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Semi-Annual Review of Research Programs of the NASA-Purdue Laboratory for Applications of Remote Sensing

The Laboratory for Applications of Remote Sensing

Purdue University

West Lafayette, Indiana

I. APPLICATIONS TO HYDROLOGY GEOLOGY AND GEOGRAPHY

A. HYDROLOGY

1. Determination of Location, Quantity and Quality of Water Resources

Objective: Effectiveness of remote sensor data in determining quality of water.

Significance: Information on water resources is becoming increasingly important as more of this scarce resource is required. Remote sensing is a potentially valuable tool for obtaining this information on the location, quantity and quality of water resources. The detection of chemical pollution and suspended matter is important to both public and private sectors of the economy.

Accomplishments: The spectral characteristics of different types of water and the correlation of the resulting spectral classes to water quality have been studied. The best set of spectral features for the discrimination and identification of water bodies containing different amounts of suspended matter, i.e., turbidity, has been determined. It was found that the largest spectral divergence between clear and turbid water occurs in the red portion of the spectrum (0.6-0.7μm). Likewise, the blue-violet region of the visible wavelengths (0.40-0.44μm) was found to be the least useful for classification of water as a function of turbidity. These results were in complete agreement with some of the theoretical work done by E.L. Krinov.

Future Prospects: Further investigations of the effect of bottom characteristics on the spectral response of shallow water bodies are expected to improve the capability to identify and determine water quality in a more quantitative manner.

Key Personnel: R.M. Hoffer, Associate Professor, Department of Forestry and Conservation.

2. Evaluation of Thermal Properties of Water

Objective: The detection of thermal differences in water with special attention to thermal pollution.

Significance: The detection of thermal pollution is important to both public and private sectors of the economy. The capability to determine with remote sensing techniques the location, extent and intensity of thermal pollution is critically needed as a tool in evaluating the potential deleterious effects of thermal affluent from atomic energy power plants. The problem has become extremely urgent because of the rapidly increasing threat of power shortages in this country.

Accomplishments: The accuracy and reliability of calibration and mapping of water bodies in the thermal portion of the spectrum was tested as a function of flight altitude and spectral band. It was found that the 8.0-13.5μm, band was more reliable and allowed radiant temperatures to be determined with an accuracy of ±0.2°C at 2,000 ft. altitude. When the altitude of the data collected was increased, the accuracy in both of these wavelength bands decreased considerably. However, a decrease in the width of the wavelength bands used for remote measurements of water temperatures, particularly by narrowing the 8.0-13.5μm band to 9.3-11.7μm, allowed a signficant increase in the accuracy of the radiometric temperature measurements at a given altitude. At 5,000 ft. altitude, the 9.3-11.7μm band yielded radiometrically accurate temperatures of ±0.5°C. These radiometric temperature figures are based upon kinetic temperature measurements made in the field at the time of the aircraft flight missions.

The thermal anomalies of the Cayuga Test Site resulting from the power plant effluent have also been automatically mapped and it was found that these temperatures differences can be accurately traced for several miles down stream.

Future Prospects: Additional research on the thermal effluent characteristics of the Cayuga Test Site will be pursued in conjunction with the ground observations in order to determine the influence of the thermal anomalies on the ecosystem of the stream.

Key Personnel: R.M. Hoffer, Associate Professor, Department of Forestry and Conservation.

B. GEOLOGIC FEATURE RECOGNITION AND MAPPING

Objective: Analysis of scanner data and digitized photography to determine rock type and geologic structure and relating this to general geologic mapping and to specific aspects of economic mineral deposits.

Significance: Applying the developing LARS analysis techniques to geologic studies allows us to determine the applicability of this automatic data processing to identifying types of unconsolidated and bedrock materials. Economic potential is enormous as ore deposits, sources of ground water, construction materials, etc. may be located in this way. Geologic material recognition is closely related to earth resources inventory and conservation.

Accomplishments: Detailed analysis of bedrock areas indicate that most prominent geological features can be distinguished and mapped: major rock groups consisting of sand dunes, two ages of alluvium, basalt flows, non-massive sedimentary rocks, and undifferentiated metamorphic and igneous rocks. In addition, such features as contacts and faults have been recognized by disruptions in spectral patterns. Several spectral classes were necessary to adequately map a single rock type in areas of irregular topography. On digitized space photography, ridges and highs within any given rock unit displayed the least reflectance, whereas reflectance increased down the slopes with the long flat area having the highest reflectance.

Several preliminary investigations involving 1971 Corn Blight Watch Experiment MSS data have demonstrated the effect of topography on spectral response. A forested ridge rending north-south with the linear axis roughly coinciding with the center line of the scan path was selected. Although it was morning, relative reflectance was highest from west-fading slopes, contrary to normal expectations. Moreover, sun-angle corrected data behaved in a similar manner. The explanation lies in the geometry relevant to the scanner, to its altitude and position relative to terrain feature and sun, and the positioning of terrain feature relative to the sun. The difference in relative reflectance in this instance was attributed to scanner look angle into rather dimly illuminated tree tops on west surfaces and into shaded tops on eastern slopes. Based on this experiment, caution is suggested in interpretation of reflectance from any topographically variable surface.

Future Prospects: A combination of visible, reflective IR and thermal IR imagery over areas of known geologic conditions will facilitate the understanding of spectral properties of rocks and identification of rock type. Additional investigations into the effects of mineral composition and rock texture on spectral properties will improve the capability to identify rock types.

Key Personnel: Don Levandowski, Associate Professor, Department of Geosciences. Ray Frederking, Instructor, Department of Geosciences.

C. FOREST AND WILDLIFE RESOURCE INVENTORIES

Objective: Analysis of remote sensor data to determine the capability and reliability of forest and wildland cover type mapping.

Significance: Applying the LARS analysis techniques to forestry and wildland studies enables a determination of the applicability of these techniques to identifying and characterizing forests and wildlands.

Forest and land managers currently rely on aerial photography and field surveys to map and evaluate existing forest resources. Resource surveys are of paramount importance to ensure that a sufficient resource base exists to meet increasing demands for wood and fiber products. Since forestry involves management of extensive areas and has a very small margin for profit, there exists a need for inexpensive inventories of the forest resources over large geographical areas. Automatic data processing of remote sensor data offers a potential for meeting this need.

Accomplishments Using Data From Airborne Platforms: Research to date has indicated that automatic data processing techniques are capable of mapping forest cover to within an accuracy of 90 per cent or greater. This is based on analysis performed on low-altitude (10,000 feet) multispectral scanner data collected by the University of Michigan.

When a comparison was made between the low-altitude MSS data and digitized color photography, the photography compared poorly. Poor classification accuracy of the digitized photographic data can be attributed to: problems associated with the textural characteristics of natural hardwood forest stands, poorer spectral resolution of the photographic emulsion, inadequate contrast between naturally variable classes, and a possible lack of adequate training of the classifier.

During the research which led to these conclusions a project to determine the optimum number of channels for classification was undertaken. Results from this project indicate that for identifying and classifying central Indiana hardwood cover a five-channel classification is optimum.

During the development of the above-mentioned results a study was conducted to determine if all four spectral regions, that is, visible, near-IR, middle-IR, and thermal, are important in classifying hardwood forest cover types. A study of two sets of airborne MSS imagery indicate that all four spectral regions are considered important. However, when specifically concerned with forest cover mapping, a combination of the visible with either near-or middle-IR produces satisfactory results. It appears that the thermal region does not aid in separating various vegetative cover types.

Accomplishments Using Data From Spaceborne Platforms: The natural extension of airborne data analysis efforts to include spaceborne data has been undertaken with available ERTS-1 data. Forest cover mapping in some form has been accomplished for areas in the mid-west, south and west.

Preliminary results from these analyses indicate great potential of ERTS data for identifying forest cover. Research with these data will be continued during the next year.

Hardwood and mixed hardwood/softwood forests in ERTS-1 data, Texoma frame, collected in July were readily identified and mapped with good distinction discernable between forest cover and all other cover types. In addition, drought stress and light and dark forest cover caused by topographic relief were identified in the data, classified and confirmed by ground observation. Several hardwood forest areas having strikingly different spectral responses were found, when checked on the ground, to have been treated by aerial application of the chemical defoliant 2,4,5-T. The treatment had been carried out in some areas to clear completely the forest and convert the land to use as grazing for cattle. Other areas had been treated as a forestry management tool to release young pine stands from overstories of undesirable scrub hardwoods. Both areas were identified in the data and evidence of spraying several years in the past were also found and confirmed by local foresters.

Forest mapping in the midwest using ERTS-1 data appears feasible as late in the season as mid-October. Acreage estimates have been attempted but have not been confirmed by ground observation.

We have not yet had data available with sufficiently large tracts of uniform softwoods to check accuracy of separation of hardwoods and softwoods.

Future Prospects: A capability to distinguish between coniferous and deciduous forest from other cover types will be developed. Area measurements will be incorporated into the analysis system.

Key Personnel: R.M. Hoffer, Associate Professor, Department of Forestry and Conservation.

R.P. Mrocynski, Professional Staff, Forestry
F.E. Goodrick, Professional Staff, Forestry

D. ATMOSPHERIC EFFECTS

Objective: To study the effect of atmospheric conditions upon aircraft and satellite machine processed remote sensing data and to apply the results of this study to the development of data correction algorithms.

Significance: Atmospheric corrections to remotely sensed data which is to be machine analyzed should enable detection of second order effects that might otherwise be obscured by meteorologically induced anomalies. The effect of atmospheric conitions on analyzed results is apparently different when the data are machine analyzed than when they are analyzed manually. A data analysis system capable of making appropriate atmospheric corrections would make usable a much wider variety of data than is frequently possible under marginal weather coditions.

Accomplishments: Anomalous variations have been observed in aircraft remote sensing data when haze layers were present below the aircraft. A preliminary study showed that these effects were well correlated with the expected pattern or radiation scattered upward by a typical continental water haze layer. Therefore, it was concluded a more realistic model allowing atmosphere-surface interaction could be profitably utilized. A numerical model of the scattering and absoption by atmospheric molecules and aerosol particles in the visible and near infrared spectrum has been implemented. This will serve as the basis of a general atmospheric correction model for remotely sensed data.

Future Prospects: Results to date indicate that an easy-to-use software system to correct for atmospheric effects in both aircraft and satellite data is possible and should be developed.

Key Personnel: G.M. Jurica, Assistant Professor, Department of Geosciences.

E. LAND USE CLASSIFICATION

Objectives:

1) Use aerospace remote sensing data and computer-implemented pattern recognition techniques to produce current land use inventories.

2) Formulate procedures for utilizing computer-generated land use maps to supplement, implement, and replace, to the extent possible, conventionally produced land use inventories.

3) Develop integrated land resource information systems which can be utilized by land use planners, industrialists, agricultural scientists, and others in making wise land use decisions.

4) Cooperate with local and state government agencies in applying the results of these techniques to specific land use planning situations.

Significance: In the past 25 years many American cities and suburban areas have doubled or even tripled in population, creating an intense competition for land. As a result of this competition, subdivision developers, industry, transportation authorities, recreation planners, agricultural officials and others have turned to the land use planners for help in making decisions regarding optimum allocation of land resources for various uses. Decision-making requires timely and accurate information regarding the current land use and detailed knowledge of land resource capabilities and limitations.

This information can then be combined with socio-economic factors for locating transportation systems and other public utilities. Sanitarians can also utilize current land use and land resource information to locate areas which are potential health hazards.

Accomplishments: This Laboratory has:

1) Developed a procedure for preparing a current land use inventory of large areas by computer-implemented analysis of aerospace multispectral scanner data.

2) Prepared general land use maps of several counties in West Texas, Arizona, and Southern California through the analysis of digitized multispectral Apollo IX photography by computer-implemented pattern recognition techniques.

Future Prospects: ERTS-1 MSS digital data will be used to produce current land use inventories of both urban and rural areas. It is reasonable to suggest that the following broad categories will be identified and mapped: cultivated lands;

forests and woodlots; open, grassy areas; residential areas with large lots and open space; medium density residential areas; high density residential areas; industrial complexes; major transportation arteries; lakes, rivers and streams. Within several of these broad categories it will be possible to map subdivisions on the basis of spectral separability.

Several metropolitan areas which are potential candidates for land use studies through the use of ERTS-1 MSS data and automatic data processing techniques are Indianapolis, Louisville, Chicago, Milwaukee and Kansas City. Plans for a cooperative research project are presently being discussed with the Division of Planning and Zoning of the Indianapolis Department of Metropolitan Development.

Key Personnel:

Marion F. Baumgardner, Associate Professor
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Kenneth E. Wenner, Assistant Professor
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Stevan J. Kristof, Research Agronomist

II. SR&T

A. APPLICATIONS TO AGRICULTURE

1. Soil Classification and Survey

Objectives:

1) Develop the techniques for using aerospace multispectral scanner data as an aid to soil classification and survey.

2) Assess the feasibility and utility of mapping the internal drainage properties of soils through computer-implemented analysis of radiation data from the soil surface.

3) Determine the possibilities of utilizing aerospace multispectral data for preparing and updating a National Conservation Needs Inventory.

4) Examine the relationships between the multispectral properties of vegetative canopies for the purpose of characterizing and mapping the properties of the soils beneath these canopies.

Significance: One of the most important information resources needed by regional planning groups is a current and accurate detailed soil survey of the region under study. In Indiana alone for no more than one-third of the counties have modern, detailed surveys been completed and published. Such surveys provide information about the potential productivity of different soils, internal drainage properties, engineering properties, depth of soils, and many other facts about soils. Such information is essential for effective land use planning.

If remote sensing techniques can help to provide better soil survey data more quickly, the process of conservation planning, agricultural development, and urban land management will greatly benefit.

Accomplishments:

1) Produced with multispectral data and automatic data processing techniques many "maps" which closely resemble soil maps prepared by conventional methods.

2) Established in preliminary studies a relationship between multispectral reflectance from surface soils and gross internal drainage differences.

3) Identified in some cases surface soils accelerated losses from rainfall erosion, using aircraft scanner data.

4) Identified and mapped gross soil and geologic features from the computer analysis of ERTS-1 MSS digital data.

Future Prospects: Studies will be continued to refine the capabilities to delineate soils boundaries and to prepare spectral soils "maps", using multispectral scanner data from both aircraft and satellite altitudes. Although it is unlikely that soil types can ever be mapped satisfactorily by strictly multispectral measurements, it is highly probable that broad soils categories, such as great groups and associations, may be usefully delineated.

Key Personnel:

Marion F. Baumgardner, Associate Professor
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Jan E. Cipra, Research Agronomist

Stevan J. Kristof, Research Agronomist

2. Physical and Chemical Properties of Soils

Objectives:

1) Determine which important physical and chemical properties of soils can be significantly correlated with the multispectral radiation properties of soils.

2) Define and quantify the effects which different organic and mineral constituents have on the spectral reflectance properties of soils.

3) Evaluate the utility of multispectral measurements for diagnosing nutrient status of soils.

4) Determine the quantitative effects of soil particle size on the multispectral properties of soil.

5) Define the relationships between soil moisture content and the reflectance and emittance properties of soils.

Significance: One of the greatest limitations to land use management and agriculture in the world is man's lack of knowledge and information about land resources. And among these land resources, the soil has chemical and physical properties that greatly affect land use capability, including the potential productivity of agriculture.

Therefore, any practical techniques which can be used to provide very rapidly better information about the chemical and physical properties of soils will greatly advance the cause of more effective utilization and conservation of the land resources of the world.

Accomplishments: In the area of the physical and chemical properties of soils the Laboratory has:

1) Found organic matter content to have an overriding effect on spectral response of soils and predicted organic matter content of soils from computer-implemented analysis of multispectral data.

2) Developed a method for calibrating aircraft scanner data and successfully applied it to the detection of variations in vegetative canopy density.

3) Developed an improved multispectral procedure for identifying Southern Corn Leaf Blight infection by adjusting for spectral variations in soils background.

4) Found significant correlations between nitrogen, phosphorus, and potassium content of maize and soybeans, and the multispectral radiation from these crops.

Future Prospects: In future research the capability to recognize and characterize soil and crop conditions through multispectral analysis will be improved. Furthermore, the need for ground observations at or near the time of flight will be minimized. Some conditions which should be discriminable are severe nutrient deficiences, some crop diseases, surface moisture content, surface texture, quantity and quality of soil organic matter, and surface roughness of soils. In the future detection of these conditions will be facilitated by comparison of spectral response over time and by results of experimental field research.

Key Personnel:

Marion F. Baumgardner, Associate Professor
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Stevan J. Kristof, Research Agronomist

Jan E. Cipra, Research Agronomist

3. Crop Productivity Investigations

Objectives: The objective of crop production research at LARS is to develop a capability to effectively use remotely sensed data for making crop production estimates. The effort includes work on (1) the identification of crops and measurement of their acreage and (2) characterization of the condition and probable yield of crops using remotely sensed data. Current research projects include:

1) Determination of the amount of spectral variation among and within crop types over a large area where different soils, weather, and management practices exist. Such information is essential to the design of ground data collection systems and will provide a measure of ultimate performance of remote sensing crop identification systems since spectral variability is the key to correct identification.

2) Development of a statistical sampling model and analysis of ERTS-1 for making crop acreage estimates. The use of a sampling scheme is more efficient than classification of entire frames of data for this purpose.

3) Analysis of field spectroradiometer data to characterize the reflectance and emittance properties of crops. Two major studies were conducted in 1972 with: (1) systemic and non-systemic stresses (two major types of stress) and (2) amount of ground cover and leaf area of corn. A better knowledge of the effect of these and other factors on spectral response will result in improved interpretation of the spectral measurements made from aircraft or satellites. For instance, during the 1971 Corn Blight Watch Experiment it was not known whether mild blight infection could be detected by remote sensing. Likewise, the kind and magnitude of change in spectral response due to other factors causing changes in spectral response was unknown.

Significance: Information on agricultural crop production is collected and utilized by governments and private industry. The resulting production estimates are a major determinant of makret price and many decisions in managing the production, storage, transporation, and utilization of grain are based on these estimates. Improvements in the accuracy and timeliness of these estimates would result in significant social benefit to the country. For example, studies at LARS have shown that reduction in the error of estimate for corn, soybeans, and wheat production from three percent to two percent would result in 14 million

dollars benefit (see LARS Information Note 030872). Satellites and aircraft offer a unique vantage point for collecting data for crop production estimates. If developed, this concept will provide more accurate and timely estimates than ground surveys now offer, as well as providing a more cost effective method of gathering the information.

Accomplishments: Work at LARS has shown that agricultural crops can be reliably identified from multispectral scanner data. The feasibility of this approach has been demonstrated over increasingly larger areas. During the 1971 Corn Blight Watch Experiment, major crops were accurately identified from remote sensing data over the whole Corn Belt region. The cooperative work planned by ASCS and NASA/MSC is a direct result of the work at LARS on crop identification.

Recently completed projects provide a statistical analysis and evaluation of the classification of corn blight in the 1971 Corn Blight Watch Experiment. This analysis included a study of the relationship between remotely detectable blight classes and yield. The study showed that blight which could be detected remotely caused significant yield reduction.

Future Prospects: Results to date indicate that remote sensing offers a feasible alternative to complete reliance upon ground surveys for obtaining information on agricultural crops. In the near future it will be possible to make accurate area measurements of crops automatically. Development of procedures to improve estimates using correction factors based on the misclassification rates is underway and shows promise. Incorporation into the analysis system of a capability to utilize temporal and spatial information can be expected to further improve crop identification performance. As understanding of the relationship of the interaction of factors affecting yield and spectral response increases, it may be possible to obtain yield information directly from remote sensing data.

Key Personnel:

Marvin E. Bauer, Research Agronomist
Ludwig Eisgruber, Professor, Department of Agricultural Economics
Jan E. Cipra, Research Agronomist

4. Socio-Economic Analysis I:

Economic Analysis of Sampling Ratios for Remote Sensing Applications

Objectives:

1) To develop and assess statistical models for various sampling plans for remote sensing application.

2) To develop empirical estimates of the variance components for sampling plans.

3) To derive cost coefficients for various sampling plans.

4) To assess the trade-off between increasing precision of estimates and associated costs in remote sensing applications.

Significance: Large-scale applications of remote sensing for the purpose of preparing crop estimates, natural resource inventories, pollution monitoring, and so forth, will, in general, involve questions of sampling, since complete coverage of the total geographic region and subsequent analysis of the data appears technically and economically infeasible. Thus, it is important to know about the relationship between less than complete coverage (i.e. sampling), precision of resulting estimates, and associated costs.

Accomplishments: A statistical model for a three-stage sampling plan was developed, and empirical estimates of the variance components of this model were derived for a given application. Cost functions relevant for this model and application were developed, and optimum sampling ratios were computed. The sensitivity of this optimum solution to changes in selected factors is being analyzed. Further development of a sampling scheme when the sampling ratio is a function of cloud cover is underway.

Future Prospects: No obstacles are foreseen to prevent the reaching of limited applications objectives.

Key Personnel: Dr. Ludwig Eisgruber, Agricultural Economics

5. Socio-Economic Analysis II:

Cost/Benefit Analysis for Remote Sensing Applications

Objectives:

1) To develop a theoretical framework for a remote sensing centered information system.

2) To ascertain user requirements for selected applications within such a system.

3) To devise empirical estimates of costs and benefits of selected applications.

4) To examine the distribution of costs and benefits to various user groups.

Significance: Public scrutiny of how public funds are expended is at an all-time high. This scrutiny is particularly intense with respect to funds expended towards "space technology". Objective cost/benefit analysis is not only necessary to meet such public scrutiny and to receive continued funding, but it can also aid in directing technology development towards areas of high (economic, social) pay-off.

Accomplishments: Based on classical concepts of social costs, social benefits, and the so-called inventory adjustment model, empirical estimates were derived of marginal social benfits resulting from improved precision in crop estimates. Implications were derived for remote sensing applications in this area. A study was completed on the impact of biased information and more frequently provided information of a given degree of precision on the commodity market. This study is currently extended to ascertain the beneficiaries of different types of information, such as remote sensing might provide. Work is also underway to examine the potential role of remote sensing in monitoring the extent of monocultures and associated resource patterns and socio-economic implications.

Future Prospects: In our judgement, this is one of the high pay-off research areas. The danger with this type of research is that it tends to approach the problem at extremes, i.e. either on too small or too large a scope. Either approach produces meaningless results, albeit for different reasons. For our own work, the danger lies in approaching the problem on too small a scope (for reasons of limited resources).

Key Personnel: Dr. Ludwig Eisgruber, Agricultural Economics

B. MEASUREMENTS

1. Reflective and Emissive Properties of Stresses Vegetation

Objective: To study the reflective and emissive properties of vegetation, especially stressed vegetation, in order to better understand the physical aspects of the spectral and spatial distribution of reflective radiation from these cover types. To apply the results of these studies to the development of data preprocessing algorithms in remote sensing data processing technology.

Significance: During the planning and conduct of field experiments involving the measurement of reflected radiation from stressed vegetative canopies a strong interaction between instrumentation engineers and technicians and life scientists in other program areas at LARS takes place. In fact, the research scientist, who is a specialist on the particular vegetative canopy under study, participates in the direction of the on-site experiment. Such activity enhances both the natural and physical aspects of the experiment.

The results of these field experiments directly benefit the research scientist involved in understanding the spectral and spatial radiative characteristics of the vegetative canopies. However, an equally important benefit is the eventual application of the results of the experiment to the development of data preprocessing algorithms for the interpretation of remotely gathered mulitspectral data on stressed vegetation.

Accomplishments: Field data on systemic and non-systemic stressed corn canopies have been obtained during the 1972 growing season. In addition, data concerning the effects of percentage ground cover upon the spectral characteristics of stressed and unstressed vegetative canopies have also been obtained. These data were acquired under field conditions and represent the first complete data set of its kind that has yet been obtained over the wavelength region from .4 to 15μm. These data are currently being processed and studied in order to facilitate the development of improved data preprocessing algorithms with regard to the classification of stressed corn canopies. The research is in relatively early phases due to the natural difficulty of carrying out accurate meaningful spectral measurements under field conditions.

Future Prospects: Experiments of this type will be expanded during the next growing season to include detailed goniometric measurements and to other cover types, such as wheat. The results of this work will aid in the improvement of the detection of stressed vegetation from aircraft and satellite altitudes.

Key Personnel:

LeRoy F. Silva, Associate Professor, Electrical Engineering
Barrett Robinson, Research Engineer

2. Spectral and Emissive Properties of Soils

Objective: To study the spatial and spectral characteristics of soils in the reflective and emissive portions of the spectrum and to use the results of this research in the development of data preprocessing algorithms for remotely sensed soils data.

Significance: Spectral and temperature measurements on several soil types under field conditions have been made under the close supervision of soils scientists from the Agronomy Department of Purdue.

The results of this research will be used to improve the classification accuracies of soil types and to develop problem-oriented data preprocessing algorithms.

Accomplishments: A catalog of data on soil types over the wavelength range of .4 to 15μm has been oriented over a wide variety of soil types that have been nurtured under field conditions. The effect of surface texture upon soil spectral characteristics has been carefully researched. Preliminary investigation of these spectral characteristics and their effect upon difficult soil classification problems has been undertaken.

Future Prospects: The separation of soil surface texture from the soil bulk properties appears to be one of the principal early future benefits from this research work.

Key Personnel:

Barrett Robinson, Research Engineer
LeRoy F. Silva, Associate Professor, Electrical Engineering

3. Specialized Instrument Development

Objective: To develop laboratory and field instrumentation systems especially appropriate to the acquisition of data regarding the spectral and spatial characteristics of natural materials.

Significance: Activity in this particular research area is contained principally within the Measurements Research Area. However, frequent communication with potential users of instruments strongly influences the instrumentation system design, development and implementation.

The data produced in these specialized instrumentation systems are of direct use to research acientists from other program areas, and the results have a direct bearing upon data processing methodology that may be used in the preprocessing and reduction of remotely sensed data.

Accomplishments: The following instrumentation systems have been designed and developed:

1) An extended wavelength field spectroradiometer,

A field spectroradiometer that covers the wavelength region from .4 to 14μm has been designed, developed and implemented. This system can acquire data in the field under a wide variety of natural conditions, and it is so designed to permit goniometric spectroradiometric measurements. An accompanying software system is being designed to take the digitized data from the instrument and process it into a form suitable for analysis by the research scientist. The instrument may be fully calibrated under field conditions.

2) Low-cost field spectroradiometer.

A field spectroradiometer capable of operating under a wide variety of natural conditions over the wavelength region from .4 to 2.5μm has been designed and developed and is being implemented. This instrument is capable of being constructed for a cost of less than $5000. Its intended usage is for those projects which desire an essentially dedicated field spectroradiometer setup.

3) Portable digital field thermometer.

A high precision portable field thermometer has been developed and implemented that enables accurate temperature measurements of soil and water for both ground truth and research field use. These instruments are used frequently by research scientists in the other program areas, and the data used in their research as well as in the training of airborne multispectral data.

4) Field calibration sources.

Several inexpensive field calibrators have been designed and developed with suitable accuracy for the calibration of field instruments on the experimental site.

Key Personnel:

LeRoy F. Silva, Associate Professor, Electrical Engineering
Barrett Robinson, Research Engineer
Thomas Martin, Associate Program Leader

4. Electrical Parameters in Soil Moisture Measurements

Objective: To study the electrical properties of soils as a function of available moisture profile and to apply the results to the development of simple soil moisture instruments and possibly extend the results to the technology of the remote sensing of soil moisture using radar systems.

Significance: Electrical engineers in this research program have been working closely with soil scientists at LARS and soil chemists in the Agronomy Department in a carefully researched and documented study of the electrical properties of soils as a function of moisture content.

Since soil moisture is an important parameter in agriculture and land use planning, measurements of this parameter are of direct benefit to research scientists working in this area and to the remote sensing community that is attempting to develop rapid low-cost methods to make large-scale measurements of this parameter.

Accomplishments: A coaxial probe has been developed that enables relatively accurate measurements of soil moisture in a wide variety of both laboratory and natural soil materials. Measurements have been made at radio frequencies and proper account taken for polarization effects. The results are being extended to higher frequencies, and a study of the transmission analogy is currently under way. At the very least, an instrument will be developed that will make accurate field measurements of soil moisture and will be relatively easy to use.

Future Prospects: Whether or not the results of this research can be extended to the general measurement of available soil moisture profile using radar technology remains to be seen. This is a very difficult problem, but the results of the research described here will enable an intelligent assessment of the potential success of the program.

Key Personnel:

Floyd V. Schultz, Professor, Electrical Engineering

III. APPENDICES

A. GRADUATE RESEARCH PROJECTS - 1972-1973

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Vanderbilt, Vern, Reflectance of Leaves

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1971 Corn Blight Watch Experiment Data Processing Analysis, and Interpretation. T. L. Phillips and Staff. 012272

Corn Blight Watch Experiment Results. C. J. Johannsen, M. E. Bauer, and Staff. 012372

Data Processing I: Advancements in Machine Analysis of Multispectral Data. P. H. Swain and Staff. 012472

Data Processing II: Advancements in Large-Scale Data Processing Systems for Remote Sensing. D. A. Landgrebe and Staff. 012572

Differentiating Elements of the Soil-Vegetation Complex. M. F. Baumgardner and Staff. 012672

Land Utilization and Water Resource Inventories over Extended Test Sites. R. M. Hoffer and Staff. 012772

Measurements Program in Remote Sensing at Purdue University. L. F. Silva and Staff. 012872

Some Experimental Results for Linear Classifiers Applied to Agricultural Remote Sensing Data. T. V. Robertson. 020972

The Effect of Subsampling Ratios on Precision of Estimates from Remote Sensing. L. M. Eisgruber. 021072

Calibration of Aircraft Scanner Data Using Ground Reflectance Panels. P. E. Anuta and W. R. Simmons. 030672

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Potential Benefits of Remote Sensing: Theoretical Framework. L. M. Eisgruber. 030872

Research Project Description - Use of CMS for Updating LARSYS Program. Kay Hunt. T-1 041872

Multispectral Data Compression Through Transform Coding and Block Quantization. P. J. Ready and P. A. Wintz. TR-EE 72-2, and Ph. D. Thesis, School of Electrical Engineering, Purdue University; and LARS Information Note 050572, May 1972.

Notes on Image Correlation and Registration System Improvements. Stanton Yao. T-2 060672

A Cluster Oriented Analysis of Multispectral Data. P. E. Anuta T-3 060772

Comparison of Gaussian and Linear Classifiers on Multispectral Image Processing. T. V. Robertson. T-4 060972

An Educational Program for Computer-Oriented Remote Sensing Data Analysis. P. H. Swain T-5 062072

Data Handling and Analysis for the 1971 Corn Blight Watch Experiment. P. E. Anuta, T. L. Phillips, and D. A. Landgrebe. Presented at the National Telecommunications Conference, Houston, Texas, December, 1972. 080172

Measurement of Available Soil Moisture. F. V. Schultz. T-9 082272

Final Report for the LARS/Purdue-IBM Houston Scientific Center Joint Study Program. P. E. Anuta, E. M. Rodd, R. E. Jensen and P. R. Tobias. September, 1972.

A Simulation Technique for the Generation and Classification of Multivariate - Normal Samples. S. V. Whitsitt and D. A. Landgrebe. 081572

The Spectral Characteristics of Normal and Nutrient - Deficient Maize Leaves. A.H. Al-Abbas, P. Barr, J.D. Hall, F.L. Crane, and M.F. Baumgardner. 111472

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Minimum Distance Classification in Remote Sensing. A.G. Wacker and D.A. Landgrebe. Presented at the First Symposium for Remote Sensing, February, 1972, Ottawa, Canada. 030672-R

Multispectral Data Compression Through Transform Coding and Block Quantization. P.J. Ready and P.A. Wintz. TR-EE 72-2, and Ph.D. Thesis, School of Electrical Engineering, Purdue University; and LARS Information Note 050572, May, 1972.

Influence of Haze Layers Upon Remotely-Sensed Surface Properties, G.M. Jurica and W.L. Murray. Presented at the Conference on Atmospheric Radiation, Fort Collins, Colorado, August 7-9, 1972. 060272

Application of Multispectral Remote Sensing to Soil Survey Research in Indiana. A.L. Zachary, J.E. Cipra, R.I. Diderickson, S.J. Kristof Agronomy, Tucson, Arizona, 1972. (In Press)

Optimum Time of Year for Identification of Land Classes Using Multispectral Data. P.N. LeBlanc, M.S. Thesis. Department of Agronomy, Purdue University, Lafayette, Indiana. 1972.

ADP of Multispectral Scanner Data for Land Use Mapping. R.M. Hoffer. Presented at the 2nd UNESCO/IGU Symposium on Geographical Information Systems, Ottawa, Canada, August 1-9, 1971. 080372

Results of the 1971 Corn Blight Watch Experiment. R.B. MacDonald, M.E. Bauer, R.D. Allen, J.W. Clifton, and J.D. Erickson. Presented at the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, October 2-6, 1972. 100272

Definition of Spectrally Separable Classes for Soil Survey Research. J.E. Cipra, P.H. Swain, J.H. Gill, M.F. Baumgardner and S.J. Kristof. Presented at the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, October 2-6, 1972. 100372

Agricultural and Forest Research Surveys for Space. R.M. Hoffer. Presented at the 23rd International Astronautical Congress, Vienna, Austria, October 9-14, 1972. 100972

Mapping of Soils and Geologic Features with Data from Satellite-Borne Multispectral Scanners. M.F. Baumgardner, S.J. Kristof, and W.N. Melborn. To be presented at the 10th International Congress of Soil Science, Moscow, U.S.S.R., August 12-20, 1974. 110872

Application of Multispectral Remote Sensing to Soil Survey Research in Indiana. A.L. Zachary, J.E. Cipra, R.I. Diderickson, S.J. Kristof, and M.F. Baumgardner. Presented at the ASA Meetings in Tucson, Arizona, 1972. 110972

Multispectral Determination of Vegetative Cover in Corn Crop Canopy. E.R. Stoner, M.S. Thesis. Department of Agronomy, Purdue University, Lafayette, Indiana, 1972.

Determining Density of Maize Canopy: I. Digitized Photography. E.R. Stoner, M.F. Baumgardner, and P.H. Swain. 111172

Determining Density of Maize Canopy: II. Airborne Multispectral Scanner Data. E.R. Stoner, M.F. Baumgardner and J.E. Cipra. 111272

Determining Density of Maize Canopy: III. Temporal Considerations. E.R. Stoner, M.F. Baumgardner, P.E. Anuta and J.E. Cipra. 111372

Land Use Classification Utilizing Remote Multispectral Scanner Data and Computer Analysis Techniques. P.N. LeBlanc, C.J. Johannsen and J.E. Yanner. M.S. Thesis, Department of Agronomy, Purdue University. 1972. 111672

1972 - 1973

PAPERS AND INFORMATION NOTES

Measurements Programs

Completed Manuscripts:

011573	Atmospheric Effects on Radiation Measurements - Jurica
021973 T-11	Data Acquisition Control Module, etc. - Haselby

In - Progress:

022373	Light Ray Tracing, etc. - Kumar-Silva
022473	Reflection Model of Leaf, etc. - Kumar-Silva
040173	EXOTECH Manual - Robinson
041873	IR Radiometry of Plants - Kumar-Silva
041973	Max. Weighted Ave. Stat. Separability between Spectral Class Pairs of Corn Blight Levels - Kumar-Silva
042573	Geometric Analysis and Restitution of MSS Dig. Data Arrays - Baker (Mikhail)

Data Processing & Analysis Research Programs

Completed Manuscripts:

080172	Data Handling and Analysis for the 1971 CBWE - Anuta-Phillips
111572	Pattern Recognition: A Basis for R/S Data Anal. - Swain
111772	Moire Patterns and 2-Dimensional Aliasing, etc. - McGillem/ Riemer
022573	Constrained Optimization of Image Restor. Filters - Riemer/ McGillem
032973	Urban Land Use Mapping by Machine Proc. of ERTS-1,-etc. - Ellefsen/Swain
040473 T-13	Investigation of Class. Results Based ... Dir. Comp.- Swain
(120271)	Scan Overlap Redundancy to Enhance... - Lindenlaub (included because it was printed during '72-73)

In - Progress:

022073	Error Free Coding - Duan/Wintz
022673	A Linear Shift-Invariant Image Preproc. Tech... - Riemer
031773 T-12	Sun Angle Effect Preproc. with Predicted Ramp Functions - Strahorn/Anuta
041773	Automatic Boundary Finding... - Kettig/Landgrebe

Ecosystems Research Programs

Completed Manuscripts:

080372	ADP of MSS Data for Land Use Mapping - Hoffer
100272	Results of the 1971 CBWE - MacDonald, Bauer
100972	Ag. and Forest Resource Surveys fr. Space - Hoffer
030573	Basic Forest Cover Mapping using Digitized Remote Sensor Data and ADP Techniques - Coggeshall/Hoffer

In-Progress:

042373	Bartolucci thesis

Earth Sciences Research Programs

Completed Manuscripts:

100372	Def. of Spectrally Separable Classes for Soil Survey Research - Cipra, Swain, Gill
102372	Changes of Multispectral Soil Patterns with Increasing Crop Canopy - Kristof/Baumgardner
110872	Mapping of Soils and Geologic Features with Data from Satellite-Borne MSS - Baumgardner, Kristof, Melhorn
110972	Application of Multispectral R/S to Soil Survey Research in Indiana - Zachary, Cipra, et al.
111072	Multispectral Determination of Vegetative Cover in Corn Crop Canopy - Stoner Thesis
111172	Determining Density of Maize Canopy: I. Dig. Photog. - Stoner, Baumgardner
111272	Determining Density of Maize Canopy: II. Airborne MSS Data - Stoner, Baumgardner
111372	Determining Density of Maize Canopy: III. Temporal Conditions. - Stoner, Baumgardner
111472	Spectra of Normal and Nutrient-Deficient Maize Leaves - Al-Abbas, Barr
022873	Prep. of Urban Land Use Inventories by Machine-Proc. of ERTS MSS Data - Todd, Mausel
030273	Recog. of Surface Lithologic and Topog. Patterns in SW Colorado with ADP Tech. - Melhorn, Sinnock
030373	ID and Mapping of Soils, Veg., and Water Resources of Lynn Co., Texas by Computer Analysis of ERTS MSS Data - Baumgardner, Kristof,
031673	An Interpretation of a Geologic Map of Fannin Co., Tex., Prepared by ADP Techniques from ERTS MSS Data - Henderson,

Earth Sciences (cont)

In-Progress:

022773	(Longer version of ERTS paper to become Info. Note and be sent to a journal) - Todd, Mausel
030173	Id of Ag. Crops by Computer Proc. of ERTS MSS Data - Bauer
030673	Multispectral Tech. for he Automatic Recog. & Mapping of Surface Water Bodies - Kristof
030773	Spectral Mapping of Soil Organic Matter - Kristof
030873	Stockton
031373	Airborne Scanning System Employed to Study Effect of Some Nutrients on Radiation of Corn - Kristof

Land Use (Office of the Director)

Completed Manuscripts:

092972	An Early Analysis of ERTS-1 Data - Landgrebe, Hoffer, et al.
101472	Automatic Classification of Soils and Veg. with ERTS-1 Data - Landgrebe
111672	Land Use Classification Utilizing Remote MSS Data and Computer Analysis Techniques - LeBlanc Thesis

In-Progress:

031573	Machine Processing for Remotely Acquired Data - Landgrebe

Papers + Info Notes - 1972-73

120271 Use of Scan Overlap Redundancy to Enhance Multispectral Scanner Data. J. C. Lindenlaub and J. Keat. 24 pages. The use of scan-overlap redundancy to improve the signal-to-noise ratio of multispectral scanner data is investigated. The trade-off between poorer resolution and improved signal-to-noise ratio as a function of the number of scan lines averaged is studied analytically. The line averaging procedure is implemented and the effects upon classification accuracy are studied.

080172 Data Handling and Analysis for the 1971 Corn Blight Watch Experiment. Paul E. Anuta, David A. Landgrebe and Terry L. Phillips. This paper presents the methodology developed for storing, retrieving, analyzing the data, and disseminating the analysis results for the 1971 Corn Blight Watch Experiment. An important part of the methodology was digital technique which was developed for analysis of the multispectral scanner data. The conclusions are that (1) the state-of-the art of remote sensor data acquisition and analysis was significantly advanced by this experiment and (2) the accurate detecting of southern corn leaf blight by the remote sensing techniques employed shows promise; however, technological advances in sensors, calibration and analysis techniques are required to accurately detect corn blight in earlier stage.

080372 ADP of Multispectral Scanner Data for Land-Use Mapping. Roger M. Hoffer. Many disciplines long recognized the need for reliable, faster land use information over large geographical areas. The use of MSS data in ADP, including considerations in selecting classes, methods of classification and a description of LARS computer hardware is discussed, followed by prospective temporal work. The application of ADP techniques to multispectral data has been proven feasible and will figure strongly in the handling of temporal and spatial data taken over large geographical areas.

092972 An Early Analysis of ERTS-1 Data. D. A. Landgrebe, R. M. Hoffer, F. E. Goodrick and Staff. A data set collected by ERTS-1 on the first data collection pass over the U.S. was provided to LARS/Purdue for immediate analysis and evaluation. Special classes first defined in lieu of ground information for the full data frame and two subframes were augmented by a subsequent ground mission and related to ground cover types using a computer classification procedure. Water resources, geological features, and evidence of agricultural and forestry activities were identified and classified.

100272 Results of the 1971 Corn Blight Watch Experiment. R. B. MacDonald, M. E. Bauer, R. D. Allen, J. W. Clifton, J. D. Erickson and D. A. Landgrebe. This paper describes the implementation of the CBWE, major results of the Experiment and their significance. Until publication of the final report this paper will probably be the only near-complete report describing major aspects of the Experiment.

100372 Definition of Spectrally Separable Classes for Soil Survey Research. J. E. Cipra, P. H. Swain, J. H. Gill, M. F. Baumgardner and S. J. Kristof. Two significant problems in mapping soils spectrally are the arbitrariness of spectral class selection by the researcher and the effects of moisture, crop residue, surface condition and other factors on the spectral properties of nonvegetated soils. A procedure was used for defining spectral classes such that the differences between classes could be quantified. The procedure also facilitates determination of a number of classes such that the classes are spectrally discriminable. The methods used should help to determine the extent to which spectral properties of soil surfaces can be associated with morphologic and topographic differences of interest to soil surveyors engaged in operational soil mapping.

100972 Agricultural and Forest Resource Surveys from Space. Roger M. Hoffer. Basic informational needs of various user groups and their relationship to the analysis of remote sensor data is discussed. A data analysis sequence for use with the remote sensor data is developed, followed by a discussion of the potentials for achieving even the most complex level of information requirements, as indicated by the results obtained by the 1971 Corn Blight Watch and the early analysis of ERTS-1 data in Oklahoma and Indiana. Applications of remote sensing to agricultural and forestry needs are also mentioned.

101472 Automatic Classification of Soils and Vegetation with ERTS-1 Data. D. A. Landgrebe. This paper is an abbreviated form of a more complete report entitled "Preliminary Findings from Analysis of ERTS Observations" presented at the NASA Goddard Space Flight Center, Greenbelt, Md., September 29, 1972. See the abstract for #092972.

102372 Changes of Multispectral Soil Patterns with Increasing Crop Canopy. S. J. Kristof and M. F. Baumgardner. By using the orange portion of the visible spectrum to cluster relative radiance of the soils, we produced maps of soil patterns with a striking similarity to those of the aerial photography. These patterns became less distinct as the maize canopy increased. The reflective infrared bands were used to indicate areas where the maize had deteriorated due to infection or nutrient deficiency.

Panchromatic aerial photography had been obtained in early May 1970 and multispectral scanner missions had been flown on May 6, June 30, August 11 and September 5, 1970 to obtain energy measurements in 13 wavelength bands.

110872 Mapping of Soils and Geologic Features with Data from Satellite-Borne Multispectral Scanners. M. F. Baumgardner, S. J. Kristof, and W. N. Melhorn. The ERTS-1 satellite provides opportunity for quick inventory and assessment of geologic, soils, and vegetative cover aspects of large-scale areas. Collin County, Texas, a 2270 km^2 area of relatively simple geology and soil associations was chosen for initial study, using ERTS-1 4-channel multispectral scanner data analyzed by computer-implemented pattern recognition techniques developed at LARS. The results indicate excellent visual correlation, on a gross scale, between automatically produced maps and existing geologic and soils maps and field information.

110972 Application of Multispectral Remote Sensing to Soil Survey Research in Indiana. A. L. Zachary, J. E. Cipra, R. I. Diderickson, S. J. Kristof, and M. F. Baumgardner. This study compared computer-implemented mappings based on spectral properties of bare soil surfaces with mapping units of interest to soil surveyors. Some soil types could be differentiated by their spectral properties and the maps seemed useful for delineating boundaries between soils in many cases.

111072 Multispectral Determination of Vegetative Cover in Corn Crop Canopy. E. R. Stoner and M. F. Baumgardner. This research was designed to study the relationship between different amounts of vegetative ground cover and the energy reflected by corn canopies. Low altitude photography and an airborne multispectral scanner were used to measure this reflected energy.

Field plots were laid out, representing four growth stages of corn. Two plot locations were chosen -- on a very dark and a very light surface soil. Color and color infrared photographs were taken from a vertical distance of 10 m. Estimates of ground cover were made from these photographs and were related to field measurements of leaf area index. Ground cover could be predicted from leaf area index measurements by a second order equation.

Color infrared photography proved helpful in determining ground cover on dark soil backgrounds. Color photography was useful for determining ground cover on light soil backgrounds, as long as the ground cover did not exceed about 75%.

Microdensitometry and digitization of the three separated dye layers of color infrared film showed that the near infrared dye layer is most valuable in ground cover determinations. Computer analysis of the digitized photography provided an accurate method of determining percent ground cover.

Multispectral scanner data were collected in two flights over the light soil background plots at an altitude of 305 m. Energy in eleven reflective wavelength bands from 0.45 to 2.6 μm was recorded by the scanner. A set of eight ground reflectance panels was in close proximity to the ground cover plots and was used to try to normalize the scanner data over time.

Ratio techniques were used to relate uncalibrated scanner response to leaf area index. The ratios of scanner data values for the 0.72 to 0.92 μm band over the 0.61 to 0.70 μm band and the 1.0 to 1.4 μm band over the 0.61 to 0.70 μm band were calculated for each plot. The ratios related very well to leaf area index for a given scanner flight date, but could not be generalized between flights because of uncertainty in scanner response over time.

Ground reflectance panels were used to relate laboratory reflectance measurements to scanner response. Separate prediction equations were obtained

for both flight dates for all eleven reflective wavelength bands of the multispectral scanner. In this way, scanner response was normalized to ground panel reflectance. Ratios of normalized scanner data could be related to leaf area index over time.

The normalized scanner response was used to plot relative reflectance versus wavelength for the ground cover plots. Spectral response curves resulted which were similar to those for bare soil and green vegetation as determined by laboratory measurements. The spectral response of different ground cover plots represented a "mixing" of the spectral response curves for the bare soil and green vegetation components of the scene.

The spectral response curves from the normalized scanner data indicated that reflectance in the 0.72 to 1.3 μm wavelength range increased as leaf area index increased. A decrease in reflectance was observed in the 0.65 μm chlorophyll absorption band as leaf area index increased. This confirmed the validity of using the ratio of the response from a near infrared wavelength band to that of the red wavelength band in relating multispectral scanner data to leaf area index in corn.

111172 Determining Density of Maize Canopy: I. Digitized Photography. E. R. Stoner, M. F. Baumgardner and P. H. Swain. This research studied the relationship between different densities of maize canopies and the energy reflected by these canopies. Spectral and spatial data were obtained from color and color infrared photographs taken 10 m above the maize canopies of selected plots. Microdensitometry and digitization of the three photographically separated dye layers of color infrared film showed that the near infrared dye layer is the most valuable in canopy density determinations. Computer analysis of the digitized photography provided an accurate method of determining canopy density.

111272 Determining Density of Maize Canopy: II. Airborne Multispectral Scanner Data. E. R. Stoner, M. F. Baumgardner and J. E. Cipra. Leaf area index measurements were taken from twelve subplots during two overflights of an eleven-channel multispectral scanner. Ratios of scanner values related very well to leaf area index for a given flight date, but could not be generalized between data from different flights because of uncertainty in scanner response on different dates. The results indicate that spectral data from maize canopies could be of value in determining canopy density.

111372 Determining Density of Maize Canopy: III. Temporal Considerations. E. R. Stoner, M. F. Baumgardner, P. E. Anuta and J. E. Cipra. A set of ground reflectance panels were to normalize scanner data obtained on two different dates and to relate laboratory reflectance measurements to scanner response. Thus, ratios of scanner data could be related to leaf area index over time. Reflectance increased in the 0.72 to 1.3 μm wavelength range and decreased in the 0.65 μm chlorophyll absorption band as leaf area increased. This confirmed the validity of using the ratio of the response from a near infrared wavelength band to that of the red wavelength band in relating multispectral scanner data to leaf area index in maize.

111472 The Spectral Characteristics of Normal and Nutrient-Deficient Maize Leaves. A. H. Al-Abbas, R. Barr, J. D. Hall, F. L. Crane and M. F. Baumgardner. Reflectance, transmittance and absorbance spectra of normal and mineral-deficient (N,P,K,S,Mg and Ca) maize leaves were analyzed using computer techniques at 30 wavelengths from 500 to 2600 nm. The results of the analysis of variance on reflectance, transmittance and absorbance showed significant differences (P=0.01) in the visible wavelengths among leaves with different nutrient treatments. These results should provide basic knowledge for the interpretation of air- and space-borne spectral measurements.

111572 Pattern Recognition: A Basis for Remote Sensing Data Analysis. Philip H. Swain. Pattern recognition plays a central role in numerically oriented remote sensing data analysis. This Information Note describes the theoretical basis for the pattern recognition algorithms used in LARSYS, the multispectral data analysis software system developed by the Laboratory for Applications of Remote Sensing.

111672 Land Use Classification Utilizing Remote Multispectral Scanner Data and Computer Analysis Techniques. P.N. LeBlanc, C.J. Johannsen, and J.E. Yanner. This research was designed to evaluate the utility of multispectral scanner data and automatic data processing techniques to differentiate and map land use categories in a complex urban scene. Data were obtained over a small residential subdivision with an airborne multispectral scanner and were analyzed by pattern recognition techniques. Several surface features including trees and shrubs, grass, streets, driveways, and rooftops were easily separated and mapped by computer-implemented spectral analysis

111772 Moirè Patterns and Two-Dimensional Aliasing in Line Scanner Data Acquisition Systems. C.D. McGillem and T.E. Riemer. The basic mechanism underlying the generation of Moirè patterns in line scanner data acquisition systems is examined. A general expression is developed in terms of typical system parameters for the reproduced image of such systems and the interaction of the image spectrum; the raster frequency and digital sampling frequency of the A/D conversion process are discussed and examples given. System design requirements for avoiding Moirè pattern generation and two-dimensional aliasing are discussed.

011573 Atmospheric Effects on Radiation Measurements. G. M. Jurica. The principles of radiative energy transfer relevant to remote sensing technology are briefly described. They are then utilized to assess the importance of the atomsphere in the remote detection of earth surface properties. It is concluded that through the removal of unwanted atmospheric effects the information extracted from remote sensing data can be increased.

021973 T-11 Data Acquisition Control Module: An Interface for the Exotech Model 20-C Spectroradiometer. Robert D. Haselby. This paper describes an interface for the Exotech Model 20-C Spectroradiometer. This unit controls later digitization of data recorded on an analog tape by generating sample command pulses which are recorded on the analog tape. This unit also netrieves amplitude information by recording a reference square wave prior to each data observation.

022573 Constrained Optimization of Image Restoration Filters. T. E. Riemer and C. D. McGillem. A linear shift-invariant preprocessing technique is described which requires no specific knowledge of the image parameters and which is sufficiently general to allow the effective radius of the composite imaging system to be minimized while constraining other system parameters to remain within specified limits.

022873 Preparation of Urban Land Use Inventories by Machine-Processing of ERTS MSS Data, William Todd, Paul Mausel, and Kenneth Wenner. Spectral classes of urban phenomena identified from Earth Resources Technology Satellite (ERTS) multispectral scanner data in Milwaukee included "Suburban", "Inner City", "Industry", "Grassy" (open area), "Road", "Wooded Suburb", "Water", "Cloud", and "Shadow". The Milwaukee spectral class statistics were used to classify the Chicago area, within the same ERTS frame, and similar results were achieved. In another ERTS frame, Marion County (Indianapolis) data were classified into similar classes. The Marion County ERTS study was supported by a land use classification of an area near downtown Indianapolis that utilized 12-band MSS data collected by aircraft from 3000 feet. The results of the ERTS analyses suggest that satellite data will be useful tool for the urban planner for monitoring urban land use.

030273 Recognition of Surface Lithologic and Topographic Patterns in Southwest Colorado with ADP Techniques. Wilton A. Melhorn and Scott Sinnock. Analysis of ERTS-1 multispectral data by automatic pattern recognition procedures is applicable toward grappling with current and future resource stresses by providing a means for refining existing geologic maps. The procedures used in the current analysis already yield encouraging results toward the eventual machine recognition of extensive surface lithologic and topographic patterns. Automatic mapping of a series of hogbacks, strike valleys, and alluvial surfaces along the northwest flank of the San Juan Basin in Colorado can be obtained by minimal man-machine interaction. The determination of causes for separable spectral signatures is dependent upon extensive correlation of micro- and macro field based ground truth observations and aircraft underflight data with the satellite data.

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030573 Basic Forest Cover Mapping Using Digitized Remote Sensing Data and Automatic Data Processing Techniques. Michael L. Coggeshall and R. M. Hoffer. Remote sensing equipment and automatic data processing techniques offer much potential for the procurement of information necessary to meet the demand for more intensive management of our forest resources.

On the basis of automatically calculated statistics derived from manually selected "training" samples, the feature selection processor of LARSYS was directed to select, upon consideration of various groups of the four available spectral regions, a series of "best" channel combinations whose automatic classification performances (for six cover types, including both deciduous and coniferous forest) were tested, analyzed and further compared with automatic classification results obtained from digitized color infrared photography.

Results indicate: 1) that the use of five, of the available 12, channels offers an acceptable compromise between classification accuracy and computer time; 2) that five channels (one each from the visible green and red, and the near, middle and thermal infrared) can classify basic forest cover with accuracies well in excess of 90 percent; 3) that a combination of the visible region plus either the near or middle infrared will provide sufficient spectral information for accurate basic forest cover mapping; and 4) that the qualitative nature of photographic data does not lend itself to reliable quantitative analysis.

031673 An Interpretation of a Geologic Map of Fannin County, Texas, Prepared by ADP Techniques from ERTS MSS Data. J. A. Henderson, Jr., J. V. Gardner and J. E. Cipra. Presented at the Second Annual Earth Resources Conference, March 26-28, Tullahoma, Tennessee. ERTS MSS data from Fannin County, Texas were analyzed to investigate the possibility of detecting geologic changes in an agricultural area from satellite altitudes. Digital MSS data were analyzed using the LARSYS software system and results were displayed on printouts from a line printer and also on a digital image display system. The results from these analyses seem to show that gross lithologic changes can be distinguished if changes in vegetation and soils reflect changes in lithology.

032973 Urban Land-Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Area Example.
Richard Ellefsen, Philip H. Swain, and James R. Wray.
This paper discusses the results of attempts to create computer-produced urban land-use maps using multispectral scanner data from ERTS-1. Specific study objectives include testing the applicability of the LARSYS pattern recognition software to land-use studies in an area where contemporaneous ground truth was available, and evaluation of satellite data as a support or possible replacement for land-use mapping achieved through conventional air-photo interpretation. Highly reliable classifications have been achieved within the fairly broad classes employed.