LARS Report 062981

ANNUAL REPORT
to the University
Fiscal Year 1981

Purdue University
Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907 USA

PURDUE UNIVERSITY LABORATORY FOR APPLICATIONS OF REMOTE SENSING

1980-81 Report to the University from The Laboratory for Applications of Remote Sensing

We are pleased to transmit this report on the research and educational activities at LARS for the 1980-81 fiscal year. Although adjustments had to be made during the year because of federal budget cuts, total expenditures for the year were $3,488,102, an increase of 21.7% over last year.

Long-range planning at LARS has been affected by new policies and decreased funding for earth observation programs at the federal level. This has provided added incentives to broaden the base of potential funding to support LARS activities.

Perhaps the most promising extension of LARS research and its applications has been in the area of geographic information systems (GIS). This is a logical step in that remote sensing provides important input data into georeferenced data bases.

On 30 June 1981 Dr. David Landgrebe, Director of LARS for twelve years, resigned this position and was named Director of the Engineering Experiment Station, effective 1 August 1981. A Search Committee was appointed and charged with the responsibility of nominating a new Director.

We look forward to the naming of the new Director and to a continuation of research and education in remote sensing at Purdue University.

Respectfully submitted,

Marion F. Baumgardner
Acting Director

MFB:gcb

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Annual Report
to the University
Fiscal Year 1981

The Laboratory for Applications of Remote Sensing (LARS) is an interdisciplinary laboratory within Purdue University focusing the University's capabilities on development of improved techniques for analyzing and using earth resources data.

Now, in its fifteenth year, LARS continues to express the University's traditional objectives of research, education, and service.

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An Introduction to LARS

Interdisciplinary Staff

The research, educational, and service activities of LARS are conducted within the structure of the University. The Director of LARS is responsible to a Management Committee which consists of the Directors of the Agricultural Experiment Station and the Engineering Experiment Station.

The directorate at LARS, consisting of the director, associate director, deputy director and business administrator, coordinates the logistics of financing, project implementation, and facility availability. Academic and professional personnel are members of individual University departments and/or the Engineering Experiment Station.

The research and educational mission of LARS is by definition interdisciplinary. The accomplishment of this mission requires specialists in many different disciplines. The extent to which interdisciplinary research is successful is largely dependent upon effective communication among the disciplines. This communication is encouraged by weekly meetings of directors and leaders of LARS program areas (Figure 1).

Figure 1. Program leaders share information on upcoming visitors and travel before discussion begins on the current week's agenda.

A key to the interdisciplinary research efforts at LARS is the Laboratory's organizational structure (Figure 2). The six major program areas have specific responsibilities for conducting research within their area while coordinating with and supporting each other.

Principal investigators of specific projects have the responsibility for technical and fiscal management of these projects. Although most program areas are organized along disciplinary lines, projects are generally interdisciplinary and involve personnel from two or more program areas.

This design provides a great opportunity for flexibility in programming and forming compatible teams to research specific problems.

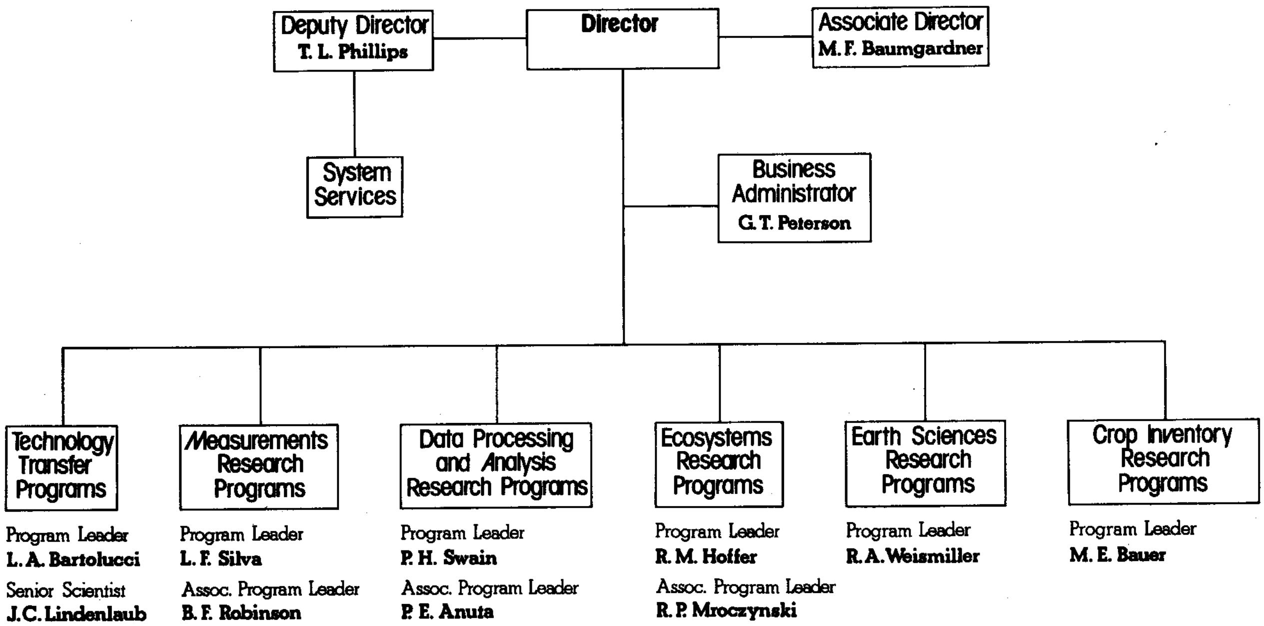


Figure 2. Organization of the Laboratory for Applications of Remote Sensing.

During FY81 there were 189 people (90.97 full time equivalent) from 11 departments in four schools assigned to LARS projects (Table 1).

Table 1. Staff involvement at LARS by department and classification.

School/Department	Faculty	Profes-sional	Graduate Students	Under-grad	Service	Clerical
Agriculture						
Agricultural Economics	1		2			
Agronomy	6	5	12			
Forestry	1	1	3			
Engineering						
Civil	1		1			
Electrical	8	4	12			
Experiment Station		30	2	61	7	17
Mechanical	1		1			
Humanities, Social Science, and Education						
Communications		1				
Science						
Computer Science			3			
Geoscience	2		2			
Statistics	3	2				
Number of Employees	23	43	38	61	7	17
Full Time Equivalent	5.43	34.78	14.82	19.07	4.95	11.93

Further details on the LARS staff are provided on pages:

Professorial page 97
Professional page 99
Graduate Students page 73

Research Accomplishments

During FY81 the results of the interdisciplinary research effort at LARS were rewarding, with tangible results both in the successful advances in practical applications of remote sensing technology and in more basic research. The reputation of the Laboratory as a research organization and as a leader in "technology transfer" continues to attract scientists from around the world.

Research accomplishments are summarized in this section.

Measurements Research

Completion of fabrication and testing of prototype eight-band radiometer (designated Model 12-1000) to be used in field research activities for crops, soils, and forestry (Figure 3).

Figure 3. During the past several years an instrumentation system for acquiring reflectance and radiant temperature measurements of crop canopies and soils has been developed. The system includes a multiband radiometer, data logger, camera, calibration standard and aerial tower. In addition to the instrument configuration shown here, the radiometer and data logger can also be mounted in a helicopter or light aircraft to obtain multispectral data of commercial fields.

Completion of fabrication and testing of a high-speed data logger with a detachable solid state memory to digitize and store the data from the eight-band radiometer for later interface with a digital computer.

Fabrication of a data back for a 35 mm camera system to place a six-digit identification number along edge of each photographic frame.

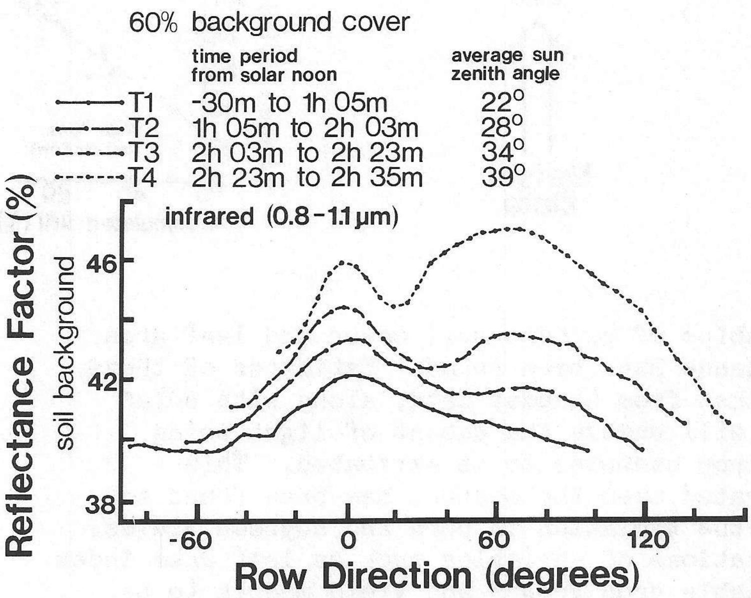
Transfer field-reflectance measurement and calibration techniques to remote sensing field research programs in other universities.

Continued development of field research spectral data base including additional spectral data, documentation, and software handling capabilities.

Fabrication of a high speed 12 bit A-D system to be used to digitize the Exotech Model 20C spectrometer data and the Clevenger spectrometer data.

Verification of model for relating the light-polarization response of a canopy to physical properties of the canopy.

Fabrication of apparatus at the Purdue Agronomy Farm including a turntable, boom, and reflectance calibration tower to be used for canopy geometry studies relative to row direction and spacing and soil background (Figure 4).



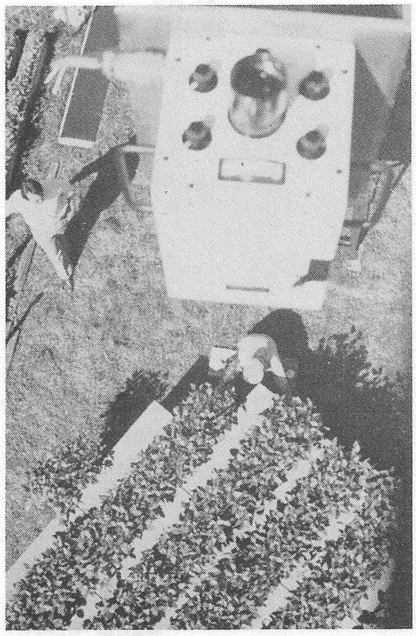


Figure 4. (Left) Reflectance of canopy as rows of soybeans planted in boxes on the turntable, four meters in diameter, were rotated through the solar azimuth direction during four time periods during one afternoon. (Right) The vertical view down on the soybean canopy from the sensor shows the trays of soil, simulating soil background, between rows of plants all positioned on the turntable which is easily rotated by the seated technician.

Crop Inventory Research

Conceptualization of how to utilize spectrally derived inputs to crop growth and yield models (Figure 5).

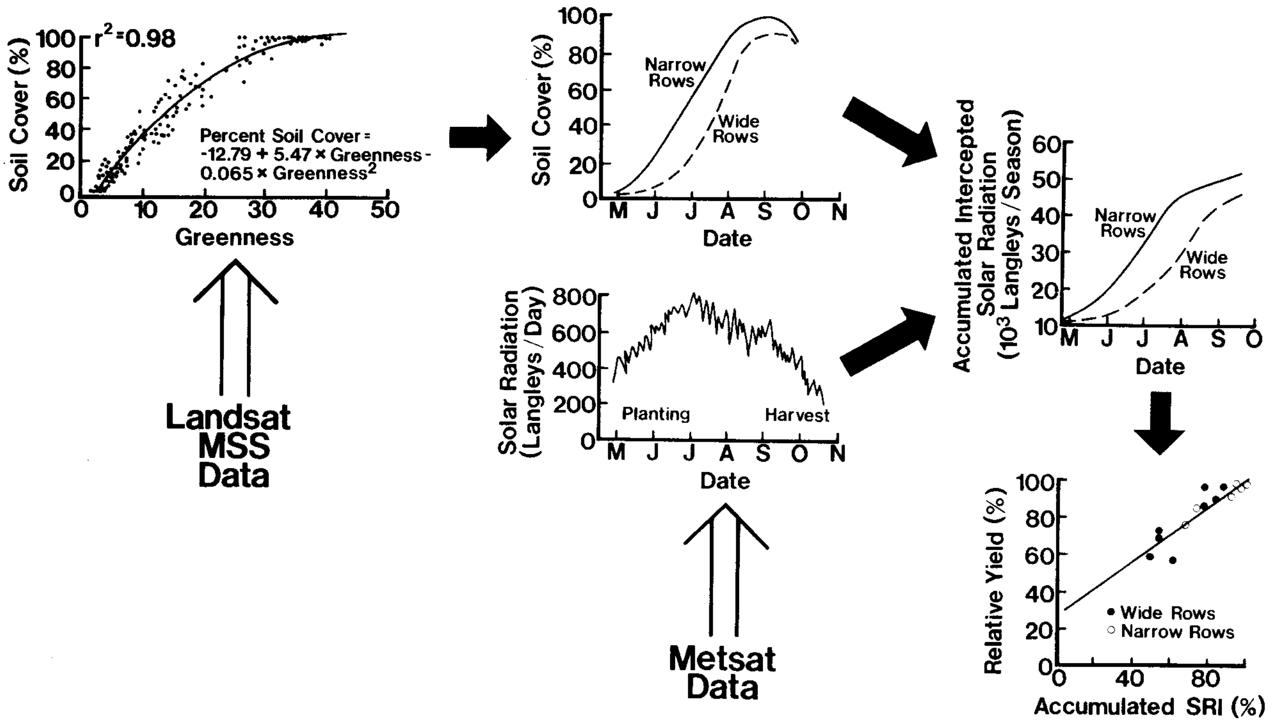


Figure 5. Strong relationships of percent soil cover and leaf area index to reflectance have been found. Estimates of these variables, obtained from Landsat data, along with solar radiation data, will enable the amount of light being intercepted by crop canopies to be estimated. This variable, integrated over the season, has been found to explain much of the variation in corn and soybean yields. Satellite observations of variables such as leaf area index will enable variable crop growth and yield models to be used over large areas.

Development of research approach for estimating crop development stage, leaf area index and canopy radiation interception from spectral measurements.

Quantitative description of the influence of nitrogen deficiency on the growth, yield and reflectance characteristics of corn and wheat canopies.

Assessment of the influence of soil background and cultural practices on the agronomic and reflectance characteristics of corn and soybean canopies.

Comparison of the precision of several levels for combining area and yield estimates to make estimates of crop production.

Development and evaluation of an approach for using full-frame Landsat MSS data for crop area estimation when training data can be acquired only for selected geographic areas (segments).

Determination of relationships between scene characteristics and Landsat classification performance for corn and soybeans.

Verification of a model relating solar illumination angle, row azimuth and canopy geometry (Figure 6).

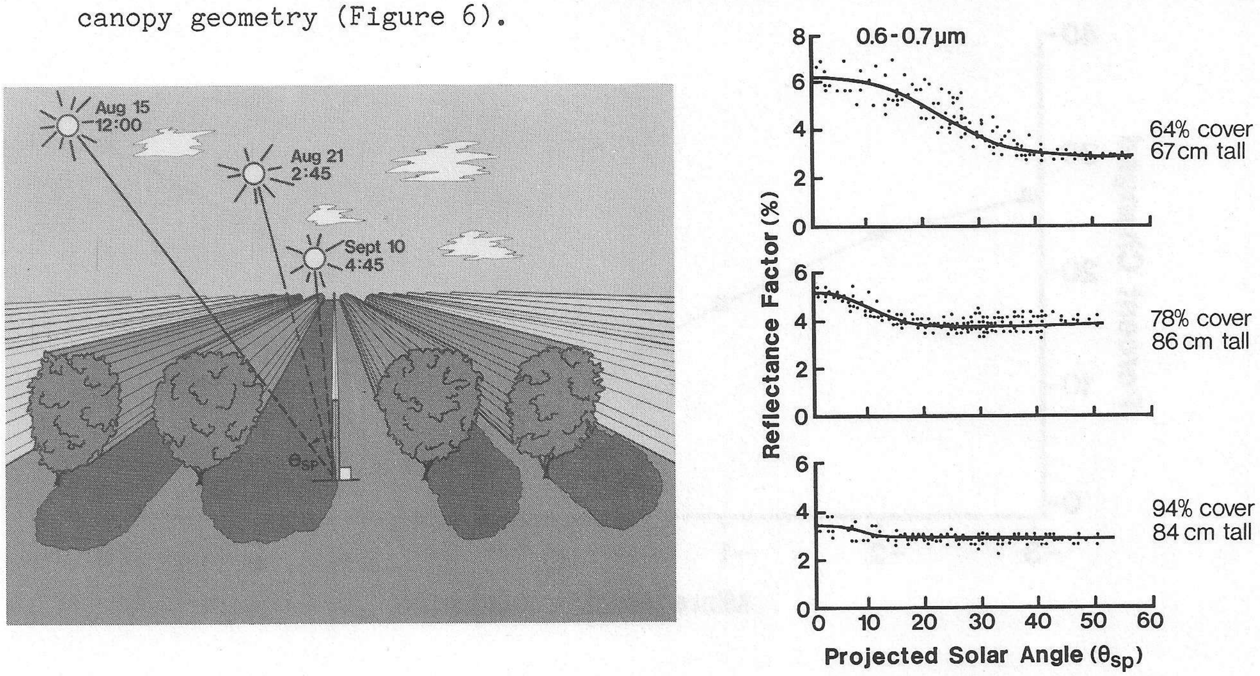


Figure 6. Under certain illumination and canopy conditions the variable, projected solar angle (left), explains much of the variation in crop canopy reflectance due to varying sun angles and row directions (right).

Data Processing and Analysis Research

Development of techniques for precisely combining Landsat vidicon sensor data with Landsat multispectral scanner data.

Development of techniques for automatic extraction of scene boundary information from Landsat data.

Investigation of methods for utilizing multiple data types for improved information extraction from remote sensing data.

Development of statistical decision method for analyzing seismic reflections.

Development of algorithm for inferring from multispectral data contextual relationships from a scene without requiring prohibitively large amounts of ground observation data.

Focus of analysis research on multiprocessor implementation of the contextual classifier to take advantage of the efficiency of evolving computer architecture.

Study of the accuracy of interband registration of multispectral data revealed that as little as 0.3 pixel misregistration among bands can have pronounced effect on classification (Figure 7).

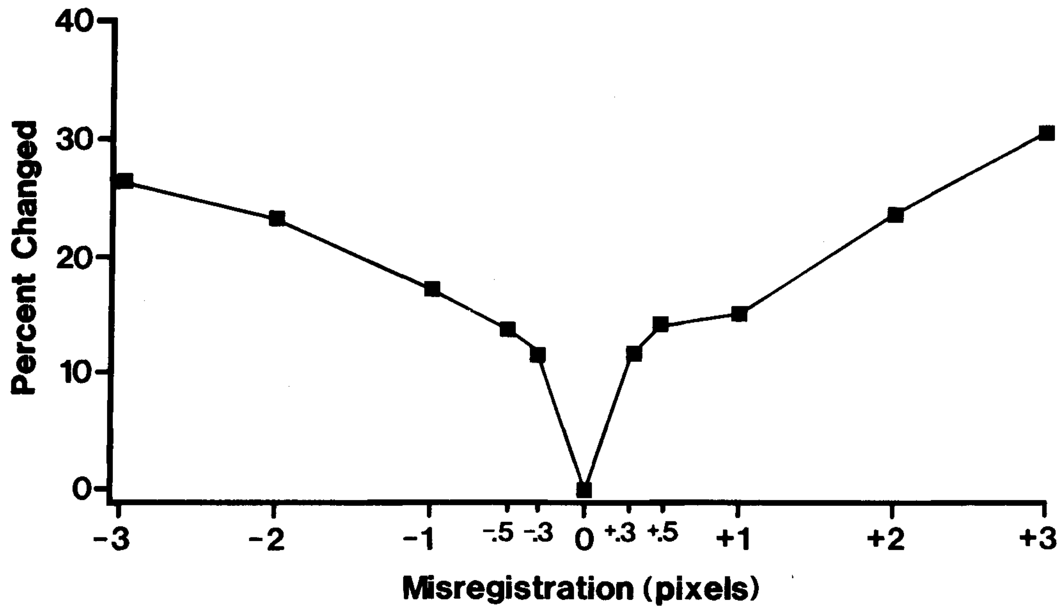


Figure 7. Effect of interband misregistration on classification of simulated Thematic Mapper data. The rapid change in classification for small amounts of misregistration demonstrates the importance of precision registration of sensor bands.

Earth Sciences Research

Demonstration that variations in the reflectance of surface soils from the humid temperate region may be related to degree of erosion, organic matter content, iron oxide content, and iron oxide ratio.

Determined that the iron oxide ratio (amorphous iron/crystalline iron) was the one parameter which most consistently related to spectral reflectance and the severity of erosion.

Determined that over the spectral range (0.5-1.1 micrometers) the reflectance at 0.8 micrometer gave the greatest spectral separation between eroded and noneroded soils.

Ecosystems Research

A classification study using simulated Thematic Mapper data at five different spatial resolutions revealed that the impact of resolution on classification accuracy is minimal for agricultural classes and that there is a dramatic decrease in classification performance for forest cover type with an increase in spatial resolution.

Demonstration that satellite acquired data provide important information for forest management.

Demonstration that satellite acquired data are most effective when combined digitally with other data sources for creating an automated mapping system.

Demonstration that an integrated data base can be created from remote sensing imagery, planimetric maps, and forest inventory data to form a multi-functional information system.

Development of an information system for Ducks Unlimited (Canada) to derive quantitative and spatial information on wetland communities 10 hectares or larger with summary statistics that identify areas of shallow and deep marsh and open water for every identified wetland (Figure 8).

62105

SIZE CLASS	NO WETLANDS	TOTAL ACRES	AREA BY CLASS (ACRES) SMARSH	DMARSH	OPWATER	TOTAL PERIMETER (MILES)	SHORELINE INDEX
0- 5	612	909.9	890.7	14.8	4.3	132.66	0.051
6- 25	109	1165.7	1144.0	12.4	9.3	95.57	0.076
26- 50	22	754.3	704.2	49.4	0.6	43.37	0.094
51- 100	11	758.0	732.0	22.9	3.1	40.51	0.125
101- 200	6	797.5	795.0	2.5	0.0	31.01	0.128
201- 300	0	0.0	0.0	0.0	0.0	0.0	0.0
301- 400	0	0.0	0.0	0.0	0.0	0.0	0.0
401- 500	0	0.0	0.0	0.0	0.0	0.0	0.0
501- 600	0	0.0	0.0	0.0	0.0	0.0	0.0
601- 700	1	650.5	593.0	56.2	1.2	17.65	0.195
701- 800	1	793.2	695.0	98.2	0.0	19.51	0.195
801- 900	1	864.2	814.8	49.4	0.0	20.51	0.197
901- 1000	0	0.0	0.0	0.0	0.0	0.0	0.0
1001- 2500	0	0.0	0.0	0.0	0.0	0.0	0.0
2501- 5000	0	0.0	0.0	0.0	0.0	0.0	0.0
5001+	4	53593.4	6181.7	3364.2	44047.4	433.84	0.275

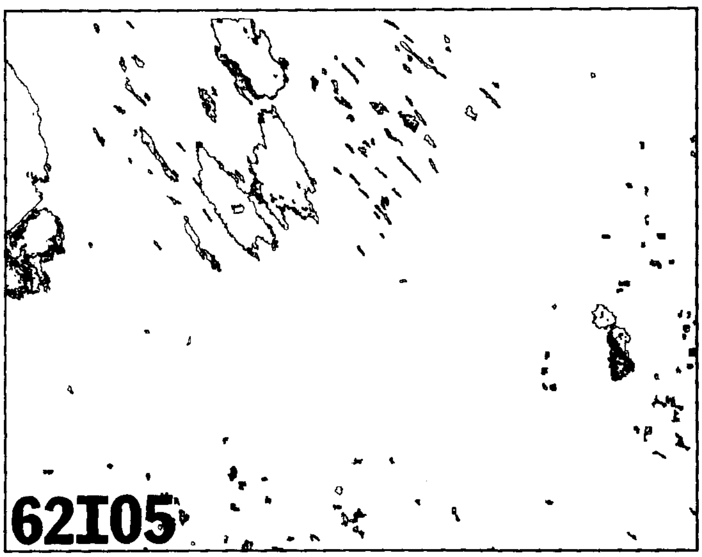


Figure 8. Waterfowl habitats classified from Landsat data collected over an area in Saskatchewan, Canada. The statistics provide location and areal extent information for wetlands which appear on the map. Approximately 100,000 square miles of the prairie provinces of Canada were classified for Ducks Unlimited (Canada) during 1981.

Publication and Presentation Statistics

The positive reputation enjoyed by Purdue University and LARS is apparent in the number and variety of invited lectures and conference papers presented. In addition, LARS encourages the free exchange of information through publication of its research results in as wide a forum as possible.

Table 2. Summary of reporting activities by LARS staff.

Type of Activity	Number Completed
Journal Articles	19
Invited Lectures	51
Technical Reports	44
Contract Reports/Internal Reports	19
Conference Papers	40

See pages 77-93 for further information.

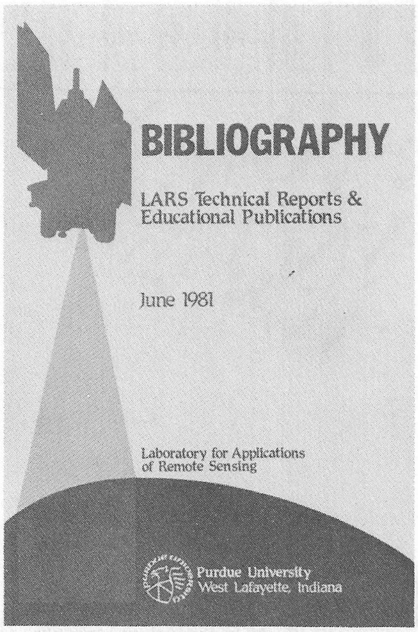


Figure 9. A bibliography is prepared and distributed periodically courtesy of the LARS System Services. It provides access to documentation of the current remote sensing research activities at LARS.

Educational Programs

In response to growing awareness of and demand for up-to-date information in remote sensing, the LARS Technology Transfer program area was established in 1974. Since then, the programs offered have grown rapidly in scope and breadth. Highlights of the 1980-1981 year follow.

The monthly short course on "Numerical Analysis of Remote Sensing Data" was updated. In addition, 78 students participated in seven specialized short courses which were created to meet the requirements of several diverse organizations.

Experts in remote sensing and related information- and image-processing technologies assembled at a workshop held in conjunction with the seventh Purdue/LARS symposium. They discussed state-of-the-art techniques in machine analysis of remote sensing data and key problems in research.

"Institution building" activities increased in importance, with significant progress being made in the cooperative efforts of LARS and the Bolivian government (Figure 10).

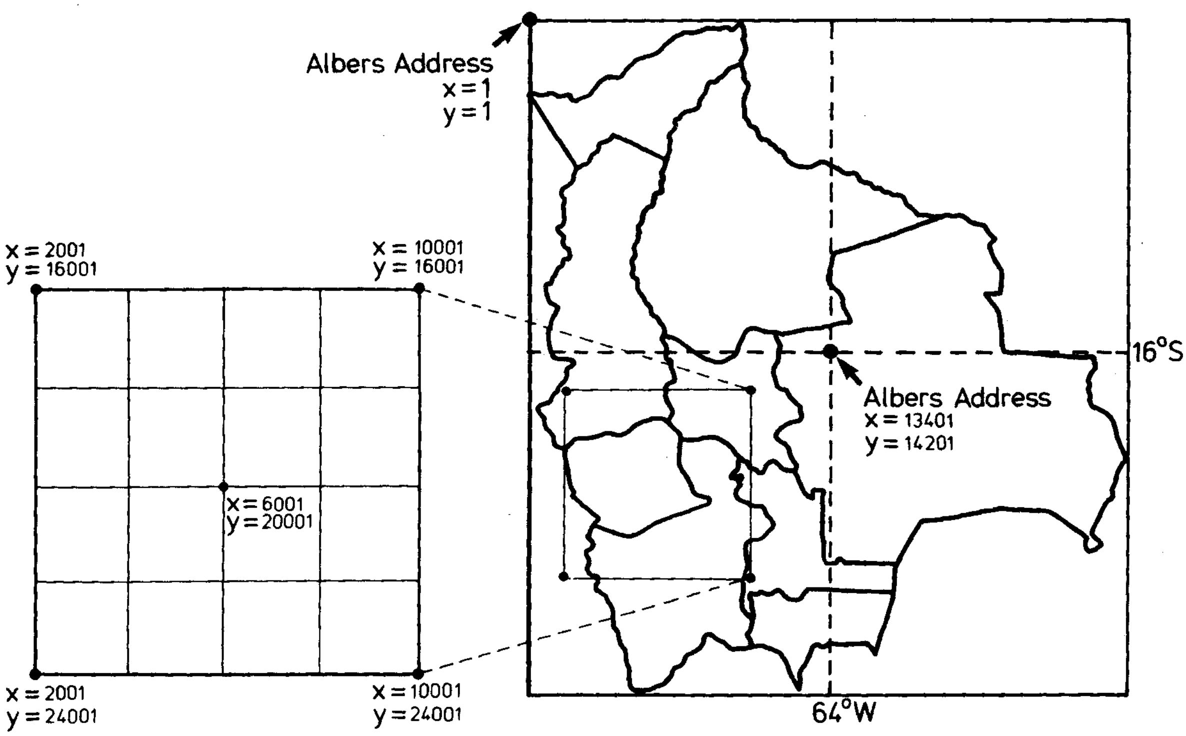


Figure 10. A hierarchical data base was designed as part of the Bolivian Geographic Information System. It allows for efficient input of local data, as well as reasonable access to information at Departmental and National levels. Here, Albers projection address coordinates are used as one reference system for cataloging data.

Purdue University hosted the first national Conference on Remote Sensing Education (CORSE-81) under the sponsorship of NASA.

Six new minicourses in the series on the "Fundamentals of Remote Sensing" were released for distribution, bringing the total number of modules to 25.

Three of five planned videotapes on "Introduction to Quantitative Analysis of Remote Sensing Data" were completed (Figure 11).

Figure 11. Two LARS staff members preview a videotape on "The Role of Remote Sensing in Forest Management."

A market survey was completed to develop guidelines for improved promotion of Technology Transfer activities. New directions for remote sensing educational programs were also outlined.

Training Program Summary

Technology Transfer activities continued to involve a wide range of participants during FY81. The United States federal and state governmental agencies were represented, along with foreign countries, Purdue University, and other educational institutions.

Table 3. Summary of training program activities.

Type of Activity	Number Involved
Monthly Short Course	32 participants
Specialized Short Courses	79 participants in 7 courses
CORSE-81	186 participants
Visiting Scientist Programs	10 scientists from 4 countries
Symposium	235 participants, 99 papers
Workshop on Key Issues	35 participants
Remote Terminal Network	8 remote sites, 22 remote ports
Minicourse Series	433 units sold in FY81
Graduate Students	38 students
Advanced Degrees	14 degrees

See pages 57 - 75 for further information.

Service Activities

Although the primary mission of LARS is research, members of the staff are called on continuously to provide services beyond their research tasks. During this year literally hundreds of visitors streamed through the LARS facility and were briefed on remote sensing technology and its applications. LARS staff give dozens of presentations each year to lay audiences--civic clubs, student groups, conferences, schools.

A considerable amount of staff time is devoted to extension-type activities. Increasing numbers of planners, farm managers and other decision-makers come to LARS for assistance in obtaining aerial photographs and satellite imagery for areas of interest. Staff members receive many requests for assistance in interpreting color and color infrared aerial photography for purposes of monitoring conditions of crops, forests and other vegetation.

Public awareness of the broad range of data acquisition and analysis methods through remote sensing has grown steadily over the past decade. With this increased awareness has come the increasing need to extend the use of remote sensing technology to resource managers, planners, and decision-makers.

See pages 94-95 for information on other special professional activities of the LARS staff.

Facilities

Computer Hardware and Software

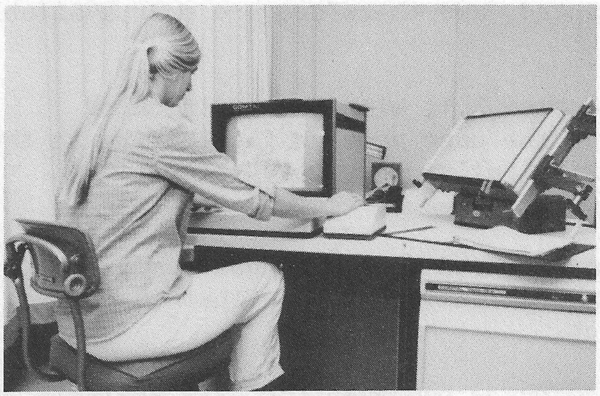
LARS has elected to supply a highly interactive, multi-user, general purpose computing environment in order to maximize the accessibility of software tools and ease of program development. Computer hardware includes the following:

An IBM 4341, operating under VM370/CMS, with four megabytes of main memory and six channels with transfer rates up to three megabytes per second. The system operates 129 hours per week, with at least one operator on duty at all times to mount tapes and monitor the system.

The Comten 3670 communications controller is used to handle serial input/output of the IBM 4341. System users are currently located in the two Purdue/LARS buildings, on the Purdue University campus, NASA/Johnson Space Center, Environmental Research Institute of Michigan (ERIM), NASA/Ames, Alabama A&M University, University of California at Riverside, Indiana State University, Ball State University, and periodically at DMA/IAGS, Panama, Central America (see Figure 50 on page 67).

Storage devices for the IBM 4341 include eight 3350 disk drives, two 3350 disk drives, seven 1600/6250 BPI tape drives.

A PDP 11/34A minicomputer with 256K bytes of main memory, 140 megabytes of disk memory, and one 1600 BPI tape drive. This minicomputer is used to handle other specialized devices (Figure 12).



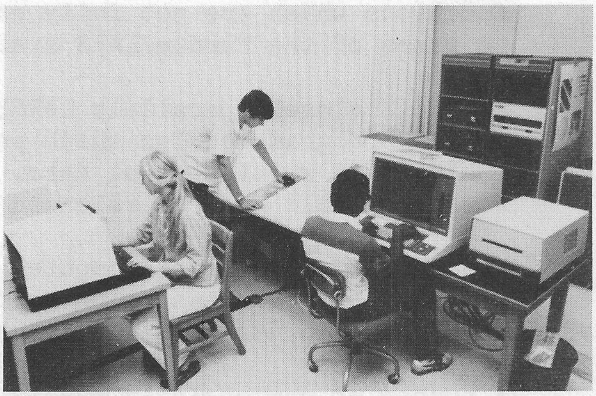


Figure 12. (Left) The Comtal Vision One/20 is a high resolution image processing color display with keyboard, trackball, LSI-11 microprocessor, four image planes or eight graphic planes per image. (Right) A table digitizer is used to input boundaries in X-Y coordinates from maps and photographs which can then be registered with remote sensing data. The Tektronix graphics terminal (center of photo) allows the user to visualize multidimensional numerical relationships through a high resolution graphics CRT screen.

Eleven printers are available, including one high speed (1100 lines/minute), two color dot matrix printer/plotters, and one electrostatic dot matrix printer/plotter.

Forty-five terminals are online to the IBM, with modem capabilities for up to twelve additional terminals on a dial-up basis. There are three terminals online to the PDP.

A card reader/card punch that is used to input or output files to or from the IBM in punched card media.

To support the research needs of the SR community, LARS maintains a computer tape library of Landsat image data and ground truth data for the years 1975 through 1978. Approximately 70,000 different scenes are stored in this data set, which translates to 5½ billion bytes of data. An additional 7000 reels of magnetic tape store other scanner, radiometer, meteorological, and political boundary data.

Over the years, several software facilities have been implemented to support research. LARS has developed the following data processing systems:

LARSYS is an integrated set of computer programs written to aid an analyst in a quantitative analysis of multispectral digital data through pattern recognition. LARSYS has evolved since 1966 when LARS was organized at Purdue University with the goal of applying modern computer technology to the quantitative analysis of multispectral earth resources data.

LARSYS Version 3.1, the most current version of LARSYS to be distributed by COSMIC (NASA's Computer Software Management and Information Center), includes eighteen processing functions which are fully documented. LARSYSDV, developmental LARSYS, contains an additional eight processing functions which are not fully documented, and therefore are only available to users of the Purdue/LARS system.

LARSFRIS closely parallels LARSYS Version 3.1, with the addition of certain program modules which provide the user greater flexibility in the analysis of multispectral data. The 23 fully documented processing functions will soon be released by COSMIC.

LARSPEC is a system of computer programs used to access and analyze data obtained by spectrometer or multiband radiometer systems that have been used for laboratory or field research.

A number of commercially available software packages for data analysis and display are also available to researchers accessing the LARS computer system.

Statistical Analysis System (SAS) and Statistical Package for the Social Sciences (SPSS) include information storage and retrieval, data modification and programming, report writing, statistical analysis and file handling.

International Mathematical and Statistical Libraries (IMSL) is a set of routines designed to be used in the development of scientific and engineering applications programs and contains over 400 subroutines covering the general fields of mathematics and statistics.

Three user oriented graphics packages are available to produce two- and three-dimensional illustrations (Figure 13).

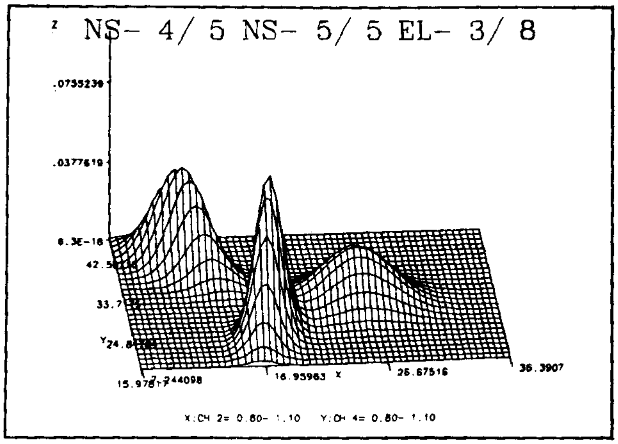


Figure 13. SAS-GRAPH, a set of programs for high resolution graphics terminals, pen plotters and/or graphics matrix printers, is used here to train the computer to recognize ground cover types.

VSMA Graphics Compatibility System (GCS) is designed for use with a wide variety of computer graphics terminals.

Interactive Graphics Library (IGL) is a structured, modular approach to interactive graphic techniques, capable of working within the concepts of distributed graphics processing and host and device independence.

This report was prepared using SCRIPT, a word processing system made available from the University of Waterloo. SCRIPT is useful for the preparation of large documents such as manuals, theses, and other research, technical, and instructional publications that contain tables, figures, indices, and tables of contents.

Field and Laboratory Instrumentation Systems

Measurements facilities include both field and laboratory instrumentation systems designed to measure reflective and radiometric characteristics of subjects ranging from agricultural crops to human skin (Table 4).

Table 4. Instrument systems used in support of field and laboratory research.

Instrument	Wavelength (micrometers)
Exotech Model 20C spectroradiometer	0.4 - 15.0
Exotech Model 100 Landsat band radiometers	0.5 - 1.1
Barnes 12-1000 Thematic Mapper band radiometers	0.45 - 14.0
Clevenger spectrometer	0.35 - 0.75
Barnes Precision Radiation Thermometer	10.0 - 12.0

Instrumentation is also available to provide large area (30 x 30 cm) parallel illumination for laboratory reflectance measurements (Figure 14).

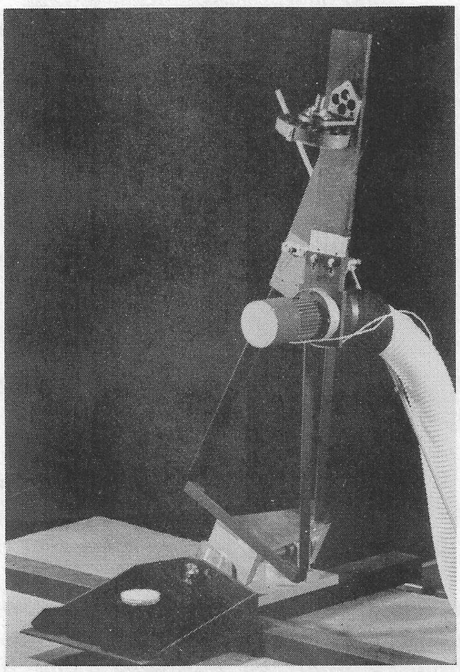


Figure 14. Bidirectional Reflectance Factor reflectometer positioned for soil sample detection by the Exotech 20C spectroradiometer.

Truck and boom systems are available to position the instruments up to 11 meters above the ground in the field. Other instrumentation includes an 8 channel, high speed, 12-bit A-D system. Instrumentation available for assisting in agronomic measurements of crops and soils include Li-Cor leaf area meters and a soil drying oven.

Other Specialized Facilities

Several small, specialized facilities are also contained in the two buildings used by LARS at Purdue University.

A wet soils laboratory is used for controlled experiments in moisture tension and other chemical and physical properties of soils. An electronics workshop allows for some in-house maintenance of equipment. Photointerpretation equipment is available for use in image interpretation projects, and in support of machine-assisted remote sensing research (Figure 15).

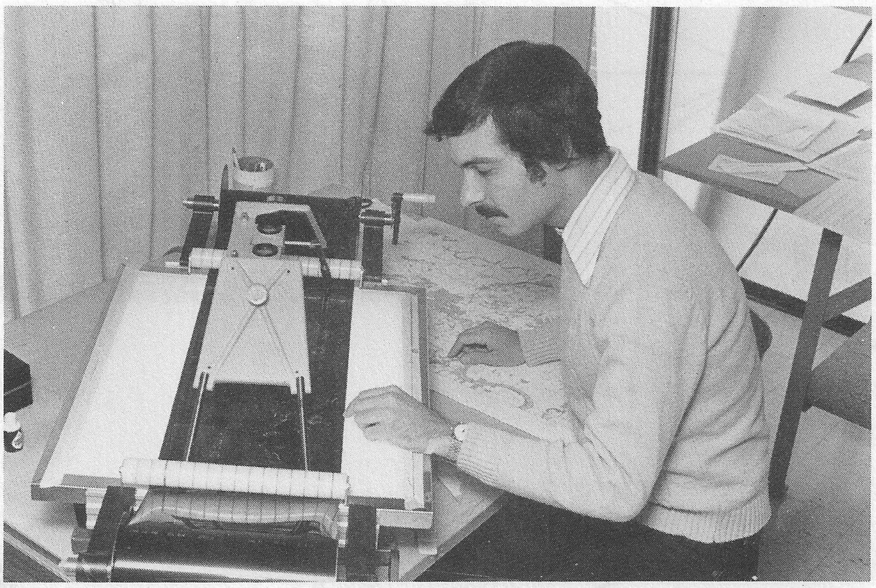


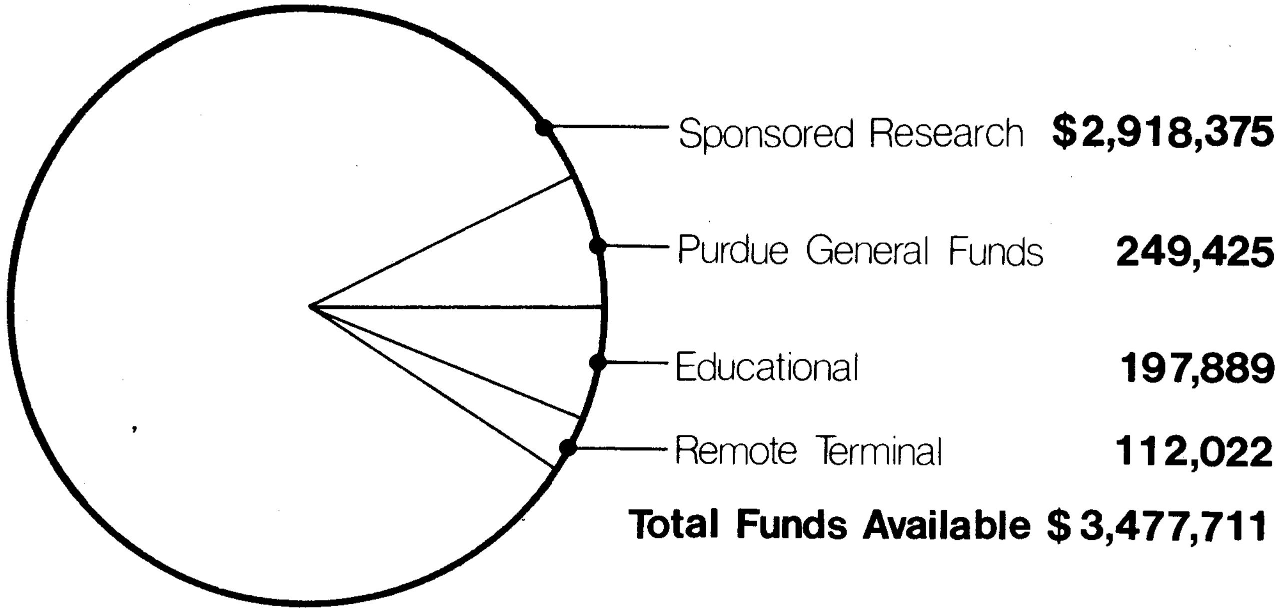
Figure 15. LARS graduate student uses a stereoscope to verify ground reference data.

Remodeling

Research and education facilities were enhanced at both buildings housing LARS in the Purdue Research Park. An additional unit in Flexible Lab 2 was changed for use by Technology Transfer activities. In Flexible Lab 1 the Crop Inventory Research and Data Processing and Analysis Research area was remodelled in order to use existing space to better advantage.

See pages 102-103 for floor plans of the two facilities.

Financial Support



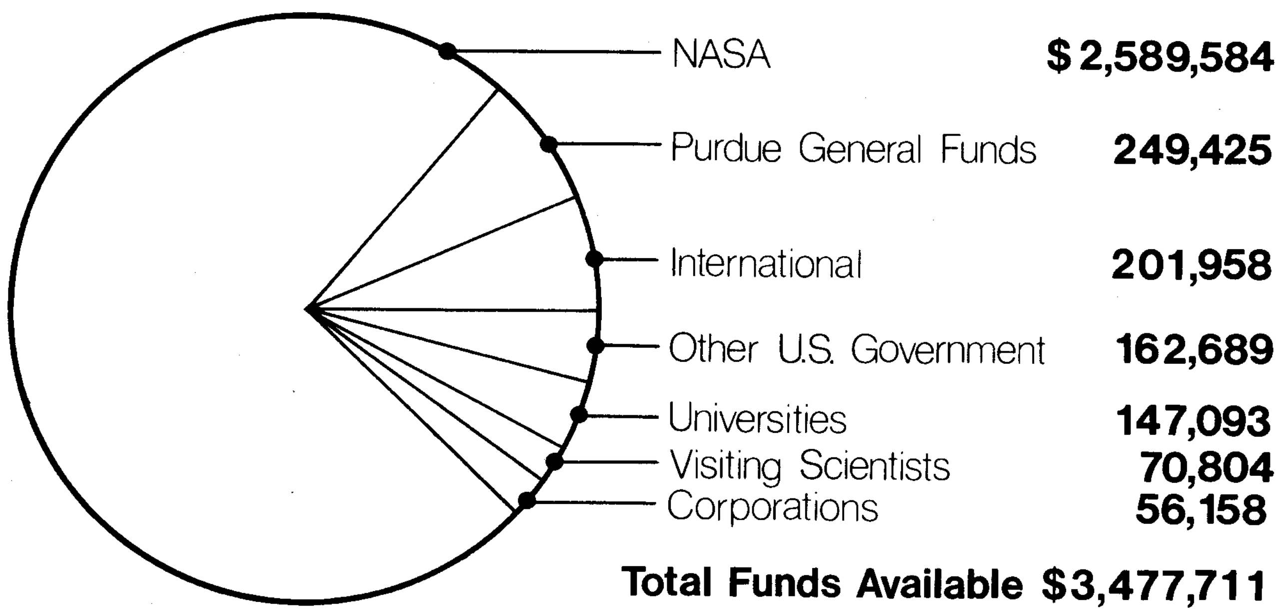


Figure 16. Summary of income, broken down by type of projects (top) and by funding source (bottom).

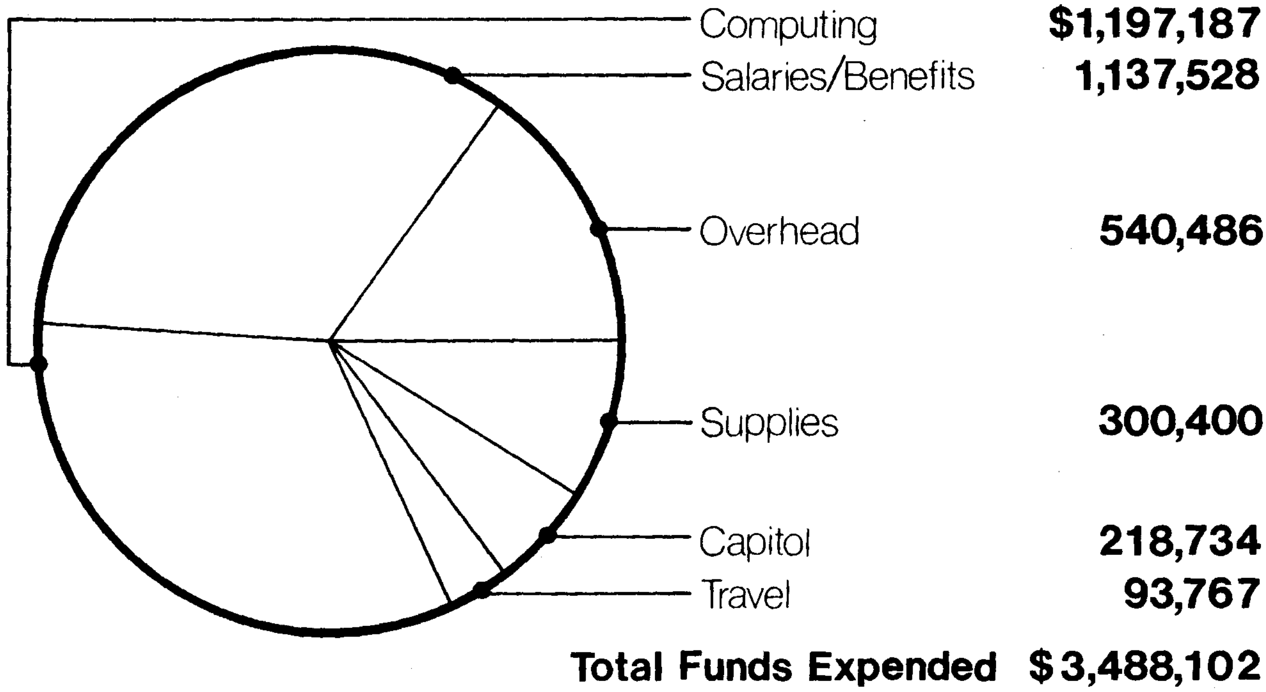


Figure 17. Summary of expenditures.

Scientific Contributions

Measurement Research

The measurements program area was established at the founding of LARS in 1965 as one of the basic components of a research program in remote sensing. Originally concerned with the relationships between laboratory and field data, the research program has developed a significant data acquisition capability of its own. The emphasis is on field data acquisition, field instrumentation development, basic research on the physical aspects of remote sensing, and spectral data handling and analysis procedural developments. Basic studies of remote sensing instruments and target characterization are required to support the technological developments in remote sensing during the 1980's.

Field Data Acquisition and Preprocessing

The LARS field data acquisition capability centers around three instrument systems, namely, the model 20C wide range spectroradiometer, the model 100 multiband radiometer, and the model 12-1000 multiband radiometer. All three of these instruments are truck-mounted. The model 20C is mounted on a mobile aerial tower, whereas the model 100 and model 12-1000 are mounted on a specially developed pick-up truck platform. All three systems have been equipped to simultaneously acquire boresighted radiance temperature and photographic data.

During the past and current growing season the LARS field data acquisition systems have been deployed at the Purdue University Agronomy Farm while conducting a series of integrated experiments on corn, soybeans, sorghum, and sunflowers. Additionally, correlated experiments at test sites located in North Dakota and Iowa are being conducted with a spectroradiometer mounted on a helicopter operated by NASA/JSC and at test sites in Nebraska and Kansas with multiband radiometers mounted on truck platforms operated by respective University researchers.

During the past year a specially designed apparatus was fabricated for use at the Purdue Agronomy Farm to study and model the effects of rows, row direction, and soil background on the reflectance properties of canopies such as soybeans, wheat, and sorghum. The apparatus includes a four meter diameter turntable, a boom to mount the model 100 or model 12-1000 multiband radiometers up to 9 meters above the turntable, and a reflectance calibration platform. Boxes of canopies such as soybeans are placed on the turntable in rows with trays of soil or painted boards providing a range of reflectance backgrounds. The turntable is easily rotated to obtain any desired row direction (Figures 18-20).

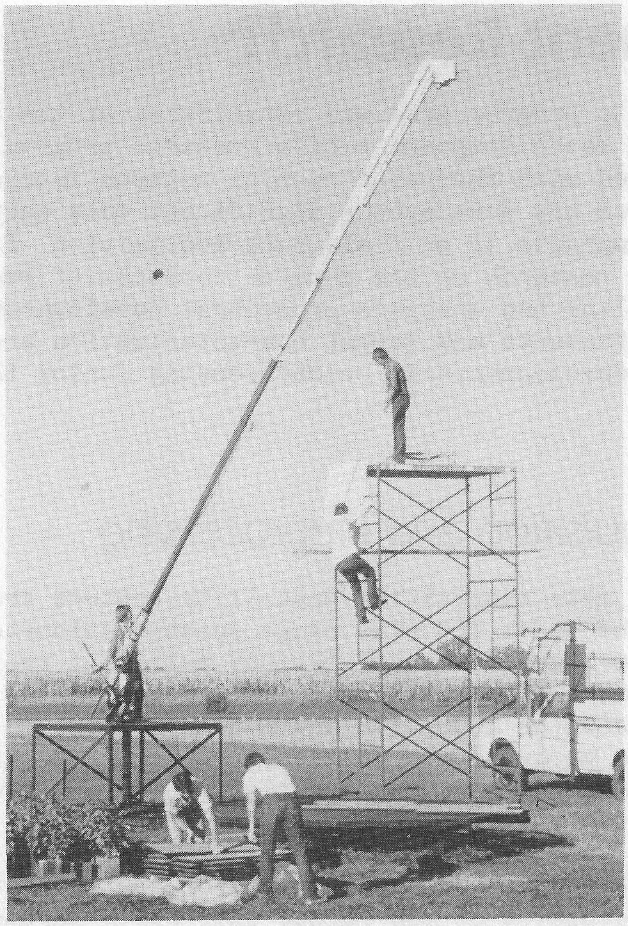
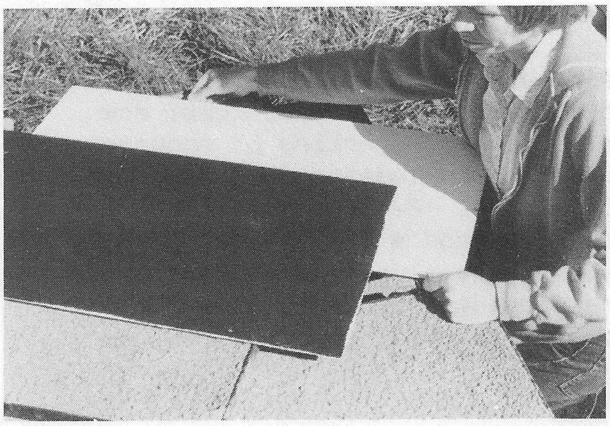


Figure 18. Instrument boom, turntable, and calibration tower used for soybean row direction experiment.



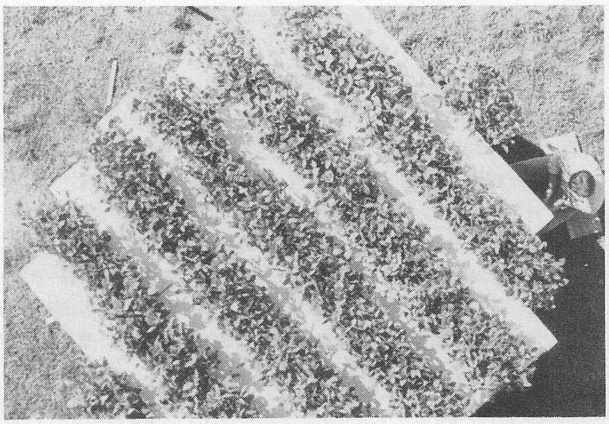


Figure 19. (Left) Three backgrounds - white, black, and soil - used for experiment. (Right) Soybean trays set-up on turntable with white background.

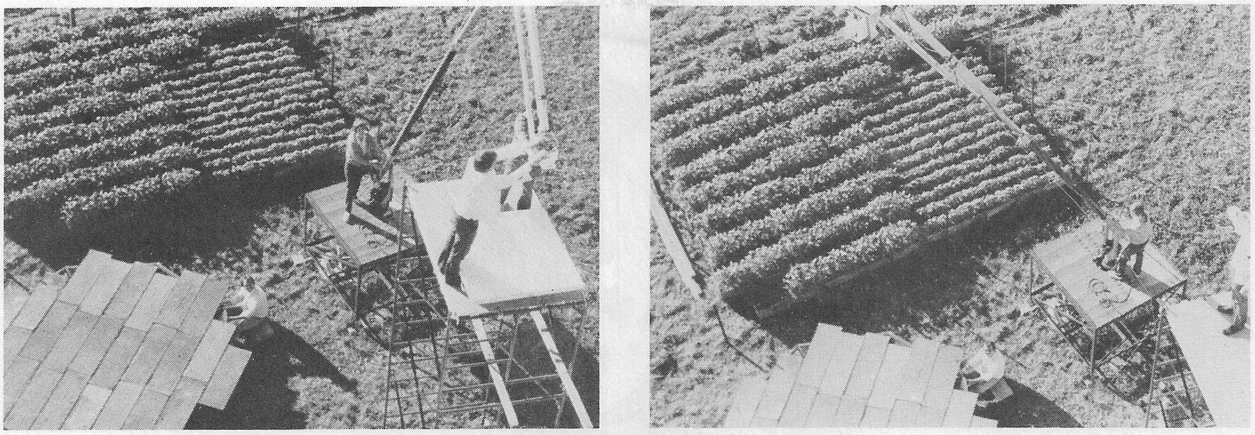


Figure 20. (Left) Multiband radiometer being positioned over painted barium sulfate panel for reflectance calibration. (Right) Multiband radiometer positioned over turntable set-up with soybean trays and soil background.

The data from all of the instruments (radiometers and spectroradiometers) are calibrated, correlated, and verified before being placed in the LARS field research data base. The data base now includes over 175,000 spectral observations. The data are available to the remote sensing community by issuing data requests to NASA. Several institutions can access the data directly via terminals to the computer system.

Instrument Development

On September 2, 1980 an eight-band radiometer was received from Barnes Engineering Company, Stamford, CT. This instrument was developed to meet performance specifications prepared by Measurements Research program engineers. The receipt of this instrument (designated Model 12-1000) marked the end of a several year development effort, involving LARS, NASA, USDA, and other university researchers, to make commercially available a high quality instrument for remote sensing field research. The radiometric performance of the instrument was evaluated at LARS for severe environmental conditions and modifications to the instrument were directed. Based on final tests of the modified prototype instrument (Figure 21), construction (by the vendor) of production instruments was begun.

The radiometer may be used from small plane, helicopter, mobile aerial tower, or pick-up truck boom platforms. Hand-held operation of the unit is possible and may be employed when appropriate. The Model 12-1000 measures seven wavelength bands of reflected sunlight and one band of thermal radiation. Seven of the bands are identical to the bands on the Thematic Mapper Scanner due to be launched into earth orbit in calendar year 1983.

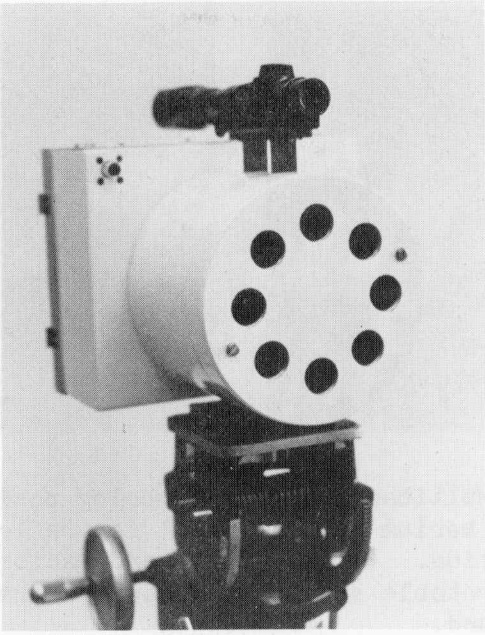


Figure 21. Prototype multiband radiometer used in performance evaluations prior to production of the Model 12-1000 instrument produced by Barnes Engineering Company.

A special data logger that digitizes and stores the data produced by the model 12-1000 radiometer was constructed by Measurements Research program technicians. The data-logger system features a solid state memory that can be used to reformat and analyze the data. Also, a special camera system that takes and automatically numbers photographs of the scenes under study by the multiband radiometer was fabricated along with a controller that integrates the system functions of the multiband radiometer, camera system, and data logger.

Several Model 12-1000 instruments are being made available to researchers in field research programs at other universities. A major effort is on-going to train researchers in these other university field research programs in how to use the Model 12-1000 instrument systems to obtain calibrated, meaningful measurements for furthering our understanding of the reflectance properties of crops and soils.

Linear Polarization of Light by Wheat Canopies

Remote sensing is potentially capable of providing information to aid in predicting the global production of key, economically important crops. Current approaches to solve these problems involve satellite data from the visible and near infrared spectral regions. It is possible that more information, information in data from other spectral regions (e.g., middle infrared, thermal infrared, and microwave) and in polarization data from all spectral regions, may be needed if we are to better discriminate crops and assess their condition with remotely sensed data. During FY81, a study on how visible light is linearly polarized and reflected by wheat canopies as a function of sun-view directions, crop development stage and wavelengths was completed. The data were collected using the Model 20C spectroradiometer fitted with a polarizer.

The results (Figure 22) demonstrate that the light polarizing processes in the two wheat canopies are not wavelength dependent in the manner of green vegetation spectra. The amount of incident flux polarized by the canopy monotonically decreases with wavelength, revealing no maximum in the green nor minima in the blue and green, characteristics typical of green vegetation spectra.

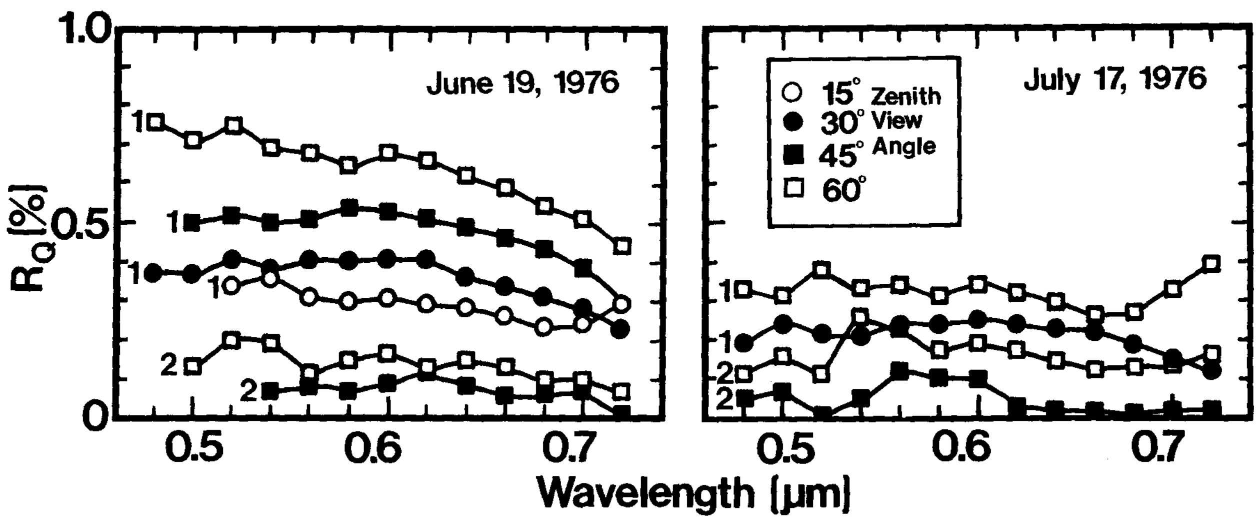


Figure 22. Polarized portion of reflectance factor (R_Q) for view zenith directions toward (1) and away from (2) sun azimuth direction for wheat.

The results also show that the linearly polarized light from the canopies is generally greatest in the azimuthal direction of the sun and tends toward zero as the view direction tends toward the direction of the anti-solar point. The results demonstrate that the single angle, angle of incidence of sunlight on the leaf, explains almost all of the variation of the amount of polarized light with sun-view direction.

Visual observations with polarizing sun glasses suggest the amount of polarized light from a wheat canopy decreases significantly with the advent of the heading development stage. Therefore, polarization data may be a key feature in determining particular development stages from satellite data.

Diurnal Changes in Reflectance Factor Due to Sun-Row Direction Interactions

Row direction is an important factor influencing the radiance, and therefore the reflectance factor, of a row crop canopy. The range of row directions of fields of a particular crop is an important source of variation in satellite radiance measurements, adding uncertainty to crop identification and yield prediction. To investigate the changes in the spectral reflectance factor related to row direction, sun direction, soil background, and crop development stage, Model 100 Landsat band radiometer data were collected for row crop canopies of soybeans (Glycine max), during two years. During FY81 data were collected using the "turntable" apparatus (Figure 18 on page 25).

The results (Figure 23) demonstrate that the direction of rows in a soybean canopy can affect the reflectance factor of the canopy by as much as 230%. The results for the red spectral region tend to support the validity of many well known canopy reflectance models; results for the infrared spectral region indicate that these models are inadequate.

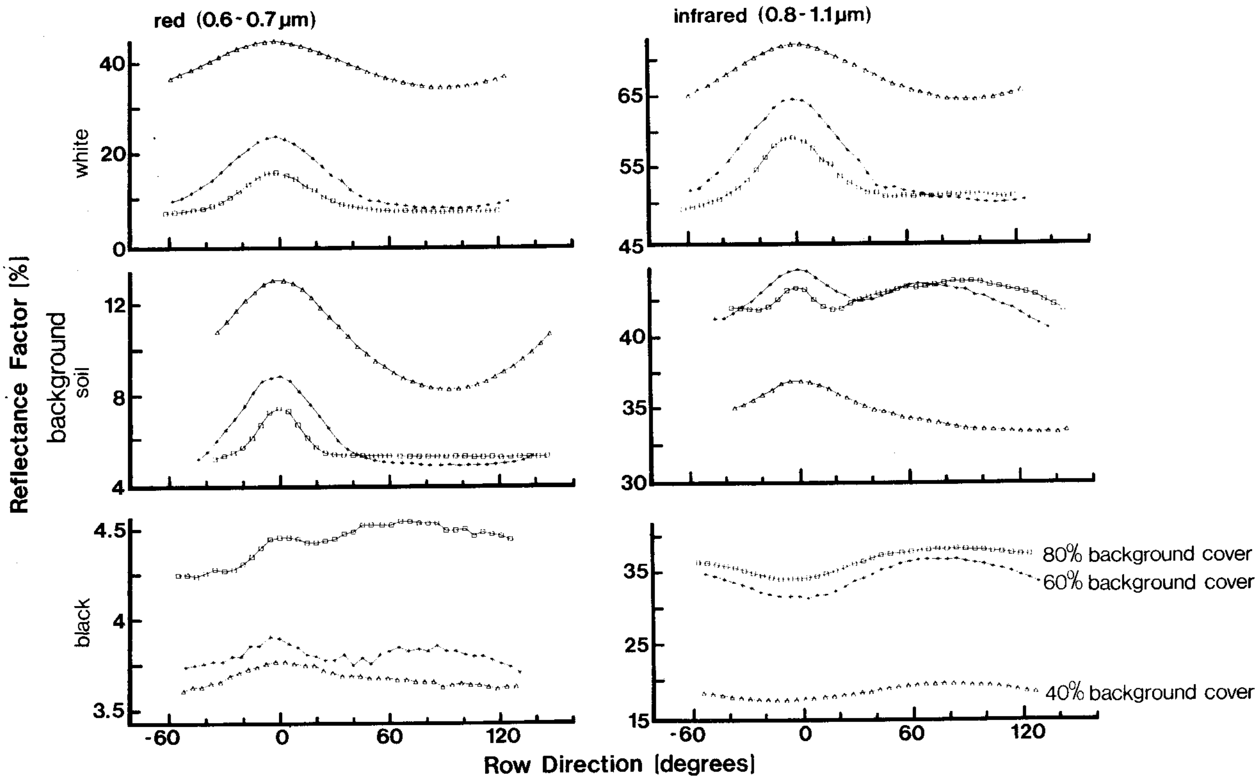


Figure 23. Soybean canopy reflectance factor with row direction and three percentages of background cover. Zero row direction is the sun azimuth direction. Sun zenith angle is between 24 and 36 degrees.

Crop Inventory Research

Mankind is becoming increasingly aware of the need for better management of the resources of the earth--atmosphere, water, soils, vegetation and minerals. As the world's population increases and a higher standard of living is sought for all, more careful planning and effective use of these resources, particularly soils, vegetation and water, is required to produce adequate food supplies. Agricultural crop production is highly dynamic in nature and dependent on complex interactions of weather, soils, technology and socio-economics.

Accurate and timely information on crops and soils on a global basis is required to plan for and manage crop production successfully. The repetitive, synoptic view of earth provided by satellite-borne sensors such as Landsat MSS provide the opportunity to obtain the necessary information on soil productivity and crop acreage and condition. For example, the recently completed Large Area Crop Inventory Experiment established the feasibility of multispectral remote sensing to inventory global wheat production. However, rigorous research and development are required if the potential of multispectral remote sensing for monitoring and inventorying crop production is to be fully achieved.

The primary mission of the Crop Inventory Research Program is to conduct basic and applied research to accomplish the following goals:

- To increase our quantitative understanding of the radiative properties of crops.

- To research and develop procedures for obtaining crop production information from remotely sensed spectral measurements, together with meteorological, soils and ancillary data.

We are actively involved in the AgRISTARS Supporting Research Project, under the sponsorship of the NASA Johnson Space Center and are conducting tasks on (1) field research of the spectral properties of crops and soils, (2) formulation of crop development and condition models utilizing spectral inputs, and (3) development and evaluation of training, classification, and sampling approaches for use with Landsat MSS data. The specific tasks and accomplishments of FY81 are summarized in the following paragraphs.

Field Research on the Spectral Properties of Crops and Soils

Understanding the interaction of radiation with crops and soils is an important component of developing satellite remote sensing technology. The necessary understanding is best achieved from measurements of fields and experimental plots where complete data describing the crops and frequent, timely spectral measurements can be made. This concept and approach is referred to as field research.

During FY81 our primary activity was the acquisition and analysis of spectral and agronomic measurements of corn and soybean canopies. Data were acquired from several experiments at the Purdue Agronomy Farm, where our objectives have been to:

- Determine relationship of spectral response to crop development stage.
- Determine relationship of spectral response to amount of vegetation (leaf area index, biomass, and percent soil cover).
- Determine effects of stress (moisture, nutrition, disease) on spectral response.
- Determine effects of agronomic treatments (variety, plant population, planting date) on spectral response.
- Determine effects of soil background (color, moisture, roughness) on spectral response of crops.
- Determine effects of view angles and solar illumination angles on reflectance in relation to canopy geometry.

Additionally, spectral and agronomic data have been acquired at test sites in Iowa and North Dakota to study the spectral discriminability of corn and soybeans and spring wheat and barley as a function of crop development and cultural practices.

Key results of analyses conducted during the past year quantify (1) the reflectance characteristics of corn and soybeans as a function of development stage, soil background condition and agronomic practices; (2) the relationship of leaf area index to reflectance of wheat, corn, and soybeans; and (3) the effect of nitrogen deficiency on the spectral response of corn and winter wheat (Figure 24). In addition, a model relating solar illumination angle, row direction and canopy geometry was developed and initial analysis and modeling of the interaction of solar illumination and view angles on the reflectance of soybean canopies were achieved.

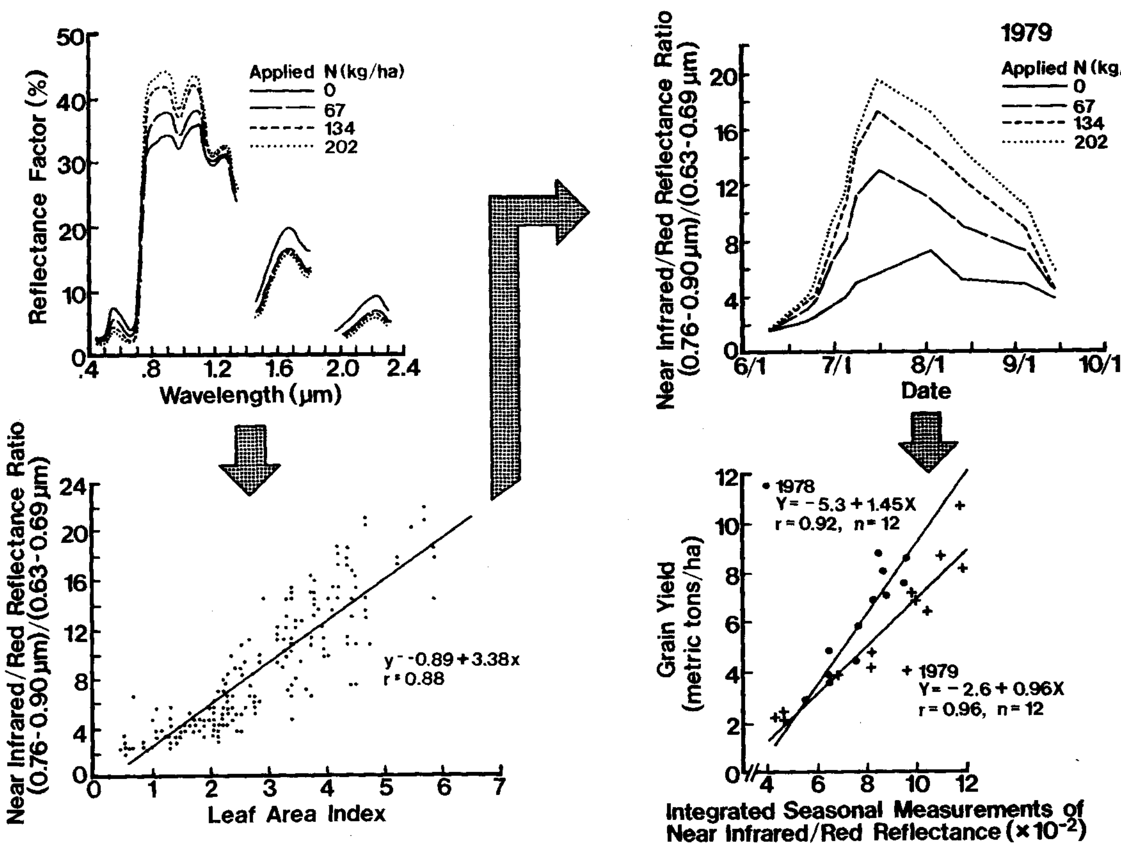


Figure 24. Low levels of nitrogen fertilization reduced chlorophyll content of leaves, leaf area index and percent soil cover; these canopy changes were manifested spectrally as increased visible and decreased near infrared reflectance. A strong linear relationship between near infrared/red reflectance ratio and leaf area index was found. Substantial differences were present throughout the season in the IR/red ratio. When integrated over the season, this ratio was was found to be related to grain yield.

Estimation of Leaf Area Index, Soil Cover, and Solar Radiation Interception

Solar radiation as an energy source for plants is available only when it interacts with leaves. The ratio of total solar radiation intercepted (SRI) by a corn canopy has been described as a function of leaf area index (LAI) and is included in models which predict final corn grain yield. LAI for corn may vary greatly over large areas due to differences in planting dates, hybrids, stresses, and plant populations. Measurement of LAI is tedious and time consuming, which limits the use of models requiring LAI to relatively small areas. Spectrally-derived estimates of SRI may more accurately depict conditions of fields and permit the application of crop models to large areas (see Figure 5, page 7).

Agronomic and spectral data of corn were collected in 1979 and 1980 on planting date-population-soil type experiments at the Purdue Agronomy Farm. In addition to the Agronomy Farm data, Landsat MSS data for ninety corn fields in nine other test sites were analyzed. Leaf area index and calculated SRI were regressed on spectral data. In both years studied, SRI was better predicted than LAI, by the Greenness transformation. Spectrally estimated SRI, linearly interpolated and summed from planting to maturity, was found to be positively correlated with final grain yield (Figure 25).

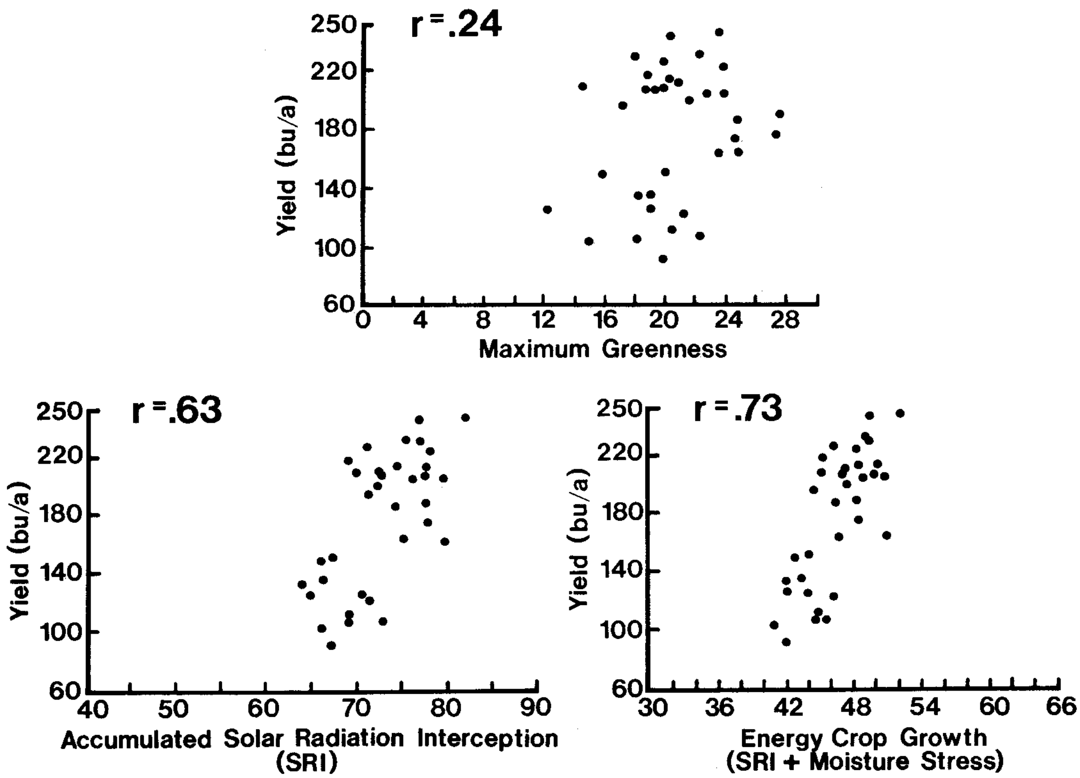


Figure 25. Comparison of three methods for predicting corn yields: (1) spectral response (maximum greenness) measured on a single date, (2) use of spectral data to cumulatively estimate solar radiation interception (SRI), and (3) spectral plus meteorological data (SRI + Moisture Stress).

The relationships developed from the data acquired at the Purdue Agronomy Farm were then applied to the commercial corn fields using Landsat MSS data. In six of the nine sites, spectrally estimated SRI, summed from six weeks prior to six weeks post silking, was found to be positively correlated with final grain yield.

The use of spectrally estimated SRI alone to predict crop yields is not recommended. Spectrally estimated SRI used in conjunction with ancillary data, including meteorological data, is recommended in applications over large areas where it is not feasible to measure LAI directly.

Estimation of Crop Development Stages from Spectral Measurements

Crop development stage is an important variable in Landsat image analysis. To identify crop species accurately, the image analyst must be able to determine the development patterns throughout the growing season for each crop (temporal characteristics), as well as the characteristic spectral response in specific time periods corresponding to given crop-type biostages (Figure 26).

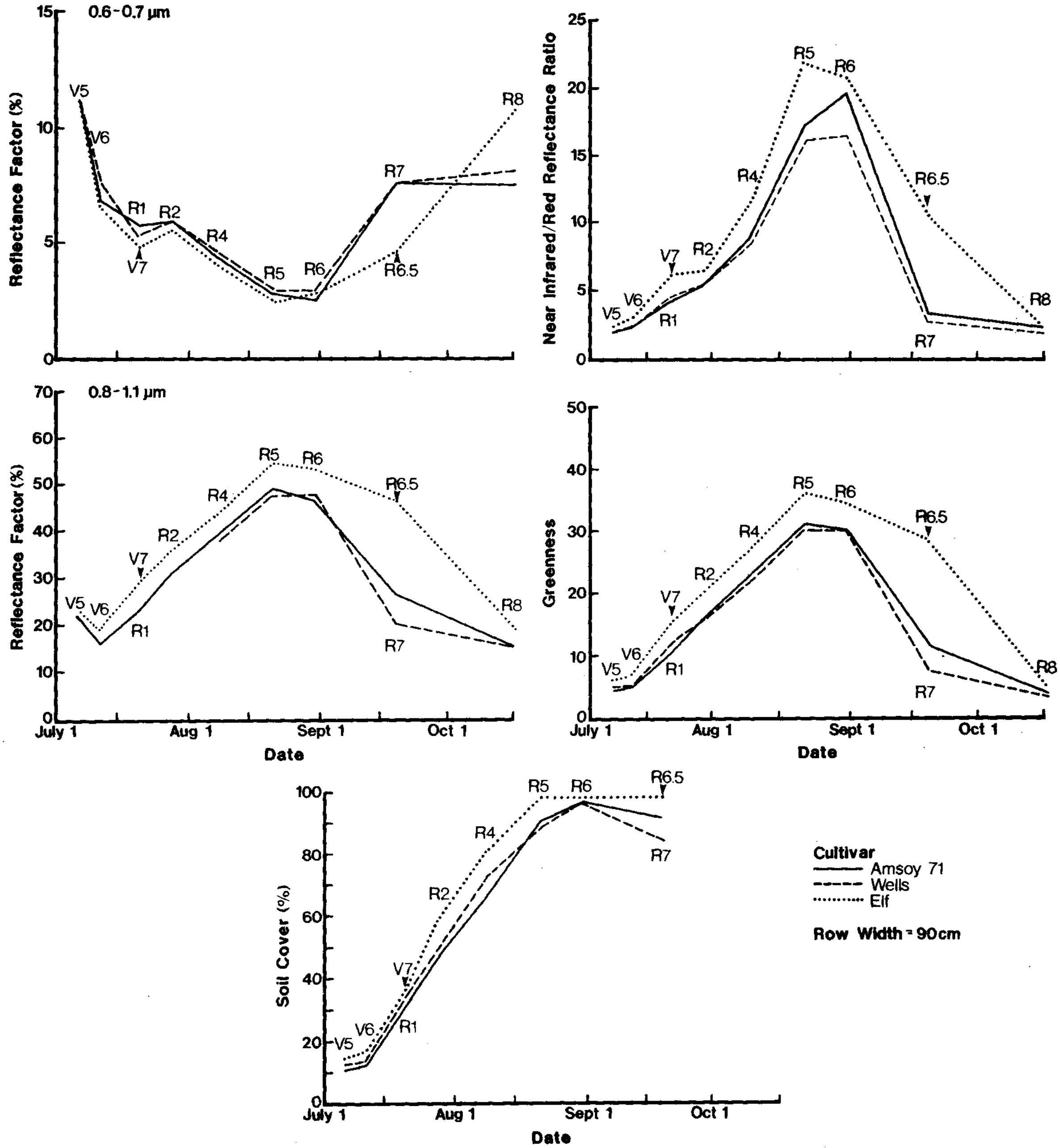


Figure 26. Seasonal changes in 1978 for three soybean cultivars. Development stages are identified for each observation date; arrows indicate stages that are unique to that cultivar.

Crop development stage is a key factor in the creation of crop yield models which utilize spectral inputs. It is needed to relate weather events and history to specific development stages. There has been, however, only general information available relating development stage to spectral response of corn and soybeans.

The spectral response to the crop represents the integrated effect of all cultural, soil, and meteorological factors affecting crop growth and development. The possible use of satellite-acquired spectral data to determine crop development stages offers the advantage of making yield estimates at the segment, field, or even pixel level. Satellite estimates of development stage also can be used to check and adjust statistical or physiological models of development stage periodically during the growing season.

The relationships of a number of spectral variables to development stages of corn and soybeans have been examined. A model was proposed that uses a spectral variable to specify prediction probabilities for a development stage. Evaluating the model with the spectral variable greenness showed that the technique has promise. However, use of the greenness variable alone did not provide a suitable distribution for predicting development stage. Additions of ratio and brightness variables to the model appeared to enhance the prediction capability.

The next step in this continuing study will be to examine the usefulness of other spectral variables including the tasseled cap feature of yellowness. In addition to spectral variables, we plan to evaluate meteorological variables for a development stage model. This includes implementing a predictor variable derived from meteorological data such as growing degree days. This approach has the advantage that it would enable refinement of development stage prediction on the basis of both meteorological and spectral variables.

Evaluation of Landsat Spectral Inputs to Crop Condition and Yield Models

After initial development and testing of crop models utilizing spectral inputs, the most promising approaches are being evaluated with independent data from a variety of locations having different cropping practices, soils, and weather. The major component of this task is work with the Earth Satellite Corporation to evaluate the utility of satellite-acquired spectral data in conjunction with meteorological and soils data to estimate crop development stage, condition, and yield.

Purdue has the lead role in design and evaluation of the experiments. Estimates of planting date, development stage, crop albedo, and stress made by Purdue from spectral data are being combined with the EarthSat model, CROPCAST, to affect yield estimates by a calculation of the crop stress term. EarthSat will run CROPCAST with and without spectral data or spectrally-derived variables at segment and lower levels. The evaluation will be conducted on a field-by-field and segment basis using 1978-80 data. Additionally, Purdue will be evaluating spectral inputs to other crop growth and yield models.

Application and Evaluation of Landsat Training, Classification, and Area Estimation Procedures

The overall objective of this three-year project, completed during FY81, was to advance the development of large area crop inventory systems by applying and evaluating recently developed techniques for crop identification and classification. Landsat data acquired over segments in the U.S. Corn Belt were used. Three components of the project were completed during the past year.

Training Methodology. Variable size and fixed size training sample units were compared. Use of the variable size generally resulted in selection of more pixels for use in training. When the total sample size was constrained to be relatively constant for each segment, percent correct classification of other cover types was significantly higher for the variable size method than for the fixed size. There was, however, no significant difference in corn or soybean proportion estimates between the two methods.

Sampling Methodology. As the registration of Landsat full frames enters the realm of current technology, sampling methods which utilize other than segment data should be examined. The objective of this study was to assess the effect of separating the functions of sampling for training and sampling for area estimation. Three sampling schemes were compared as a basis for classification and crop area estimation in eleven counties in Iowa: a segment-based method for training and classification and two methods using segments for training and a systematic sample for area estimation.

The results indicate the potential for using pooled statistics from several segments to represent a spectral stratum. The results demonstrate that separation of training from classification-area estimation can provide area estimates that are as accurate as segment-based estimates and are more precise. However, a key factor in using a systematic sampling approach for area estimation is the definition of spectral strata - that region over which one set of training statistics can apply. Research into the physical factors defining the strata and into methods of stratification will be an important task in the development of a full-frame sampling strategy.

Relationship of Classification Performance to Scene Characteristics. Segment-to-segment variability has a significant effect on classification performance. Information about the relationship of classification performance to characteristics of the scene would aid in the design of a sampling scheme for crop inventory. Twenty-four segments sampling a wide variety of conditions present in the U.S. Corn Belt were analyzed. Quantitative analyses of the relationship of scene characteristics to classification performance were conducted. The analyses showed that field size, soil characteristics, and crop mix and diversity were key variables determining crop classification performance. One phase of the study showed that a combination of Landsat data acquisition dates from emergence and tasseling of corn resulted in crop identification as high as when several additional dates were included (Figure 27).

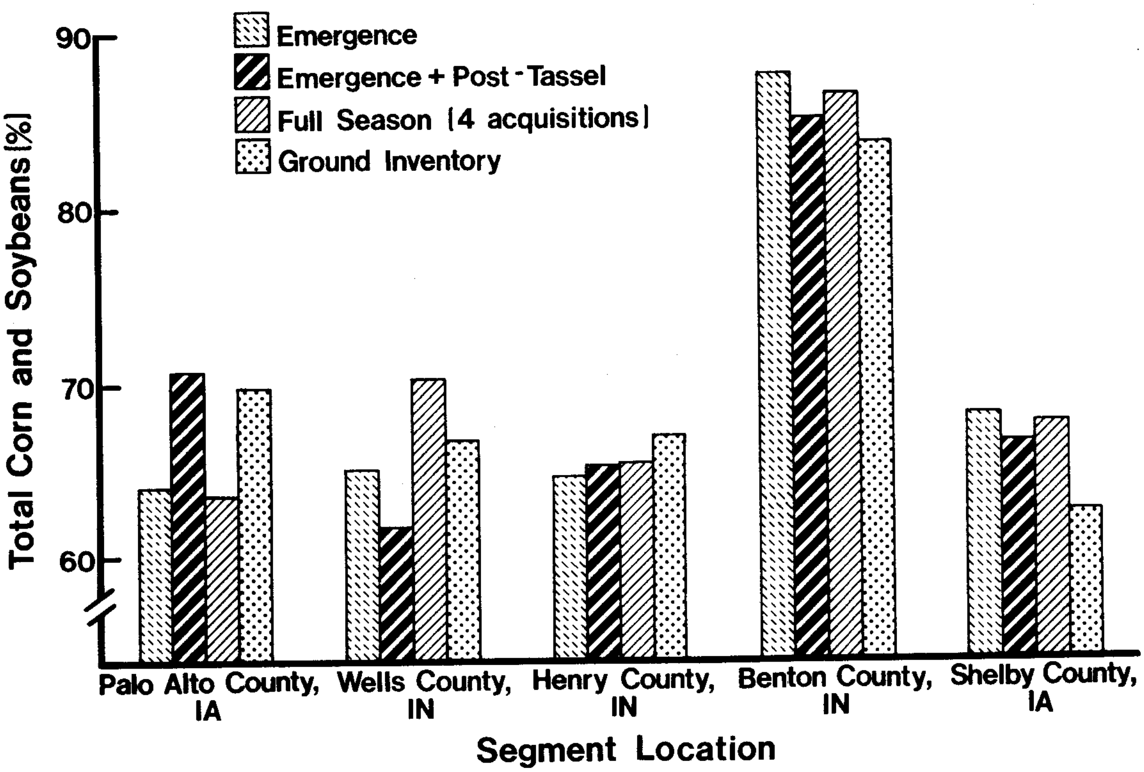


Figure 27. Comparison of classification estimates of total corn and soybean areas with ground inventory proportions.

Determination of the Optimal Level for Combining Area and Yield Estimates

The eventual aim of crop inventory studies is production estimates, not area or yield estimates alone. Production estimates can be made only at a level where area and yield strata intersect. The variance of the production estimates is dependent upon the means and variance of both area and yield in the stratum. Thus, it is important that the stratifications for area and yield estimation be coordinated, and that the levels for aggregation be selected so that acceptable variances are obtained.

The overall objective of this task is to determine the optimal level for combining area and yield estimates of corn and soybeans. The investigation will assess the optimal level with respect to the current technology: digital analysis of Landsat MSS data on sample segments to provide area estimates and regression models developed from historical data and used with current weather data to provide yield estimates.

Several levels of obtaining both area and yield estimates will be considered: county, refined strata, refined/split strata, crop reporting district, and state.

Regression equations have been derived to predict yield using the historical weather and yield data. A weather smoothing function was utilized to provide estimates of meteorological variables for the various strata studies. Using the 1978 weather data, current year yield estimates were made for corn and soybeans in Iowa for all the strata in each stratification system (Figure 28). The production estimate and its variance were computed for all the candidate aggregations. No bias in the production estimates due to stratification scheme was found.

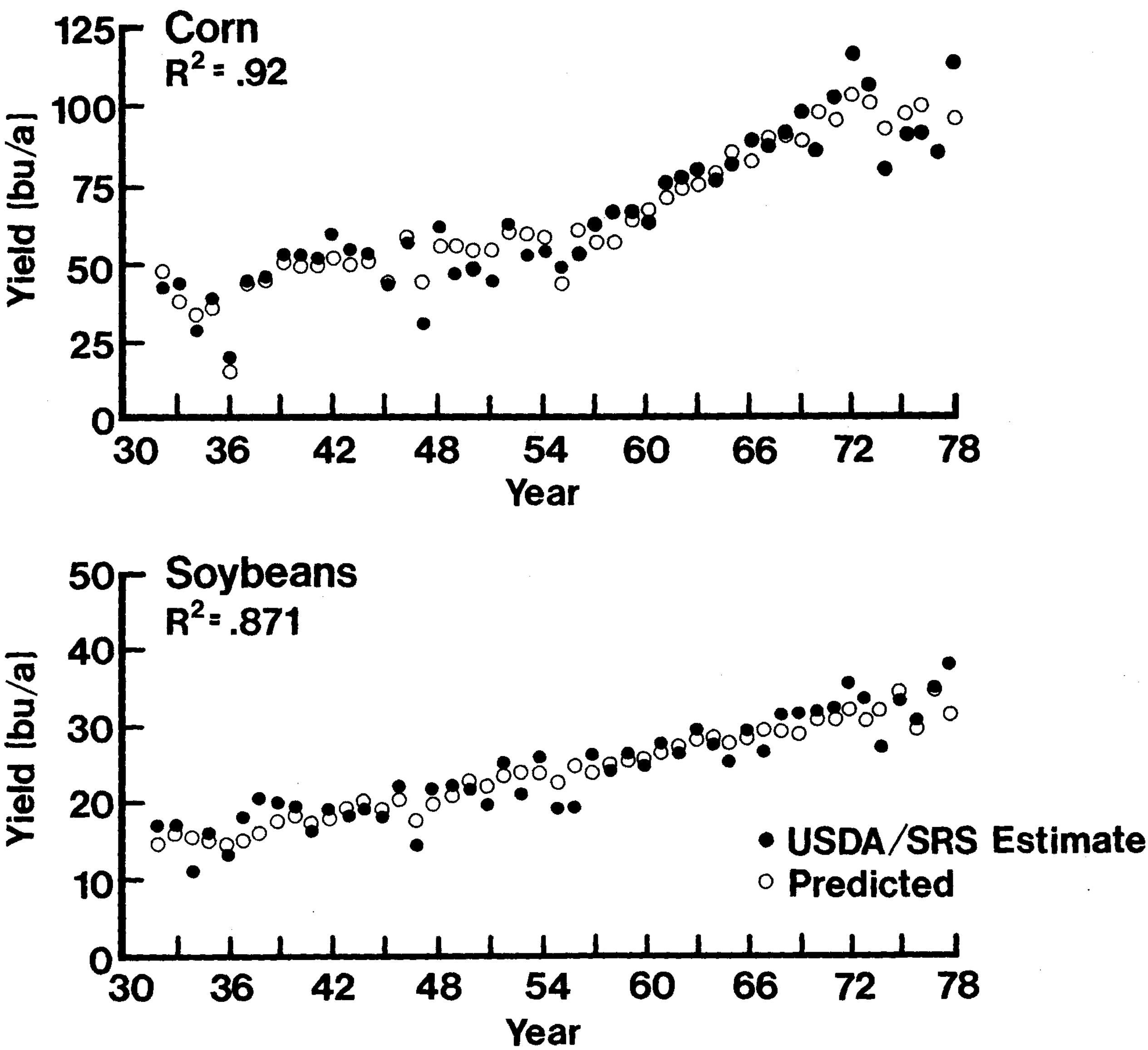


Figure 28. Comparison of corn and soybean yields predicted by the regression equations of historical weather data and the USDA/SRS estimates for the entire state of Iowa.

Data Processing and Analysis Research

This area of research has focused on generalizing basic principles and methods of earth resources data processing to cover more extensive and complex forms of data. Increasingly complex collections of data from multiple sources were constructed and studied; new methods for incorporating spatial information in scene classification were investigated and the impact of future sensor system characteristics on the quality of information obtainable from remote sensing data was evaluated. Also studied was the implementation of complex data processing tasks on advanced computer systems.

Data Processing

Over the past several years, research has been conducted on methods of geometrically aligning multiple images of the same scene to enable multivariate analysis and analysis of temporal changes in the images. Research addressed the problem of automatically correlating image pairs to find the geometric misalignment between them. The problem of mathematically describing the geometric differences between images also was researched and the results have been incorporated into operational procedures at LARS for registering remote sensor imagery. In the past year, particular attention was directed to the vidicon sensor aboard the Landsat satellite which offers high resolution earth surface imaging capability. Techniques for precisely combining these data with the widely used Landsat MSS were developed. Techniques for automatic extraction of scene boundary information were also researched.

The general thrust of work in this group has been to investigate methods for utilizing multiple data types for improved extraction of information from remote sensing data. In previous years, the multi-image concept was studied in the context of exploration for mineral deposits. In one test area in southeastern Arizona, several prospects were located using a combination of Landsat spectral reflectance data, gamma-ray radiation data, earth magnetic field, and digitized geology data. The prospects were field-checked and several were found to have good potential for copper mineralization. In the current year, methods of information processing techniques were pursued. Seismic signal filtering and transformation methods were studied and statistical decision method for analyzing seismic reflections was developed. A mathematical simulation of a typical oil and gas trap in earth strata is being used as a model to evaluate the data processing techniques (Figure 29).

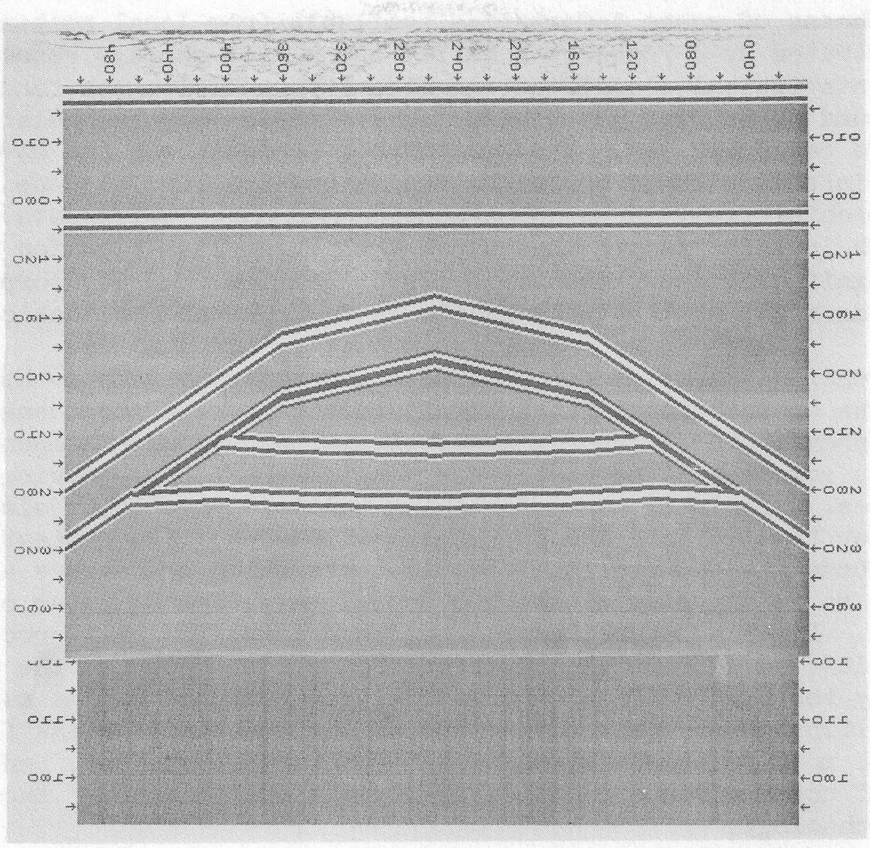


Figure 29. Image reproduction of a gas/oil trap zone in earth subsurface strata known as a bright spot. The dome-shaped area in the center represents a gas sand and the layer below it is an oil sand.

Data Analysis

Since multispectral remote sensing image data first became available for use in earth-observational applications in the 1960s, LARS and other remote sensing research organizations have concentrated on using analytical techniques for classifying the ground scene one pixel at a time. Even this level of data complexity represented a considerable challenge for the available information extraction techniques. Today, however, our research emphasis has widened from simply looking at spectral data pixel-by-pixel to incorporating diverse sources of scene information, including spatial and temporal variations, topographical data, geopolitical data, and geophysical data such as described above under Data Processing Research. Evidence of the successes achieved to date may be found in both the data processing and applications-oriented publications which have appeared from LARS this year.

The richness of scene information available from local spatial context has been demonstrated by a research activity which will shortly result in a Ph.D. thesis. A statistical classification algorithm exploits the tendency of certain ground cover classes to occur in particular spatial relationships to other ground cover classes. The key to this approach was the development of a method for inferring these contextual relationships from a scene without requiring prohibitively large amounts of ground observation data. A breakthrough in this research has meant that this classification method, which achieves significant improvements in classification accuracy compared to pixel-wise methods, will soon be available for general application.

As increasingly complex forms of data and data analysis methods are employed, the computational requirements tend to become more demanding. Although improvements in the raw speed of digital computer components can be exploited to some extent to meet these requirements, the evolving computer architectures, especially those involving multiple processing elements, have much to offer to alleviate the computational burden. The context classifier described above has computational requirements which are severe and rapidly become more so as the size of the contextual neighborhood under consideration is expanded. It is a natural candidate, therefore, for multiprocessor implementation. A commercial multiprocessor system known as the Cyber-Ikon, developed by the Control Data Corporation, has been the target machine for studying multiprocessor implementations of the contextual classifier. Still more general multiprocessor systems are of interest, however, and these are the focus of ongoing research aimed at maximal utilization of the evolving computer technology.

The Thematic Mapper, a remote sensing instrument offering characteristics tremendously improved over the multispectral scanner system orbited on Landsat satellites 1, 2, and 3, is under development and expected to be orbited on later Landsat satellites. The specifications for this satellite system have been the topic of an investigation to determine how sensitive typical classification analysis will be to the satellite design parameters. During this year, sensitivity to the accuracy of interband registration was studied. It was shown that misregistration among the spectral bands of as little as 0.3 pixel can have a pronounced effect on the classification of both field center pixels and pixels associated with edges and small objects in the scene. Moreover, a significant loss in potentially achievable classification accuracy will result because the resolution of the thermal band Thematic Mapper will be 120 meters rather than the 30 meters of the other six bands (Figure 30).

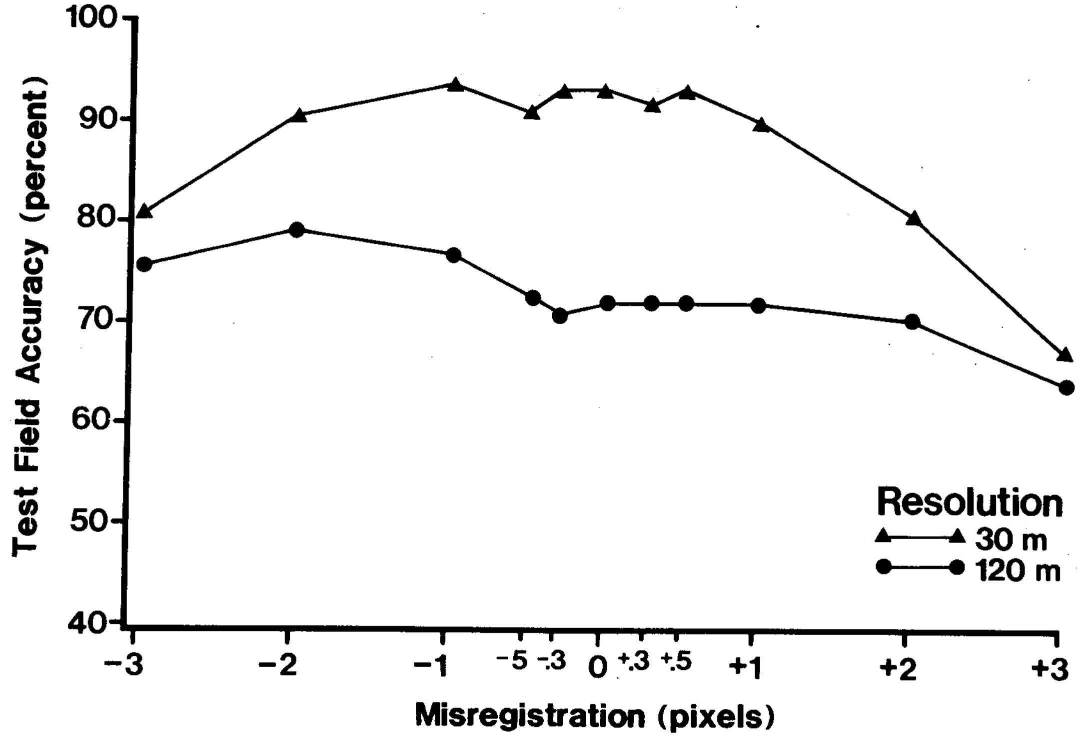


Figure 30. Comparison of classifications based on 30m and 120m resolution thermal bands. Much could be gained by improving the resolution of the thermal imagery of the Thematic Mapper so it would be comparable with the resolution of the imagery from the reflective spectral bands.

Earth Sciences Research

The loss of agriculturally productive soil due to water erosion is a serious problem and one which continues to increase. In order to develop agricultural practices to decrease this loss of fertile crop land and prevent stream pollution from water run-off, a method of identifying, mapping and monitoring soil erosion is needed.

A study of eroded soils collected from different locations in Indiana was conducted to investigate the relationship between their chemical and physical properties and their spectral reflectance. Soil samples included six eroded toposequences (topographic sequences) with varying degrees of erosion and representing the three primary soil orders common in Indiana, i.e., Mollisol, Alfisol and Ultisol (Figure 31). Another series of soil samples was collected by depth from an Alfisol profile. These samples were used to compare a simulated erosional condition to the naturally eroded toposequences.

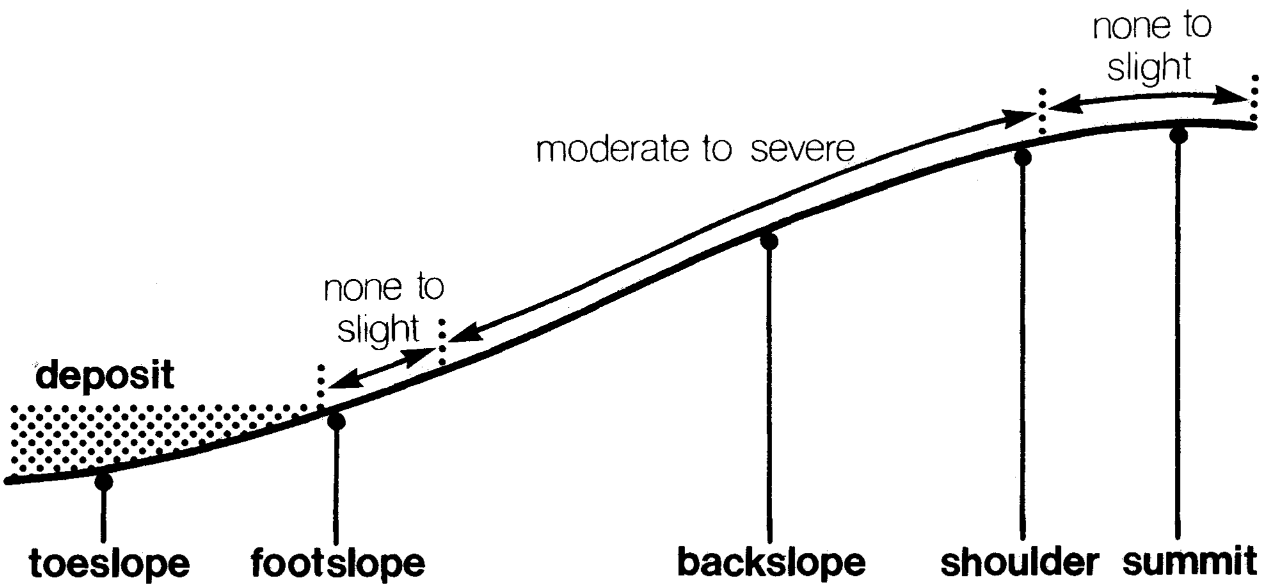


Figure 31. Toposequence with varying degrees of erosion.

All soil samples were prepared and analyzed under similar laboratory conditions. Analyses included organic carbon, total and amorphous iron oxides, particle size, moisture content and continuous scan spectral reflectance measurements. Three curve types were identifiable from the spectral reflectance. The Type 1 curve was indicative of the higher organic matter, uneroded soils of the Mollisols. The Type 2 curve was characteristic of soils having a lower organic matter content and better drainage than soils characterized by Type 1 curve. The Type 2 curve was descriptive of eroded Mollisol and uneroded Alfisol and Ultisol spectral curves. The Type 3 curve represented eroded Alfisols and Ultisols, in addition to the uneroded Ultisols with higher iron oxide content.

The soil parameters that appeared to affect the spectral reflectance most were organic matter and iron oxide content and the iron oxide ratio. Higher amounts of organic matter may have the ability to mask the influence of the higher iron oxide content upon the spectral reflectance curves of the eroded Mollisols whereas the spectral curves of eroded Alfisols and Ultisols showed more prominent iron absorption bands. The effects of erosion may be detected at about 0.8 micrometers; high iron oxide contents may tend to broaden the wavelength range over a 0.1 micrometer range. Although the amorphous iron oxide content showed little correlation with respect to erosion or spectral reflectance, the iron oxide ratio was the one parameter that most consistently related to the spectral reflectance and the severity of erosion of the six toposequences and the Russell profile. The highest iron oxide ratio occurred in the severely eroded soils. As the degree of erosion decreased, the iron oxide ratio decreased. This suggests that less eroded soils may contain lower crystalline iron oxides and/or higher amorphous iron oxides and more eroded soils may increase in crystalline iron oxides and/or decrease in amorphous iron oxides (Figure 32).

	Degree of Erosion	Morley	Sidell (B)	Sidell (M)	Miami	Fred-erick	Bedford
% O.M.	Deposit	2.8	3.4	3.3	1.7	1.9	—
	None	2.6	2.8	2.8	—	1.7	1.7
	Slight	—	—	2.2	1.4	—	1.4
	Moderate	2.1	1.9	—	1.2	1.5	1.9
	Severe	1.7	1.7	2.2	1.2	2.1	—
	Very Severe	—	—	—	—	1.9	—
% Total Iron Oxide	Deposit	.88	.94	1.09	1.02	2.14	—
	None	1.07	.85	1.18	—	1.33	1.15
	Slight	—	—	1.41	.96	—	1.54
	Moderate	1.22	.66	—	1.36	2.13	1.36
	Severe	1.75	.62	1.55	1.40	2.19	—
	Very Severe	—	—	—	—	3.16	—
% Amorphous Iron Oxide	Deposit	.31	.32	.55	.45	.22	—
	None	.38	.41	.43	—	.17	.22
	Slight	—	—	.43	.25	—	.20
	Moderate	.31	.27	—	.44	.23	.17
	Severe	.29	.25	.37	.25	.15	—
	Very Severe	—	—	—	—	.20	—
Iron Oxide Ratio	Deposit	2.84	2.94	1.98	2.27	9.73	—
	None	2.82	2.07	2.74	—	7.82	5.23
	Slight	—	—	3.28	3.84	—	7.70
	Moderate	3.94	2.44	—	3.09	9.26	8.00
	Severe	6.03	2.48	4.19	5.60	14.60	—
	Very Severe	—	—	—	—	15.80	—

Figure 32. Chemical and physical data of selected soil parameters for the eroded toposequence.

Several examples of simulated Landsat graphs were produced to determine the practicality of using actual Landsat MSS data to delineate eroded soils under natural conditions. The graphs verify the general trend of the slope of the spectral curves. Three curve types are represented and are quite separable spectrally (Figure 33).

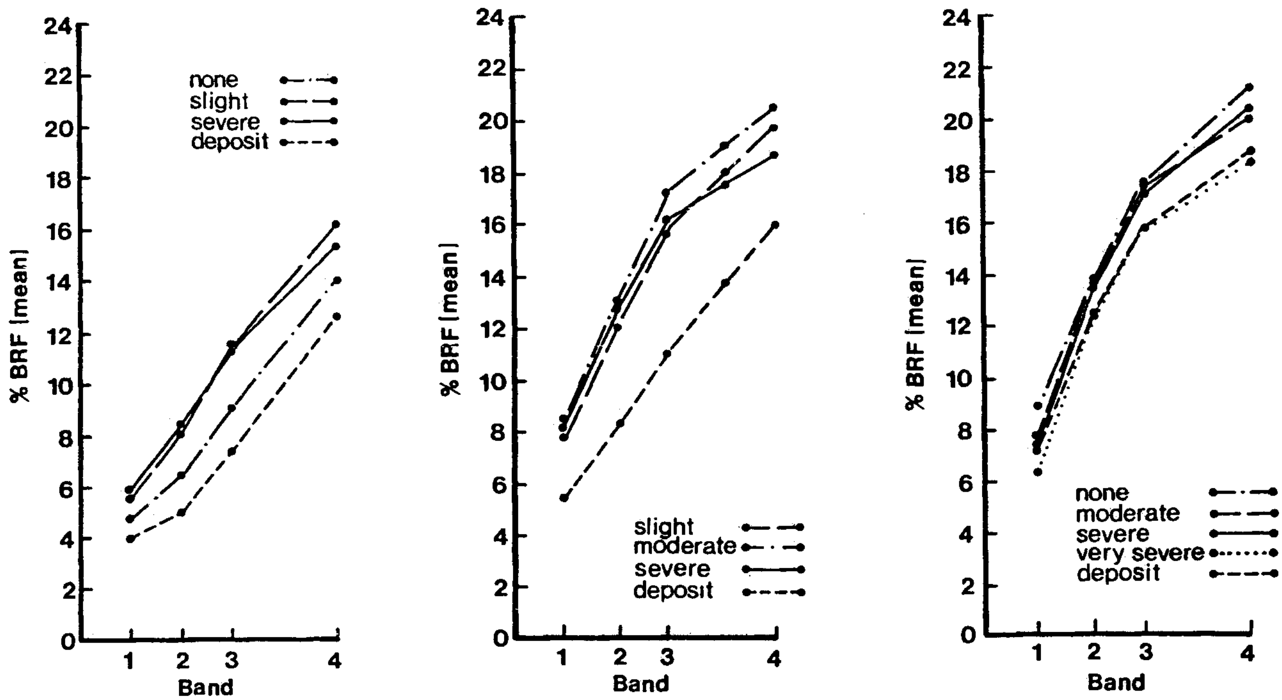


Figure 33. Simulated Landsat reflectance curves for three eroded toposequences: (left) Sidell - Mollisol; (center) Miami - Alfisol; (right) Frederick- Ultisol.

These Landsat graphs demonstrate the curve of an eroded soil undercutting another spectral curve between band 3 and 4 as also seen in the laboratory data (the eroded soil curve has a less positive slope than the other soil curve). At this point, the slope of that curve decreases more acutely than elsewhere in the spectrum. Inferences from the chemical analysis of these toposequences suggest that a combined effect of the organic matter, total and amorphous iron oxide contents may strongly influence the slope of the curve.

Knowledge of the soil order and relative topographic position within a catena would greatly aid in the identification of eroded soils by spectral reflectance measurements, especially if significance is to be placed on the specific curve types and slopes between 0.75 and 0.9 micrometers (Landsat bands 3 and 4).

The spectral curves as plotted by the simulated Landsat bands illustrated that the eroded soils were spectrally separable from the uneroded soils. The most important difference in the spectral reflectance appeared around 0.8 micrometers or band 3 in the Landsat graph. Although the detailed leveling off of the slope of the curve was not as obvious as in the continuous scan of the spectrum, a distinct decrease in slope and even the undercutting of several of the curves could be seen in bands 3 or 4.

Ecosystems Research

NASA plans to launch a new generation of satellite scanner systems in August, 1982. This new scanner, called the Thematic Mapper, will have 30 meter spatial resolution (compared to 80 meter on the Landsat scanner systems) and seven wavelength bands (compared to four on Landsat). In looking ahead to the increased amounts and characteristics of data that will be obtained from the TM scanner, a research effort has been directed at assessing the spatial and spectral characteristics of the Thematic Mapper scanner for purposes of identifying and mapping forest cover types.

Data were obtained with the NASA NS-001 Thematic Mapper Simulator (TMS) on May 2, 1979 and again on August 29, 1980 from an altitude of approximately 20,000 feet above terrain. The 2.5 milliradian instantaneous field of view of the TMS resulted in a nominal 15 meter spatial resolution at nadir for the original TMS data. The data were put through a fairly complex series of geometric and radiometric correction procedures to adjust for scanner look-angle effects.

Four spatial resolution data sets (15 x 15, 30 x 30, 45 x 45, and 60 x 75 meter) were generated in order to evaluate the impact of spatial resolution on classification. Data from each resolution were then classified with a conventional per-point Gaussian maximum likelihood (GML) classifier. The 30 meter spatial resolution data were also classified with an *SECHO classifier. The classification accuracies were assessed with both training and test areas, based upon the agreement of cover class identifications that were determined from aerial photographs and from test site visits. The percentage of pixels correctly classified for data for each resolution and with each classifier were compared with appropriate statistical analysis techniques (Figure 34 and 35).

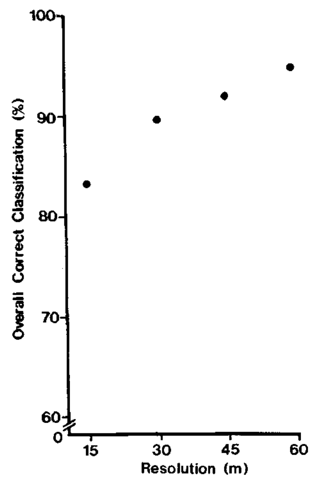


Figure 34. The results shown here indicate that the use of successively higher spatial resolution data resulted in lower overall classification accuracies when classifications were conducted with a per-point GML classifier.

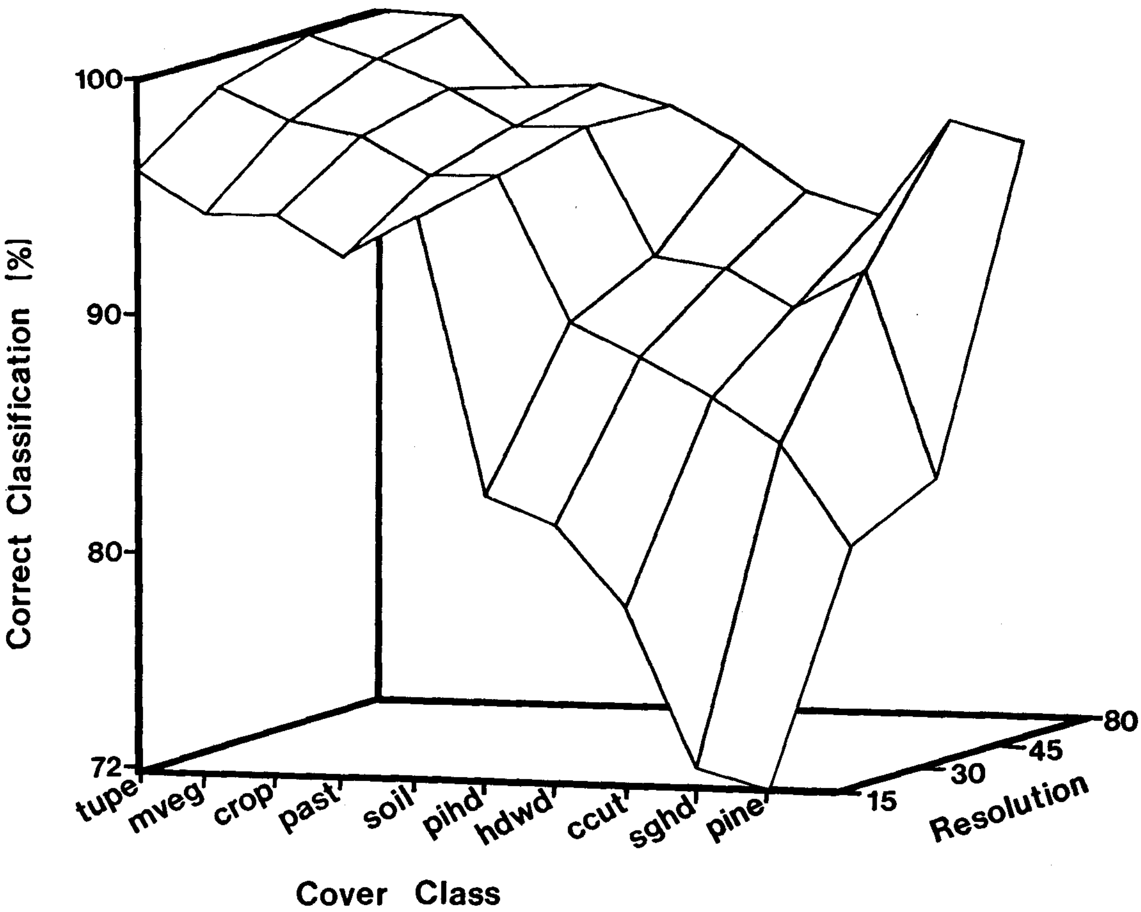


Figure 35. A response surface in which the classification performance for each individual cover class is shown for each of the four spatial resolutions.

There is a much greater effect of spatial resolution on classification performance for the forest cover classes than for the agricultural classes (with the exception of tupelo, which has a relatively smooth crown characteristic and therefore does not have a large amount of pixel to pixel variability). This result was not surprising, in that agricultural cover types do not have a large amount of spectral variation from pixel to pixel (i.e., what a photo interpreter would call texture). Therefore the impact of scanner spatial resolution on classification performance for agricultural cover types is relatively minimal. However, for the forest cover types (pine-hardwood, hardwood, clearcut, second growth hardwood and pine) there is a dramatic decrease in classification performance as the spatial resolution of the scanner system becomes finer. These results indicate that in order to make best use of the Thematic Mapper 30 meter spatial resolution data for forestry applications, more efforts will need to be focused on the development and refinement of classifiers which utilize the spatial as well as the spectral characteristics of the data.

In addition to evaluating the spatial characteristics of the TMS system, work is in progress to evaluate the spectral characteristics of data which will be obtained from the Thematic Mapper satellite scanner. Preliminary results indicate that a significant improvement in identifying and mapping forest cover types using pattern recognition techniques will be realized through the use of the Thematic Mapper data as compared to the current Landsat data.

The second major phase of this investigation involves the analysis of dual-polarized, X-band radar data. SAR (Synthetic Aperture Radar) data were obtained on July 30, 1980 by NASA's RB-57, flying at a height of 60,000 feet. Qualitative evaluation of the radar data has indicated that deciduous forest has a very high response on the HH polarization whereas coniferous forest cover has relatively low response. However, on the HV polarization, there is relatively little difference in tone between deciduous and coniferous. Water and bare soil both have relatively smooth surfaces and therefore have a very low response (e.g., black appearance) on both polarizations of the radar data (Figure 36).

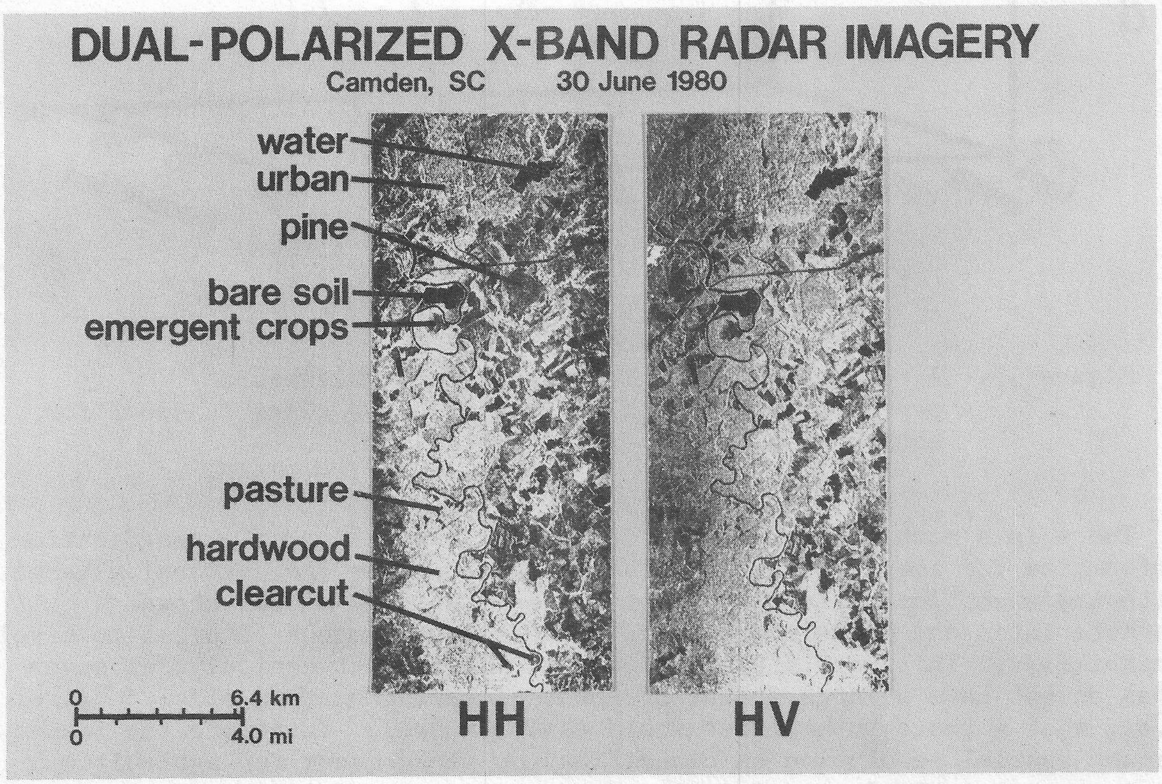


Figure 36. An illustration of SAR data depicting the appearance of various ground cover types.

Current work involves assessment of SAR data for delineating other cover types and ground surface features. The dual-polarized data sets will be digitally registered and a series of pattern recognition algorithms will be utilized to quantitatively assess the value of such radar data for forestry applications.

Forest Resource Information System (FRIS)

The year 1981 marked the successful completion of the Forest Resource Information System (FRIS) Applications Pilot Test Project. FRIS was a cooperative undertaking between the St. Regis Paper Company and the National Aeronautics and Space Administration. LARS was under contract to NASA to provide technical assistance to St. Regis.

The FRIS Project was significant because it conclusively demonstrated the utility of digital aerospace remote sensing data to private industrial forestry operations in the southeastern United States. LARS staff played a key role in transferring both the remote sensing capability and the Purdue University developed software to St. Regis. These activities made FRIS the first operational remote sensing facility in the forest industry.

Key accomplishments of the FRIS Project in which LARS staff were involved:

- Demonstrating that satellite acquired data provide important information for forest management.

- Demonstrating that satellite acquired data are most effective when digitally combined with other data sources for the purpose of creating an automated mapping system.

- Demonstrating that an integrated data base can be created from remote sensing imagery, planimetric maps, and forest inventory data to form a multi-functional information system.

- Demonstrating that satellite acquired and computer analyzed remote sensing data can provide forest managers with accessible and retrievable information in a timely and efficient manner.

Waterfowl Habitat Inventory

Ducks Unlimited (Canada), a non-profit conservation organization, has contracted LARS to conduct a Waterfowl Habitat Inventory of the prairie provinces of Canada. Landsat data acquired from the Canada Centre for Remote Sensing are being analyzed to derive quantitative and spatial information on wetland communities 25 acres or larger. Classification products are in the form of line maps at a scale of 1:250,000 and summary statistics that identify the UTM coordinate and area of shallow and deep marsh and open water for every identified wetland (Figure 8 on page 10).

System Services

The primary objective of LARS System Services has been to construct an excellent research computing capability to support LARS research projects. Hardware, software, policies, and organization are all oriented towards meeting this objective. For a number of years the computer at LARS has been used for remote sensing research by groups throughout the United States. One goal set for FY81 was to make Purdue University more aware of the unique research computing capabilities which have been amassed at LARS and which could significantly expand the computational tools available to all University researchers.

A good beginning was made in introducing the LARS computing capabilities to campus. Thirty-six new accounts were established by Purdue researchers in eleven university departments which had not previously used System Services. During FY81, LARS serviced one or more accounts from 33 university departments. In addition, the Department of Computer Technology established a hard-wired link to LARS and has made use of the LARS system in courses to familiarize students with features unique to IBM operating systems. The Statistics Department is also teaching courses which utilize the software tools uniquely available on the LARS system to introduce students to advanced statistical analysis packages.

LARS has elected to provide researchers with a highly interactive, multi-user, general purpose computing environment in order to maximize the accessibility of software tools and the speed and ease of program development. The LARS system uniquely offers Purdue the following ensemble of benefits:

1) Access to a system designed and tuned to large scale, interactive, research computing rather than small scale instructional jobs.

2) Access to a standard operating system.

3) Access to IBM hardware and software.

4) Access to widely recognized software packages which are uniquely available on IBM systems (e.g. SAS).

5) Access to a wide variety of remote sensing software and data.

The IBM computing environment LARS provides to Purdue is the only planned or existing environment available to Purdue researchers which will easily support the large number of IBM-dependent software systems developed outside of the university (Figure 37).

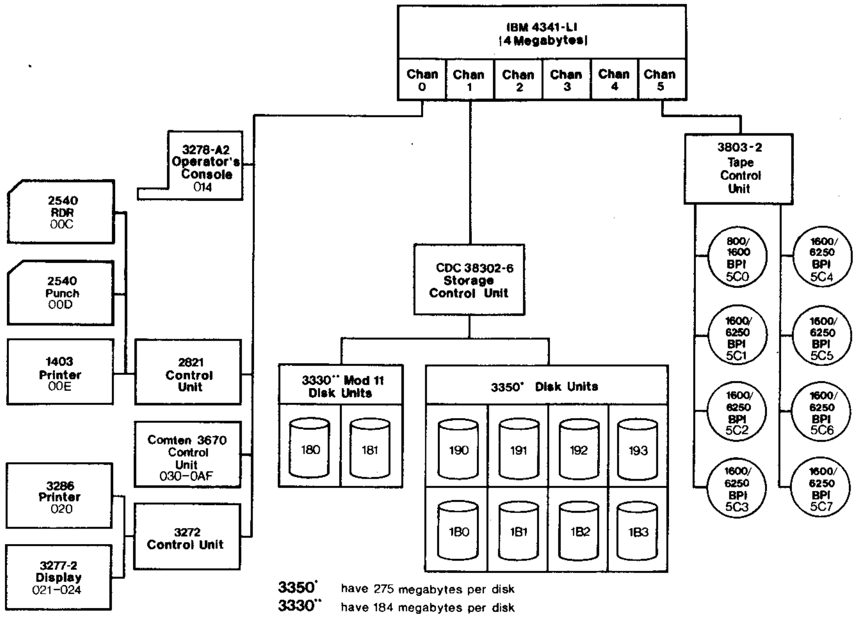


Figure 37. The hardware configuration of the LARS computer system. During FY81, the disk space on the system was doubled. Approximately 3 gigabytes of direct access storage are now available.

Hardware

Faster, quieter printers with upper/lower case characters, 600 line/minute print rates, graphics and grey-tone capabilities were acquired (Figure 38). They replaced aging, upper case only, 400 line/minute printers in Flexlab I and Flexlab II. The new printers cost less to purchase than one year's rental of the equipment they replaced.

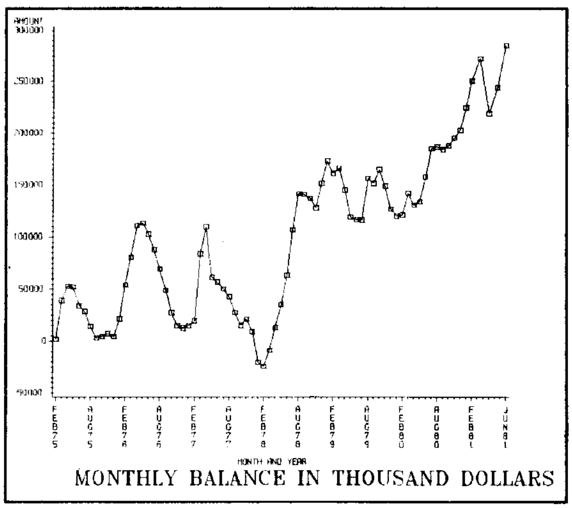


Figure 38. This chart was produced using the SAS/GRAPH software package, and was printed on one of the new matrix printers.

To meet the increasing demand for interactive computing capabilities, Johnson Space Center (LARS' principal sponsor) acquired an AS/3000 computer in early 1981. This machine was selected to duplicate the capability at LARS. The AS/3000 at JSC and the IBM 4341 and PDP11/34 at LARS have been joined to form the Earth Resources Data Applications network (ERDAnet). LARS is responsible for systems maintenance and development for ERDAnet (Figure 39).

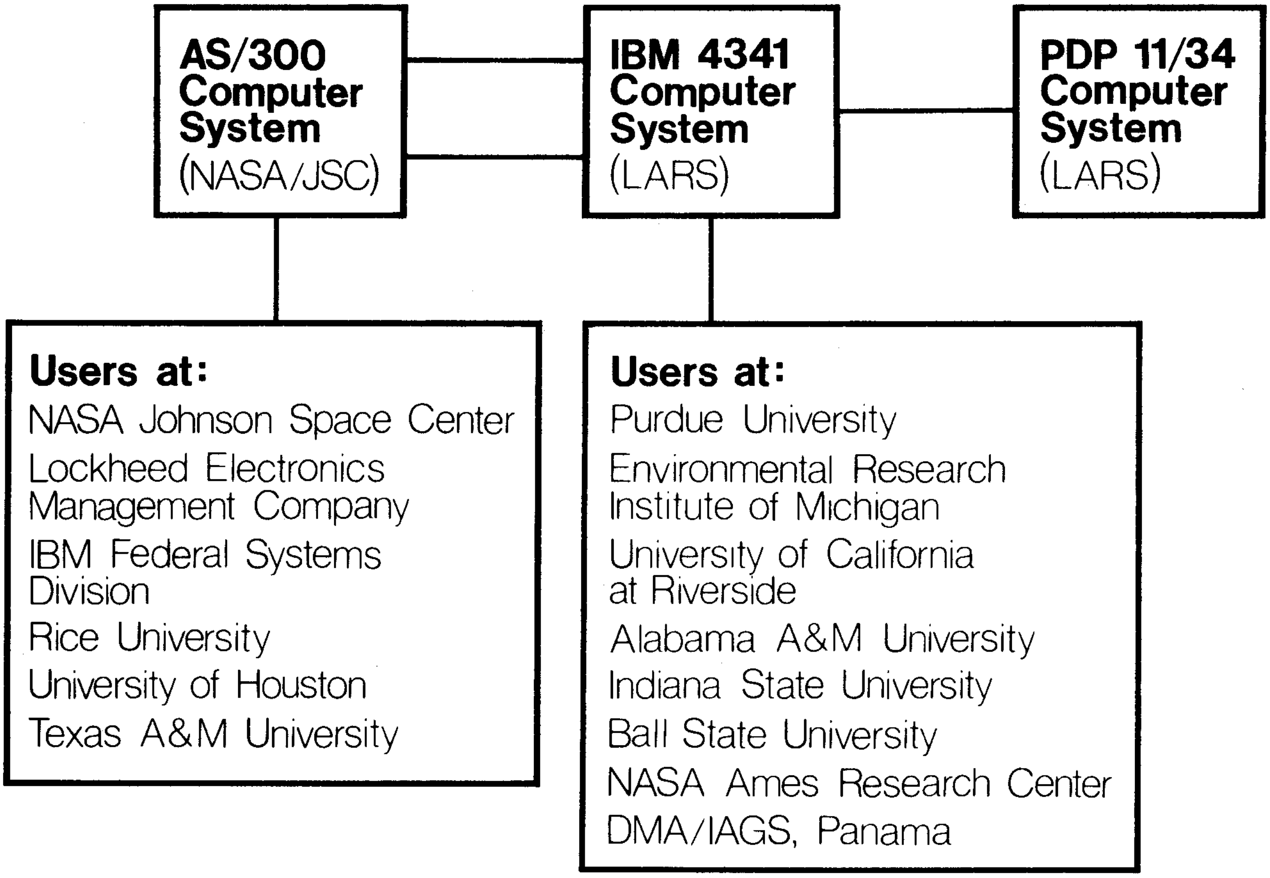


Figure 39. A new Computing System at Johnson Space Center has been joined to two Purdue Computer's to form the Earth Resources Data Applications network (ERDAnet).

Two Apple II mini computers were acquired during FY81 to support the development of inexpensive demonstration packages and to experiment with the off-loading of several functions from the ERDAnet mainframes (Figure 40). A mini-LARSYS data access package and digitizer driver are currently under investigation.

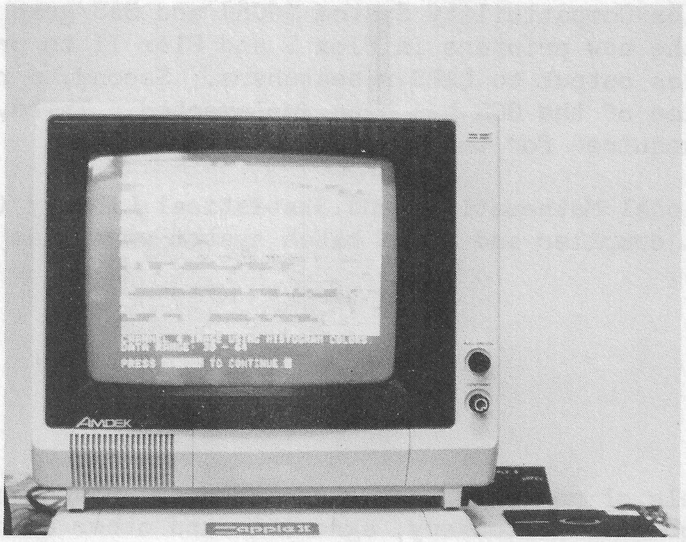


Figure 40. Apple II mini computers are being used to explore distributed processing of remotely sensed data.

Software

During FY81, word processing was added to the capabilities available at LARS. A text processing package, SCRIPT, and a full screen editing package, EDGAR, have been implemented. Secretaries have been trained in the use of these packages, full screen editing terminals and letter quality output devices were installed in the clerical area at Flex I and Flex II (Figure 41).

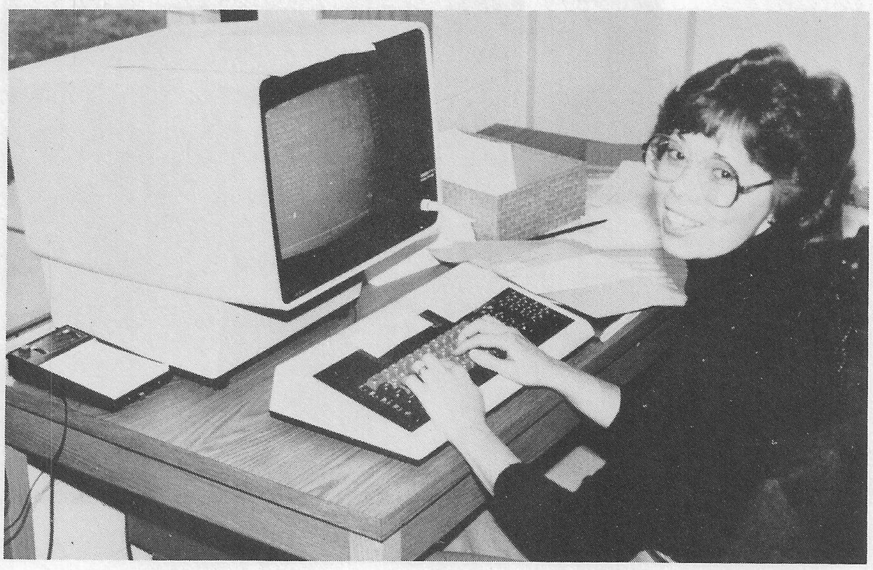


Figure 41. Debbie Woodruff of Continuing Education uses the LARS Word Processing System to send out 230 individualized form letters.

Graphics capabilities have been upgraded in several ways during FY81. First, the Graphics Compatibility System (GCS) and SAS/graph have been interfaced with the new printers in Flex I and Flex II to provide quick, high resolution graphics output to LARS researchers. Second, a new, three dimensional version of the GCS has been implemented. Third, a hard copy device has been acquired for the Tektronix 4054.

The International Mathematical and Statistical Library (IMSL) subroutine package, a PASCAL compiler and a new batch system were made available to LARS users during FY81.

Data

Over 7000 reels of magnetic tape store scanner, radiometer, meteorological, political boundary, agronomic and other data used by researchers at LARS and at a number of remote sites throughout the nation.

Training

In order for new users from within Purdue University and at the remote terminal sites to become quickly familiar with the LARS computing environment, a 15 module, tape/slide introduction to the LARS computer, its operating system and software packages has been developed (Figure 42).

Figure 42. Kim Jackson, a Computer Technology Department student, uses the LARS Tape/Slide module to pursue a semester project.

Professional and Academic Education Programs

Technology Transfer

The primary goals of the LARS Technology Transfer program area are to provide training for a range of audiences, to develop educational and training materials that contribute to the effective transfer of remote sensing technology, to provide technical assistance to foreign countries interested in acquiring this technology, and to provide access to the LARS remote sensing data processing capabilities.

During FY81 Technology Transfer continued to attract representatives from various groups to its programs (Figure 43).

These programs are explained in detail over the next few pages.

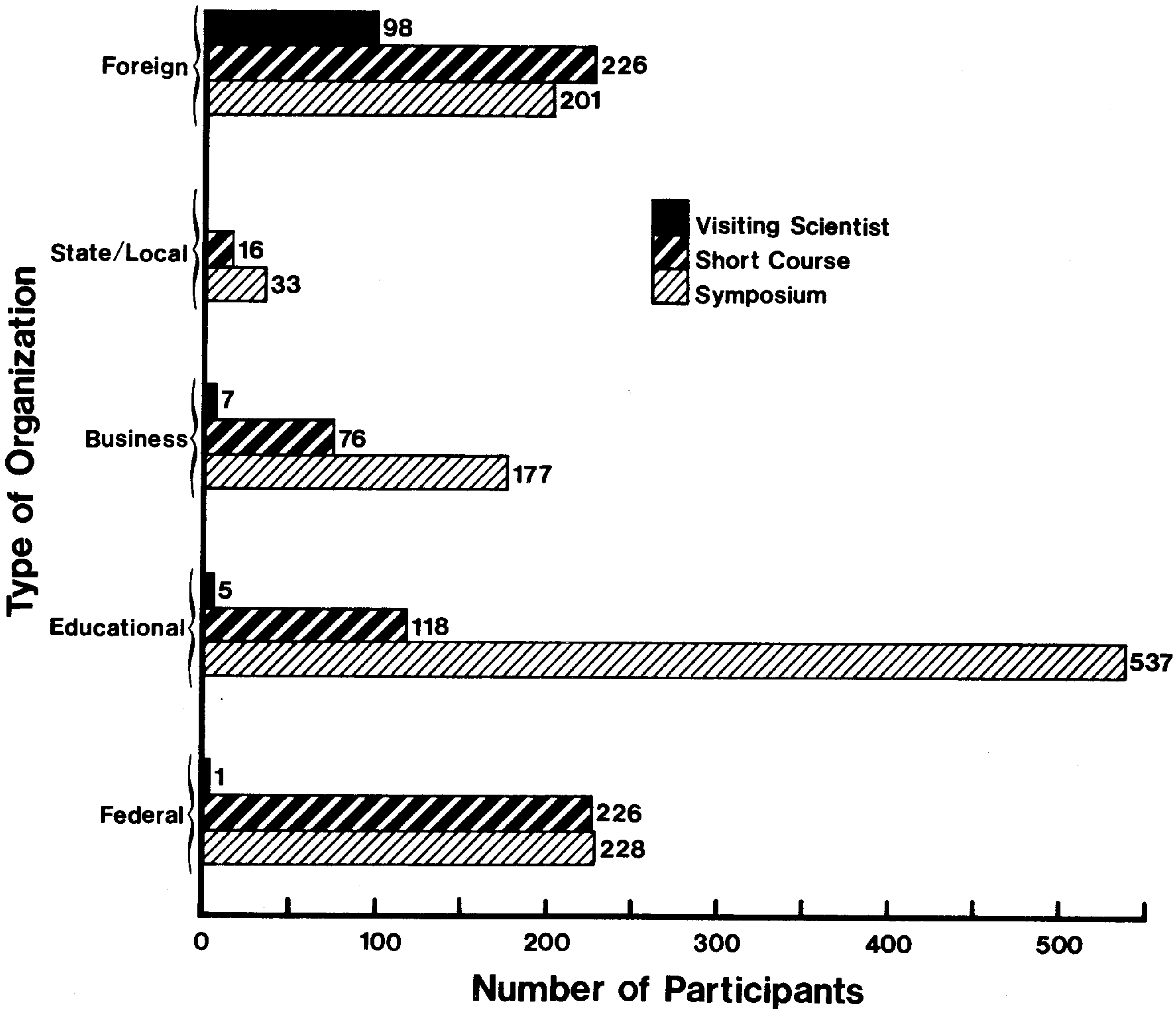


Figure 43. Three major activities demonstrate the diverse backgrounds of personnel participating in Technology Transfer programs from 1974-1981.

Short Courses

An updated version of a course first taught in 1972 on "Numerical Analysis of Remote Sensing Data" was offered monthly with 32 attendees, 11 of whom also participated in the "Hands-On" computer exercises option (Figure 44). These 32 included 11 from foreign countries, bringing the number of foreign participants to 186, out of 662 total attendees (Figure 45).

Figure 44. "Hands-on" computer experience during the Short Course enhances understanding of the remote sensing technology.

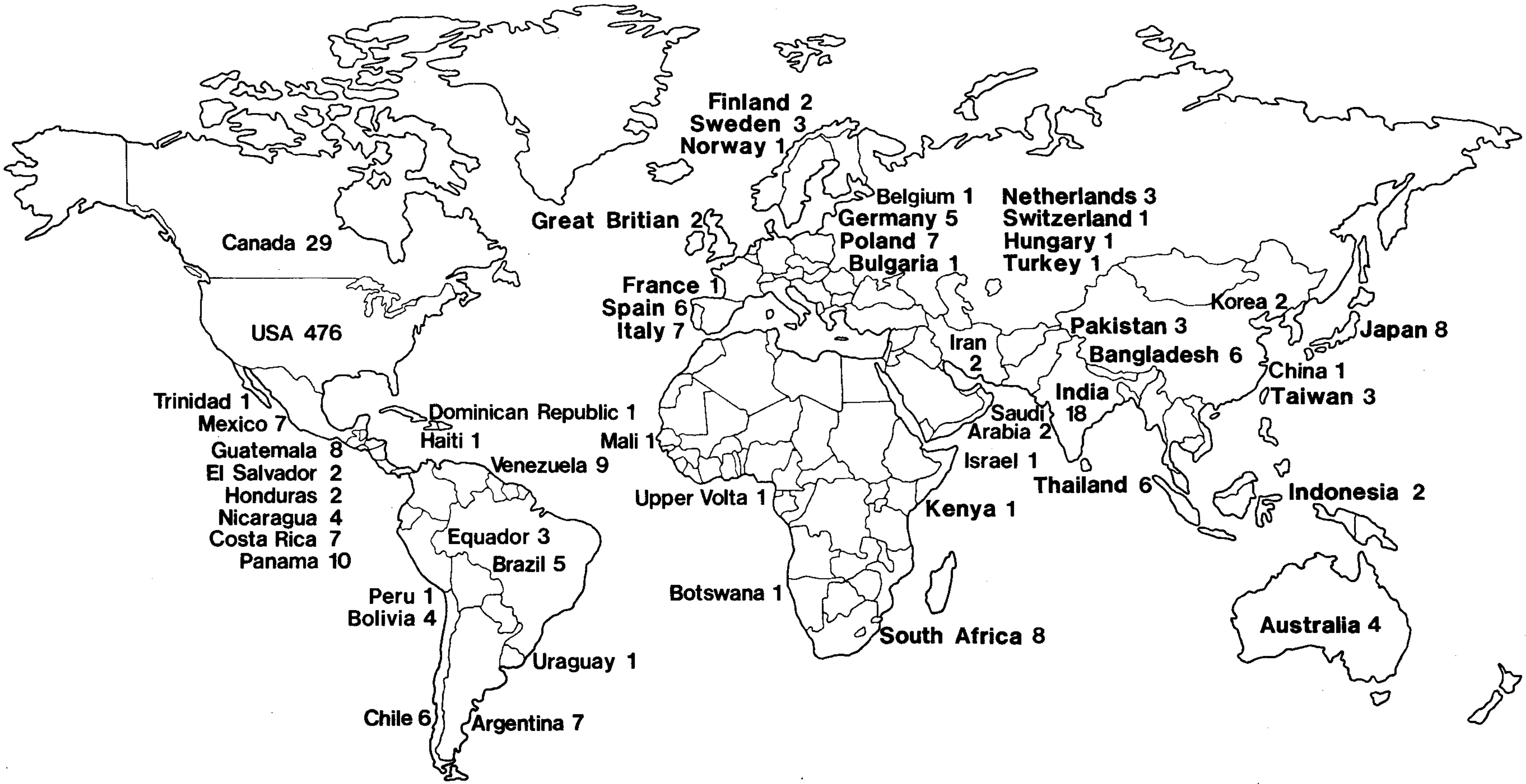


Figure 45. Monthly short course attendees from 1972 through June 1981 (662 total).

As in previous years, the participants were a heterogeneous group coming from federal government agencies (13%), foreign countries (34%), Purdue and other universities (53%).

This fiscal year saw the creation of seven specialized short courses, offered to meet the special requirements of the requesting groups. Five of these courses were prepared to meet the specific requirements of U.S. governmental agencies; two were given for international research organizations. Course titles, duration, sponsors and locations are listed below:

1. Remote Sensing for Mineral Specialists -- Digital Analysis
   4 1/2 days
   Bureau of Land Management
   Denver Federal Center

2. Remote Sensing Fundamentals
   5 days
   U.S. Army Corps of Engineers
   West Lafayette

3. Remote Sensing Manager
   3 days
   U.S. Army Corps of Engineers
   West Lafayette

4. Advanced Digital Image Processing and Analysis
   5 days
   U.S. Army Corps of Engineers
   West Lafayette

5. Numerical Analysis of Remote Sensing Data
   5 days
   Defense Mapping Agency InterAmerican Geodetic Survey
   Fort Clayton, Panama, Central America

6. Numerical Analysis of Remote Sensing Data
   4 1/2 days
   International Atomic Energy Agency
   Santiago, Chile

7. Reformatting Programming
   5 days
   National Institute of Investigations of Biotic Resources
   Mexico

There was a total of 79 students enrolled in these seven courses. These customized short courses offer sponsors many advantages over general-purpose courses in cost, scheduling, level, content, and delivery. The objectives of each course are defined jointly with the sponsoring organization, and the courses are organized and staffed to meet these objectives. Offering these courses is feasible because of the large body of educational materials and workshop exercises that have been developed through the last nine years of offering short courses.

Workshop on Key Issues

A workshop on "Key Issues in the Analysis of Remote Sensing Data" was held in conjunction with the 1981 Symposium on Machine Processing of Remotely Sensed Data. The workshop, partially funded by NASA/JSC, was held in lieu of the five-day course "Advanced Topics in the Analysis of Remote Sensing Data," which had been offered the previous four years. Thirty-five people attended the one-and-a-half day workshop, with about one-third of these invited to participate actively in the panel presentations.

The overall objectives of the workshop were to assemble experts in remote sensing and related information- and image-processing technologies to make an up-to-date assessment of the state-of-the-art of machine analysis of remote sensing data and to determine the nature of the key research problems remaining as barriers to broader, more effective use of machine analysis of remote sensing data. A product from the workshop will be a report detailing the findings and recommendations of the workshop participants.

Conference on Remote Sensing Education (CORSE-81)

During May 18-22, 1981 Purdue University hosted the first national Conference on Remote Sensing Education, CORSE-81. Under the sponsorship of NASA's Eastern Regional Remote Sensing Applications Center and NOAA, the conference attracted 186 people, predominantly educators from U.S. colleges and universities who were teaching or planning to teach remote sensing courses at the undergraduate or graduate level. In all, professors from 43 different educational institutions took advantage of the conference format, with people attending from 40 states across the country.

The purpose of the conference was to strengthen remote sensing education in our nation's colleges and universities and thereby to strengthen the preparation of college-educated scientists in the use of the technology. The conference program was designed to flow from the definition of what remote sensing education is now to what it needs to become and how to best accomplish this in the college and university environment. The tone of the conference was set to encourage informal interaction among participants through small group discussions and panel discussions.

A very popular aspect of the conference was the series of nine tutorial workshops, most of which were offered more than once. The workshops served a two-fold purpose: first, to give participants the opportunity to expand their own understanding of specific aspects of remote sensing, and second, to enable participants to observe and experience the educational strategies adopted by other educators in presenting remote sensing topics (Figure 46).

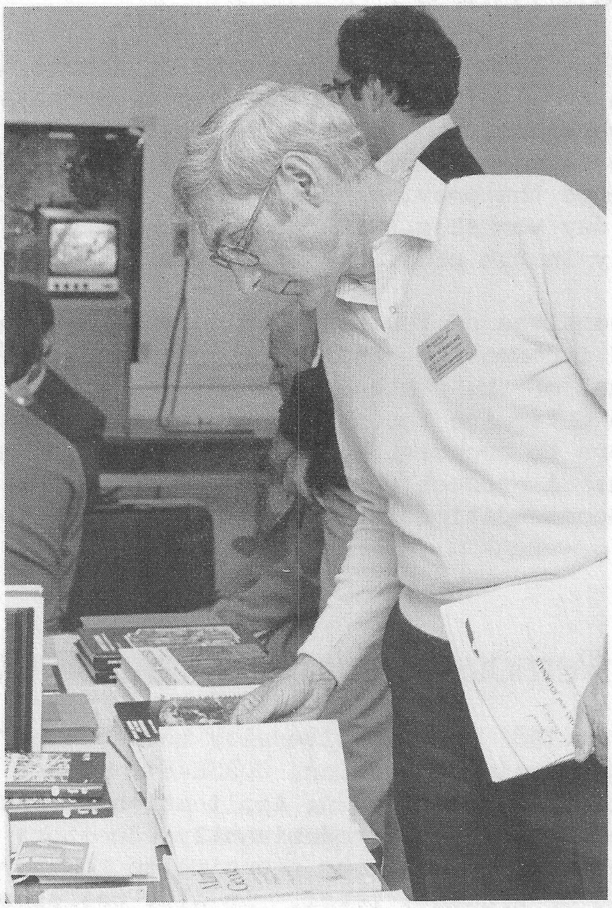


Figure 46. Robert Ragan, University of Maryland, examines one of the newest books at the 1981 Conference on Remote Sensing Education.

Written evaluations of the conference were returned by 40% of the participants. The request was strong for continuation of meetings like this on a national basis. The conference is summarized in a 382-page Conference Report, compiled by Shirley Davis and to be published by NASA in autumn 1981.

Symposium

During FY81 LARS, in cooperation with Purdue's Division of Conferences, NASA, and USDA sponsored the Seventh Symposium on Machine Processing of Remotely Sensed Data with special emphasis on Range, Forest, and Wetlands Assessment.

Two hundred thirty-five participants, representing 34 states, including 40 from 14 foreign countries, continued the international tradition of the symposium (Figure 47).

Figure 47. Symposium attendees from 1973 through 1981 (1171 total).

The Opening and Closing Plenary Sessions presented a worldwide view of "where we are and where we are going." Three parallel Technical Sessions were featured: Forestry - Machine Processing and Analysis - Other Discipline Applications, and included approximately 30% invited papers. A poster session was added.

Two special report/discussion sessions focused on recent national workshops. They were:

Landsat Classification Accuracy Assessment Procedures: An Account of a National Working Conference

Remote Sensing Education: A Special Report on the Conference of Remote Sensing Educators (CORSE-81)

Visiting Scientists

The Visiting Scientist Program has been developed to meet the specialized needs of scientists who wish to become intimately acquainted with the remote sensing technology developed at Purdue. It provides an opportunity for personalized, individual study and research at the laboratory during a period of residence established on a case-by-case basis.

The trainee or the sponsoring agency is expected to pay the cost of the training program. The cost is variable, depending on the duration of the training and the amount of computer time used. The trainee or sponsoring agency must also provide travel and subsistence expenses.

Since 1972 there have been a total of 111 visiting scientists involved in applying remote sensing technology to problems in different countries which they represented. During FY81 there were 10 visiting scientists from four different countries, bringing the total visiting scientist participation to 127 (Figure 48).

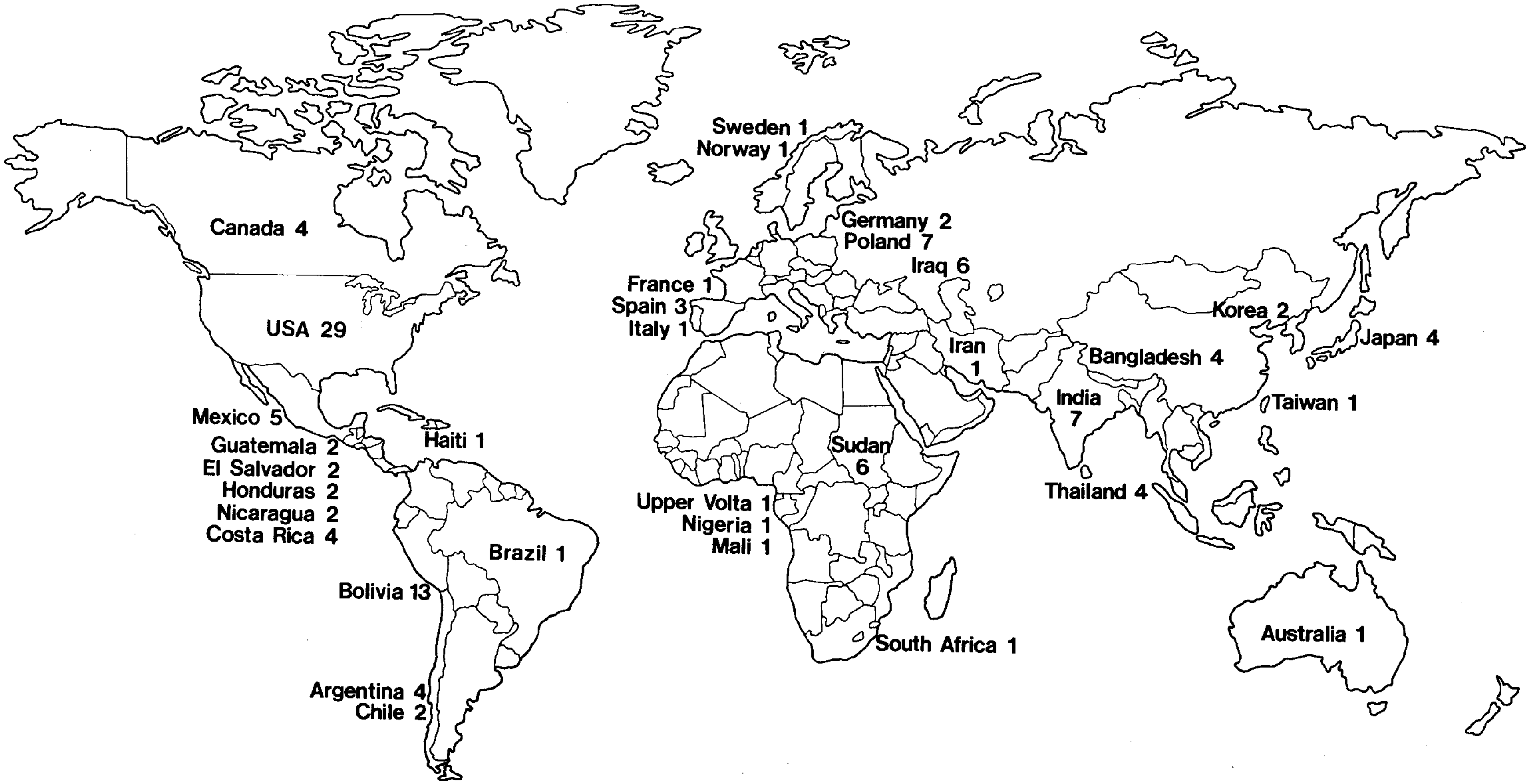


Figure 48. Visiting scientists from 1973 through June 1981 (127 total).

Technical Assistance

To support the University's involvement in "institutional development" activities abroad, the LARS Technology Transfer Program area has been providing technical assistance to countries wishing to implement their own remote sensing data processing and analysis capabilities.

Since 1973 LARS has been engaged in transferring digital remote sensing technology to Bolivia through training, in-country technical assistance, and cooperative research efforts. During FY81, technical staff from LARS and Bolivia have been jointly designing and developing a digital Geographic Information System (GIS) for Bolivia. The concept is being tested with data from the Oruro Department (Figure 49).

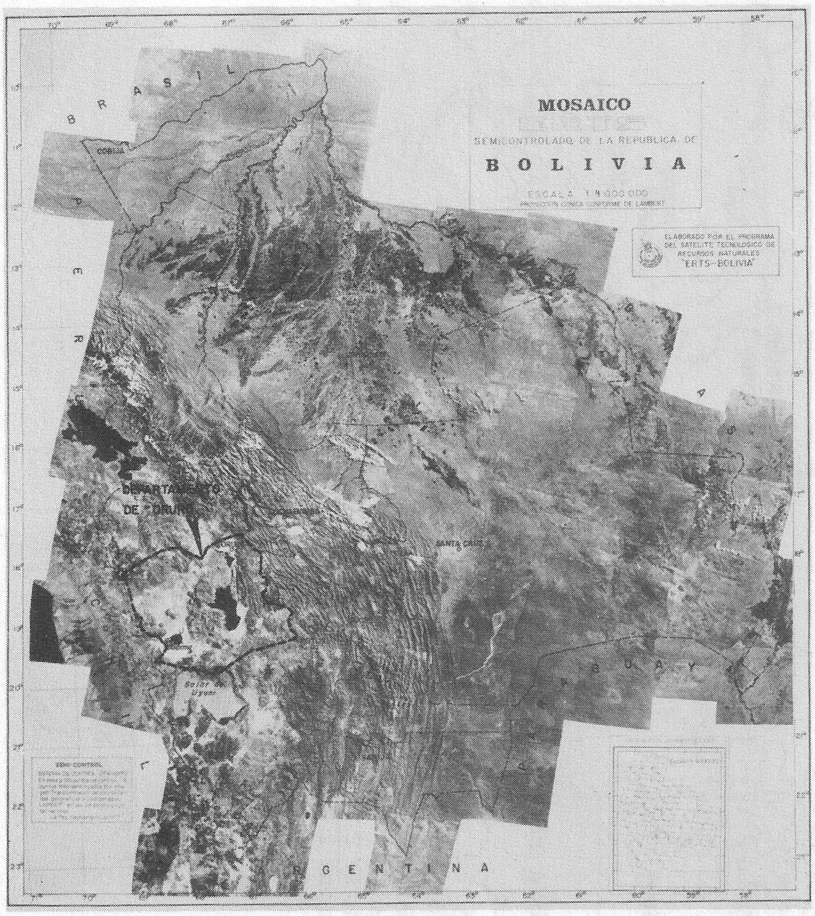


Figure 49. The Bolivian GIS consists of a series of geo-coded planes or resource elements digitally registered onto a geometrically rectified and cartographically accurate digital Landsat MSS mosaic.

In order to introduce the resource information (natural resources and socio-economic maps) into the digital data base, an "input subsystem" was designed, developed, implemented and tested. This subsystem includes such processes as digitization, geodetic projection transformations, file editing, and rasterization or conversion of polygonal files into gridded or cellular files.

Two other major components of this system remain to be developed, i.e., a data management system and the modeling capabilities that would allow the user to effectively manipulate the data and to derive useful information through appropriate combinations of the existing elements.

The most significant accomplishment resulting from this project has been the conceptualization and design of a data storage strategy to support the data management, processing, and information extraction processes.

Remote Sensing Research and Analysis Network

LARS reduces the large personnel and financial commitments normally required for entry into the remote sensing community by providing to educators and researchers a low-cost, low risk means of access to a powerful remote sensing technology through a remote terminal network (Figure 50).

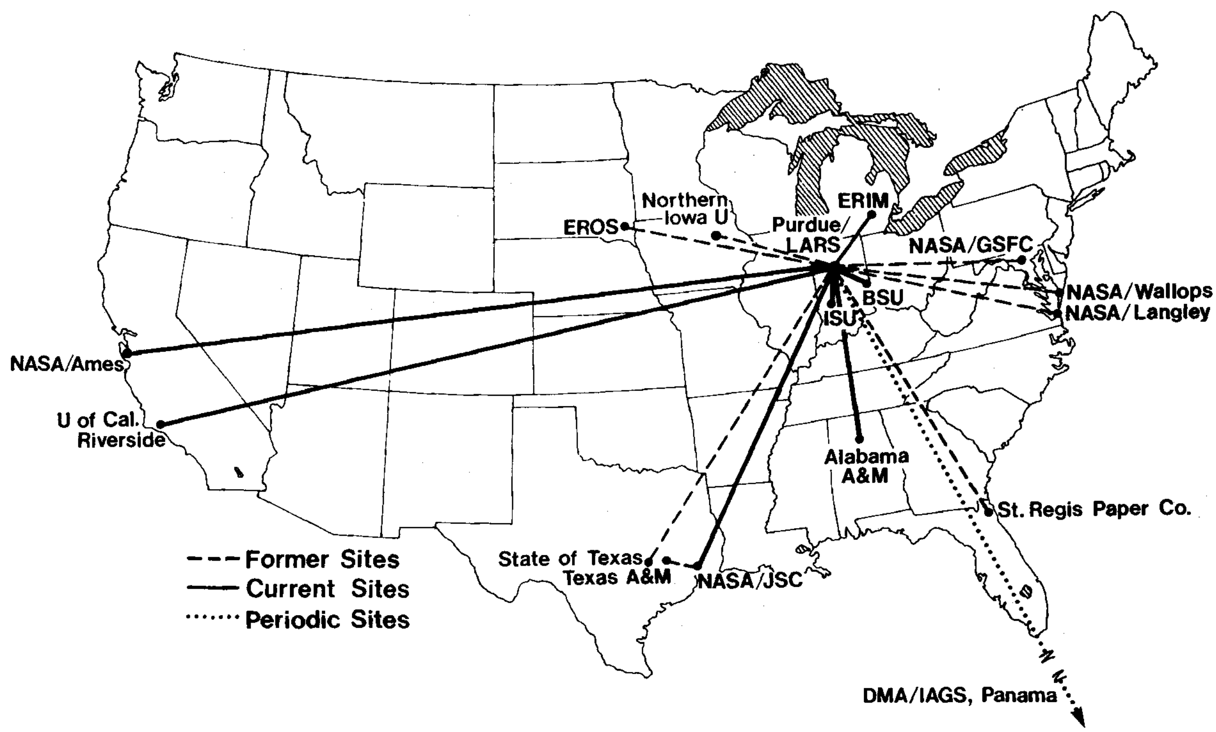


Figure 50. Since 1972, remote users have accessed the Purdue/LARS facilities from sixteen different sites. Specialized training is also provided on use of the processing tools available to members of the remote terminal network.

Through this network, remote users have access to all software implemented on the IBM 4341, as well as to the large data base of multispectral data, and to the experienced Purdue/LARS staff. The benefits received by LARS from the network include enhancing the Purdue/LARS reputation and, by increasing the number of system users, defraying the costs to all involved.

Educational Materials on Remote Sensing

Since 1974, LARS has been actively involved in the development of educational materials which present fundamental remote sensing concepts and principles in a tutorial manner. During FY81 activities in this area centered on additions to the minicourse series and the development of high-quality videotapes.

Minicourse Series
Fundamentals of Remote Sensing

The minicourses in this series are multi-media educational packages that present the fundamental concepts of remote sensing. They have been developed with funding from Purdue's Division of Conferences and Continuing Education Administration and are available for purchase, either individually or in full sets (Figure 51), from Continuing Education.

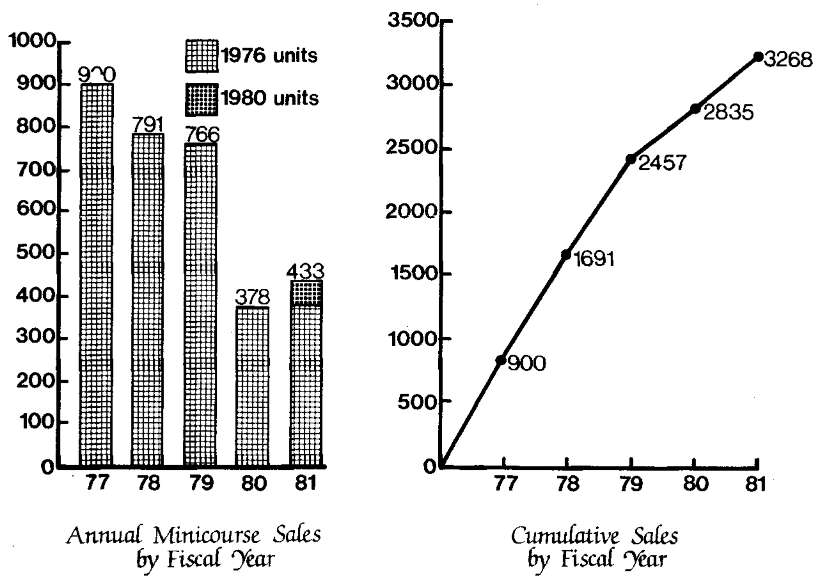


Figure 51. The new minicourses (1980 units), distributed only during the last quarter, accounted for a modest increase in sales during the last two years. The overall total sold has exceeded 3200 modules.

A minicourse represents 1 to 1½ hours of student learning time. Each minicourse includes 20-51 color, 35-mm slides, an audiotape and a printed study guide. Some of the minicourse units contain special equipment for the student's use and learning experience. Persons with a background in elementary biology, physics and mathematics can understand and work with the basic concepts presented.

During FY81 six new minicourses were released for distribution through Purdue University's Division of Conferences and Continuing Education Administration, bringing the total number of modules to 25. The new modules are:

Photogeology
by H.E.C. van der Meer Mohr, J.F.M. Mekel, and S.M. Davis

Principles of Photointerpretation
by R.M. Hoffer and S.M. Davis

Interpretation of Thermal Imagery
by L.F. Silva and J.D. Russell

Spectral Measurements for Field Research
by L.F. Silva, L.L. Biehl, and J.D. Russell

Selecting Landsat Imagery
by F.W. Hilwig and S.M. Davis

Mineral Exploration Using Satellite Data
by D.K. Scholz and S.M. Davis

Videotape Series

Introduction to Quantitative Analysis of Remote Sensing Data

Currently a videotape development project is being funded by Purdue University's Continuing Education Administration. The purpose of the project is to produce five half-hour videotapes that address moderately advanced topics central to remote sensing technology as it has evolved at LARS. The videotapes in this series "capture" a subject-matter specialist's discussion of a remote sensing topic. The primary use of the tapes will be for regular classes on the Purdue campus and, secondarily, for use in Continuing Education Administration-sponsored short courses on remote sensing.

These videotapes will also be sold to outside organizations through Purdue's Continuing Education Administration on a cost-recovery basis. Printed support materials for the videotapes will be provided through viewing notes prepared for each program and the textbook, Remote Sensing: The Quantitative Approach, edited by P.H. Swain and S.M. Davis (McGraw-Hill, 1978).

The videotapes planned for distribution during FY82 are as follows:

The Remote Sensing Information System
by D.A. Landgrebe

Correction and Enhancement of Digital Image Data
by P.E. Anuta

The Role of Pattern Recognition in Remote Sensing
by P.H. Swain

The Role of Numerical Analysis in Forest Management
by R.M. Hoffer

Multispectral Properties of Soils
by M.F. Baumgardner

Market Survey

Under the sponsorship of Continuing Education, a study was conducted by staff from the Design Section of Purdue's Creative Arts Department to develop guidelines for improved promotion and success of Technology Transfer's offerings. The specific concern of the study was to aid in promotion of the newly created minicourses and videotapes; the overall concerns of the study team have been much wider as they look at the state of the technology and its acceptance, educational offerings in remote sensing from other institutions, and potential new markets. This effort is a stellar example of cooperation among three entities of the university which will enhance the effectiveness of all three.

The final report of this survey is due in the early part of FY82.

University Courses

Courses with Definite Emphasis on Remote Sensing

Agronomy

545 Surveying Agronomic Resources
cr. 3 Prof. Baumgardner

Civil Engineering

567 Airphoto Interpretation
cr. 3 Prof. Miles

Electrical Engineering

577 Engineering Aspects of Remote Sensing
cr. 3 Profs. Swain and Silva

Forestry

291 Introduction to Remote Sensing
cr. 1 Prof. Hoffer

557 Aerial Photo Interpretation
cr. 3 Prof. Miller

558 Remote Sensing of Natural Resources
cr. 3 Prof. Hoffer

579 Aerogeology and Remote Sensing
cr. 3 Prof. Levandowski

Courses Related to Remote Sensing

Agronomy

565 Soil Classification and Survey
cr. 3 Prof. Bryant

585 Soils and Land Use
cr. 2 Prof. Yahner

655 Soil Genesis and Classification
cr. 3 Prof. Franzmeier

Civil Engineering

503 Photogrammetry I
cr. 3 Prof. Mikhail

603 Photogrammetry II
cr. 3 Prof. Mikhail

604 Analytical Photogrammetry
cr. 3 Prof. Mikhail

Electrical Engineering

661 Image Processing
cr. 3 Prof. Kak

662 Introduction to Artificial Intelligence and Pattern Recognition
cr. 3 Prof. Fukunaga

Geosciences

514 Glacial Geology
cr. 3 Prof. Melhorn

523 Geomorphology
cr. 3 Prof. Melhorn

558 Geophysical Exploration for Engineers
cr. 3 Prof. Sexton

Graduate Training

Degree Candidates Funded by LARS Contracts

Adrien, P. M., M. S., Agronomy, R. A. Weismiller, thesis title not yet assigned.

Al-Mahawili, S., M. S., Agronomy, M. F. Baumgardner, "Spectral Separability of Salinized Soils in the Tigris-Euphrates Basin."

Bonsett, T., M. S., E. E., A. J. Koivo, non-thesis option.

Brooks, C. C., Ph.D., Agronomy, M. E. Bauer, thesis title not yet assigned.

Dean, M. E., M. S., Forestry, R. M. Hoffer, "Evaluation of Transformed Thematic Mapper Simulator Data for Forest Cover Mapping."

Dickman, K. J., M. S., C. S., C. Smith, non-thesis option.

Dolan, J. P., M. S., C. S., L. Kraemer, non-thesis option.

Gallo, K. P., Ph.D., Agronomy, C. S. T. Daughtry, thesis title not yet assigned.

Golick, J. P., Ph.D., C. S., D. Freeman, non-thesis option.

Grant, L., Ph.D., Agronomy, C. S. T. Daughtry, thesis title not yet assigned.

Greene, H. G., Ph.D., E. E., P. H. Swain, thesis title not yet assigned.

Hinzman, L. D., M. S., Agronomy, M. E. Bauer and S. A. Barber, "Influence of Nitrogen Fertilization and Leaf Rust on the Reflectance Characteristics of Winter Wheat Canopies."

Huang, K. Y., M. S. and Ph. D., E. E., P. E. Anuta, "Analytic Signal Representation in the Synthetic Seismogram of Bright Spots." (M. S. thesis title)

Kalayeh, H. A., Ph.D., E. E., D. A. Landgrebe, "Classification of Remotely Sensed Multispectral Image Data Using Multitype Information."

Knowlton, D. J., M. S., Forestry, R. M. Hoffer, "Evaluation of Radar Data for Forest Cover Mapping."

Kollenkark, J. C., Ph.D., Agronomy, C. S. T. Daughtry and T. L. Housley, "Influence of Solar Illumination Angle and Cultural Practices on the Reflectance Properties of Soybean Canopies."

Latty, R. S., M. S., Forestry, R. M. Hoffer and L. A. Bartolucci, "Computer Based Forest Cover Classification Using Multispectral Scanner Data of Different Multispectral Scanner Data of Different Spatial Resolutions."

L'Heureux, D. L., Ph.D., E. E., P. E. Anuta, thesis title not yet assigned.

Machado, C. A., Ph.D., C. S., D. Freeman, research at LARS not related to thesis.

Megivern, S., M. S., Geosciences, L. Bartolucci, non-thesis option.

Muasher, M. J., Ph.D., E. E., D. A. Landgrebe, "Design and Application of Multistage Classifiers for Earth Resources Data Analysis."

Nash, L. M., M. S., Agronomy, C. S. T. Daughtry, "Multispectral Reflectance Properties of Corn Canopies as Influenced by Cultural Practices and Soil Background."

Pavey, R. R., M. S., Geosciences, R. P. Mroczynski, research at LARS not related to thesis.

Plantenga, T., M. S., E. E., L. F. Silva, thesis title not yet assigned.

Pollara, V. J., M. S., Agronomy, C. S. T. Daughtry and D. A. Holt, "Assessing Crop Development Stage with Spectral Data."

Ranson, K. J., Ph.D., Agronomy, M. E. Bauer, thesis title not yet assigned.

Roth, S., M. S., E. E., L. F. Silva, non-thesis option.

Seubert, C. E., Ph.D., Agronomy, C. S. T. Daughtry and M. F. Baumgardner, "A Comparison of Three Levels of Aggregation of Available Soil Water Information for Use in a Large Area Crop Yield Prediction Model."

Smith, B. W., M. S., E. E., P. H. Swain, "A Multiprocessor Implementation of a Contextual Image Processing Algorithm."

Spence, B. L., M. S., C. E., L. A. Bartolucci, non-thesis option.

*Stabenfeldt, M., M. S., E. E., L. F. Silva, "Design and Construction of a Special Purpose Data Logger."

Tilton, J. C., Ph.D., E. E., P. H. Swain, "Incorporating Spatial Context Into Statistical Classification of Multidimensional Image Data."

Valenzuela, C. R., Ph.D., Agronomy, M. F. Baumgardner and R. A. Weismiller, thesis title not yet assigned.

Walburg, G., M. S., Agronomy, C. S. T. Daughtry and T. L. Housley, "Maize Canopy Reflectance as Influenced by Nitrogen Nutrition."

Ward, J. P., M. S., Agronomy, C. S. T. Daughtry, thesis title not yet assigned.

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*Degree granted in FY81

Other Graduate Students Advised by LARS Staff

Accame, G., M. S., Geosciences, L. A. Bartolucci, non-thesis option.

*Adams, G. B., M. S., Ph.D., E. E., H. J. Siegel, "Properties of the Augmented Data Network in an SIMD Environment."(M. S. degree title)

Batista, G. T., Ph.D., Agronomy, M. E. Bauer and M. F. Baumgardner, "Relationships Between Scene Characteristics and Landsat Classification Performance of Corn and Soybeans."

Cline, C., M. S., E. E., H. J. Siegel, thesis title not yet assigned.

Fleming, M. D., Ph.D., Forestry, R. M. Hoffer, thesis title not yet assigned.

Grosz, M., M. S., E. E., H. J. Siegel, thesis title not yet assigned.

Henning, T. A., M. S., C. E., R. M. Hoffer, non-thesis option.

Krizan, D., M. S., C. E., R. M. Hoffer, non-thesis option.

*Kuehn, J. T., M. S., Ph.D., E. E., H. J. Siegel, "Emulation of SIMD Machine Architectures." (M. S. degree title)

Lin, G. M., Ph.D., E. E., P. H. Swain, thesis title not yet assigned.

McMillen, R. J., Ph.D., E. E., H. J. Siegel, thesis title not yet assigned.

Mueller, P. T., Jr., Ph.D., E. E., H. J. Siegel, thesis title not yet assigned.

Overvig, A., M. S., E. E., H. J. Siegel, thesis title not yet assigned.

Pazar, S. E., M. S., Agronomy, R. A. Weismiller, thesis title not yet assigned.

Safranek, R. J., M. S., E. E., H. J. Siegel, thesis title not yet assigned.

Schnabel, M. M., M. S., C. E., R. M. Hoffer, non-thesis option.

Seed, E., M. S., E. E., H. J. Siegel, thesis title not yet assigned.

Tuomenoksa, D., Ph.D., E. E., H. J. Siegel, thesis title not yet assigned.

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*Degree granted in FY81

Publications, Presentations and Professional Activities

Journal Articles

Cipra, J.E., D.P. Franzmeier, M.E. Bauer, and R.K. Boyd. 1980. Comparison of multispectral measurements of nonvegetated soils using Landsat digital data and a spectroradiometer. Soil Sci. Soc. Am. J. 44:80-84. (LARS Tech. Rpt. 011880)

Daughtry, C.S.T., M.E. Bauer, D. Crecelius, and M.M. Hixson. 1980. Effects of management practices on reflectance of spring wheat canopies. Agron. J. 72:1055-1060. (LARS Tech. Rpt. 051580)

Ernst-Dottavio, C.L., R.P. Mroczynski, and R.A. Weismiller. 1980. Using aerial survey techniques to locate abandoned strip mine land. J. of Environ. Quality 9(4):606-610, October-December 1980. (LARS Tech. Rpt. 122080)

Ernst-Dottavio, C.L., R.M. Hoffer, and R.P. Mroczynski. 1981. Spectral characteristics of wetland habitats. Photogram. Eng. and Remote Sensing 47(2):223-227. (LARS Tech. Rpt. 021081)

Hixson, M.M., D.K. Scholz, N.H. Fuhs, and T. Akiyama. 1980. Evaluation of several schemes for classification of remotely sensed data. Photogram. Eng. and Remote Sensing 46:1547-1553. (LARS Tech. Rpt. 021881)

Hixson, M.M., B.J. Davis, and M.E. Bauer. 1981. Sampling Landsat classifications for crop area estimation. Photogram. Eng. and Remote Sensing. (In press)

Landgrebe, D.A. 1980. The development of a spectral-spatial classifier for earth observational data. Pattern Recognition 12:165-175. (LARS Tech. Rept. 072180)

Landgrebe, D.A., and P.H. Swain. 1981. Characterization and extraction of information in earth observational data. J. of Elec. and Electr. Eng., Australia, 1(2):108-116.

Richards, J.A., D.A. Landgrebe, and P.H. Swain. 1981. Pixel labeling by supervised probabilistic relaxation. IEEE Trans. Patt. Anal. and Mach. Intel., PAMI-3. (LARS Tech. Rpt. 030181)

Richards, J.A., D.A. Landgrebe, and P.H. Swain. 1981. On the accuracy of pixel relaxation labeling. IEEE Trans. Systems, Man, and Cyber. SMC-11:303-309. (LARS Tech. Rpt. 042081)

Siegel, H.J. 1980. The theory underlying the partitioning of permutation networks. IEEE Trans. on Computers C-29(9):791-801.

Siegel, H.J., and R.J. McMillen. 1981. Using the augmented data manipulator network in PASM. Computer 14(2):25-33.

Siegel, H.J. 1981. Interconnection networks for parallel and distributed processing: an overview. IEEE Trans. on Computers C-30(4):245-246.

Siegel, H.J., L.J. Siegel, F. Kemmerer, P.T. Mueller,Jr., H.W. Smalley,Jr., and S.D. Smith. 1981. PASM: a partitionable SIMD/MIMD system for image processing and pattern recognition. IEEE Trans. on Computers. (In press)

Siegel, H.J., and R.J. McMillen. 1981. The multistage cube: a versatile interconnection network. Computer. (In press)

Siegel, L.J., H.J. Siegel, and P.H. Swain. 1981. Performance measures for evaluating algorithms for SIMD machines. IEEE Trans. Software Eng. (In press)

Silva, L.F. 1981. Available soil moisture measurement utilizing an UHF technique. IEEE Trans. on Geos. and Remote Sensing. (In press)

Stoner, E.R., M.F. Baumgardner, R.A. Weismiller, L.L. Biehl, and B.F. Robinson. 1980. Extension of laboratory-measured soil spectra to field conditions. Soil Sci. of Am. J. 44(3):572-574, May-June 1980. (LARS Tech. Rpt. 052680)

Stoner, E.R., and M.F. Baumgardner. 1981. Characteristic variations in reflectance of surface soils. Soil Sci. Soc. Amer. J. 45:1161-1165.

Swain, P.H., J.C. Tilton, and S.B. Vardeman. 1981. Contextual classification of multispectral image data. Patt. Recog. (In press) (LARS Tech. Rpt. 011080)

Invited Lectures

Bartolucci, L.A. 1980. Remote sensing needs in Latin America. 1st meeting of SELPER (Sociedad de Especialistas Latinoamericanos en Percepcion Remota). Quito, Ecuador, November 1980.

Bartolucci, L.A. 1981. Digital processing of remote sensing satellite data for mineral exploration. University of Santiago, Santiago, Chile, May 1981.

Bartolucci, L.A. 1981. Physical basis of remote sensing. Annual meeting of the Chilean Soc. of Prof. Engineers, Santiago, Chile, May 1981.

Baumgardner, M.F. 1980. Interdisciplinary research in the agricultural applications of remote sensing technology. Michigan State University, East Lansing, MI, November 13-14, 1980.

Baumgardner, M.F. 1980. Inventorying and monitoring earth resources from space. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Baumgardner, M.F. 1980. Manning and implementing an interdisciplinary research program in a state university environment. Michigan State University, East Lansing, MI, November 13-14, 1980.

Baumgardner, M.F. 1981. Causes and effects of world hunger. World Hunger Event at Ferris State College, Big Rapids, MI, March 23-24, 1981.

Baumgardner, M.F. 1981. Geopolitical causes of world hunger. World Hunger Event at Ferris State College, Big Rapids, MI, March 23-24, 1981.

Baumgardner, M.F. 1981. Information systems for global food monitoring. World Hunger Event at Ferris State College, Big Rapids, MI, March 23-24, 1981.

Baumgardner, M.F. 1981. Inventorying resources for populations of the future. Geosciences Honors Banquet, Purdue University, West Lafayette, IN, March 29, 1981.

Baumgardner, M.F. 1981. Mapping and monitoring soils and crops from space. Marcell Research Conf., Farm Bureau Cooperative, Marcell, IN, June 14-17, 1981.

Baumgardner, M.F. 1981. Satellite analysis of global distribution of population and natural resources. Symp. on Food, Energy and Quality of Life, Carmel, IN, February 21, 1981.

Baumgardner, M.F. 1981. Science and technology: today and tomorrow. DePauw University Alumni College, Greencastle, IN, June 3-5, 1981.

Baumgardner, M.F. 1981. What is remote sensing and what is it good for? U.S. Corps of Engineers Managers Short Course, Purdue University, West Lafayette, IN, April 14, 1981.

Hinzman, L.D., M.E. Bauer, and C.S.T. Daughtry. 1980. Spectral reflectance for assessing nitrogen fertilization and foliar disease in winter wheat. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Hixson, M.M. 1980. The role of statistical sampling in satellite crop inventories. Colloquium at Dept. of Math. and Stat., Miami Univ., Oxford, OH, October 1980.

Hixson, M.M., and M.E. Bauer. 1980. Sampling Landsat classifications for crop area estimation. 8th Annual Math. and Stat., Miami Univ., Oxford, OH, October 1980.

Hixson, M.M. 1981. Participation in panel discussion on critical issues involved in classification accuracy assessment. 7th Intl. Symp. on Machine Processing of Remotely Sensed Data, Purdue University, W. Lafayette, IN, June 23-26, 1981.

Hoffer, R.M. 1980. Computer processing of satellite data for assessing agricultural, forest, and rangeland resources. 14th Intl. Cong. of the Intl. Soc. of Photogram., Hamburg, West Germany, July 25, 1980.

Hoffer, R.M. 1980. Mapping forest cover types using Landsat and topographic data. Conf. on Remote Sensing for Resource Management, Kansas City, MO, October 29, 1980.

Hoffer, R.M. 1980. Remote sensing applications in forestry and agriculture. Short Course on Remote Sensing for Land Managers, George Washington University, Washington, DC, October 16, 1980.

Hoffer, R.M. 1981. Agriculture and forestry applications of remote sensing. Remote Sensing Short Course, George Washington University, Washington, DC, April 1, 1981.

Hoffer, R.M. 1981. Application of machine processing techniques for monitoring earth resources. Remote Sensing Short Course, George Washington University, Washington, DC, April 2, 1981.

Hoffer, R.M. 1981. Computer-aided analysis techniques for monitoring earth resources. Remote Sensing Short Course, George Washington University, Washington, DC, March 13, 1981.

Hoffer, R.M. 1981. Environmental and hydrological studies. Short Course on Remote Sensing Fundamentals, West Lafayette, IN, March 27, 1981.

Hoffer, R.M. 1981. Multisensor analysis of forest cover in South Carolina. Natl. Forestry Applications Program Research Review, Houston, TX, January 7, 1981.

Hoffer, R.M. 1981. Obtaining reference data. Remote Sensing Short Course for Corps of Engineers Managers, West Lafayette, IN, May 7, 1981.

Hoffer, R.M. 1981. Obtaining research support from outside sources. Guest Lecturer in Forestry 555 Class, Purdue University, West Lafayette, IN, April 7, 1981.

Hoffer, R.M. 1981. Recent remote sensing projects in ecosystems. Remote Sensing Short Course for Corps of Engineers Managers, West Lafayette, IN, May 5, 1981.

Hoffer, R.M. 1981. Remote sensing for forest fire protection. Guest Lecturer in Forestry 353 Class, Purdue University, West Lafayette, IN, March 3, 1981.

Hoffer, R.M. 1981. Skills, needs and opportunities in remote sensing: a challenge to the educational community. Natl. Conf. of Remote Sensing Educators, Purdue University, West Lafayette, IN, May 19, 1981.

Hoffer, R.M. 1981. Spectral characteristics of earth surface features. Guest Lecturer in EE577 Course, Purdue University, West Lafayette, IN, March 17, 1981.

Hoffer, R.M. 1981. Spectral and spatial characteristics of simulated Thematic Mapper data for mapping forest cover. Simulated Thematic Mapper Workshop, Silver Spring, MD, February 23, 1981.

Hoffer, R.M., and M.D. Fleming. 1980. Mapping forest cover types using Landsat and topographic data. Poster Paper. Conf. on Remote Sensing for Resource Management, Kansas City, MO, October 28-30, 1980.

Kollenkark, J.C., V.C. Vanderbilt, and C.S.T. Daughtry. 1980. Variability of reflectance measurements due to row azimuth and solar illumination angle. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Kristof, S.J., and R.A. Weismiller. 1980. Reflectance characteristics of soil-vegetation complexes. Indiana Academy of Science Annual Meetings, Rensselaer, IN, October 1980.

Kristof, S.J., R.A. Weismiller, L.J. Lund, D. Frehrenbacker, and L.M. Kiefer. 1980. Interpretations of Landsat data to determine soil characteristics and variations in ground cover. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Landgrebe, D.A. 1980. Managing multidisciplinary teams in research. EMBRAPA Research Admin. Workshop, West Lafayette, IN, August 13, 1980.

Landgrebe, D.A. 1980. Some observations on information content of multispectral earth observational data. Seminar, General Electric Company, Space Systems Division, Valley Forge, PA, October 9, 1980.

Landgrebe, D.A. 1981. History and future of remote sensing technology. Conf. on Space Technology and Industrial Forest Management, Jacksonville, FL, May 7, 1981.

Landgrebe, D.A. 1981. Status and directions for analysis technology for land remote sensing. Invited feature paper. 1981 Intl. Geos. and Remote Sensing Symp., Washington, DC, June 8, 1981.

Lund, L.J., W.D. Harrison, M.E. Johnson, R.A. Weismiller, and S.J. Kristof. 1980. Utilization of Landsat data in mapping soils of the Big Desert Area, Idaho. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Lund, L.J., R.A. Weismiller, and S.J. Kristof. 1980. Application of digital analysis of Landsat MSS data to aid soil survey. Symp. on Remote Sensing for Resources Mgmt., Kansas City, MO, October 28-30, 1980.

Mroczynski, R.P., and J.S. Buis. 1981. Waterfowl habitat inventory: a conservation management application of aerospace technology. Poster paper. 36th Annual Meeting of Soil Conservation Soc. of Am., Spokane, WA, August 2-5, 1981.

Mroczynski, R.P., and R.A. Weismiller. 1980. Aerial photography: a tool for strip mine reclamation. Symp. on Remote Sensing for Resources Mgmt., Kansas City, MO, October 28-30, 1980.

Nash, L.M., M.E. Bauer, and C.S.T. Daughtry. 1980. Effects of cultural practices of the spectral reflectance of maize canopies. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Pollara, V.J., and C.S.T. Daughtry. 1980. Variability of reflectance measurements with sensor altitude and canopy type. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30 - December 5, 1980.

Siegel, H.J. 1980. Can 1,000 processors do it 1,000 times faster? Local Student Chapter of the IEEE Comp. Soc., Univ. of Missouri, Rolla, MO, November 13, 1980.

Siegel, H.J. 1980. Distributed design issues. IEEE Comp. Soc. 4th Intl. Comp. Software and Applications Conf., Chicago, IL, October 1980.

Siegel, H.J. 1981. Architecture Tutorial Workshop on Applications of Non-Conventional Comp. in Image Processing: Algorithms and Programs, Madison, WI, May 27, 1981.

Siegel, H.J. 1981. Can 1,000 processors do it 1,000 times faster? Local Chapter of IEEE Comp. Soc., Rochester, NY, February 12, 1981.

Siegel, H.J. 1981. PASM: a multimicroprocessor system for image processing. Comp. Science Dept. Seminar and meeting of the Local Student Section of IEEE Comp. Soc., State Univ. of New York at Buffalo, Buffalo, NY, February 11, 1981.

Siegel, H.J. 1981. PASM: a multimicroprocessor system for image processing. Elec. and Comp. Eng. Dept. Seminar, Univ. of Mich., Ann Arbor, MI, April 17, 1981.

Siegel, H.J. 1981. Why parallel algorithms? Workshop on Applications of Non-Conventional Comp. in Image Processing: Algorithms and Programs, Madison, WI, May 27, 1981.

Siegel, H.J., P.H. Swain, and B.W. Smith. 1981. Remote sensing on PASM and CDC flexible processors. Workshop on Applications of Non-Conventional Comp. in Image Processing: Algorithms and Programs, Madison, WI, May 27, 1981.

Siegel, L.J., H.J. Siegel, and P.H. Swain. 1981. Performance measures for evaluating parallel algorithms. Workshop on Applications of Non-Conventional Comp. in Image Processing: Algorithms and Programs, Madison, WI, May 27, 1981.

Swain, P.H. 1981. Applications of remote sensing in the United States: present and future trends. Venezuela Inst. for Scientific Research, Caracas, Venezuela, May 27, 1981.

Swain, P.H. 1981. Classification of multispectral image data. Short Course on Digital Image Processing of Earth Observation Sensor Data, George Washington Univ., Washington, DC, April 6-10, 1981.

Swain, P.H. 1981. Contextual classification and image registration. Short Course on Remote Sensing Image Processing, IBM Scientific Center, Mexico City, Mex., March 16-20, 1981.

Walburg, G., M.E. Bauer, and C.S.T. Daughtry. 1980. Spectral information for discriminating nitrogen treatment levels in maize canopies. Am. Soc. of Agron. Annual Meetings, Detroit, MI, November 30-December 5, 1980.

Weismiller, R.A. 1980. Remote sensing in agriculture. Agricultural Lectures, Vincennes Univ., Vincennes, IN, April 17, 1980.

Weismiller, R.A. 1980. What is remote sensing? Agricultural Lectures, Vincennes Univ., Vincennes, IN, November 19, 1980.

Technical Reports

020179. Computer-aided analysis techniques for mapping earth surface features. R.M. Hoffer. Chapter 11 in Remote Sensing Application in Agriculture and Hydrology, pp. 133-152, G. Fraysse (ed), A.A. Balkema, Rotterdam, The Netherlands.

020279. Computer-aided analysis of satellite and aircraft MSS data for mapping snow-cover and water resources. R.M. Hoffer. Chapter 24 in Remote Sensing Application in Agriculture and Hydrology, pp. 373-388, G. Fraysse (ed), A.A. Balkema, Rotterdam, The Netherlands.

011080. Contextual classification of multispectral image data. P.H. Swain, J.C. Tilton, and S.B. Vardeman. In Pattern Recognition 13(6):429-441.

011880. Comparison of multispectral measurements of nonvegetated soils using Landsat digital data and a spectroradiometer. J.E. Cipra, D.P. Franzmeier, M.E. Bauer, and R.K. Boyd. In Soil Sci. Soc. Am. J. 44:80-84.

051580. Effects of management practices on reflectance of spring wheat canopies. C.S.T. Daughtry, M.E. Bauer, D. Crecelius, and M.M. Hixson. In Agron. J. 72:1055-1060.

052680. Extension of laboratory-measured soil spectra to field conditions. E.R. Stoner, M.F. Baumgardner, R.A. Weismiller, L.L. Biehl, and B.F. Robinson. In Soil. Sci. of Am. J. 44(3)572-574.

060280. Application of multispectral reflectance statistics of soils: pre-Landsat. S.J. Kristof, M.F. Baumgardner, R.A. Weismiller, and S.M. Davis. In Proc. 6th Symp. on Mach. Proc. of Remotely Sensed Data, pp. 52-61, Purdue University, West Lafayette, IN, June 3-6, 1980.

060380. Parallel processing implementations of a contextual classifier for multispectral remote sensing data. H.J. Siegel, P.H. Swain, and B.W. Smith. In Proc. 6th Symp. on Mach. Proc. of Remotely Sensed Data, pp. 19-28, Purdue University, West Lafayette, IN, June 3-6, 1980.

060480. An assessment of Landsat data acquisition history on identification and area estimation of corn and soybeans. M.M. Hixson, M.E. Bauer, and D.K. Scholz. In Proc. 6th Symp. on Mach. Proc. of Remotely Sensed Data, pp. 72-77, Purdue University, West Lafayette, IN, June 3-6, 1980.

060580. A model of plant canopy polarization response. V.C. Vanderbilt. In Proc. 6th Symp. on Mach. Proc. of Remotely Sensed Data, pp. 98-108, Purdue University, West Lafayette, IN, June 3-6, 1980.

060880. Procedure 1 and forestland classification using Landsat data. R.F. Nelson, and R.M. Hoffer. In Proc. 6th Symp. on Mach. Proc. of Remotely Sensed Data, pp. 319-325, Purdue University, West Lafayette, IN, June 3-6, 1980.

070180. A multiprocessor implementation of a contextual image processing algorithm. B.W. Smith, H.J. Siegel, and P.H. Swain. (Thesis)

070980. A multispectral data simulation technique. M.J. Muasher, and P.H. Swain.

071380. Spectral properties of agricultural crops and soils measured from space, aerial, field and laboratory sensors. M.E. Bauer, V.C. Vanderbilt, B.F. Robinson, and C.S.T. Daughtry. In Archives of Intl. Soc. of Photogram. Congress, Vol. XXIII, pp. 56-73, Hamburg, West Germany, July 13-25, 1980.

071480. A multiband radiometer and data acquisition system for remote sensing field research. B.F. Robinson, M.E. Bauer, D.P. DeWitt, L.F. Silva, and V.C. Vanderbilt. In Archives of Intl. Soc. of Photogram. Congress, Vol. XXIII, pp. 783-793, Hamburg, West Germany, July 13-25, 1980.

071580. Simulated response of a multispectral scanner over wheat as a function of wavelength and view/illumination directions. V.C. Vanderbilt, B.F. Robinson, L.L. Biehl, M.E. Bauer, and A.S. Vanderbilt. In Archives of Intl. Soc. of Photogram. Congress, Vol. XXIII, pp. 942-952, Hamburg, West Germany, July 13-25, 1980.

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081580. Contextual classification of multispectral image data: approximate algorithm. J.C. Tilton.

082680. Exploration for porphyry copper deposits through multivariate analysis of computer-registered Landsat and geophysical data sets. D.M. L'Heureux, D.W. Levandowski, and P.E. Anuta.

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083080. Quarterly Report for June 1, 1980 - August 31, 1980. R.M. Hoffer, R.S. Latty, M.E. Dean, and D.J. Knowlton. Evaluation of SLAR and Thematic Mapper MSS data for forest cover mapping using computer-aided analysis techniques. Contract No. NAS9-15889.

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Siegel, L.J., H.J. Siegel, and A.E. Feather. 1981. Parallel image correlation. In Proc. 1981 Intl. Conf. on Parallel Processing, Bellaire, MI, August 1981.

Smith, B.W., H.J. Siegel, and P.H. Swain. 1981. Contextual classification on a CDC flexible processor. In Proc. 7th Intl. Symp. on Mach. Proc. of Remotely Sensed Data, pp. 283-290, West Lafayette, IN, June 1981.

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Swain, P.H., V.C. Vanderbilt, and C.D. Jobusch. 1981. A quantitative applications-oriented evaluation of Thematic Mapper design specifications. In Proc. 1981 Intl. Geoscience and Remote Sensing Symp., Washington, DC, June 8-10, 1981.

Tilton, J.C., P.H. Swain, and S.B. Vardeman. 1981. Contextual classification of multispectral image data: an unbiased estimator for the context distribution. In Proc. 7th Intl. Symp. on Mach. Proc. of Remotely Sensed Data, pp. 304-313, West Lafayette, IN, June 1981.

Vanderbilt, V.C., B.F. Robinson, L.L. Biehl, M.E. Bauer, and A.S. Vanderbilt. 1980. Simulated response of a multispectral scanner over wheat as a function of wavelength and view/illumination directions. In Archives of Intl. Soc. of Photogram. Cong., Vol. XXIII, pp. 942-952, Hamburg, West Germany, July 13-25, 1980. (LARS Tech. Rpt. 071580)

Vanderbilt, V.C., and R.W. Kilgore. 1981. Application of computer axial tomography (CAT) to measuring crop geometery. In Proc. 1981 Geos. and Remote Sensing Symp., Washington, DC, June 8-10, 1981. (LARS Tech. Rpt. 060881)

Special Professional Activities

Anuta, P.E. Consultant to ARCO Oil & Gas Co. on remote sensing system planning.

Bartolucci, L.A. Chairman, 1st meeting of SELPER (Society of Latin American Remote Sensing Professionals), Quito, Ecuador, November 1980.

Bauer, M.E. 1980-81. Member steering group for defining and planning a long term, NASA-sponsored, basic research program in Scene Radiation and Atmospheric Effects Characterization.

Bauer, M.E. Editor-in-Chief, Remote Sensing of Environment Journal.

Bauer, M.E. Member, planning committee for International Colloquium on Spectral Signatures of Objects in Remote Sensing, to be held September 8-10, 1981 at Avignon, France. Sponsored by International Society of Photogrammetry, Remote Sensing Commission.

Bauer, M.E., B.F. Robinson and L.L. Biehl. Conducted workshop on Remote Sensing Field Measurements at CORSE-81 Conference, May 22, 1981, Purdue University.

Baumgardner, M.F. Vice Chairman, International Working Group on Remote Sensing, Commission on Soil Classification and Survey, International Society of Soil Science, 1978-81.

Baumgardner, M.F. Member, Advisory Editorial Board, International Journal of Remote Sensing, Remote Sensing Society and Taylor and Francis, Ltd., London.

Baumgardner, M.F. Member, Editorial Board, Book Series on Remote Sensing of Earth Resources and Environment, Martinus Nijhoff Publishers, The Hague.

Baumgardner, M.F. Chairman, Soils Panel, American Association for the Advancement of Science, 1981-82.

Daughtry, C.S.T. 1980-82. Vice Chairman of Publications Review Board, Remote Sensing Applications Division, American Society of Photogrammetry.

Daughtry, C.S.T. 1981-82. Chairman, Plant Science Committee, Remote Sensing Applications Division, American Society of Photogrammetry.

Davis, S.M. 1981. Co-Chairman of 1981 Conference on Remote Sensing Education, Purdue University.

Hoffer, R.M. President, Western Great Lakes Region, American Society of Photogrammetry (through November, 1980).

Hoffer, R.M. Chairman, National Long Range Planning Committee, American Society of Photogrammetry (March 1980 - present).

Hoffer, R.M. Member, Executive Committee of the Board of Directors, Western Great Lakes Region, American Society of Photogrammetry (November 1978 - present).

Hoffer, R.M. Consultant, FAO for two weeks in Brazil during November-December 1980.

Hoffer, R.M. Member, Planning Committee for the National Conference of Remote Sensing Educators.

Hoffer, R.M. Co-Chairman, Seventh International Symposium on Machine Processing of Remotely Sensed Data, held at Purdue University, June 23-26, 1981.

Hoffer, R.M. Recipient, Ford-Bartlett Award, American Society of Photogrammetry, March 1981.

Landgrebe, D.A. Member, Administrative Committee of the IEEE Geoscience and Remote Sensing Society.

Landgrebe, D.A. Member, National Academy of Sciences, Space Science Board Committee on Data Management and Computation.

Landgrebe, D.A. Treasurer, Central Indiana Section of the IEEE, 1980-81.

Landgrebe, D.A. Secretary, Central Indiana Section of the IEEE, 1981-82.

Phillips, T.L. Vice President, Sagamore Chapter of Data Processing Management Association.

Silva, L.F. Associate Executive Editor, IEEE Transactions on Geosciences and Remote Sensing.

Silva, L.F. Lecturer, Corps of Engineers Intensive Short Courses on Remote Sensing, April and May 1981.

Silva, L.F. Consultant to Sperry Microwave Electronics Corp., Clearwater, Fl., on "Infrared Modeling of Battlefield Targets".

Swain, P.H. Secretary/Treasurer, Central Indiana Chapter, IEEE Computer Society, 1980-81.

Swain, P.H. Member, Working Group for Design of Basic Research Plan in Pattern Recognition and Image Analysis, National Aeronautics and Space Administration (NASA), 1979 - present.

Swain, P.H. Member, Committee on Image Processing, Digital and Photogrammetric Processing Division, American Society of Photogrammetry.

Weismiller, R.A. Member, ECOP Agriculture, Forestry and Related Industries Subcommittee Task Force on Cooperative Extension Services Involvement in Remote Sensing Programs. 1978-80.

Weismiller, R.A. Member, Committee-1, Soil Survey, North Central Regional Technical Work-Planning Conference, Soil Conservation Service. 1979-present.

Weismiller, R.A. School of Agriculture, 208 Non-Point Pollution Committee. 1978-present.

Appendix I—Staff

Professorial Staff

School of Agriculture

M. F. Baumgardner - Professor of Agronomy and Associate Director of LARS

R. M. Hoffer - Professor of Forestry and LARS Program Leader

S. E. Hollinger - Post Doctoral Research Associate

D. A. Holt - Professor of Agronomy

J. C. Kollenkark - Post Doctoral Research Associate

W. L. Miller - Professor of Agricultural Economics

J. B. Peterson - Professor of Agronomy (Emeritus appointment), Associate Director Emeritus, and Senior Scientist

H. F. Reetz, Jr. - Assistant Professor of Agronomy

School of Engineering

D. P. DeWitt - Associate Professor of Mechanical Engineering

D. A. Landgrebe - Professor of Electrical Engineering

C. S. Lin - Post Doctoral Research Associate

J. C. Lindenlaub - Professor of Electrical Engineering and Senior Scientist

C. D. McGillem - Professor of Electrical Engineering

E. M. Mikhail - Professor of Civil Engineering

C. A. Pomalaza - Post Doctoral Research Associate

H. J. Siegel - Assistant Professor of Electrical Engineering

L. F. Silva - Professor of Electrical Engineering and LARS Program Leader

P. H. Swain - Associate Professor of Electrical Engineering and LARS Program Leader

School of Science

V. L. Anderson - Professor of Statistics

D. W. Levandowski - Professor of Geosciences

K. S. Pillai - Professor of Statistics

J. T. Snow - Assistant Professor of Geosciences

S. B. Vardeman - Assistant Professor of Statistics

Professional Staff

School of Agriculture

*L. A. Bartolucci - LARS Program Leader

M. E. Bauer - Research Agronomist and LARS Program Leader

C. S. T. Daughtry - Research Agronomist

S. J. Kristof - Research Agronomist (Research Consultant)

R. P. Mroczynski - LARS Associate Program Leader

R. A. Weismiller - Research Agronomist and LARS Program Leader

School of Engineering

R. M. Aiken - Applications Programmer

P. E. Anuta - Research Engineer and LARS Associate Program Leader

L. L. Biehl - Project Manager/Engineer

G. M. Brammer - Senior Computer Analyst

J. S. Buis - Systems Training Specialist

R. Chung - Systems Analyst IV

J. C. Cochran - Systems Analyst I

M. D. Collins - Computer Operations Supervisor

S. M. Davis - Senior Education and Training Specialist

S. L. Ferringer - Visual Designer

B. J. Pratt Francis - System Services Coordinator

D. M. Freeman - Manager of Data Reformatting

N. C. Fuhs - Applications Programmer/Data Analyst

R. A. Garmoe - Manager of Computer Systems

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*Joint appointment with School of Science

M. C. Hodge - Administrative Assistant

S. K. Hunt - System Analyst III

P. L. Jobusch - Senior Computer Analyst

P. K. Johnson - Business Office Administrative Assistant

J. L. Kast - Manager of User Services

B. C. Kozlowski - Systems Analyst III

L. A. Kraemer - Systems Analyst III

C. N. Lue - Systems Analyst II

G. E. Majkowski - Systems Analyst II

R. L. Pan - Software Analyst

D. E. Parks - Publications Coordinator

T. L. Phillips - Deputy Director of LARS

M. E. Pierson - Applications Programmer

B. F. Robinson - Research Engineer and LARS Associate Program Leader

S. K. Schwingendorf - Systems Analyst II

C. R. Smith - Systems Analyst I

D. L. Snyder - Applications Programmer I

V. C. Vanderbilt - Research Engineer

J. C. Welch - Systems Engineer I

T. D. Wilson - Software Analyst

School of Humanities, Social Sciences, and Education

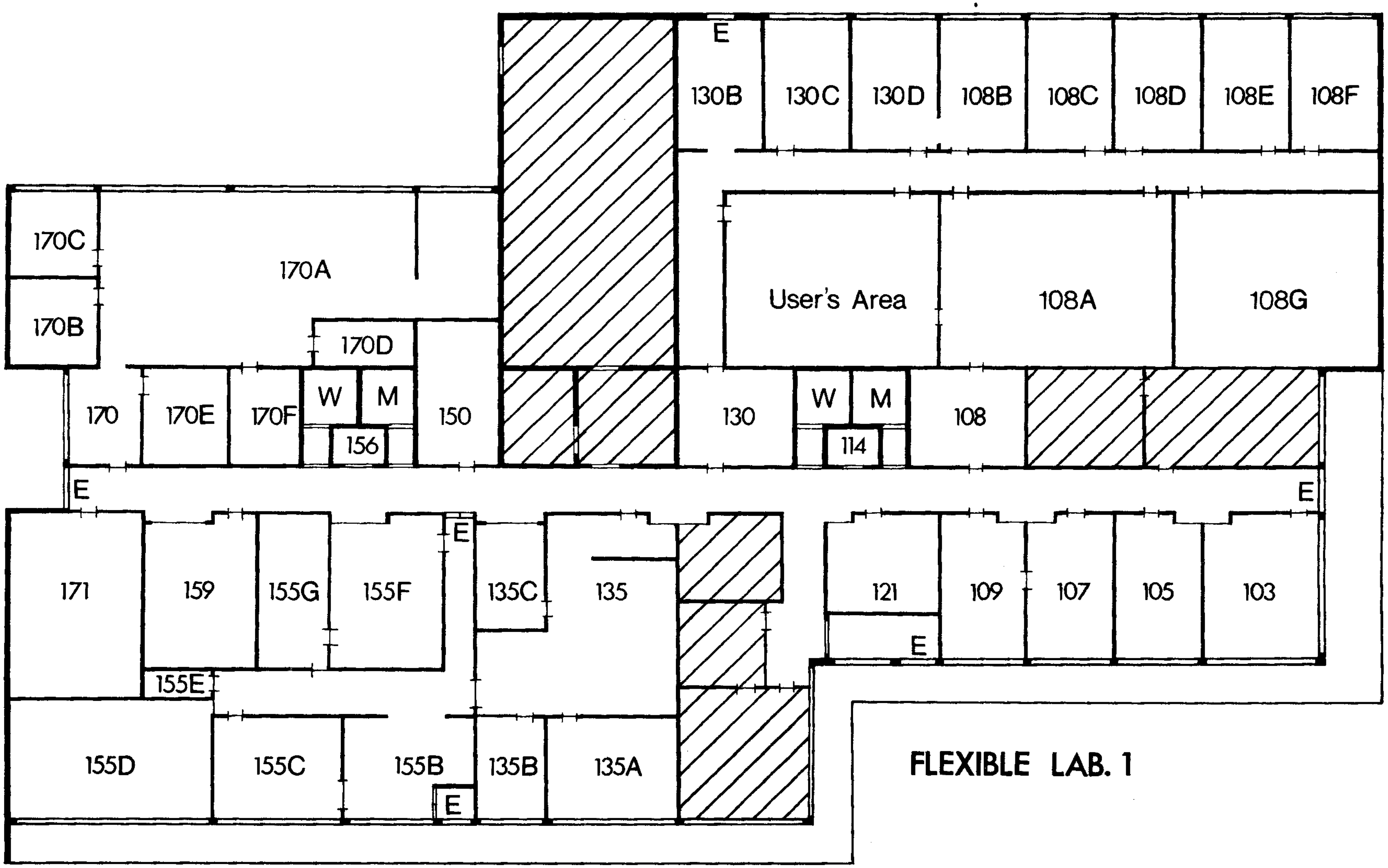
D. B. Morrison - Education and Training Coordinator

School of Science

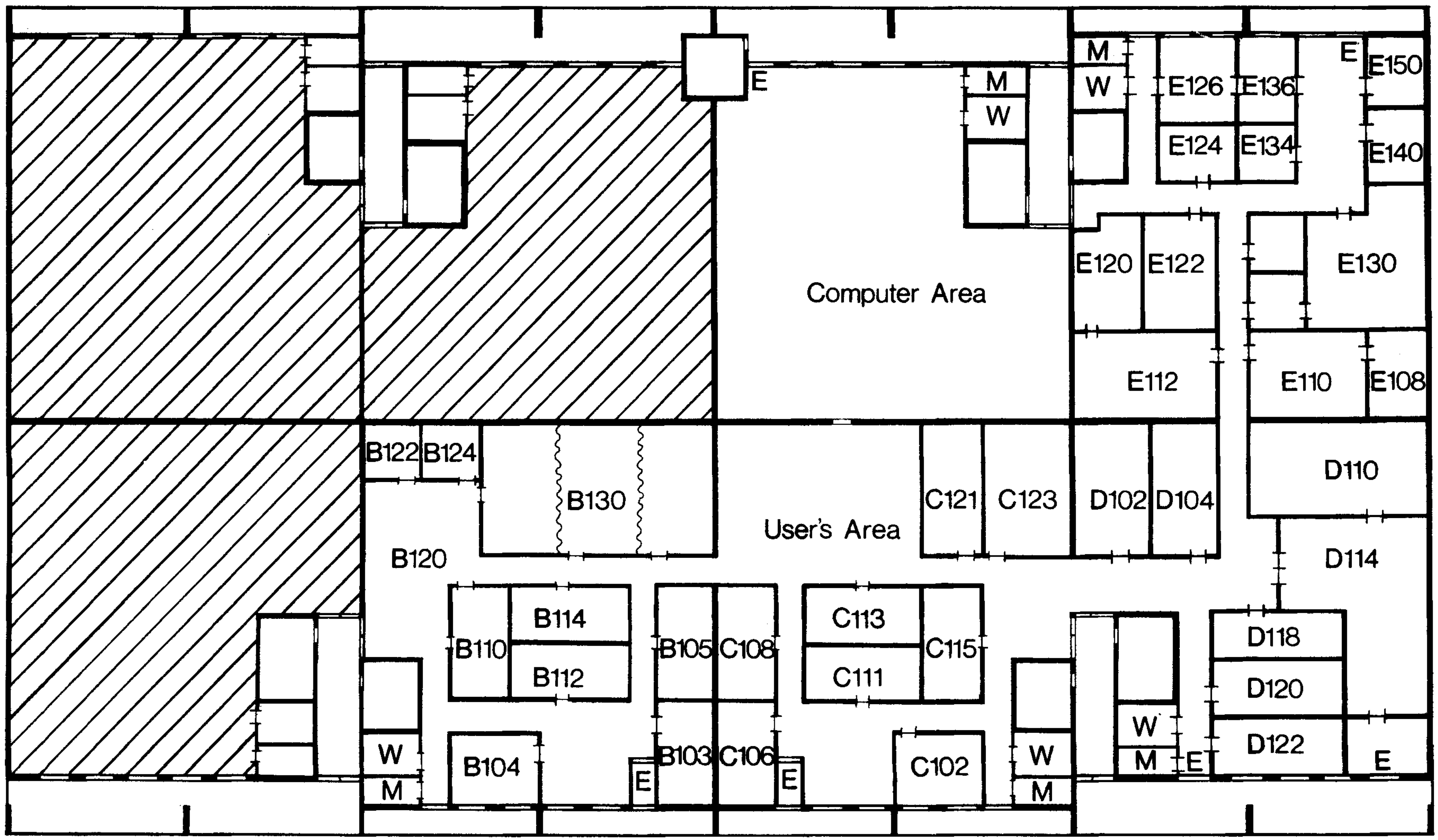
M. M. Hixson - Research Statistician

C. D. Jobusch - Data Analyst

Appendix II—Floor Plans



FLEXIBLE LAB. 1



FLEXIBLE LAB. 2