were correctly classified. A field was assumed to be correctly classified if more than 50% of the points (exclusive of the boundary points) were rice. Boundary elements were recognized as corn and occasionally milo.

About half of the dozen safflower fields were correctly recognized. The remainder were called stubble. Examination of the color IR simulated imagery reveals a subtle destination between the pale yellow tone of safflowers and the white tone of stubble. Apparently, safflowers were mature at the time and some may have been harvested.

Stubble recognition was correct in all 20 areas examined. As previously mentioned, wheat and barley stubble could not be distinguished, and the stubble training set also solidly recognized some safflower fields.

Tomatoes and sugarbeets were correctly classified in each of the ten fields examined. There was a tendency for scattered sugarbeet and tomato recognition to occur in other areas, particularly in melon fields.

Melons were poorly recognized in the three fields examined. Closer examination of one of these fields on the CIR simulation reveals a varied planting pattern with some areas in melons and some bare areas. Since the recognition map classifies melons in those areas which are planted, and bare soil recognition elsewhere, the map is felt to be more indicative of the true situation than the ground information.

Water was consistently well recognized, with rivers, large irrigation canals, lakes and some flooded fields all recognized. A fallow field signature obtained from one of the flooded fields proved very specific, recognizing that field and one or two others. The combination of the recognition of these two training sets is felt to accurately portray all water in the scene.

Alfalfa, orchard, corn, and milo recognition was disappointing. Areas of these crops were correctly classified, but a great amount of recognition showed up in other areas. Alfalfa and orchard signatures were derived from areas of sparse cover and probably represent only a subtle departure from bare soil. This fact may account for the appearance of so much orchard and alfalfa recognition outside orchards and alfalfa fields.

Bare soil was consistently correctly classified. Sudan grass was also correctly classified in the three areas examined.

3.2 Mensuration

Since we had good success recognizing rice, we addressed the problem of acreage estimation. We had acreages of some fields available from ground information and concentrated on these fields for a test of rice acreage recognition.

At the outset we knew that the boundary elements being misclassified would impair our acreage estimation accuracy. So we estimated the percentage of rice in the boundary elements using special techniques developed by Nalepka (Ref. 3). We found that about 75% of a typical boundary element was rice and 25% bare soil and water. This value is in good agreement with the ground measured 50-60 ft irrigation canal width. A canal of this size would occupy about 1/4 of an ERTS digital tape sample point.

The results of acreage estimates for the seven rice fields studied are shown in Table II. Notice that all fields are greater than 100 acres in size. Acreage estimates taking only samples recognized as rice are consistently low, even though solid recognition was obtained in each field. Using a revised estimate based on recognition and mixtures, much better acreage estimates are obtained. (Mixtures analysis was used to estimate the amount of rice in the boundary elements. Boundary elements separating two rice fields were assigned equally to both fields.) The improvement in acreage estimation using the mixtures technique is felt to be significant.

TABLE II

COMPARISON OF RICE FIELD ACREAGES ESTIMATED BY RECOGNITION AND BY RECOGNITION PLUS CONVEX MIXTURES

RICE FIELD	TRUE ACREAGE	RECOGNITION ESTIMATE	RECOGNITION PLUS CONMIXED
1	150	119	144
2	212	174	205
3	106	71	95
4	159	130	163
5	176	149	179
6	194	173	196
7	224	214	236
TOTAL	1221	1030	1218

4. SIGNIFICANT RESULTS

Several significant results have accrued from this investigation.

1. Concise display of ERTS digital tape video or recognition data can be obtained by D/A conversion of data and printing on 70 mm filmstrip printers developed for the airborne scanner program. Alternatively, special purpose color digital displays may be generated by devices which print in colored inks directly on paper using 0.014" resolution cell size.

2. Accurate crop species recognition can be done in areas of large field agriculture under relatively clear atmospheric conditions. Crops most accurately recognized are those which are green and substantially completely cover the underlying soil. Mature or harvested crops can be discriminated with lesser degrees of accuracy. Crops with incomplete cover can be recognized inside their field boundaries, but recognition also occurs outside agricultural fields yielding a large number of false alarm detections.

3. Accurate acreage estimation of crops in fields 100 acres in size or smaller requires that some estimate be made of the amount of crop contained in possibly misclassified boundary elements. Without this estimate, acreage determined from pattern recognition results will be biased low. The amount of bias increases with decreasing field size, and is also dependent on field shape.

5. REFERENCES

1. Thomson, F. J., Gordon, M. and Morgenstern, J., "Environmental Research Institute of Michigan Computer Processing of ERTS-1 MSS Data from the "San Francisco" Frame (1003-18175), Environmental Research Institute of Michigan, Ann Arbor, Michigan, Report No. 011229-4-S.

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3. Nalpeka, R. F., Horwitz, H. M., and Thomson, N. S., "Investigation of Multispectral Sensing of Crops", Infrared and Optics Laboratory Willow Run Laboratories, Institute of Science and Technology, The University of Michigan, Technical Report No. 31650-30-T, May 1971.

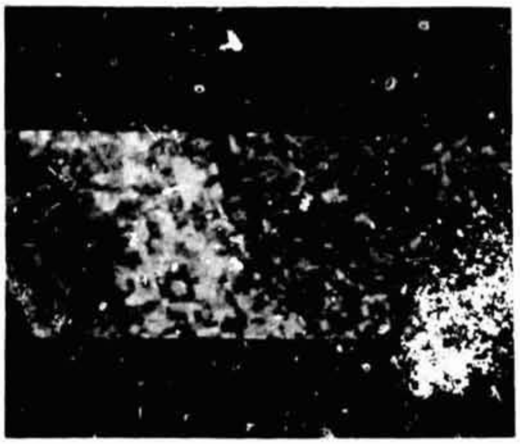

Figure 1a
Imagery of Sacramento Valley Test Area
(original in color)

Figure 1b.

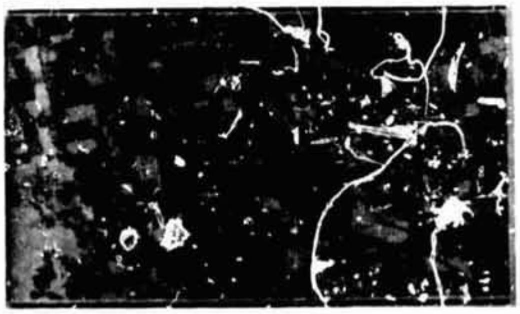

Figure 2
Crop Species Map of Sacramento Valley ERTS Data
(Original in color)