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THE RESULTS OF AN AGRICULTURAL ANALYSIS OF THE ERTS-1 MSS DATA AT THE JOHNSON SPACE CENTER

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ABSTRACT

This report describes the initial analysis of the ERTS-1 multispectral scanner (MSS) data at the Johnson Space Center (JSC), Houston, Texas. The primary data set utilized was the scene over Monterey Bay, California, on July 25, 1972, NASA ERTS ID No. 1002-18134. It was submitted to both computerized and image interpretative processing.

An area in the San Joaquin Valley was submitted to an intensive evaluation of the ability of the data to (1) discriminate between crop types and (2) to provide a reasonably accurate area measurement of agricultural features of interest.

The results indicate that the ERTS-1 MSS data is capable of providing the identifications and area extent of agricultural lands and field crop types. Later data sets of Hardin Co., Iowa, and Holt Co., Nebraska, have undergone preliminary analyses as a part of a joint USDA/ASCS-NASA/JSC ERTS-1 data evaluation project. These preliminary results using the same techniques as those carried out on the Monterey data show an ability to discriminate major crops which are representative of different agricultural practices.

1. INTRODUCTION

The Earth Observations Division (EOD) at JSC is involved in an extensive program related to the evaluation of the utility of the Earth Resources Technology Satellite (ERTS) in terms of applications related objectives. This report is intended to describe some of the early results achieved from the analysis of System Corrected MSS data over agricultural target areas.

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Two separate but interrelated efforts related to agricultural applications are described here. The first is a general investigation directed to familiarization and feasibility type objectives. The second is a more specific investigation directly intended to determine the utility of the ERTS-1 MSS data to meet defined functional requirements of the Agricultural Stabilization and Conservation Service (ASCS).

The initial data set received at JSC of Monterey Bay, California, of July 25, 1972, was utilized to accomplish our first general objectives: 1) to obtain a cursory evaluation of the potential of satellite acquired multispectral data to provide information which would support applications related objectives; 2) to checkout existing, and initiate the development of necessary additions to the earth resources data processing facilities; and, 3) to develop and define the initial analysis techniques and operational procedures necessary to support the subsequent activities related to the EOD ERTS-1 Project. The area selected for the initial analysis lies in the San Joaquin Valley, a major agricultural region in the Monterey Bay frame which is representative of farmlands developed due to the application of irrigation systems. The area is approximately 23 x 38 km in size or 218, 352 acres. "Ground truth" information for approximately 5 percent of the area was available through the courtesy of the Anderson, Clayton and Co. They maintain an extensive farming operation in the San Joaquin Valley and utilize monthly aerial photographic missions over their fields as operations management tools. The specific information supplied to us was an annotated map and a related aerial photograph depicting crop types for several fields in the Delta Mendota region on July 13, 1972.

In order to accomplish our overall objective in a reasonably short period of time, the following specific objectives were defined at the completion of our initial examination of the ground truth information and associated crop calendars: (1) Crop type discrimination — to obtain some measure of the ability to discriminate between crop types using the ERTS data, it was decided to concentrate our efforts on rice because it is one of the major crop types within the Delta-Mendota, and several ground truth fields were available. It is a warm weather crop with a 120 to 175 day growing season, and, thus, being July 25 it is basically at its mid-stage of growth and should be fairly uniform between fields. Both computerized and image interpretative techniques were evaluated. (2) Detection of cultivation practices — the ground truth information revealed that one crop, barley, was in the processes of undergoing change as related to the local farming practices. Although there were no known mature barley fields in the study area, there were fields in three distinct phases which were selected for further analyses and performance evaluation investigations: (a) barley stubble — the remains of a mature barley field after undergoing harvesting operations, (b) burned barley stubble, and (c) barley fields which have been plowed under in preparation for the next season's crop. In the above objective, it is obvious that in the case of the burned fields, it would be highly improbable to discriminate between a plowed under barley field and a plowed under wheat field, and it is not the objective of this exercise to do so. What we are attempting to do is merely to detect what the field condition of the known fields are at the time of the ERTS overpass, July 25, 1972. And for a few fields compare

them with what their respective conditions were at the time of the ground truth acquisition, July 13, 1972. This should give us an indication in crop growth of the utility of the repeat coverage from ERTS-1 to monitor temporal changes and farming practices. (3) Mensuration accuracy — for a few selected fields of various dimensions an exercise was conducted to determine how well one may be able to obtain a measure of the area extent of a crop type after it has been detected and identified. The baseline or control data was generated in-house utilizing the best available rectified high resolution aerial photographs.

The first image interpretation analysis performed was of a black and white image of MSS 5 (the red band). Using a known, triangular-shaped rice field as a key, the entire study area was searched for fields having a similar characteristics. Within the study area nineteen (19) fields or groups of contiguous fields were identified as rice. The two known rice fields, in addition to the training field, were correctly identified using this one black and white image. No attempt was made to identify the barley crop using this imagery.

The second task was to analyze an optically enhanced color IR image composited from B/W MSS System Corrected images of bands 4, 5, and 7, on an additive color viewer printer (ACVP). This viewer permits individual filter densities to be selected and enlarges the original image approximately eight times. Because of this enlargement factor only a part of the study area is covered on this image. Only rice was interpreted using this imagery. Ths same field indicated earlier was used as a key, and a total of seventeen fields or contiguous areas were identified as rice. The results using this technique were not as reliable as the preceding or subsequent technique.

The third task was to identify the crops (rice, barley stubble, and burnt barley stubble) using two images generated from the digital computer compatible tapes (CCT) with an electron beam film writer. One image was a pseudo- or false-color composite of MSS bands 4, 5, and 6 and the other was a color IR composite of MSS bands 4, 5, and 7. Due to the saturation of other highly vegetative fields in the IR band (MSS 7), the rice fields could not be uniquely identified on the color IR image. However, using the false-color image 18 contiguous rice fields were identified with all of the known or ground truth fields readily detected. Also, for the barley stubble fields the false-color image appeared to provide better distinction characteristics and a total of 22 fields were identified. However, when trying to identify the burnt barley stubble fields the color IR image exhibited the best visual discrimination characteristics. Twelve fields in this category were identified using the color IR imagery.

The accuracies achieved from this analysis is currently being evaluated. In all cases, the known fields were correctly identified, however, information on the other fields identified at the time of the ERTS-1 overpass is not complete. This may point out one of the benefits of a cyclic data acquisition system such as ERTS, i.e., as a source of information for historical reference which heretofore was nonexistent on a regional basis.

The results of this analysis of the ERTS 1 MSS data satisfactorily achieved our objectives. Using only the images produced in this analysis, additional crop species could have been discriminated and we are confident

that with the proper application of existing enhancement techniques most of the major crop types in the study area could be identified.

In the computerized processing phase the known fields for rice, barley, stubble, etc., were defined to an automatic pattern recognition routine, the statistics for the required classes were computed, then each data point in the entire set was classified according to their spectral "signature" as defined by the 4 MSS bands and the generated statistical parameters. The results are shown in the following table:

CLASSIFICATION SUMMARY REPORT FOR KNOWN FIELDS IN DELTA MENDOTA

Classes	Rice	Stubble	Burned	Turned	Other	Overall
No. Pixels	13,528	6,483	4,155	22,820	153,915	200,901
% Total	o.7	3.2	2.1	11.4	78.6	100%
Equivalent Acreages	14,703	7,046	4,516	24,802	167,285	218,352
Training Field Accuracy	92%	97%	90%	98%	93%	94%
Test Field Accuracy	97%	98%	76%	94%	95%	93%

In addition to these, other major crop types in the study area were identified, e.g., safflower, alfalfa, cotton, etc., as a result of the computer processing operations. Also, the utilization of image interpretation analysis of the computer generated images yielded additional information related to crop condition and/or farming practices, e.g., areas depicted as water in curiously familiar rectangular shapes were deduced and later confirmed to be, flooded rice fields.

The results achieved from the computerized processing far exceeded our original expectations. In fact, for the purpose of detecting and identifying crop species in fields of 10 acres or more over large areas (10 miles square or more), our experiences here and with airborne multi-spectral data would at this time dictate a preference for the ERTS-1 MSS data for accomplishing an application objective of that scope. This observation assumes a reasonable requirement for accuracy of the results, e.g., does not require location or area measurement within 1 percent.

Upon completion of the classification of the identified crop species, the mensuration investigation was initiated. The objective here was to obtain a preliminary quantitative measure of the digital ERTS-1 ability to provide reasonably accurate area measurements. For this investigation three rice fields of known dimension were located on rectified, high resolution, aerial photography, and the ground equivalent units or acreages were determined. Then the acreages for these fields were extracted from outputs acquired as a result of the computerized and image interpretative classification schemes. For the computerized this was a simple count of the picture elements (pixels) which were classified in the three known rice fields and applying a conversion factor of 1.1 acres/pixel to this count (Note: The 1.1 value was determined from an evaluation of known distances in this particular study area and may not necessarily apply to other areas.)

The following table lists the results achieved from this cursory investigation:

RESULTS OF THE MENSURATION ACCURACY INVESTIGATION

(Results in Acres)

Field	A/C Ground Truth	Image Interpretation	Converted Pix. Counts
R1	164	150	144
R2	190	170	176
R3	161	161	150

The significance of the converted pixel count discrepancy with the aerial photograph measurement lies not only in the 15 acre average difference but the fact that it is in all cases smaller. This could be attributable to two effects: (1) the aerial photographic measurements are not absolute but relative based on the accuracy of actual registration especially in scale to the map positions used for the initial control, i.e., the values derived from the aerial photo is in all cases larger than the true ground measurements and (2) the only pixels converted were those which were actually classified as rice. Post-analysis communications with Anderson, Clayton and Co., revealed that although the field size of one of the ground truth fields (R3) was listed at 160 acres, that included a fringe area, outside the actual growing rice boundary, which extended to the center of the road adjacent to the field. Thus, the acreage as determined by the converted pixel count of actual rice should in reality be less than the listed field size. Although an attempt to rectify the classification images to remove the known geometric distortions was not conducted, it is expected based on past experience that these accuracies could be improved. Additional studies in mensuration are being conducted in order to obtain a verification of the accuracies which may be achieved. In any case, the simple study described here indicates that accuracies in the order of 90-95 percent or approximately 15 acres of error in a 160 acre field, is not unrealistic.

Utilizing basically the techniques developed during the Monterey Bay analysis, a separate analysis is being conducted as part of a joint project whereby NASA through JSC and the USDA through the ASCS will jointly evaluate the feasibility of using ERTS type data to meet the ASCS functional requirements for crop identification/land use classification, acreage measurements, and correlation of crop and land use data to ground position. For the purpose of the overall JSC/ASCS analysis, six agricultural study areas of 12 square miles each were selected for intensive study. These study areas were selected to provide a manageable size working area while retaining a variety of crop types, geographical conditions, and varying problem complexity levels.

Within the selected study area for each county, ASCS personnel have made a very thorough one-time ground truthing of every field. In addition, ground truth was collected for selected fields in the study area on the day of each ERTS overflight during the agricultural growing season.

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With the ground truth information the study areas may now be used as controlled test, training, and evaluation sites in regard to the objectives of crop species identification, acreage measurement, and tract registration.

The six counties selected for this overall analysis at JSC were: (1) Hill County, Montana with strip-fallow farming practices and wheat/barley as major crops; (2) Hardin County, Iowa with typical corn belt farming practices and primary crops of corn, soybeans, oats, and smaller field sizes; (3) Butte County, California, with a combination of rice, fruits, and nut crops and larger irregular shaped fields; (4) Imperial County, California, with its larger size fields, complex variety of winter and summer crops, and abundant historical ground truth; (5) Worth County, Georgia, with cotton and tobacco crops in small size fields of irregular shapes, and (6) Holt County, Nebraska, with a small number of crop types and large known size fields in a unique pattern. The emphasis at this time will be to present some preliminary results from two of these study areas: Holt County, Nebraska, and Hardin County, Iowa, as obtained primarily from a clustering technique.

Holt County is located in the upland sand on the eastern edge of the Nebraska sand hills and bordered to the north by the Niobrara River. Holt County comprises an area of 2,400 square miles of which 1,500,000 acres are in agricultural use. The crop variety of Holt County is limited with corn being by far the major crop type, with alfalfa hay ranking second and in lesser amounts, popcorn, sun flowers, christmas trees, oats, grain sorghum, and irrigated pasture lands. This area was made a priority study area because of its unique and relatively high contrast targe s of a known acreage and its small variety of major crop types. The higher contrast targets are provided as a result of the development of the center pivot irrigation systems to convert the low productivity, sandy, shallow profile soil to productive cropland. These uniform circular field patterns of irrigation are clearly visible from ERTS-1 altitude and comprise a target of an accurately known dimension and area (135 acres).

Due to an ERTS launch relatively late in the growing season, it was highly desirable to make use of the earliest possible clear coverage of the area. The earliest data pass over Holt County occurred on July 30, 1972, and was found to be cloud free. This data was contained in a digital form as a portion of a MSS CCT as produced by NDPF and GSFC and designated by NASA identification number 1007-16551MB-4 of 4.

After screening and reformatting the data to a form compatible with our analyses systems, the next step was to utilize the clustering algorithm to cluster the data measurements into unique groupings which could be correlated to actual ground truth information. The necessary ground truth information was collected for each study area by the ASCS County Executive Director's Office.

The results of the clustering analyses were displayed on the DAS and color coded for correlation to the ground truth data. These results are shown to be correlated reasonably well with the known ground data.

As represented by the DAS output, the cultivated land is fairly well separated from the noncultivated farmland and the sand hills to the north. Within the noncultivated area three major groupings are clearly

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detectable: short grasses and active grazing areas represented by one cluster, ungrazed thick grasslands represented by a second cluster, and bare sandy soil areas represented by a third cluster. Of interest in the bare soil areas are a 1/2 circle of fallow land in the southwest corner of the study area and a quarter mile wide strip of fallow in the south center of the study area, which are well correlated with the ground truth map. The remainder of the bare soil areas are primarily representative of a Dune sand area between Big Sandy Creek and Brush Creek in northern Holt County and correlates well with existing soil maps. Within the cultivated portion of the study area, 32 separate fields of field corn are shown in the ground truth map, of this number 30 are partially or fully represented by the information within several clusters. The second major cluster grouping within the study area is representative of the remaining cultivated area. This clustering distinctly defines two popcorn fields of the three in the ground truthed area, the one known sun flower field and the remaining two fields of field corn. The discrepancies noted within this grouping appear to be tied to either a differing maturity stage or possibly a difference in irrigation practices, which will require further analysis. Additional analysis using temporal data separated by 18 days and color additive techniques has shown an ability to differentiate between the popcorn and sun flower fields of this same data set and is being evaluated at this time.

The statistical data developed as a part of the cluster analysis will as a next step be input into one of the automatic pattern recognition routines implemented in the Monterey Bay analysis for further refinement and development of a classification map.

The second county to be discussed at this time is Hardin County, Iowa, with results again being of a preliminary nature using the clustering algorithms. Hardin County is located in the North Central portion of the state and bisected by the Iowa River. The area is in the heart of the fertile, gently rolling, north central glacial till plain. Hardin County covers an area of 574 square miles, of which 350,000 acres, or 95 percent, is in farm land, with about 75 percent being cultivated cropland. Corn, soybeans, oats, and other feed grains are the most extensively grown. Crops with a small portion of the crop land are in hay, permanent pasture, tame and native grasses. The selected study area is representative of typical corn belt farming practices, and as opposed to Holt County, nonirrigated crops.

The earliest useable data pass over this area occurred on August 13, 1972, with some limited amount of cloud cover to both the north and south of the study area. This data is contained in a digital form on MSS CCT designated by the NASA identification number 1021-16324MB-4 of 4.

Again as with Holt County, the data was submitted to be processed only with the clustering algorithm and color coded on the DAS for correlation with the ground truth. Being typical corn belt, the major crop types in Hardin County are the corn, soybeans, and oats. At this maturity stage it is expected that those three crops could be reasonably well separated. For corn and soybeans the clustering results seem to indicate this as being true; however, the oats being harvested in July

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now have a strong cover of secondary growth and appear mixed with other grasses and legumes. The corn is represented by the major cluster output from the clustering and is fairly well defined. A total of 76 corn fields are represented on the ground truth tabulation, and of these 73 are partially or wholly clustered uniquely by the clustering algorithm. Those three fields unaccounted for are small individual fields that are beyond the expected resolution limit and the larger fields are all fairly well defined with very little extraneous data. A thin scattered cloud to the south of the study area casts a weak shadow along the northern edge of the area and causes a lumping of other crop types with the corn in this area. A later date separation indicates that the soybeans are also uniquely clustered and separable from the corn and oats; however, further analysis of these crop types is required.

2. CONCLUSIONS

In conclusion, in order to meet agricultural applications related objectives, these analyses concerning the utility of ERTS-1 multispectral scanner data have yielded the following significant findings: (1) most important, with existing technology, we are right now able to extract information from the ERTS-1 data which satisfy certain agricultural related objectives. Specifically, we were able to detect and identify major crop species over large geographical regions and to determine the location and areal extent of the associated fields; however, additional analysis and evaluation must be made to determine which and to what extent specific requirements of ASCS can be accomplished. With the development of new techniques and improved application of the existing ones, we hope to meet the more stringent requirements; (2) The greater radiometric fidelity of the system corrected digital data and the subsequent flexibility available for the application of enhancement techniques to this data suggests a preference of this data for the detection and identification processes; (3) The discrimination capability of the data is good and in some cases better for crop species identification activities, as compared to similar experiences with low altitude airborne multispectral data; and (4) This investigation revealed that significant results could be achieved with limited ground truth information or, at most, utilize merely aerial photography to provide most of the control information required for training, test and verification purposes.

In summary, these preliminary results achieved here indicate that with proper selection of data based on crop calendars, and ground truth information, and the utilization of enhancement and pattern recognition systems currently available, major crop types can be detected, identified, and their area extent determined from the ERTS-1 multispectral scanner data.