80-10330
CR-163416

Applied Remote Sensing Program (ARSP)

1979–1980 Annual Report

(E80-10330) APPLIED REMOTE SENSING PROGRAM (ARSP) Annual Report, 1979 - 1980 (Arizona Univ., Tucson.) 87 p HC A05/MF A01 CSCL 08B N80-32821

Unclas
G3/43 00330

An Annual Report of Work Performed Under
NASA Grant No. NGL03-002-313

OFFICE OF ARID LANDS STUDIES
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA
JULY, 1980

APPLIED REMOTE SENSING PROGRAM (ARSP)
1979-1980 ANNUAL REPORT

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An Annual Report of Work Performed
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Office of Arid Lands Studies
University of Arizona
Tucson, Arizona
July 1980

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INTRODUCTION

The University of Arizona Applied Remote Sensing Program (ARSP) of the Office of Arid Lands Studies (OALS) has participated with the National Aeronautics and Space Administration (NASA) in promoting the use of NASA remote sensing technology and data in the state of Arizona since 1972. The objective of ARSP is to foster the use of remote sensing techniques in solving policy and management problems at the local, state, national and international levels. Toward this end ARSP has completed 37 major projects in the past eight years (see Appendix B) and seven have been initiated this year (see Figure 1).

ARSP works in three broad areas of activity to achieve its objective. The first is planning and executing cooperative projects with local, state or federal agencies. In cooperative projects, ARSP applies remote sensing techniques to specific problems in response to agency requests. For example, ARSP is now demonstrating the use of Landsat data to identify irrigated lands in the state of Arizona for the newly created Department of Water Resources (see Chapter 1). The data generated will be used to allocate water resources. ARSP is also working with the Division of Forestry of the State Lands Department to inventory desert hardwoods and riparian tree species. It is using Landsat and aerial photography as part of a mesquite management effort (see Chapter 2).

Cooperative project activities effectively foster the use of remote sensing because projects allow potential users to judge for themselves the efficiency of the technology in solving their specific problems. Projects also allow them to acquire some experience and confidence in using the technology.

The role of remote sensing technology is growing rapidly in Arizona as state agencies seek non-traditional solutions to problems of inventory and monitoring. State agencies are responsible for regulating water resources and generating revenues from state lands. So, pressed by the limitations of time and the need for detailed inventories, these agencies are turning to remote sensing solutions. Thus, cooperative projects with state agencies should increase in the short term while other ARSP activities should increase in the long term.

The second major area of ARSP activity is education or training. The University of Arizona offers comprehensive formal programs in remote sensing. These are overseen by the university-wide Remote Sensing Committee (see Chapter 16). Three ARSP staff members serve on the Committee, and two teach courses at the undergraduate and graduate levels. ARSP also provides application-oriented consultation, workshops, short courses and seminars in addition to formal courses. The ARSP staff also offers

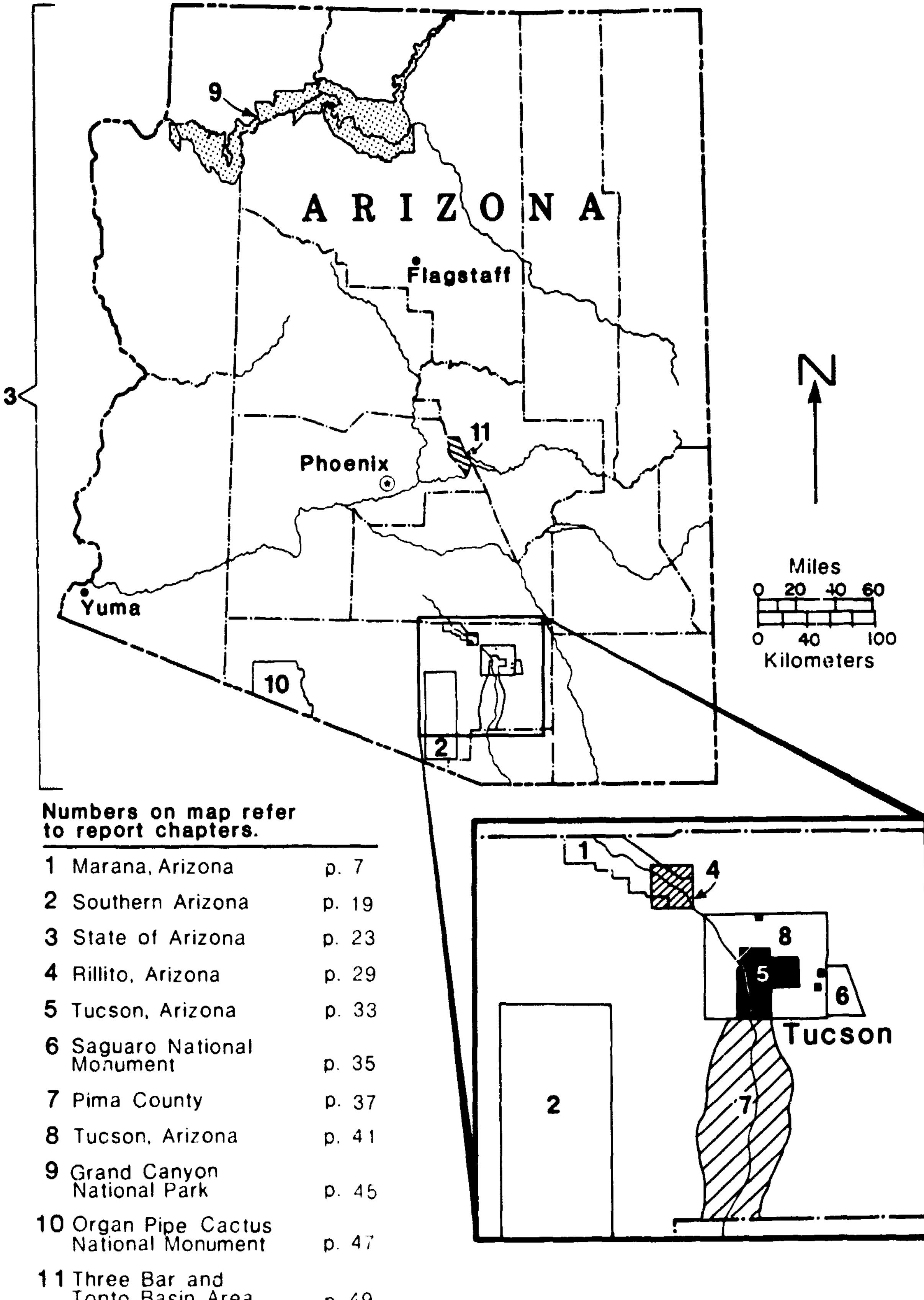


Figure 1. PROJECT LOCATIONS CONTRACT YEAR 1979-1980.

expertise that can be accessed by the community at large. Advice is given to agencies, individuals, or corporations who either work in the state of Arizona or who need general technical expertise.

However, the largest share of ARSP's educational activities is directed toward special training. ARSP has recently completed a series of workshops in Albuquerque, New Mexico; Corpus Christi, Texas; and Washington, D.C. (see Chapter 12). The courses offered by ARSP are tailored to the needs of resource managers, and the regions they work in. The training is comprehensive as well as specific. ARSP workshops reach out to large numbers of potential users who later share their experience and training with co-workers. The importance of special training in Arizona is expected to increase as state agencies increase their operational capabilities.

Research is the third area. Research activity serves two distinct functions. One is to find solutions to specific user problems. These arise during cooperative projects or in the routine use of remote sensing by agencies with operational capabilities. Often the techniques available do not meet the needs of users. For example, the objective of the demonstration for the Department of Water Resources is to determine the irrigated acreage within a study area. However, the number derived with digital techniques is total vegetated pixels rather than total irrigated acreage because of uneven field response. So ARSP is developing a method to tally total irrigated acreage rather than pixels alone, thus satisfying the needs of the agency.

The second function of the research activity is to maintain state-of-the-art capability within ARSP. Remote sensing technology advances at a quick pace. ARSP must participate in that advance to keep abreast. Thus, ARSP staff are encouraged to engage in research whether part of a larger effort or the result of individual endeavor. In the past, ARSP research has focused on a diverse set of topics ranging from the problems of merging data sets of differing resolutions to devising techniques for improving Landsat classification (see Chapter 18).

Considerable effort will be directed toward establishing a geographic information system (GIS) capability within ARSP in the coming year. To that end, ARSP has recently acquired the Spatial Information Processing System (SIPS) from the University of California, Riverside (see Appendix A). The hardware required to support in-house digitization and cursory geographic data manipulation will be acquired in the coming year. This new thrust will enhance ARSP capabilities in the following ways: (1) graphic output of digital image processing, (2) manipulation of large map-based data sets generated by more traditional activities, (3) and capability of merging these two sources of information.

Section I

New Activities

CHAPTER 1. LANDSAT APPLICATIONS TO WATER MANAGEMENT, MARANA, ARIZONA

Introduction

The use and allocation of scarce water supplies are immediate concerns in Arizona. The state's 10-year water plan will be updated in the coming year. And debate over future allocations of water between the urban and agricultural sectors will be considered then. However, the signing on June 12, 1980, of a bill which created a Department of Water Resources to regulate the pumpage of groundwater has overshadowed other water issues in the state. At present, 52 % of the water used in Arizona is groundwater; only 6 % is recharged annually. The Central Arizona Project, which will bring Colorado River water to heavily populated regions of the state, is intended to offset the imbalance between groundwater withdrawals and natural recharge.

The single largest user of water in Arizona is agriculture. It accounts for 89 % of all water used. Future allocations of water in the agricultural sector will be based on past water usage. It is proposed that a flat allocation be made to each farmer based on the maximum number of acres irrigated at one time in the past five years. Thus, the accuracy of the estimate of irrigated acreages over the last five years plus the ability to monitor water use in the future, is of considerable importance. However, reliable irrigation data for the entire state are not available.

In January 1980, the State Water Commission (now the Department of Water Resources) requested that ARSP evaluate the use of Landsat data in delineating irrigated acreage and identifying crop types and that if possible both be summarized by water conservation district. ARSP agreed to evaluate an area near Tucson and suggested that the accuracy and cost of manual and digital techniques be compared. The Water Commission also requested that the Western Regional Applications Program (WRAP), NASA Ames Research Center, similarly evaluate Landsat in an area near Phoenix. ARSP and WRAP have cooperated and ARSP has participated in a workshop for the Water Commission held at the WRAP facility at Ames.

Impact

The Arizona Department of Water Resource (DWR) must determine the maximum number of acres irrigated by each farmer in the past five years in order to allocate future water supplies. DWR must also monitor the amount of acreage irrigated yearly to determine future compliance with water regulations. To do so, DWR will develop operational capabilities in the use of Landsat data. Landsat data, unlike historical data, are unequivocal regarding cropped land. Landsat also provides a convenient and efficient method of monitoring water and land use in the future. ARSP is demonstrating systems that DWR is likely to use. And it will participate in the selection, design and implementation of the system that DWR ultimately acquires. It will also train their personnel. All future water allocations in the State of Arizona will be based on information derived from this system.

Methodology

The first objective of the project was to demonstrate the use of Landsat in identifying irrigated agriculture in Arizona. The second objective was to identify crop type within the irrigated acreage. The accuracy and cost of both digital and manual techniques were to be compared for the Marana-Cortaro Water Conservation District near Tucson.

Digital and photographic Landsat data from the year 1974 were acquired for four dates from the EROS Data Center (Table 1; Figure 2). 1974 offered a good selection of cloud-free images of good quality. The selected scenes are evenly spaced throughout the year to permit analysis of multiple cropping, a common practice in Arizona. Records of irrigated acreage and crop types of the water conservation district are available by field. These were acquired from the Agricultural Extension Service, University of Arizona.

The methods of digital and photographic data analysis are described below.

Digital Processing

Introduction. Digital image processing has several advantages over photointerpretation in the mapping of irrigated lands. They are as follows:

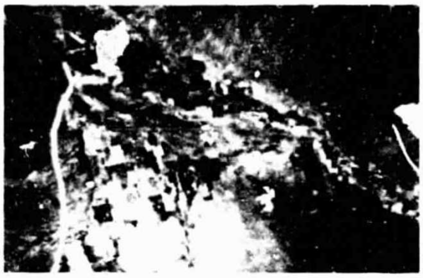
1) quantitative description of vegetation response,
2) potential for more accurate area calculations,
3) easy assimilation of multispetral data.

One drawback to the digital approach is the difficulty in estimating irrigated acreages on a field count basis, i.e., the identification of unevenly vegetated fields as fully irrigated is not possible with simple procedures.

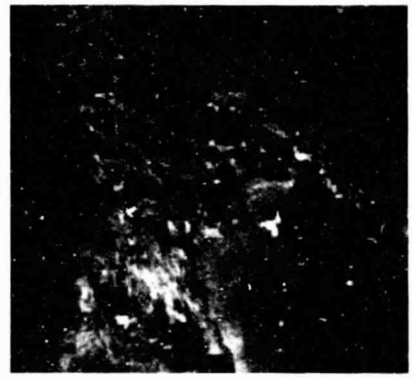
TABLE 1

LANDSAT SCENES FOR IRRIGATED LAND INVENTORY

Scene ID	Date	Solar Elevation	Solar Azimuth
5711-7284	2/14/74	34°	140°
6611-7261	5/15/74	60°	111°
7691-7231	8/31/74	52°	123°
8591-7201	11/29/74	28°	149°

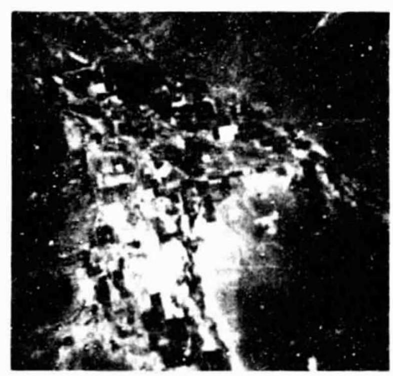


February 14, 1974



May 15, 1974

August 31, 1974



November 29, 1974

Figure 2. LANDSAT BAND 5 (RED) IMAGES FROM EACH OF THE DATES USED IN THE ANALYSIS.

Computer compatible tapes (CCTs) for the four dates were preprocessed using a program developed at the University. The preprocessing consists of geometric corrections for MSS distortions, destriping (removal of detector response variations), and reformatting. The resulting data consist of 80 - by - 80 - meter pixels.

Registration. The first step in the digital analysis was registering the four scenes. The study area of about 500 -by -500 pixels was extracted from each CCT and displayed on the color cathode ray tube (CRT) in the Digital Image Analysis Laboratory (DIAL) at the University. Six ground control points were selected on the basis of their constancy throughout the year; i.e., they were not affected by any temporal changes. One date was chosen as a reference and a least-square polynomial fit was made between its control point coordinates and those of other dates.

Band 5 (red) from each of the four registered dates is shown in Figure 1. Note the right and bottom edges of the data are defined by the extent of the original Landsat data.

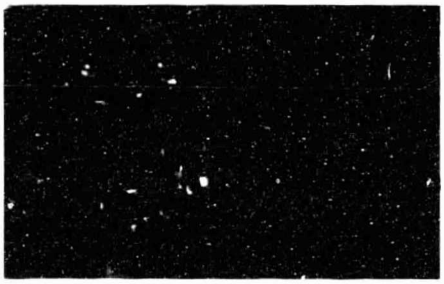
Multispectral Ratios. The ratio of near infrared to red spectral bands has been shown to correlate strongly with the vegetative biomass of an area. Several types of ratios have been used, one of the simplest being band 7/band 5. This ratio is shown for each of the four dates in Figure 3. Irrigated vegetation is enhanced relative to natural desert area.

Solar elevation differences (Table 1) are automatically normalized by ratio analysis and so do not affect subsequent analysis. Also, brightness variations due to topographic slope and aspect are removed, although this is of little consequence for flatland farming.

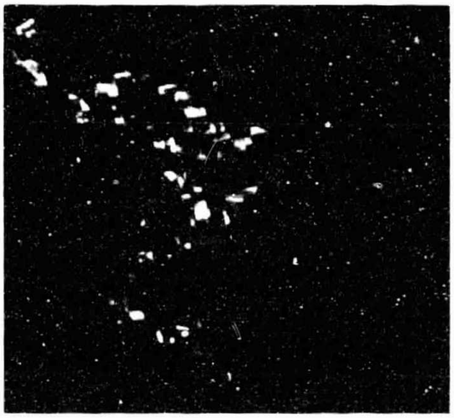
It is assumed that high vegetative response indicates irrigated farming. Thus, total acreage figures can be compiled by counting the pixels showing high vegetation response. The essential input of the analyst is the threshold or minimum ratio value to be used for inclusion of pixels in the vegetation tally. The project is currently in this phase.

Data Tabulation by Irrigation District. One of the requirements of the DWR is that statistics must be available on an irrigation district basis. So the Cortaro-Marana Water Conservation District boundary has been digitized and overlayed on the Landsat imagery using SIPS and SADIE (see Appendix A). Figure 4 illustrates the results. All statistics generated will be based on the data within the water conservation district.

SIPS and SADIE permit the specification of polygonal areas with different attributes in the same set of image data. Thus data within several water conservation districts or other units of aggregation may be analyzed simultaneously.



February 14, 1974



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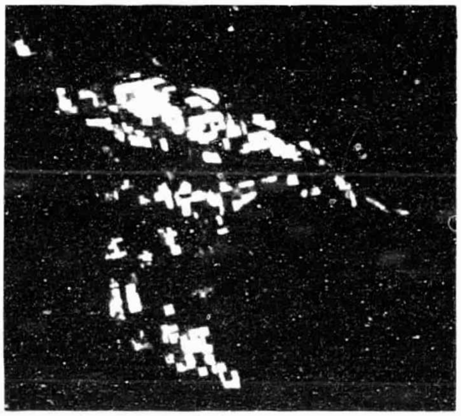

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Figure 3. LANDSAT RATIO IMAGES OF BAND 7 (INFRARED)/ BAND 5 (RED) FOR EACH DATE.

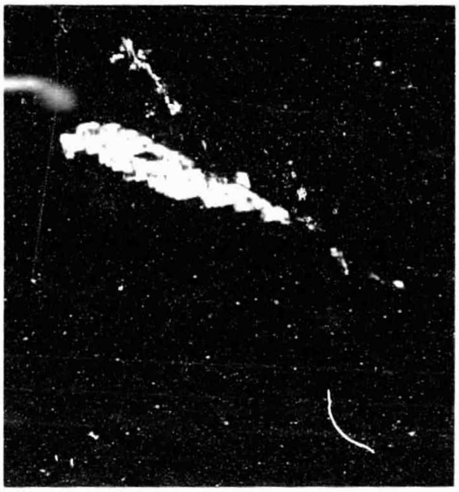

Figure 4. "WINDOW" OF THE CORTARO-MARANA
WATER CONSERVATION DISTRICT.

Multitemporal-Multispectral Classification. Water use may be estimated more accurately if crop types are known. However, multispectral data from a single date are insufficient to classify crop types because of different planting calendars for different crops, multiple cropping, and similarity of vegetation signatures. By contrast temporal series of images, with crop calendars, permits a more complete analysis.

Training sites are currently being defined for a supervised multitemporal-multispectral classification of the data described above. The most appropriate combination of spectral bands, ratios, and image dates are included.

Photographic Interpretation

Introduction. Photographic interpretation of Landsat products has several advantages over digital image processing in the mapping of irrigated lands. They are as follows:

1) economy, both in staff training requirements and in acquisition of equipment and materials;

2) better availability of Landsat data in a photographic format; and

3) tabulation of irrigated acreage on a field count basis.

One drawback to the manual approach is the subjective nature of field classification. Interpreters vary in their perception of color, skill and consistency.

Data Acquisition. False color composites were ordered from EROS Data Center for the four scenes. Again the four scenes are of the same area but were taken at four different times, hence, "scene date" data was masked, then copied as a conventional 35 mm color transparency and then projected onto the base map. Six classes of color response (red, pink, blue, violet, yellow, and white) were then mapped for each scenedate of the study area.

Base Map. A mapping base was drafted using three USGS 15-minute topographic maps that include portions of the Cortaro-Marana Water Conservation District (Figure 4). Field boundaries within this district were drafted from 1974 crop maps supplied by Agricultural Extension Service, University of Arizona. The acreage of each field was planimetered with a Numonics 1224 electronic digitizer and tabulated for total district area.

Irrigated Acreage Estimate. Each field was classified according to its spectral response class to estimate total irrigated acreage within the conservation district. A moderate to high MSS Band 7 response (pink to red) indicates vigorous vegetation which is almost exclusively irrigated in lower elevations of southeastern Arizona. The acreage for each field that contained more than 10% of this class of response was summed to yield a total annual irrigated acreage estimate (Table 2).

The total area of moderate to high Band 7 response was calculated for each scene and compared to the total irrigated field acreage for the same scene. The percent difference for each data (Table 2) indicates the error that results from planimetering only the area of irrigated vegetative response rather than actual field area. The latter figure is more accurate since an entire field is planted and irrigated. Variations in soil condition, slope, plant density and exposure affect the date of emergency and the ultimate level of vigor of most crops; therefore, the area of vigorous vegetation response often does not correspond with the actual acreage under irrigation.

Crop Classification. Characteristics of the band 7 response are monitored over time and are compared with a known crop calendar in order to identify different crop types. The period a species appears is indicated by a high band 7 response on the following scene data. Similarly, the harvesting of a crop is indicated by the absence of band 7 response on the following scene. Plant phenology may also be used to classify crops. Phenology is inferred from multi-temporal imagery and crop calendars (supplied by the Agricultural Extension Service). Figure 5 lists crops and respective calendars for the study area. The response of unvegetated fields should also be observed. Recently plowed or watered fields are darker than fallow fields. These activities generally precede plant emergency in the cropping cycle. Combining these observations with a crop calendar can also be used to identify crop type.

TABLE 2

IRRIGATION SUMMARY AND COMPARISON OF RESPONSE AND TOTAL FIELD AREA

	Feb.	April	Aug.	Nov.
Irrigated response area (acres)	444	3,555	7,169	748
Irrigated field area (acres)	881	3,600	7,779	944
Difference (%)	98	1	8	26
Total study area (%)	7	29	62	8

Total annual irrigated field acreage: 10,411 acres
Total study area: 84%

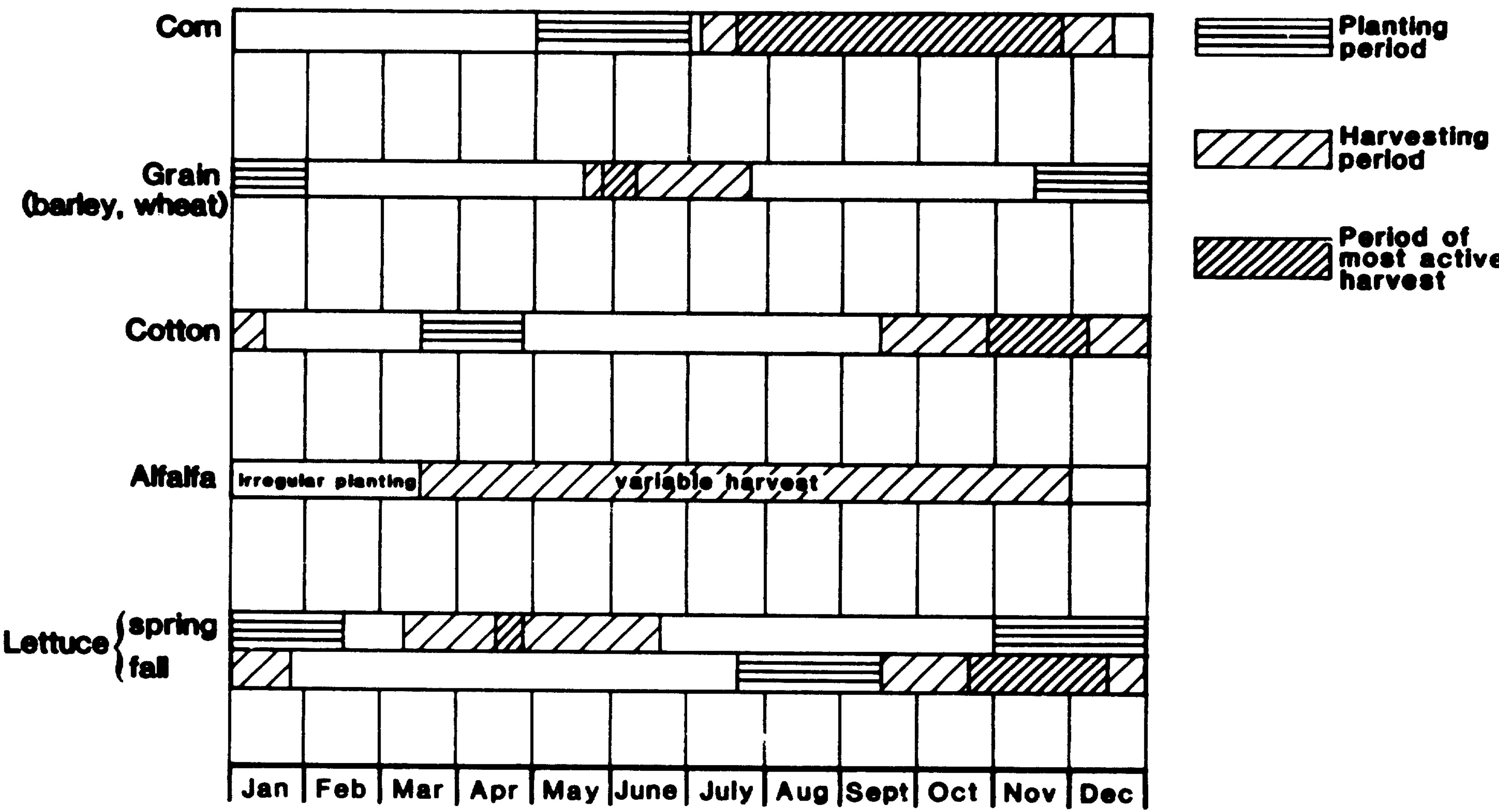

Figure 5. CROP CALENDAR FOR CORTARO-MARANA WATER CONSERVATION DISTRICT.

CHAPTER 2. LANDSAT APPLICATIONS TO MESQUITE MANAGEMENT, SOUTHERN ARIZONA

Introduction

The governor of Arizona has directed that the State Land Department increase revenues earned by state trust lands. More profitable management of the existing renewable resources on state lands is an approach to achieving this objective that fits well within the existing system. The desert hardwood mesquite, generally viewed as a weed species, has been used traditionally as a high quality fuelwood in the U.S. Southwest and thus is being evaluated now as a likely resource for increasing the flow of revenues to the state. The value of mesquite for fuelwood is widely accepted. However, its value for use in biomass production, livestock feed and forage, and human food has also been demonstrated. The use, or combination of uses, that might be most profitable is not clear.

On those lands leased from the state for livestock grazing, mesquite has been dealt with in a variety of ways: it has been clear-cut and sold as fuelwood; attempts have been made to eradicate it by burning, spraying or chaining to restore grasses; or it has been tolerated as a necessary evil. An occasional rancher in southern Arizona will claim that mesquite provides the only forage for his cattle during the driest part of the year, and beekeepers will testify to its economic importance for honey and pollen production. However, basic information on the distribution and characteristics of the resource needed to make management decisions for increasing revenues from state lands has not been available. No suitable state vegetation maps exist. Thus, even if a plan of balanced uses developed, it could not be implemented due to lack of information.

A multiple-use, long-range plan for utilizing the mesquite tree could generate additional millions of dollars in state revenues annually. There are an estimated 610,000 acres of state land in southern Arizona where mesquite grows. However, characteristics of the plant are not uniform throughout its range. The life-forms, pod production and wood production vary greatly with the area in which it grows. Thus, an appropriate use of mesquite on one section of land may be totally inappropriate to another section. ARSP initiated a project to supply the information needed by the State Land Department for making such management decisions.

The principle objective of the project is to map standing cordwood and pod production per acre using Landsat imagery.

Impact

The inventory of mesquite on state lands and estimates of its productivity will aid in managing the lands for maximum revenues. A preliminary assessment of present and potential revenues that might be generated by different uses of mesquite vegetation is shown in Table 3.

Improved inventory techniques will reduce the amount of revenues used for inventories. At present, 10% of state revenues received from wood sales are spent for inventory. Assuming one-half cord of fuelwood per acre at $20 per cord, $1.00 per acre or $610,000 would be spent for a mesquite fuelwood inventory of lands where mesquite is found. A reduction by only 10% of inventory costs would be substantial.

Methodology

A classification system for mesquite vegetation types is being developed by ARSP. The system focuses on the attributes of density, cordage, growth form, pod production and associated species. These attributes will be correlated with terrain variables such as landform, slope, elevation, soil texture, rainfall, minimum temperatures and the presence of limiting soil horizons. Much of the data needed to establish these relationships will be derived from previous ARSP projects (see Chapters 10 and 11, and ARSP Annual Report, 1977-1978).

Using Landsat data, a small area of southern Arizona will be mapped at a small scale with this classification system. Accuracies for mapping mesquite vegetation will be determined, and projections of wood yields (cords per acre) and pod production (pounds per acre) will be verified. Control data for cordage estimates will be provided by the State Land Department based on actual harvests; pod production figures, based on a five-year monitoring program will be provided by the Arizona-Sonora Desert Museum Research Department. The techniques that are developed will be suitable for mapping the mesquite resource at a scale suitable for a statewide inventory.

TABLE 3

POTENTIAL VALUE OF VARIOUS USES OF MESQUITE VEGETATION

Management Strategy	Potential Value Revenue per Acre to State ($)	Total Annual Revenve for 610,000 Acres ($)
Grazing permits[1]	.10	61,000
Fuelwood[2]	10.00	305,000
Mesquite fruit for livestock feed[3]	3.00	366,000
Mesquite pod (mesocarp) only for human food[4]	11.30	1,378,600

[1] Grazing revenues based on actual FY 1979 revenues received by state.

[2] One-half cord of harvestable wood per acre is estimated, with a return to the state of $20.00 per cord (actual returns; market value of $125 - $140 per cord);5% annual harvest of total acreage is projected.

[3] Ten trees per acre are estimated with a production of 20 pounds of fruit per tree, dry weight. Only 20% of the entire area is assumed to be harvestable annually. The 1980 price of soybean meal used for feed is $200 per ton. Return to the state is assumed to be proportional to fuelwood (15% of market value).

[4] Production and harvest assumptions are the same as number 3. The mesocarp of fruit (pod, excluding seed) is approximately 50% of total dry weight. The 1980 retail price of carob flour is $.75 per pound. A return to the state of 15% of market value is assumed. NOTE: The mesquite seed, a potentially valuable source of high quality protein, is not used.

CHAPTER 3. LANDSAT APPLICATIONS TO MINED LAND INVENTORY AND HAZARD MONITORING IN ARIZONA

Introduction

To partially implement the 1977 Surface Mining Control and Reclamation Act (SMCRA), the Office of Surface Mining (OSM) has requested that each state inventory its hazardous abandoned mining area. The legislation also requires complete inspections of each mine four times annually, and partial inspection monthly. The OSM has contracted ARSP and the University of Arizona Mining and Geological Engineering Department to demonstrate Landsat utility in meeting these requirements. The objectives of this project are:

1. to inventory mining activity in Arizona;
2. to develop a mine monitoring system; and
3. to delineate mined lands with high hazard potential.

Impact

There are a total of 41 active surface mines scattered throughout the state of Arizona (Figure 6). The mines represent 13% of Arizona's income with total annual revenues of $1.7 billion and a combined workforce of 21,400 in 1979.

To comply with the monitoring regulations stipulated by the SMCRA a field staff of at least three would be required. Salaries and administrative and travel expenses required to support this effort would exceed $100,000 annually. The Landsat monitoring system that is being developed by the University of Arizona would require no more than $60,000 annually, including staff, salaries, data acquisition, computer time and travel expenses. Thus, a gross savings of $40,000 conceivably could be realized by the state of Arizona by adapting a monitoring system based on using Landsat data.

Methodology

Initial Mine Inventory

A total of 19 Landsat scenes have been acquired, providing complete, recent coverage of all the major surface mines in Arizona.

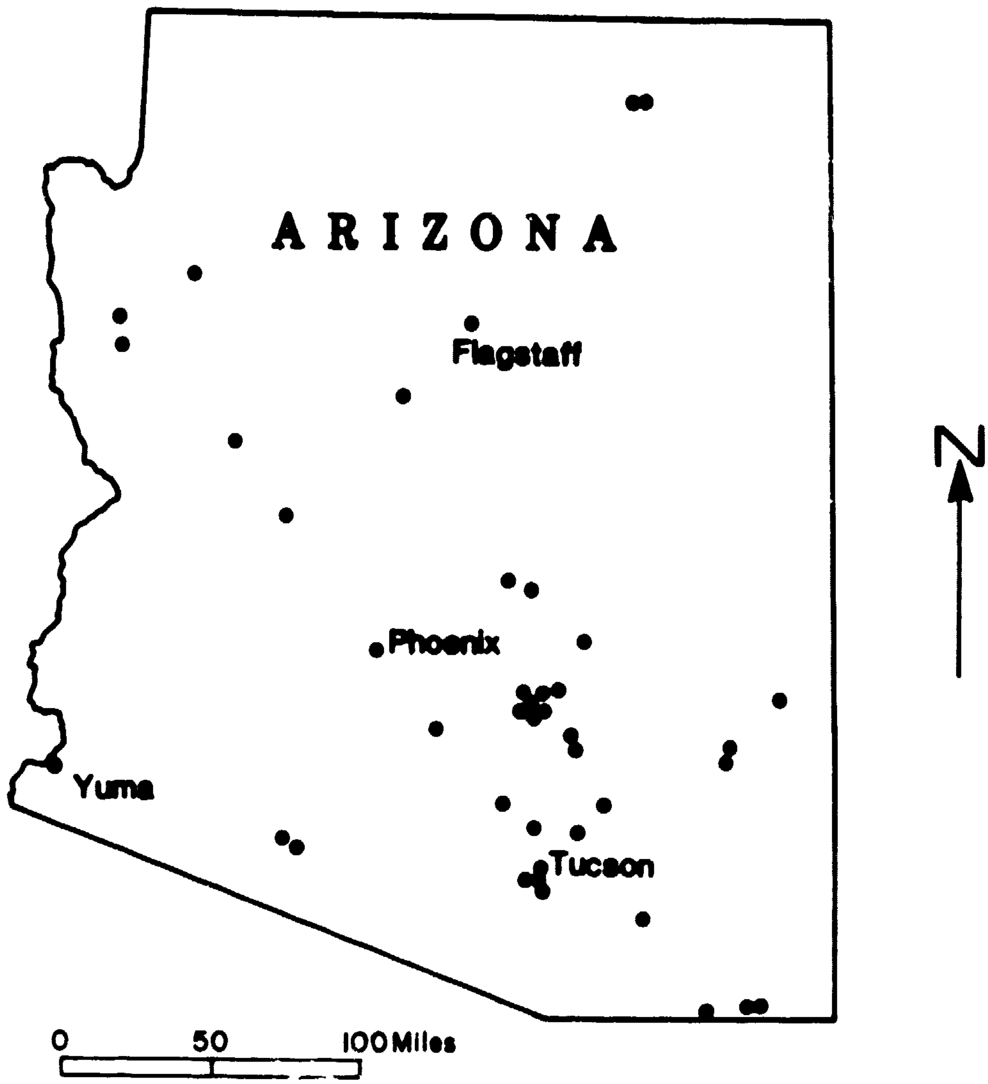

Figure 6. MAP OF ACTIVE SURFACE MINES IN ARIZONA.

A variety of collateral data also is being collected where available. Training site selection and Landsat data classification currently are underway.

Monitoring Program

Development of an efficient monitoring program using satellite data is being approached by utilizing multitemporal analysis techniques such as post-classification change detection, difference change detection and color composition. Initial results using color composite images of specific mines for the years 1972 and 1979 indicate that a high degree of success can be expected. A series of seven Landsat scenes of a large copper mining area south of Tucson is shown in Figure 7. The large wastebanks in this area are close to the retirement community of Green Valley, Arizona, population 7,700.

Hazards Mapping

Inevitable changes in land use and population growth often result in hazardous juxtapositions of population and existing or abandoned mined areas. Examples of these land use changes can be found in Arizona where active tailings dams are located adjacent to, and uphill from, populated areas, resulting in hazard from ground failure and water contamination.

One inherent asset of digital classification maps is that they provide a readily accessible and flexible data base, valuable for historical reference, periodic monitoring and correlation with other data. The last item is increasingly important in land-use surveys. Collateral data, integrated properly with imagery, can provide valuable additional information for classification and can improve interpretation of the results.

Collateral data will be used in this project for: 1) delineating present high hazard areas; and 2) producing a data base suitable for future updating to aid in risk reduction. The following sets of data now are available in Arizona.

Topographic -- digitized elevation values with a grid spacing of 64 meters for the entire U.S. available from the U.S. Geological Survey National Cartographic Information Center (NCIC).

Population distribution -- computer format tapes available from the University of Arizona Economics and Business Administration Department.

Earthquake motions -- available on-line at the University of Arizona from the National Oceanic and Atmospheric Administration (NOAA) Hypocentral Data File. Analysis of these data will

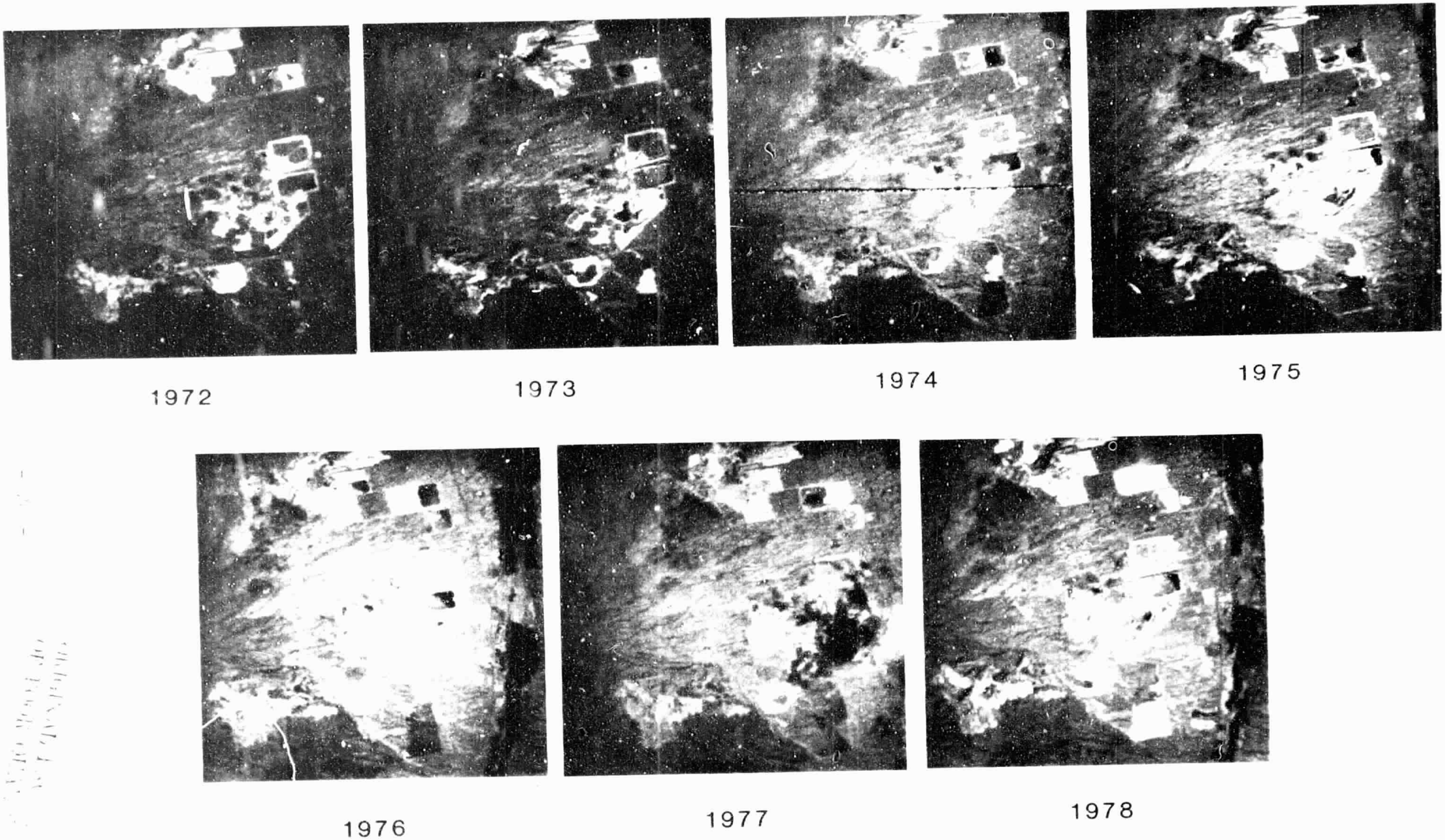

Figure 7. TEMPORAL SERIES OF LANDSAT SCENES OF TUCSON COPPER MINES.

be in conjunction with seismic wave attenuation software currently being used by the principal investigator.

Geology, groundwater -- available from the Arizona Bureau of Geology and Mineral Technology, Geological Survey Division. These data must be digitized from the present map format. It will be used to infer potential for waste contamination of potable water supplies.

Rainfall -- available from the University of Arizona Geography and Urban Development Department and College of Agriculture. These data will be used for estimating transport of waste materials to the groundwater and surface streams and potential for flash flood damage to tailings dams and waste piles.

Mine production -- limited availability from mining companies. These data may be difficult to obtain and is often difficult to interpret accurately. When used the data should provide information on waste quantities.

These data, once digitized and registered to Landsat imagery, may be used directly in the classification process,for example, by defining "high risk" classes, or may be used after image classification as a digital overlay to stratify mined land-use classes into various degrees of risk and potential for environmental damage.

Proposed Training Program

To enable state agency access to results of the current research program a continuation of this program has been proposed that is designed:

1. to develop a training manual detailing step-by-step procedures for conducting digital image analysis on an operational level;

2. to develop videotape training courses in remote sensing and digital image processing and classification; and

3. to develop a procedural guide for the use of computer classification to map and monitor mining activities.

This training package could serve as a guideline for state programs to insure homogeneity in national mined-land reclamation inventory and monitoring programs.

CHAPTER 4. LAND USE MAPPING FOR AIR QUALITY MANAGEMENT, RILLITO, ARIZONA

Introduction

ARSP was contracted by the Pima Association of Governments (PAG) to produce two land use/land cover maps of the Rillito, Arizona area: a small-scale microinventory map and a medium-scale regional map. The request was made to help resolve a debate between PAG and the U.S. Environmental Protection Agency (EPA). The issue was over the representativeness of the Rillito air quality monitor data (see Figure 8). The objective of the PAG study was to determine whether the monitor accurately measures ambient air quality or whether local emissions influence the readings. The map and inventory produced by ARSP indicated that local emissions do influence the readings. They illustrate the proximity of emission sources of total suspended particulates (TSP) to the Rillito air quality monitor.

Impact

The PAG report containing the ARSP products is being reviewed by the EPA. Expected results of the review are as follows:

1. Agreement of EPA with PAG that pollution sources immediately surrounding the monitor (unpaved parking lots and roads, agricultural fields) affected the monitor readings so that ambient air quality was not being measured by the monitor.

2. Agreement of the two agencies that expenditures of up to $1 million for additional pollution controls by Arizona Portland Cement Plant and the Rillito community would not substantially affect ambient levels of TSP.

3. Relocation of the Rillito monitor to more accurately record ambient air quality.

4. The release of federal funds (possibly more than $140 million) to Pima County for having attained federal air quality standards.

The total cost to PAG of the microinventory and regional map delineating other sources of TSP was $232, including photointerpretation, field verification and preparation of maps and report.

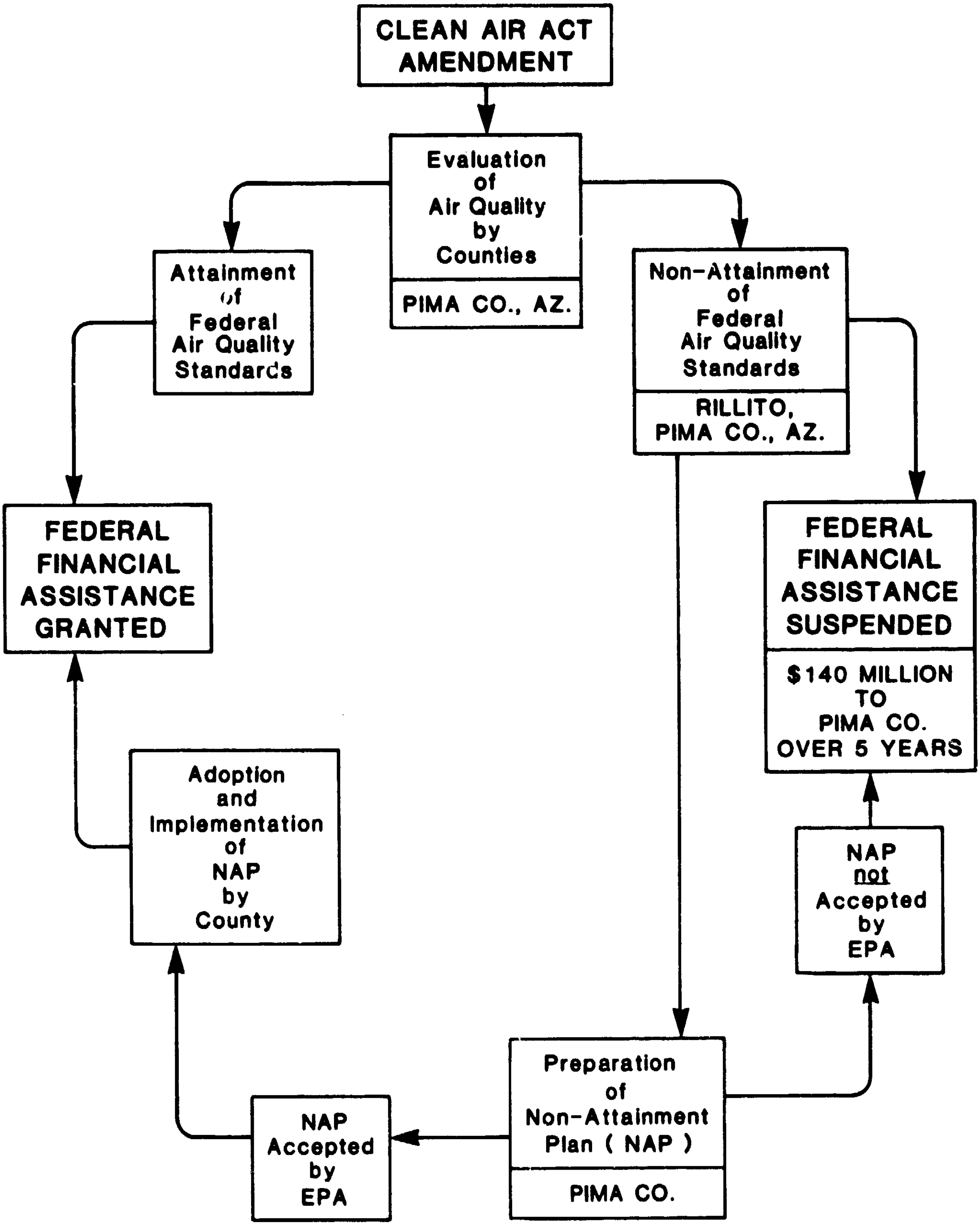

Figure 8. SCHEMATIC OF EPA AIR QUALITY ENFORCEMENT.

Methodology

The microinventory centers on the Rillito air quality monitor. The area comprises three square miles (1:24,000 scale). Color aerial photographs at the same scale were studied and preliminary image types were delineated on a clear acetate overlay. The Rillito study area and surrounding regions were visited: major roads were driven and sites representative of each image type were visited on foot. Notes about vegetation types were made on the acetate overlay. Percent of perennial crown cover was estimated and road surfaces were also. Cultural features were identified. Potential sources of high TSP levels were noted. And a classification scheme was developed based on quantity of bare ground and land use.

All easily identified roads on the 1:24,000 scale color photograph were traced onto the overlay in the laboratory. These were within one-mile radius of the state air quality monitor. Preliminary delineations and boundaries were adjusted in light of field observations. The Rillito microinventory map was then manually adjusted to fit a topographic map of the same scale to eliminate photographic distortion in the final product.

The regional land use/land cover map was produced from color infrared positive transparencies (1:125,000 scale). Classification types were delineated on a clear acetate sheet overlaying the transparencies. Verifications were made by viewing larger scale color photographs and black and white orthophotoquads. Notes from previous field visitations were consulted. The regional map was transferred onto a reduced topographic map.

PAG submitted a report to the EPA. The ARSP inventory and map were used to illustrate potential TSP sources. The low cost demonstrated the desirability of using remote sensing techniques for such a purpose.

CHAPTER 5. LAWN INVENTORY FOR WATER USE MANAGEMENT, TUCSON ARIZONA

Introduction

In May 1979, Tucson Water contracted with ARSP to evaluate the efficacy of their peak water demand reduction program by assessing trends in lawn water use and water consumption between 1976 abd 1979. Additional information on the increment of water consumption attributable to lawn irrigation and an estimate of the change in residential water consumption accompanying the transition from irrigated to unirrigated landscaping were requested. These data were required to facilitate the design and implementation of future water conservation efforts relevant to residential landscaping.

Impact

This study, funded by Tucson Water, was conducted using both high- and medium-altitude aerial photography to identify irrigated lawns within a residential sample area. ARSP selected a study area of 15 square miles from within Tucson Water's service area and sampled on three dates (1972, 1976 and 1979) 1,500 single-family residences for the presence or absence of irrigated lawns.

The results of this study, presented in a report to the Tucson Water staff and in a formal discussion with the Tucson Citizen's Water Advisory Committee in November 1979, show a significant decline in irrigated lawns (15.89%) between 1972 and 1979. This decrease was accompanied with a substantial decrease in water consumption (37.8%). During the period 1974-1979, an average increment of 1,000 cubic feet of water per month is attributable to lawn irrigation during the dry summer season. This increment is 27.9% of the average monthly consumption of residences irrigating both front and back lawns. The correspondence of this reduction with the implementation of the Peak Demand Reduction Program suggests that the program was successful.

A moderately high direct relationship was found between residential property valuation and water consumption, suggesting that water consumption is closely related to property value. An insignificant relationship between both water consumption and lawn irrigation practice and parcel age suggests that new subdivisions are not using water conserving landscaping to any greater degree than older ones as had been previously hypothesized.

This study also shows the merits of aerial photography as a data source for analyzing urban landscape irrigation practices. The total sample was surveyed on three dates in a period of two weeks by one research assistant at a small fraction of the cost that would have been involved by conducting a field survey for one season alone.

The study resulted in further investigation of landscaping in Tucson and its relationship to water consumption. A project funded by the U.S. Department of Interior Office of Water Research and Technology (OWRT) and Resources for the Future currently is studying the impact of price policies on public conservation behavior, including landscaping change.

Methodology

To establish lawn irrigation trends during the study period, both high- and medium-altitude (1:24,000 and 1:125,000, respectively) color infrared photography was used. Determination of the presence or absence of irrigated lawns was indicated by infrared response from residential yards. Summer season photography was acquired to provide coverage during the dry period (June through August) when infrared response from unirrigated lawns would be at its lowest. For a sample of 1,500 residences, front and back lawn irrigation status was determined from the photography. Water consumption data supplied by Tucson Water for a subsample were compared with lawn irrigation status to determine consumption changes related to changes in irrigation practice. To assess the impact of the peak water demand reduction, a pre-program (1976-1979) trend was compared with the post-program trend.

CHAPTER 6. VISITOR USE IMPACT ASSESSMENT, SAGUARO NATIONAL MONUMENT, TUCSON, ARIZONA

Introduction

In April 1979 the National Park Service (NPS) contracted ARSP to investigate the impacts of visitor use on the natural resources of Saguaro National Monument. Visitor use of the giant cactus (saguaro) forest of the Monument's Rincon Mountain Unit (adjacent to Tucson's eastern edge) has increased both on foot and horseback in recent years. Yearly, the Monument is visited by 600,000 people and by 15,000 - 20,000 horseriders. Total visitor use is increasing at 15% per year and horse use at 60%. The response of this environment to heavy use, especially by horseriders, is a subject of some debate. Thus, NPS was anxious to establish a program for assessing visitor use impact and the impacts sustained by establishing and abandoning roads and historical trails.

The project had three objectives: (1) to review literature pertinent to visitor use impact assessment, (2) to assess the adequacy of previous research on visitor use impact conducted within the Monument, (3) and to prepare maps of historical and current trails within the Monument with a description of current trail conditions.

Impact

ARSP assessors of visitor use impact research found previous research done in the Monument to be inadequate. Part of their assessment was based on a literature review. A more reliable course of investigation was outlined and a new research on visitor use impact will be initiated.

Maps prepared from aerial photography for the late 1930s and for 1978 allowed staff to compare trail and road networks. They identified sites that are particularly popular and also estimated rates of recovery from abandoned and disturbed areas. Ground checking established the magnitude of impact associated with trail types and use. Based on these data, specific management decisions will be made about restricting certain uses and about the intensity of use that will be allowed in sensitive areas.

Methodology

Research literature on visitor use impact was comprehensively searched. References were organized according to the variable studied (e.g., soil, vegetation, visitor behavior, visitor enumeration). A summary of work in each area was prepared after review. Research procedures conducted at the Monument were compared with accepted procedure. Several shortcomings were found in scope and technique. Each was documented and alternatives were suggested.

Aerial photography and ground study were used to make maps of historical and current roads and trails. Trails were delineated on enlarged topographic base maps at a scale of 1:12,000. Trail locations and widths were determined through photointerpretation and extensive field checking. Black and white prints at a scale of 1:4,800 were prepared from 1978 contact negatives at a scale of 1:24,000. Locations of current trails wider than about four feet were mapped from the photos. Locations were verified and smaller trails were indicated on photographs during field checking. Depths of trails were measured at that time and other characteristics noted, such as slope, soil texture, trail orientation and trail objective. Researchers relied on the experience gained in photointerpretation to map historic trails on 9 x 9 inch black and white aerial photographs at a scale of 1:30,000 and taken in 1936. A 1936 land status map, a 1939 vegetation map, and 1:40,000 scale black and white prints taken in 1954 were used to corroborate location of photointerpreted trails due to the poor quality of the 1936 prints. Information from current and historic trails maps was transferred to the same base map for ease of comparison.

CHAPTER 7. LAND USE INVENTORY UPDATE, PIMA COUNTY, ARIZONA

Introduction

Pima Association of Governments (PAG) is a participant in the Upper Santa Cruz Mines Task Force. It contracted ARSP in July 1979 to update a land use map for a 137 square mile area of the Santa Cruz River Valley between Tucson and Arivaca Junction, Arizona. A previous update of the Pima County-Papago Indian Reservation Resource Inventory was prepared by ARSP in 1978 (see ARSP Annual Report, 1977-1978). This one furnished baseline data for a long-term evaluation of the effect of land use on groundwater quality, particularly mining activities and agriculture. It was requested by the Arizona State Water Commission.

Impact

The Upper Santa Cruz basin provides a substantial portion of the water for metropolitan Tucson. Much of this groundwater approaches or exceeds Federal recommendations for concentrations of nitrates, sulfates, and total dissolved solids (TDS). Specific mechanisms and rates of groundwater degradation are not known at this time. However, the establishment of baseline land-use and water quality data will provide the information necessary for assessing future impacts upon this vital resource.

Land-use data were produced in map form for analysis of zones of anomalously high water contaminants. However, the coincidence of particular land uses with particular groundwater constituents is not necessarily causally related. But, land-use data produced by ARSP,plus the detailed information on groundwater movement and pumping capacity being assembled by the Task Force, will ultimately help to relate surface activities and water quality.

Methodology

1977 high-altitude color infrared photography and 1979 medium altitude color photography were compared with 1978 land-use maps from the Resource Inventory of Pima County and the Papago Indian Reservation (compiled from 1972 and 1974 photography).

Areas of land-use change were identified and then field checked. These data were used to produce an updated land-use map. Its refined system of classification categorizes uses that have a high potential for groundwater quality impact. A brief history of area land use was also submitted, along with an analysis and tabular breakdown of current land use.

Section II

Continuing or Completed Activities

CHAPTER 8. LANDSAT APPLICATIONS TO AIR QUALITY MANAGEMENT, TUCSON, ARIZONA

Introduction

The purpose of this project is to test the suitability of using Landsat multispectral data to monitor air quality in the Tucson Air Planning Area (TAPA). TAPA was designated as a nonattainment area for total suspended particulates (TSP) by the EPA because of violations of national ambient air quality standards. Federal law requires a Nonattainment Area Plan (NAP) for TSP in order to bring air quality into compliance with national standards. The Plan for Tucson was submitted to the EPA in 1978 by the Pima Association of Governments (PAG), Environmental Programs Division. It is based in part on a gridded, detailed emission inventory for TSP, completed in 1978 for the base year 1975. Estimates of future emissions were done in five-year increments from 1975 through the year 2000. The inventory allowed PAG to devise air pollution control strategies. It was funded by the EPA.

The annual general emission inventory for TAPA and Pima County covers all EPA regulated pollutants. It is prepared by the local Air Quality Control District and is used by local planners, PAG, in this case. Dust sources account for over 90% of the total estimated TSP emissions in the inventory. Projection methods incorporate changes in population, population density, and land use acreage to estimate the annual change in dust emissions. Projections are based on 1975 data. The problems with these projection methods is that changes in the location and extent of major dust sources are not monitored at all. Only total areawide changes in emissions are projected with these annual updates.

Land surface classifications of potential dust emissions for TAPA are being completed using Landsat data. If local air quality analysts and planners judge the results to be accurate, then ARSP could annually update the information, thus contributing to the quality planning process for the TAPA Nonattainment Area Plan.

Impact

1) Failure to meet EPA air quality standards could result in a loss of federal funds from the Departments of Transportation and Housing and Urban Development amounting to $140 million through 1982. If the proposed Landsat updates are implemented in the NAP, federal funding suspension might be averted.

2) Conducting such inventories is totally dependent on EPA funding due to the high cost of preparing detailed, gridded emission inventories. Landsat updates could be used to identify source areas responsible for specific TSP violations at a fraction of the cost of traditional methods.

3) Monitoring the locations of variables and the extent of dust sources could be useful to local planning agencies responsible for identifying dust problem areas. Such abatement measures as road paving and land use regulation could be focused on the areas of high potential dust emissions that are located by Landsat updates. These measures could reduce the estimated cost of $20 million of implementing NAP strategy.

4) Annual Landsat updates could be used to evaluate sites for new TSP samplers and to relocate existing samplers now designated as site specific and thus useless for areawide air quality planning.

Methodology

CALSCAN, an automated scene classification software package (see Appendix A) was used to classify surface conditions on a Landsat image of TAPA. Training sites of homogeneous areas for each class are analyzed by the computer using reflective values in all four Landsat spectral bands. The probability that a pixel belongs to one of the classes is computed and the entire area is then classified according to these probabilities. Subsequent techniques -- thresholding, for example -- aid in refining this classification. And test sites are examined to determine the accuracy of the classification.

Two types of land have been classified accurately with Landsat: disturbed vacant land and developed disturbed land (industrial areas with unpaved parking and storage areas, residential areas with a large degree of vacant lots and unpaved roads, and areas of new construction). There has been some confusion between other classes such as developed areas and areas of native vegetation in foothill areas. However, stratifying the planning area into built-up and outlying areas should allow distinct classifications of these areas to be made.

Nick Buchholz, is the chief air quality planner at PAG. He has inspected the initial classification maps of the TAPA and is optimistic about their possible utility in the NAP. From a letter to [illegible] dated June 11, 1980 he states:

> "The use of Landsat to determine what type of cover a particular area has and what use the land is being put to could help the emissions inventory process a great deal. Having the latest data available is always important and a technique of this type should enable more frequent updating of the particular emissions inventory."

CHAPTER 9. VEGETATION MAPPING, GRAND CANYON NATIONAL PARK, ARIZONA

Introduction

In September 1977 NPS was contracted with ARSP to map the vegetation of Grand Canyon National Park. This is one of the most ambitious projects undertaken by ARSP. Grand Canyon National Park encompasses approximately 1.2 million acres, with a considerable amount of terrain that is entirely inaccessible. To document vegetation types in such an extensive region the funding was divided into two contract periods during four years. The second phase of funding was begun in 1979 and will terminate in 1981.

The vegetation map is a primary component of the resource base inventory mandated by the U.S. Department of the Interior and is intended to supply the necessary information to assess, protect and conserve natural resources at the Park.

Field investigations are nearly completed and draft maps have been prepared for several regions of the Park. ARSP efforts are supported by NPS who provides primary funding, field personnel, ground transportation, lodging and fixed and rotary winged aircraft flights.

Impact

Use of the vegetation map and related products by NPS will provide savings in the costs of development planning, environmental assessment studies, and interpretation of the Park by NPS naturalists.

ARSP research has already led to significant action by the Park Service. The Forest Service planned to spray their spruce-fir forests and similar forests on adjacent land in the Grand Canyon National Park for spruce budworm. This program was postponed by request of the Park Superintendent when the ARSP staff was able to demonstrate, with a vegetation map, that the area to be sprayed within the Park comprises approximately 90% of the areal extent of spruce-fir within the Park's holdings. It was originally believed that a much smaller area would be affected by the proposed spraying. Not only has this prevented untold and perhaps needless disruption of the forest ecosystem, but it has saved the considerable cost of treatment.

Based on a draft map, the NPS also made several decisions with significant short-term economic and long-term ecological, aesthetic and economic consequences. For example, a draft of the North Rim vegetation map has been used for creating a Fire Management Plan and will save NPS an estimated $150,000 in fire control during the next 10 years.

Also on the North Rim, the vegetation map has been used to locate study sites for bird censusing. Wildlife management is an integral part of resource management which requires adequate vegetation maps for accuracy.

Methodology

In the laboratory, preliminary boundaries of vegetation units are delineated on mylar overlays and the units are tentatively typed. A team is then fielded to verify boundaries and typing and also gathers sample data within the area. Samples include species composition, abundance and cover, and also terrain features at the sample site, such as land form, slope, slope aspect and geology. Final boundaries and classification designation are transferred to a 1:62,500 base map.

The virtual inaccessability of many areas within the Park poses obvious problems in vegetation mapping. Foremost is the difficulty of verifying the preliminary identification that is assigned to units mapped on the aerial photograph. To overcome this problem, ARSP has developed a technique for discrimiating vegetation types, based on helicopter observation and the correlation of vegetation with terrain features. More than 1,000 sites have been sampled in all parts of the Park to document the relationships between terrain and vegetation.

CHAPTER 10. VEGETATION MAPPING AND FLORAL SURVEY, ORGAN PIPE CACTUS NATIONAL MONUMENT, ARIZONA

Introduction

The vegetation mapping and floral survey of Organ Pipe Cactus National Monument began in August 1977 and was completed by ARSP in March 1980 under contract with NPS. The project provided five primary products for NPS: 1) a vegetation map of the Monument; 2) a floral inventory of the Monument (see Chapter 18); 3) an annotated bibliography of references pertinent to the botanical resources of the Monument, particularly historical changes in the vegetation; 4) a narrative summary of the past and present condition of Monument vegetation; 5) a suggested management plan; and 6) a workshop covering the results of the project and management recommendations.

Impact

This project was unique in that it first produced an initial resource inventory and an analysis of historical land-use impact. Subsequently, an estimate of projected impact of proposed management actions was made on the historical analysis and inventory data.

The products of the project have provided basic information on the vegetative resources of the Monument and also their response to varying uses. As a result, decisions on managing the Monument's resources can be made more efficiently with less time spent in the field and with more confidence in the consequences of those decisions.

The workshop was of special value. It was convened to review the management plan proposed by ARSP and, for the first time brought together personnel with similar responsibilities and problems from a variety of agencies within the area. Discussion of the proposed management plan focused on many of the problems facing land managers in the region. Different management approaches were discussed and solutions to common problems were shared. For example, methods of grading dirt roads are of some concern: repeated use of a grader lowers the level of the road and creates large berms along each side. The result is a channel with extreme erosion hazard. Managers of the Cabeza Prieta Game Range independently devised a drag leveling system for maintaining roads that eliminates the erosion problem and is less expensive than grading with a blade. The technique was readily adopted by others attending the workshop.

After incorporating suggestions made at the workshop, the management plan proposed by ARSP was adopted by the Monument. Several other indirect benefits derived from the project and have been described previously (ARSP 1977-1978 Annual Report):

1. Elimination of the need for a special map of threatened and endangered cactus estimated to cost $50,000;

2. Elimination of a plan to re-seed rangeland estimated to cost $20,000; and

3. Increasing visitor use by facilitating trail planning and exotic plant removal that resulted in an estimated increase in local revenues by $84,000.

Methodology

Vegetation maps were prepared at two scales (1:62,500 and 1:24,000) by photointerpretation of 1:24,000 scale natural color aerial photographs. Mapping units were documented by detailed field observations. The mapping unit descriptions include floristics and physiognomy of vegetation and their relations to topography, soils and other terrain features. As part of the survey, a flora was produced (see Chapter 18).

For a number of sites within the Monument, historical ground photographs were compared to recent photographs to assess changes in vegetation. Causal relationships between vegetation change and land-use patterns and climate patterns were discussed on the basis of information in the literature and photographic documentation.

CHAPTER 11. WILDLIFE HABITAT MAPPING, THREE-BAR AND TONTO BASIN STUDY AREAS, ARIZONA

Introduction

ARSP began the Three-bar project in August 1978 under contract with the Arizona Game and Fish Department (AGFD). It completed the project in June 1980. Vegetation and features of related wildlife habitat of a 120 square mile study area were mapped at 1:24,000. Ongoing radio-telemetry studies by the AGFD will provide location data for black bear, javelina and mule deer. And location data can be correlated with vegetation information to determine habitat use of wildlife species. The AGFD needed the maps to identify the vegetation characteristics of habitats of important game species.

Impact

The results of the study will be used to precisely define habitat use by wildlife species, particularly game species. The resultant habitat information will be extrapolated elsewhere in the state to estimate wildlife population and range, identify areas of critical habitat and determine hunting permit quotas. Accurate estimates are important since AGFD reports revenues from hunting licenses and game tags in excess of $3.3 million annually.

The AGFD has developed a strong interest in using aircraft and spacecraft imagery and in developing their own expertise through training workshops. Presentations by ARSP concerning this project at the Pecora IV Symposium, the Western Black Bear Biologists Association, and in a chapter in the Wildife Techniques Manual published by the Wildlife Society have fostered interest in the use of remote sensing techniques among other wildlife biologists.

Methodology

Conventional photointerpretation of 1:24,000 scale color infrared photos, plus detailed ground-surveys , was used to produce the maps. More information was gathered by a larger scale

Section III

Technology Transfer and Remote Sensing Education

CHAPTER 12. REMOTE SENSING WORKSHOPS FOR RESOURCE MANAGERS, BUREAU OF LAND MANAGEMENT: ALBUQUERQUE, NEW MEXICO; CORPUS CHRISTI, TEXAS; AND WASHINGTON, D.C.

Introduction

ARSP prepared a workshop series on introductory remote sensing for presentation to BLM personnel while under contract with the Remote Sensing Branch of the Bureau of Land Management (BLM). The series consisted of three separate workshops conducted at Albuquerque, New Mexico (October 1979); Corpus Christi, Texas (February 1980); and Washington,D.C. (June 1980).

The orientation of the workshop series was toward applications for resource management. Each workshop was attended by a selected group of personnel: range conservationists and foresters in New Mexico; outer-continental-shelf management personnel in Texas; and, cartographic personnel in Washington,D.C. The selection of personnel and the choice of workshop sites suited instructional resources and the needs of attendees.

The primary products of this project were workshops, a syllabus, course outlines, visual aids for presentation of introductory material and direct applications, and class exercises that provided hands-on experience with equipment and techniques. Aerial photography and Landsat imagery selected for each workshop site were used in class exercises. A one-day field trip during each session provided field experience in ground data collection for the attendees.

Impact

The project was directed toward developing qualified remote sensing personnel within the field offices of the BLM. After being trained, attendees were able to assess information needs, select appropriate remote sensing technology, and interact with both academic and private remote sensing facilities to solve resource management problems. Preliminary responses from post-workshop questionnaire forms indicate that attending personnel found the instruction valuable for their specific job duties. For many, the introduction was their first exposure to remote sensing technology and its products. And the applications within their respective fields of expertise were new to most.

The syllabus also furthered the technology transfer benefits of this project. Copies of the syllabus circulated within the various field offices of BLM. BLM's exposure to remote sensing stimulated interest in applications beyond those covered by ARSP. The syllabus also served as a reference for imagery acquisition and evaluation. Establishing contacts among related disciplines at different BLM field offices was an important by-product of the workshop series. Attendees compared needs, capabilities, and interests, thus achieving an internal technology transfer and exchange. Post-workshop questionnaire responses also indicated that workshop-trained personnel are assisting others with applications and problems.

Methodology

Basic instruction included the following: general remote sensing principles, platform and imagery descriptions, photogrammetry, photointerpretation, image processing, and field verification procedures. Examples of state-of-the-art applications were provided during lectures, in the syllabus, or as part of a chapter and as reprints, references, or summaries.

ARSP develops its curricula uniquely by tailoring course work to the needs of users. Material for each of these workshops was suited to the participants and to the areas in which they worked. ARSP personnel traveled to the workshop sites to collect data on existing local imagery, proposed field exercise sites, and workshop facilities in order to design workshops that would meet users' needs.

CHAPTER 13. VEGETATION CLASSIFICATION WORKSHOP, EL CORONADO RANCH, ARIZONA

Introduction

ARSP organized a workshop on vegetation classification which met at the El Coronado Ranch, Arizona, March 2-3, 1979. The workshop was designed to serve as a forum for discussing approaches to vegetation classification, and problems and experiences of federal, state and local agency personnel involved in vegetation mapping. Attendees represented the U.S. Forest Service, U.S. Geological Survey, National Park Service, Arizona Game and Fish Department, the Nature Conservancy, Museum of Northern Arizona and the University of Arizona.

Impact

It was agreed that statewide cooperation would benefit those active in all aspects of vegetation inventory and classification. As a result, a Committee on Vegetation Classification was organized and now functions under Arizona-Nevada Academy of Sciences auspices. Meetings and workshops are planned periodically to describe and discuss vegetation classification problems and innovations.

CHAPTER 14. REMOTE SENSING SCIENCE COUNCIL, NASA WESTERN REGIONAL APPLICATIONS PROGRAM

ARSP continued to play an important role in NASA's Western Regional Application Program (WRAP). The WRAP-sponsored Remote Sensing Science Council (RSSC) serves to provide both NASA and educational institutions (such as the University of Arizona) with advice that ultimately results in mutually beneficial activities.

The RSSC was organized to implement remote sensing curricula in colleges and universities. It was also aimed at improving and upgrading existing remote sensing courses. This is achieved by training modules, conferences and workshops and by exchanging ideas. NASA has been instrumental in effecting this program both by direct sponsorship and through materials development.

NASA's benefits include training module development for its own programs as well as a more direct link to state problems. State governments also benefit as a result of the increased communication among state agencies, NASA and the universities.

ARSP personnel are involved in the program. The ARSP director is in constant communication with other members of the Council as well as with NASA headquarters. Another senior staff member serves as the Arizona RSSC representative. A third senior staff member assists with direct participation in RSSC and NASA-sponsored workshops and conferences.

CHAPTER 15. UNIVERSITY OF ARIZONA REMOTE SENSING COMMITTEE

The University of Arizona Remote Sensing Committee was formed in 1975 to assist in coordinating University remote sensing activities and to oversee the Graduate College remote sensing minor program. The Remote Sensing Committee consists of 13 members representing 10 University departments. Figure 9 describes the multidisciplinary Ph.D. minor degree program, the remote sensing course offerings and available research opportunities and lists members of the Remote Sensing Committee.

GRADUATE
REMOTE SENSING PROGRAM
AT THE
UNIVERSITY OF ARIZONA

The University of Arizona offers a multidisciplinary Ph.D. minor in remote sensing. Course work ranges from the fundamentals of the physics and optics of remote sensing, image processing, and pattern recognition, to applications in the fields of agriculture, geography, geology, hydrology, and renewable natural resources. The curriculum is supplemented by numerous contract-funded research projects in both applied and basic aspects of remote sensing.

Academic Opportunities

A graduate student wishing to minor in remote sensing may major in any field related to remote sensing. The major is typically in a relevant area of engineering (e.g. atmospheric physics, optical sciences, systems engineering) or natural sciences (e.g. agriculture, geography, geosciences, renewable natural resources). Students electing a minor in remote sensing are required to take Fundamentals of Remote Sensing (Optical Sciences 550) and Image Processing Laboratory (Systems and Industrial Engineering 536) and 6 additional graduate units from the courses listed below. Students emphasizing applications of remote sensing may substitute Introduction to Remote Sensing (Interdisciplinary Studies 330), with no graduate credit, for 2 units of remote sensing electives. Approval of course work for the remote sensing minor is made by the Remote Sensing Committee, consisting of 13 University faculty (see below).

University of Arizona Courses in Remote Sensing

Course	Department	Course Title (semester units)	Instructor
330	Interdisciplinary (Undergraduate)	Introduction to Remote Sensing (3)	D.A. Mouat
550	Optical Sciences	Fundamentals of Remote Sensing (3)	P.N. Slater
534	Optical Sciences	Image Processing Devices, Systems and Applications (3)	J.J. Burke/ B.R. Hunt
535	Optical Sciences	Automatic Information Extraction and Classification (3)	P.H. Bartels
558	Optical Sciences	Radiometry (3)	W.L. Wolfe
550	Optical Sciences	Infrared Techniques (3)	W.L. Wolfe
567R	Optical Sciences	Photographic Recording Processes (3)	P.N. Slater
524	Optical Sciences	Optical Data Processing (3)	J.D. Gaskill
539	Optical Sciences	Methods of Image Restoration and Enhancement (3)	B.R. Frieden
552	Optical Sciences	Optical Properties of the Atmosphere and Ocean (3)	B.R. Frieden
536	Systems & Indus Engineering	Image Processing Laboratory (3)	R.A. Schowengerdt/ B.R. Hunt
656a-b	Atmospheric Sci	Atmospheric Optics and Radiation (3-3)	B.M. Herman
561	Atmospheric Sci	Radar Meteorology (3)	L.J. Battan
683	Atmospheric Sci	Principles of Atmos. Remote Sensing (3)	S. Twomey
606	Electrical Eng	Propagation of Radio Waves (3)	J.A. Reagan
454	Civil Engineering	Photogrammetry (3)	F.B. Newlin/ H.F. Hillman
420	Watershed Mngt	Photogrammetry (2)	P.N. Knorr
422	Watershed Mngt	Photointerpretation (2)	G.S. Lehman
453	Agriculture	Remote Sensing in Agriculture (3)	W.O. Rasmussen
483	Geography	Geographic Appl. of Remote Sensing (3)	D.A. Mouat
407	Geological Eng	Photogeology (3)	C.E. Glass
507	Geological Eng	Applied Multispectral Imagery (3)	C.E. Glass

Research Opportunities

Opportunities and financial support for dissertation research in remote sensing exist in several departments at the University. Campus units particularly active in remote sensing are the Applied Remote Sensing Program, Office of Arid Lands Studies, the Institute of Atmospheric Physics, the Laboratory for Remote Sensing and Computer Mapping, School of Renewable Natural Resources, the Optical Sciences Center, and the Mining and Geological Engineering Department. Recent research projects include:

- Inventory and hazard mapping of Arizona surface mining using computer classification of Landsat imagery
- Vegetation mapping in the Grand Canyon National Park
- Computer enhancement of Landsat and topographic data for geologic lineament mapping
- Correlation of soil characteristics and vegetation in Arizona rangelands with Landsat spectral signatures
- Analysis of the correction of spectral signatures for atmospheric effects

Most research projects are externally funded by federal, state or local agencies through grants and contracts. Graduate students are strongly encouraged to participate in these projects and to publish their findings in professional journals.

Figure 9. BROCHURE FOR UNIVERSITY OF ARIZONA GRADUATE REMOTE SENSING PROGRAM.

Excellent facilities exist at the University for support of remote sensing research. The Digital Image Analysis Laboratory contains a PDP 11/70 computer and a color interactive digital image video display. In addition, high speed film digitizers and recorders are available in the Optical Sciences Center for analysis of film imagery. Comprehensive software is operational for image processing (SADIE) and classification (CALSCAN). The University Computer Center operates a CDC Cyber 175 and DEC PDP 10 for batch and interactive processing from numerous terminals around campus. A hand held spectroradiometer with four spectral bands matching those of the Landsat Multispectral Scanner System is available for field work, the Institute of Atmospheric Physics has a broad assortment of optical and electronic sensors used for atmospheric probing and the Optical Sciences Center has spectrophotometers and sensor calibration facilities.

Remote Sensing Committee

The Remote Sensing Committee was formed in 1975 to assist coordination of remote sensing activities across campus and to oversee the graduate remote sensing minor program. The Committee members are:

DANIEL D. EVANS, professor, Hydrology and Water Resources, Ph.D., 1952, Iowa State University (Soil Physics). Soil moisture assessment, hydrology.

KENNITH E. FOSTER, assistant professor and associate director, Office of Arid Lands Studies, Ph.D., 1972, University of Arizona (Watershed Management). Resource inventories, watershed management, environmental assessment.

CHARLES E. GLASS, assistant professor, Department of Mining and Geological Engineering, Ph.D., 1974, University of California, Berkeley (Geological Engineering). Application of remote sensing to earthquake engineering and active faulting, rock dynamics.

BENJAMIN M. HERMAN, professor, Department of Atmospheric Sciences, Ph.D., 1963, University of Arizona (Meteorology). Atmospheric radiative transfer, scattering, remote sensing.

HARRY F. HILLMAN, assistant professor, Department of Civil Engineering and Engineering and Engineering Mechanics, Ph.D., 1976, University of Arizona (Civil Engineering). Photogrammetry, analytical photogrammetry, precise ground control surveying techniques.

BOBBY R. HUNT, professor, Department of Systems and Industrial Engineering, Ph.D., 1967, University of Arizona (Systems Engineering). Image processing, computer and system theory, digital image restoration, pattern recognition.

CHARLES F. HUTCHINSON, Director, Applied Remote Sensing Program, Office of Arid Lands Studies, Ph.D., 1978, University of California at Riverside (Earth Science). Remote sensing applications, physical geography, natural resource inventory.

DAVID A. MOUAT, assistant professor and research fellow, Office of Arid Lands Studies, Ph.D., 1974, Oregon State University (Geography). Remote sensing applications, natural resource inventory, geoecology, arid lands geography.

DONALD F. POST, professor, Department of Soils, Water, and Engineering, Ph.D., 1967, Purdue University (Soil Survey). Soils teaching and the application of remote sensing to soil and other natural resources.

WILLIAM O. RASSMUSSEN, assistant research professor and director, Laboratory for Remote Sensing and Computer Mapping, School of Renewable Natural Resources, Ph.D., 1973, University of Arizona (Watershed Management). Computer mapping, computer graphics, simulation of forest ecosystems.

RICHARD W. REEVES, professor and head, Department of Geography, Regional Development, and Urban Planning, Ph.D., 1970, University of California, Los Angeles (Geography). Physical geography, arid lands, cartography.

ROBERT A. SCHOWENGERDT, assistant professor of remote sensing, Department of Systems and Industrial Engineering and Office of Arid Lands Studies, Ph.D., 1975, University of Arizona (Optical Sciences). Remote sensing systems and techniques, digital image processing and classification.

PHILIP N. SLATER, professor, Optical Sciences Center, chairman, Committee on Remote Sensing, Ph.D., 1958, Imperial College (Applied Optics). Systems and methodology of remote sensing, design and evaluation of space optical systems.

Further Information

Prospective students interested in the academic and research programs in remote sensing should contact:

P. N. Slater, Chairman
Committee on Remote Sensing
Optical Sciences Building
University of Arizona
Tucson, Arizona 85721
(602) 626-4242

For details on current research opportunities in particular areas of remote sensing, contact the appropriate Committee member.

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CHAPTER 16. UNIVERSITY OF ARIZONA REMOTE SENSING NEWSLETTER

In the past ARSP has supported the publication of a Remote Sensing Newsletter which focused on remote sensing activities at the University in general, and ARSP in particular. Due to changes in personnel, publication of the Newsletter was suspended; none were issued during this reporting year. However, interest in remote sensing within the state of Arizona is currently high and ARSP has proposed to the Remote Sensing Committee that publication be resumed under a modified format.

Future issues will be published semiannually. Each issue will feature an article submitted by a University researcher. The remainder of each issue will be devoted to the current activities of ARSP and others. The next issue will be published in August 1980.

CHAPTER 17. PUBLICATIONS AND CONFERENCE PARTICIPATION

Publications

Bowers, J.E. 1980. "Catastrophic freezes in the Sonoran Desert," Desert Plants, in press.

-----. 1980. "Flora of Organ Pipe Cactus National Monument," Journal of the Arizona-Nevada Academy of Sciences, in press.

Foster, K.E., R.A. Schowengerdt, and C.E. Glass "The use of Landsat imagery in groundwater exploration," Water Resources Bulletin, American Water Resources Association, Vol. 16, No. 5, October 1980.

Hutchinson, C.F. 1980. "A review of techniques for combining Landsat and ancillary data for digital classification improvement," submitted to Photogrammetric Engineering and Remote Sensing, July 1980.

Mouat, D.A., J.B. Bale, K.E. Foster and B.D. Treadwell 1980. "The use of remote sensing for an integrated inventory of a semi-arid area." submitted to Journal of Arid Environments, June 1980.

Mouat, D.A. and J.B. Bale 1980. "Remote sensing resource inventories in semi-arid environments," submitted to Photogrammetric Engineering and Remote Sensing, July 1980.

Schowengerdt, R.A. 1980. "Reconstruction of multispatial, multispectral image data using spatial frequency content," Photogrammetric Engineering and Remote Sensing, in press.

-----. 1980. An introductory digital image processing laboratory course for application scientists," NASA Conference of Remote Sensing Educators (CORSE-78), June 1978, NASA CP-2102.

Papers

Bowers, J.E. "Flora of Organ Pipe Cactus National Monument," Second Conference on Scientific Research in the National Parks. San Francisco, November 1979.

Glass, C.E. and R.A. Schowengerdt "Application of digital image analysis to mined lands reclamation," Sixteenth Application of Computer Methods in the Mineral Industry (APCOM) Symposium, AIME Society of Mining Engineers. October 1979.

Mouat, D.A. "Vegetation mapping in semi-arid regions: terrain feature analysis to augment conventional remote sensing techniques," Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences, University of California, Davis, May 1979.

Mouat, D.A. and R.R. Johnson "The importance of vegetation mapping for managing Park Service natural resources," Second Conference on Scientific Research in the National Parks. San Francisco, November 1979.

Mouat, D.A., K.L. Reichhardt, P.L. Warren and B.K. Mortensen Vegetation mapping at Grand Canyon National Park: An analysis of techniques," Second Conference on Scientific Research in the National Parks. San Francisco, November 1979.

Reichhardt, K.L. "Preserving riparian habitats in the Southwest: Identification of vegetation and land use with color infrared aerial photography," Poster Session, Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences. University of California, Davis, May 1979.

-----. "Water resources in Arizona's future," Poster Session, Conference of Governor's Commission on Arizona Environment. Flagstaff, August 1979.

Schowengerdt, R.A. "Data compression and reconstruction for mixed resolution multispectral sensors," Anuual American Society of Photogrammetry Convention, March 1980.

Schowengerdt, R.A., L. Babcock, L. Ethridge and C.E. Glass "Correlation of geologic structure inferred from computer-enhanced Landsat imagery with underground water supplies in Arizona," Fifth Annual William T. Pecora Symposium. Sioux Falls, June 1979.

Warren, E.H., J.R. Huning and C.F. Hutchinson "Equity and electric power generation facility siting in California," Annual Meeting Association of American Geographers. Louisville, April 1980.

Conference Attendance

Seventh Biennial Workshop on Color Aerial Photography in the Plant Sciences. University of California, Davis, May 1980.

Remote Sensing Sciences Council Conference, NASA-Ames Research Center, June 1979.

Conference of the Governor's Commission on Arizona Environment. Flagstaff, August 1979.

Committee on Vegetation Classification/Arizona-Nevada Academy of Science. Lake Pleasant, Arizona, September 1979.

NASA Western Regional Applications Program (WRAP) Conference, Monterey, October 1979.

Second Conference on Scientific Research in the National Parks. San Francisco, November 1979.

Nineteenth Annual Meeting of the Western Regional Science Association. Monterey, February 1980.

Fifth Annual Symposium on the Gulf of California Region. Mexicali, Mexico, February 1980.

Remote Sensing Sciences Council Conference. Corvallis, February 1980.

Bilateral Meeting of the United States and Mexico for Arid Lands Management and Desertification Control. Lubbock, March 1980.

Conference on the U.S. Operational Land Remote Sensing Satellite Program. Albuquerque, March 1980.

Annual Meeting of the American Society of Photogrammetry. St. Louis, March 1980.

Annual Meeting of the Association of American Geographers. Louisville, April 1980.

Invited Lectures

Mouat, D.A. "Remote sensing applications in arid lands." South Dakota State University, July 1980.

Schowengerdt, R.A. "Extraction of information from remotely sensed data." NASA-WRAP Short Course on Remote Sensing. Colorado State University, January 1980.

CHAPTER 18. THESIS SUPPORT

ARSP has engaged in project activity with graduate students from various departments whose interests coincide with ARSP project activity. The problems they work on are generally intended to be submitted for thesis topics. With such an arrangement, all parties benefit: ARSP acquires a motivated staff member; the student receives support, advice, and the opportunity to work on an applied problem; and the University produces a graduate with a modicum of experience in his chosen field.

Currently, four students are receiving various forms of ARSP support. One student is working on a master's in the Geography, Regional Development and Urban Planning Department and is employed on the Landsat applications to air quality management project described in Chapter 8. Work on his degree and on the project will be completed in August 1980.

Another student in the Geosciences Department is expected to complete a master's in September 1980. His thesis topic is "The Multispectral Reflectance and Image Texture Signature of Desert Alluvial Surfaces." He examines the influence of multispectral reflectance, geomorphic types, vegetation type and density, and geologic and terrain characteristics of desert alluvial surfaces in digitally processed Landsat and X-band SAR imagery. He has three objectives: 1) to quantify and isolate those field parameters that control the spectral tone and texture signatures of desert surfaces, 2) to use field measurement to generate discriminant functions for image enhancement of specific features, 3) and to produce an accurate and detailed morphogenetic classification of alluvial surfaces in the study area.

Finally, ARSP is providing imagery and advice to two students in the Geosciences Department. One student is working in Tucson on "River Meander Migration and Bank Erosion as a Social and Geologic Hazard." The study may result in Tucson's adopting a new floodplain ordinance. The other is working on evidences of geologic hazards in the alluvial fans south of Tucson.

Appendix A

Digital Techniques Development

APPENDIX A. DIGITAL TECHNIQUES DEVELOPMENT

Introduction

ARSP staff continued to utilize and develop the processing hardware and software facilities available at the University of Arizona. These facilities enable ARSP to use and combine data from computer compatible tapes (CCTs), aerial photography and other film sources such as SLAR imagery and cartographic or map data. The processing of these various forms of digital image information is summarized in Figure A-1.

Preprocessing Landsat data involves geometric and striping corrections and is a standard procedure for all Landsat CCTs received. Photography and map sources are digitized with the microdensitometer and Numonics digitizer, respectively. The digitized data bases then may be manipulated by the image processing routines, either individually or in register.

Image processing and pattern classification can be performed either in a batch mode with the CYBER 175 or in an interactive mode with the I^2S/PDP 11/70 system. The two systems are interfaced by magnetic tape. Each system offers particular advantages. Processing on the Cyber 175 offers extremely high precision and large core memory for large or complex programs. The I^2S/PDP 11/70 offers fast turnaround and immediate viewing of processing results.

ARSP has continued to expand use of SADIE for image processing and CALSCAN for image classification during the past year. Application projects for which this software has been used include dust source mapping in the Tucson valley, irrigated lands mapping northwest of Tucson and surface mining classification for all of Arizona. A major acquisition by ARSP during the past year was the Spatial Information Processing System (SIPS), a software package for geographic data manipulation. SIPS is described in detail in the next section.

SIPS

There is an increasing need to merge Landsat image or classified data with other spatial data, such as maps of natural features or political/administrative boundaries. This merger permits using the remote sensing information directly to assist resource managers. The merged data can be displayed as imagery with map overlays, may be selectively displayed by selection of specific map attributes or statistics and other analysis products may be generated according to specific map units.

SIPS is a comprehensive set of software routines designed to handle map-type data. Basically the map information must be digitized in the form of polygonal boundaries for input to the program. SIPS then can scale and shift these data to conform to any specified map scale, produce various plotter outputs (an example is shown in Figure A-2), or convert the data to an image raster format. This last capability is of particular interest to ARSP since it provides an interface to SADIE and CALSCAN.

The merger of the SIPS polygon-to-raster conversion with SADIE recently has been accomplished and its first application is in an irrigated lands inventory for the Arizona Department of Water Resources (see Chapter 1). During the coming year SIPS will be implemented on the University DEC-10 computer and ARSP will acquire a smart terminal to assist in digitizing maps. The terminal will serve as a data preprocessor between the ARSP Numonics digitizer and the DEC-10. Calcomp plots of the digitized map data then can be produced through the DEC-10.

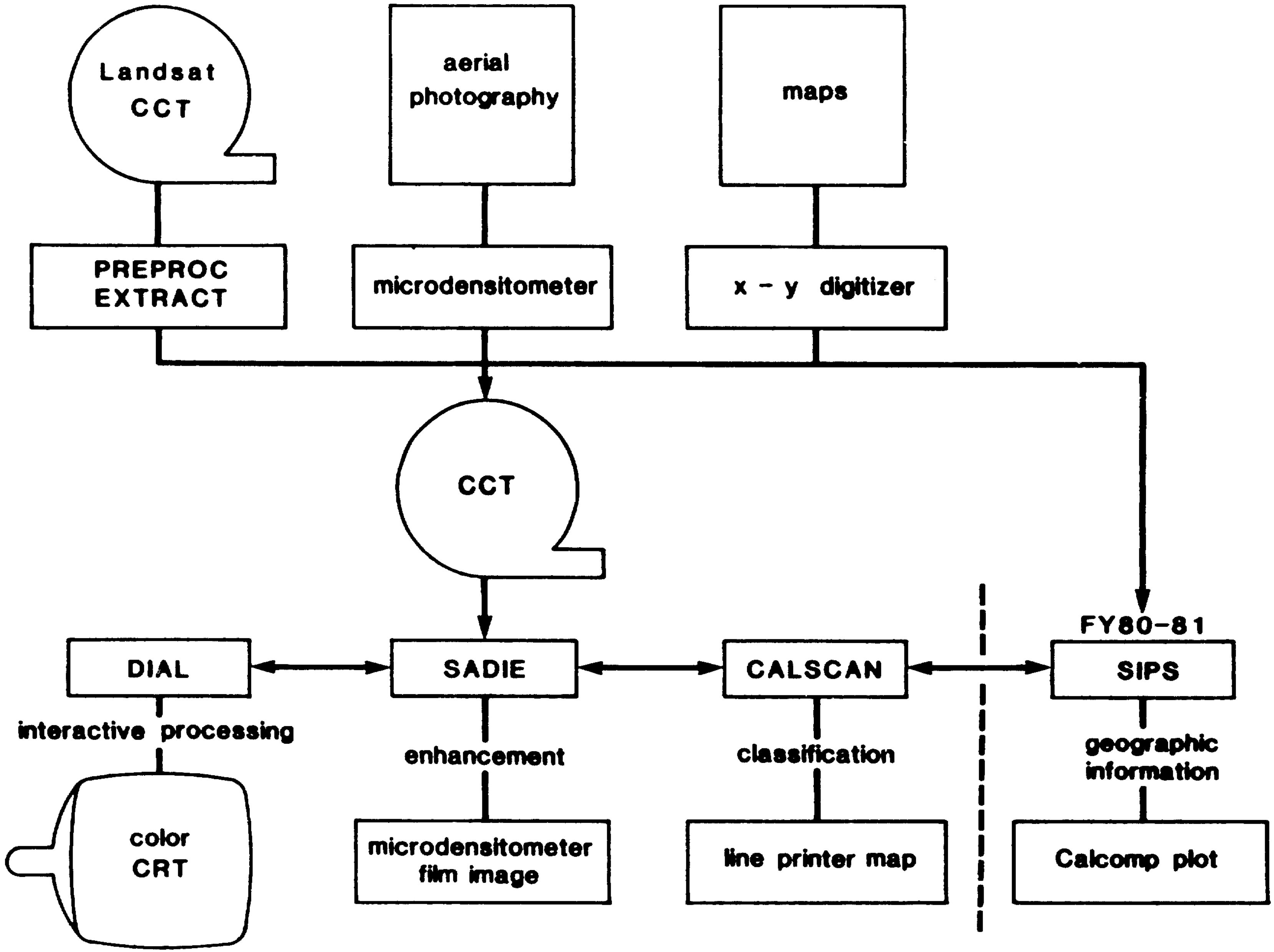

Figure A-1. SCHEMATIC OF UNIVERSITY OF ARIZONA DIAL/GIS INTERACTION

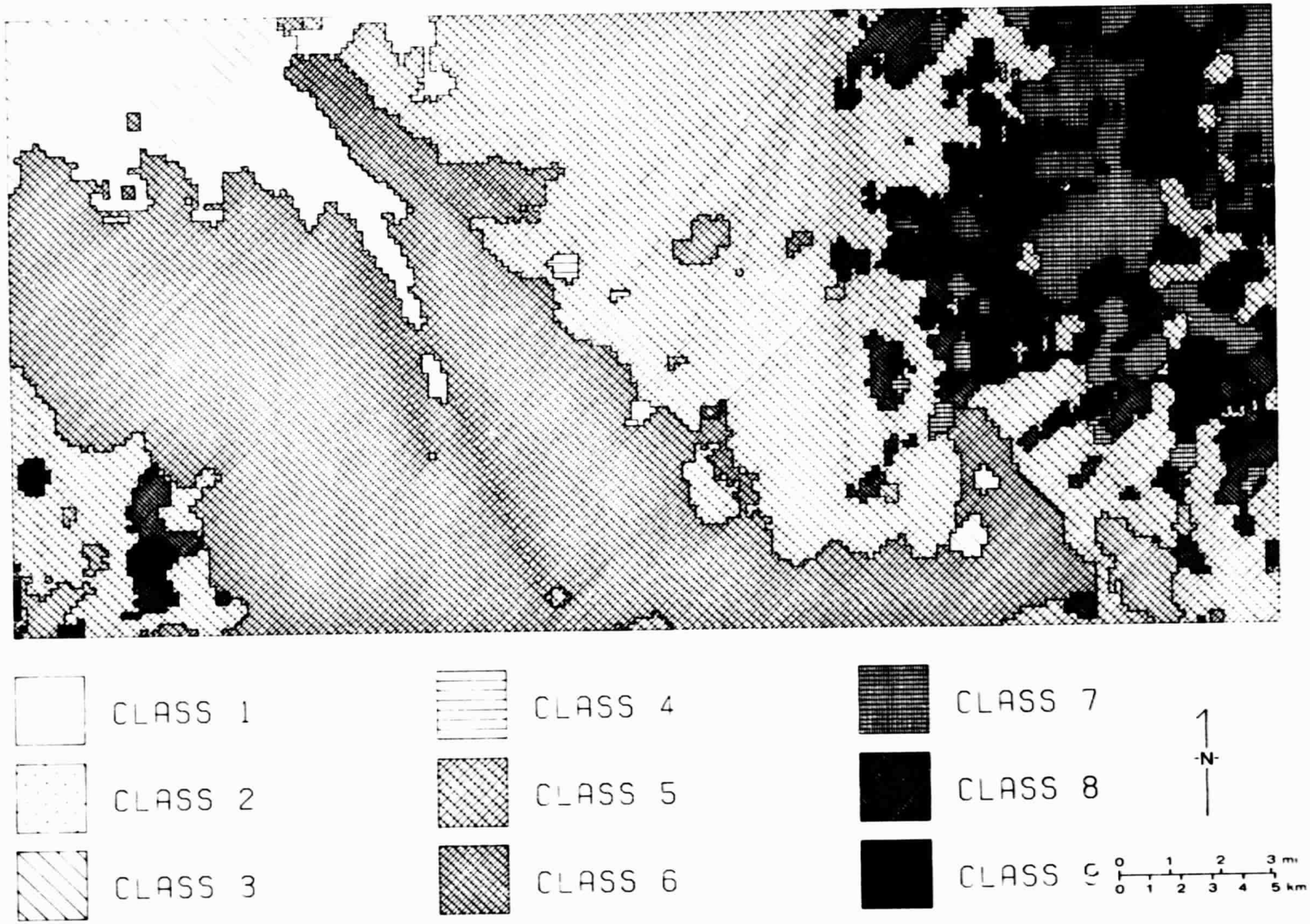

Figure A-2. EXAMPLE OF OUTPUT FROM SPATIAL INFORMATION PROCESSING SYSTEM.

Appendix B

Synopsis of ARSP Activities 1972-1980

Introduction

ARSP has conducted 37 major projects since January 1972. The main features and benefits from the projects are summarized in the following pages. Cooperating agencies, funding sources, purpose, data sources, final products, and direct and indirect benefits are detailed for each project.

Project	Project Title	Cooperating Agency/s	Supplemental Funding		Project Purpose	Source of Data	Begun
			Source	Amount			
I	Application of Remote Sensing to Land Use	Pima County Planning Department (PCPD)			1. Soil/vegetation survey in urbanized areas. 2. Monitor areas due to urban encroachment.	1. High altitude repetitive aircraft imagery	1/1/72
II	Application of Remote Sensing to Urban Environmental Plan	Planning Division City of Tucson			Analysis of the Pantano Wash, Arizona 1. Determine the drainage configuration. 2. Determine the vegetation and wildlife habitat. 3. Determine the geological and general characteristics	1. Color and B/W NASA high altitude photography	1/1/72
III	Assessment of Potential Irrigation Water Savings in Critical Groundwater Area of Douglas Basin, Cochise County	1. Cochise County Planning Department 2. U.S. Soil Conservation Service			1. Monitor surface water runoff from various types of irrigation systems in the Douglas Basin. 2. Determine crop types and retired acreage.	1.High altitude aircraft repetitive imagery	1/1/72

[illegible]

Project	Project Title	Cooperating Agency/s	Supplemental Funding Source	Supplemental Funding Amount	Project Purpose	Source of Data	Begun
IX	Mohave County Land Use Planning	Mohave County Planning Department (MCPD)	MCPD	$ 2,000	A pilot floodplain/land use delineation was conducted in order to comply with federal flood insurance requirements and reduce loss of life & property damage due to flooding.	1. Low altitude imagery, scale 1:6,000	3/1/74
X	Tucson International Airport Master Planning Study	Tucson Airport Authority (TAA)	TAA - sole source of funding	$20,000	The project products were used for long-range master plan of Tucson International Airport	1. NASA high altitude color & color infrared photography 2. Landsat imagery	3/1/74
XI	Northeast Arizona Oil & Gas Conservation Commission	Arizona Oil & Gas Conservation Commission	Department of Geoscience, University of Arizona, Arizona Oil and Gas Conservation Commission	$ 1,000	Use of geological formation to locate potential oil and gas fields	1. Landsat imagery	3/1/74
XII	Southern Arizona Riparian Habitat: Spacial Distribution and Analysis	Arizona State Senate Natural Resources Committee, Department of Watershed Management, University of Arizona			1. Map riparian vegetation. 2. The demonstration of remote sensing as an inventory tool	1. High altitude color infrared transparencies, scale 1:125,000 2. Landsat digital data	3/1/74
XIII	Remote Sensing Techniques Applied to Land Use and Flood Hazard Mappings	Apache, Graham, Yavapai, Cochise and Yuma Counties	Counties	$ 10,000		1. Landsat imagery, scale 1:1,000,000 2. Contact scale B/W 1:120,000 3. High altitude natural color photographs	3/1/74

NASA grant for 1974-75 [illegible] $1[illegible] [illegible]%
Other funding [illegible] [illegible]%
Total funding for 1974-75 $1[illegible] [illegible]%

Project	Project Title	Cooperating Agency/s	Supplemental Funding		Project Purpose	Source of Data	Begun
			Source	Amount			
IV	The Use of SLAR (Side Looking Airborne Radar) for Mapping Urban Land Use, Desert Soil and Emergency Landing Sites	Pima County Planning & Zoning Commission, Engineering Department, State of Arizona Property Evaluation Department, Aeronautics Department, Game & Fish Department, Federal Government National Park Service			Project objectives were multidisciplinary embracing conservation, civil engineering, aeronautics, land use and vegetation.	1. Side looking air borne radar 2. High altitutude photography	3/1/73
V	Application of Remote Sensing Techniques to Assess Wildlife Management Potential and Status	Department of Watershed Management, University of Arizona and Arizona Water Commission (AWC)			To assess management alternatives for improved water yield in Arizona's ponderosa pine watersheds.	N/A	3/1/73
VI	Development of a Remote Sensing Technology to Study the Hydrology of Earth Stock Tanks in a Semiarid Watershed	U.S. Forest Service, Salt River Project, & the Water Resources Research Center, University of Arizona (WRRC)			Examination of watering tanks effect on stream flow, water loss from stock tanks and use of water content of stock tanks as indicator of water sheds.	1. Low altitude B/W photography 2. NASA high altitude photography 3. Satellite imagery ERTS-1	3/1/73
VII	Advance Land Use Planning in Pima County	Pima County Planning Department (PCPD)	PCDP	$26,790	Utilization of innovative composite mapping techniques and remote sensing to develop a comprehensive geographically based resource inventory.	1. Composite mapping system (CMS) 2. NASA high altitude color infrared	7/1/74
VIII	Delineation of Geothermal Reservoirs in Southern Arizona	The Arizona State Land Department, The Department of Geoscience, University of Arizona			Produce a map which delineates area wherein reservoirs of geothermal steam might be expected to occur.	1. Satellite photography ERTS-scale 1:500,000	3/1/73

NASA Grant FY 1973-74	$ 75,000	74%
Other Funding	26,790	26%
Total Funding FY 1973-74	101,790	100%

Applied Remote Sensing Program
First Year Projects
(1972)

Current Status	Final Products/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	1. Maps 2. Report	Strengthened PCPD's argument that the Rincon Area should be left intact. Thus, the esthetic value of the area has been maintained. Zoning changes reduced the residential density.			
Completed	1. Maps of: a. Floodplain, source of runoff b. vegetation	Products of the project were used as a basis for master plan. Restriction of development in the floodplain has saved lives and property.			A new position created in the Planning Division, City of Tucson to extend the mapping of soils begun in this project.
Completed	1. Maps 2. Report	No known water conservation techniques were applied and as a result over 25% of the farmers in the area have gone out of business since 1972 (Economic loss is estimated at more than $5.0 million per year).			

Applied Remote Sensing Program
Third Year Projects
1974-75

Current Status	Final Product/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	Maps at scale 1:7,200 including: a. Soils b. Geomorphology c. Vegetation d. Hydrology e. Land use	The study recommended dike channelization for a major wash running through Bullhead City, Arizona. Inaction resulted in flood damage to property of more than $400,000 in 1977		$400,000	
Completed	Maps (scale 1:25,000): a. Landform types b. Topographic relief c. Caliche conditions d. Gravel deposits e. Soil maps f. Vegetation	The study recommends construction of a new carrier runway.			
Completed	1. Preliminary map showing the distribution & geometry of folds in the Colorado Plateau. 2. OALS Bulletin	Since this study, one well has been drilled and commercially attractive uranium has been discovered.			
Completed	1. Delineation of riparian vegetation 2. Literature review documenting the multiple use of riparian vegetation 3. OALS Bulletin	1. The mapping was used in support of Arizona's legislation pertaining to public lands, protection of water courses and riparian environment			
Completed	Set of topic maps 1. Land use 2. Flood hazard areas 3. OALS Bulletin	1. Yuma County prohibited subdivision in Gila River floodplain. 2. Apache County changed floodplain boundaries allowing areas for additional urban expansion. 3. Graham County prohibited development in flood hazard areas. 4. Cochise County adopted floodplain ordinance.			

Project	Project Title	Cooperating Agency/s	Supplemental Funding		Project Purpose	Source of Data	Begun
			Source	Amount			
XIV	An Assessment of the Impact of Water Impoundment and Diversion Structures on Vegetation in Southern Arizona	Arizona Water Commission (AWC) and Soil Conservation Service (SCS)	SCS	$ 2,950	Determine whether the water impoundment and diversion structures are responsible for change in vegetation.	1. NASA high altitude aircraft imagery.	4/75
XV	Remote Sensing Analysis and Literature Survey Pertaining to the Vegetation of the Petrified Forest National Park	National Park Service (NPS)	NPS	$13,000	To assist the Park Service in making park management decisions.	1. High altitude natural color photography. 2. Medium altitude 1:24,000 color aerial photography 3. Satellite imagery	10/1/75
XVI	Bureau of Land Management Rangeland Vegetation Mapping	Bureau of Land Management BLM Safford District	BLM	$ 3,000	Assist BLM to develop capability in grazing allocation	1. NASA high altitude photography 2. Color photography 3. Satellite imagery, Landsat & Skylab	2/1/76

NASA Grant FY 1975-76	$1[illegible]	[illegible]
Other Funding	18,950	1[illegible]
Total Funding FY 1975-76	$118,95[illegible]	100%

Applied Remote Sensing Program
Fourth Year Projects
1975-76

Current Status	Final Product/s	Impact	Economic Benefits		Spin-Offs
			Direct	Indirect	
Completed	1. Maps 2. Report summarizing findings	1. A decision was made to redesign impoundment structure to minimize downstream effect to habitat. 2. Improved downstream habitat will enhance wildlife and therefore bring about increased hunting revenues.			
Completed	1. An annotated bibliography of Park related literature 2. Report 3. General and detailed vegetation maps 4. Management recommendations	1. Led to additional commitments between ARSP and NPS. Total value $124,000. 2. Management Recommendation not to chemically treat undesired shrubs saved NPS $25,000. 3. Decision not to eradicate Tamarisk	$200,000 $ 25,000		As a result of the project the National Park Service had modified its contract policy. The modification had commerical implications
Completed	Vegetation maps: General (scale 1: 250,000) Specific (1:63,360)	1. Use of remote sensing instead of traditional mapping techniques saved BLM $50,000. 2. Higher forage production and subsequent increased cattle production will increase economic benefit by $50,000.	$ 50,000	$50,000	BLM had contracted for a soil survey based on aerial photography. BLM contracted ARSP to conduct remote sensing training workshop 1977.

Project	Project Title	Cooperating Agency/s	Supplemental Funding		Project Purpose	Source of Data	Began
			Source	Amount			
XVII	The Use of Thermal Infrared Technology in Urban Energy Conservation, Tucson, Arizona	Arizona Office of Economic Planning and Development (OEPAD), City of Tucson, NASA-Ames Research Facility University of Arizona	OEPAD	$ 8,426	Assist the City of Tucson and the State of Arizona in designing future public education campaigns related to energy conservation.	Thermal infrared imagery in negative and digital tape formats	7/1/76
XVIII a.	Natural Resources Inventory of Papago Indian Reservation & Pima County	The Papago Tribal Unity Authority (PTUA) The Papago Planning Department Pima Association of Governments (PAG) Native American Development Systems Analysis & Applied Technology (NADSAT)	PTUA NADSAT PAG Total	$20,000 10,000 17,000 47,000	Integration of existing imagery and resource map products to support the needs of the 208 Water Quality Planning Program	1. High altitude ARIS orthophotoquads scale 1: 24,000. 2. High altitude photographs, scale 1: 120,000 U-2 transparencies 3. Landsat imagery 4. Skylab photos	8/1/76
XVIII b.	Natural Resources Inventory of the Papago Indian Reservation & Pima County (Amendment)	Papago Tribal Utility Authority & Pima Association of Governments	PTUA	$ 4,223	Floodplain mapping		4/15/78
XIX	Subsurface Coal Fire [illegible]ntification on B[illegible]ck Mesa	U.S. Environmental Protection Agency (EPA) & the Department of Watershed Management, University of Arizona (WM)	WM	$ 4,000	To analyze coal fires through the use of thermal infrared techniques to minimize personal injury, pollution & property damage.	1. Low & medium altitude overflights, 9x9 color transparencies 2. Thermal infrared imagery.	1/77
XX	Tumacacori Mission National Monument Floral Inventory	National Park Service (NPS)	NPS	$ 1,800	Vegetation map to be used for planning, management, interpretation & research.	Black & white photograph, scale 1 inch = 20 ft.	9/20/76
XXI	Alternative Water & Land Use Study of the Gila River Portion of the San Carlos Apache Indian Reservation	Economic Development Administration (EDA) San Carlos Apache Tribe (SCAT), Laboratory of Native Development & Applied Technology Systems Analysis (NADSAT) University of Arizona	NADSAT	$ 6,100	The information of potential arable land was used to establish priorities for development of various fields & thereby optimize utilization of irrigation water	1. NASA high altitude natural color photography, scale 1:24,000	1/77

NASA Grant FY 1976-77	$100,000	58%
Other Funding	71,559	42%
Total Funding FY 1976-77	171,559	100%

Applied Remote Sensing
Fifth Year Projects
1976-77

Current Status	Final Product/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	1. Thermograms B/W prints 2. Report of analysis	1. The value of energy saved by homeowners as direct result of thermograms. Utilization is estimated at $10,000 a year. 2. Value of insulation added to roofs $40,000	$40,000	$10,000	Due to the success of the program, a private firm has been established to monitor heat loss using remote sensing.
Completed	1. Overlays of land use in standard 15 foot topographic sheets, blackline on mylar. 2. Procedural manual & narrative legend 3. Floodplain maps of reservation	1. Maps were used to locate sewage treatment facility value of ARSP service assessed at $40,000. 2. Maps were used in range development planning, amount saved in use of the maps was $35,000. 3. Maps were used in rezoning of the site selected for an IBM plant.	$40,000	$35,000	Contract given to private consulting firm (Ag. International) to suggest range improvement methods for a portion of the Papago Reservation.
Completed	1. Overlays of flood-prone areas on a scale 1:62,500				
Completed	Report of analysis of distribution of surface "hot spots."	1. As a result of the study, mining methods have been altered to reduce surface collapse, thus, pollution and potential personal hazard have also been reduced.			
Completed	1. Large scale vegetation map 2. Report containing common names & description of species, management recommendations.	The National Park Service began a Tamarisk (an exotic species) eradication program.			
Completed	Maps showing vegetation, land use, flood hazard, soils & potential arable land, scale 1:250,000	1. Tribe is currently rehabilitating 384 acres (estimated income per year $40,000). 2. Approximately 1,148 acres of new land were recommended for development (estimated income per year $120,000).		$ 40,000 $120,000	The San Carlos Apache Tribe extended the study to the San Carlos River Drainage Basin.

Project	Project Title	Cooperating Agency/s	Supplemental Funding		Project Purpose	Source of Data	Begun
			Source	Amount			
XXII	Havasupai Environmental Impact Statement	Havasupai Indian Tribe (HIT)	HIT	$77,827	Prepare soil, vegetation, landforms and drainage and slope maps. The maps were used as a primary data source for the EIS team analysis of a recent land use plan.	1. Medium altitude natural color aerial photography, scale 1:24,000	5/1/77
XXIII	An Inventory to Determine Land Use and Potential Agricultural Land in the San Carlos River Drainage Basin Region.	San Carlos Apache Tribe (SCAT)	SCAT	$14,945	Define areas which have a potential for agricultural development.	1. Computer processed Landsat imagery 2. Medium altitude stereoscopic 1:24,000 color photography.	2/1/77
XXIV	Vegetation Mapping & Survey of Vascular Flora of Organ Pipe National Monument	National Park Service (NPS)	NPS 1 yr. 2 yr. 3 yr. Total	 $ 7,000 16,700 16,500 40,000	Enable the Monument to make ecologically sound management decisions.	1. Medium altitude 1:24,000 natural color photography	9/20/77
XXV	Vegetation Inventory of Grand Canyon National Park	National Park Service (NPS)	NPS 1 yr. 2 yr. Total	 $35,374 $45,979 $81,353	Provide the Park detailed baseline information to 1) make management decisions, 2) monitor environmental changes.	1. Medium altitude perspective aerial photography 2. Low altitude color photography 1:24,000 3. Landsat images	9/20/77
XXVI	Geologic Applications of Landsat Images in Northeastern Arizona to the Location of Water Supplies for Municipal and Industrial Use	U.S. Department of Interior Office of Water Resources & Technology (ORWT), Arizona Water Commission	OWRT	$18,385		1. Landsat images bands 5 & 7 scale 1:250,000 2. Landsat CCT	10/1/77

NASA Grant 1977-78	$100,000	30%
Other funding	237,343	70%
Total funding FY 1977-78	337,343	100%

Applied Remote Sensing Program
Sixth Year Projects
FY 1977-78

Current Status	Final Product/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	1. Maps of soils, vegetation, landform, drainage and slope, scale 1:24,000 reduced to 1:62,500 for publication. 2. EIS Report	1. Decision by the Tribe not to develop 200 acres since the analysis showed that development was not economically viable (total savings $200,000). 2. Potential benefit from campsites if constructed $60,000 per year.		$200,000 $ 60,000 per yr.	
Completed	1. Maps showing land use, vegetation, potential agricultural land and flood-prone areas 2. Seminars on photo interpretation 3. Summary report	1. Land on 650 acres is being recommended for development. 2. Two hundred fifty acres are being developed in Jojoba. Annual income projected at more than $100,000 per year. 3. Will employ 35 people.		$100,000 per yr.	An agricultural economist was contracted to set up a program of development.
Completed	1. Vegetation maps, scale 1:24,000 2. Annotated bibliography 3. Report 4. Workshop	1. Eliminate the need for threatened and endangered species survey ($50,000 saved). 2. Recommendation not to seed rangeland saved $20,000. 3. Location of trails - increased visitor benefits by $84,000.	$50,000	$ 20,000 $ 84,000	
Phase I: Completed Phase II: Field work in progress	1. Vegetation maps of scale 1:62,500, black-lines-on-mylar and legend 2. Paper copies of the above maps 3. Report	1. Fire control plan based on the study will save the park $150,000. 2. Management problems averted by use of data - $250,000. 3. Conservation of natural resources by use of management plan, estimated value of these resources $800,000.	$250,000	150,000 $800,000	A general vegetation map of the canyon will be published by the National Park Service for the general public.
Completed	1. Report research finding in scientific journals 2. Final report 3. Arizona Water Resources New Bulletin 4. Computer enhanced imagery	Landsat imagery has been shown to have considerable value in surveying large areas for lineaments which cue hydrologists to promising regions for detailed work from photographs and ground survey.	$ 20,000		Arizona Water Commission is using statistical procedures developed during this project for studies of well production in various types of rocks and soil. Computer image enhancement procedures for geologic structure are currently being applied to earthquake hazard prediction for nuclear power plant sites.

Project	Project Title	Cooperating Agency/s	Supplemental Fundging		Project Purpose	Source of Data	Begun
			Source	Amount			
XXVII	An Inventory of Wildlife Habitat Along the San Pedro River	The Nature Conservancy (TNC)	TNC	$ 4,833	The study will enable the Nature Conservancy to select optimal wildlife habitat areas for conservation purposes.	Orthophotoquads 1:24,000 Aerial photographs 1935,1955,1974, 1977	11/15

NASA Grant 1977-78	$100,000	30%
Other Funding	237,343	70%
Total Funding FY 1977-78	337,343	100%

Current Status	Final Product/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	1. Maps showing habitat, vegetation, land use, soils, landforms. 2. Orthophotoquads, 1:24,000 3. Summary report	1. The maps reduced the survey costs by $78,000. 2. Saving in future research expenses $50,000. 3. Preserved areas will serve recreational needs of Metropolitan Tucson, estimated income per year $1.0 million.	$ 78,000 $ 50,000	$1,000,000 per year	1. The Colorado Natural Areas Council will undertake inventory of three riparian areas. 2. A project to map Tamarisk has been initiated as a result of this project. 3. TNC is planning to acquire property of conservation easement along the river.

Project	Project Title	Cooperating Agency/s	Supplemental Funding Source	Supplemental Funding Amount	Project Purpose	Source of Data	Begun
XXVIII	Wildlife Habitat Mapping of the Three-bar and Tonto Basin Study Area	Arizona Game and Fish Department (AGFD)	AGFD	$ 6,305	To produce a map of vegetation types and related wildlife habitat.	1:24,000 infrared photography	7/6/78
XXIX	Supplemental Master Plan Studies for the Tucson International Airport.	Tucson Airport Authority (TAA)	TAA sole source of funding	$35,000	Documentation and assessment of environmental impacts associated with airport improvements	1. Enlargement of high altitude color photography 1:31,000 2. Large scale B/W photography 1:7,200	8/24/78
XXX	Environmental Impacts of IBM Development Site, Tucson	Albert C. Martin & Associates (ACM)	ACM sole source of funding	$35,000	To assess the impact of plant construction on the natural environment	1. Large scale natural color photography 1:6,000	10/15/78
XXXIII	Analysis of Dust Hazards in Southern Arizona	Arizona Department of Public Safety and Transportation			To identify dust sources along major transportation routes within the Tucson-Phoenix corridor.	1. Landsat imagery & digital tapes	3/1/78
XXXIV	Landsat Application in Monitoring Particulate Matter Sources & Spatial Distribution	Pima County Air Quality Control District (PCAQCD) Pima Association of Governments Air Quality Planning Program (PAG)			The project will involve: 1. Construction of land use data base for air quality monitoring. 2. Spectral analysis to define sources and spatial distribution of particulate emission.	1. Landsat digital tapes. 2. High altitude color photography	3/1/78

NASA Grant FY 1978-79	$100,000	57%
Other funding	76,305	43%
Total funding FY 1978-79 (not including funds from continuing projects)	176,305	100%

Applied Remote Sensing Program
Seventh Year Projects
FY 1978-79

Current Status	Final Product/s	Impact	Economic Benefits		Spin-offs
			Direct	Indirect	
Completed	1. Map of vegetation types and related wildlife habitat features. 2. Report describing project methodology and mapping units	The map product of this project will provide data for wildlife research and management. Preliminary results have been presented in several wildlife symposiums and workshops.			
Completed	1. Final report a. map of vegetation b. map of drainages c. air, water quality assessment	As a result of the studies one runway will not be constructed and one will be relocated.			
Completed	1. Map of vegetation association	Value of native desert vegetation saved estimated at $2,000.	$2,000		
Discontinued		Dust hazard along major highways will be alleviated by: 1. Location of major dust sources. 2. Reduction of amount of dust generated using surface treatment, land-use regulations, etc.			
First Phase Completed	1. Land use data base 2. Completion report. 3. Computer classification of Tucson	1. The project will assist local, air quality control agencies in their planning & monitoring efforts. These efforts are mandated by EPA to reduce dust pollution to below health standards. Failure to do so could result in loss of an estimated 140 million in federal funds to the county. 2. Identifying particulate emission sources with Landsat can save Pima County the $25,000 cost of another inventory. 3. By directing mitigation efforts at specific problem areas this study could reduce substantially the estimated $20 million cost of paving roads, a major source of dust.	$ 25,000	Up to $140 million Up to $20 million	PAG has recommended to the Environmental Protection Agency that an expanded study be funded.

Serial No.	Project Title	Cooperating Agency/s	Funding			Project Purpose	Source of Data	Begun
			Source	Code	Amount			
XXXV	Visitor Use Impact Assessment, Saguaro National Monument	National Park Service (NPS)	NPS	F	$ 11,200	To 1) review literature pertinent to visitor use impact assessment 2) evaluate previous research done in the Monument, and 3) map historic and current roads and trails.	1. 1:30,000 B/W (1936) 2. 1:40,000 B/W (1954) 3. 1:24,000 B/W (1978)	4/79
XXXVI	Lawn Inventory for Water Use Management	Tucson Water	TW	L	2,017	To 1) monitor trends in irrigated lawn area, 2) correlate it with water consumption and estimate the impact of water conservation programs.	1. 1:125,000 CIR, 1972 2. 1:24,000 B/W, 1976 3. 1:9,600 CIR, 1979	5/79
XXXVII	Land Use Inventory Update	Pima Association of Governments (PAG)	PAG	R	1,500	To update existing ARSP-produced land use map for monitoring water quality	1. 1:62,500 CIR, 1977 2. 1:9,600 C, 1979	7/79
XXXVIII	Landsat Applications to Mined Land Inventory and Hazard Monitoring	Office of Surface Mining (OSM), U.S. Department of Interior	OSM	F	78,000	To 1) inventory existing mines in Arizona, 2) develop a mine monitoring system, and 3) delineate hazardous mined areas	Digital Landsat	10/79
XXXIX	Landsat Applications to Water Management	Arizona Department of Water Resources (DWR)				To develop and demonstrate manual and digital techniques for estimating irrigated acreage	Landsat (digital and photographic)	1/80
XL	Land Use Mapping for Air Quality Management	Pima Association of Governments (PAG)	PAG	R	232.50	To map local sources of total suspended particulates (TSP) affecting air quality sampler	1:20,000 color aerial photography	3/80
XLI	Landsat Applications to Mesquite Management	Arizona State Land Department				To map the distribution of mesquite vegetation and its characteristics of cordage and fruit production	1. Landsat (digital) 2. 1:130,000 color infrared aerial photography 3. 1:20,000 color and color infrared aerial photography	5/80

*NASA Grant [illegible] $125,000.00 51%
Other Sources 122,949.50 49%
Total Funding 247,949.50 100%

Current Status	Final Products	Impacts	Economic Benefits		Spinoffs
			Direct	Indirect	
Completed	1. Evaluation of previous research 2. Literature review 3. Map of historic roads and trails 4. Map of current roads and trails	1. Closure of trails which have sustained heavy impact is pending 2. New research activity will be initiated incorporating ARSP suggested modifications			
Completed	1. Final report submitted to Tucson Water staff 2. Presentation of findings to Tucson Citizen's Water Advisory Committee 11/79	1. Provides support for success of Tucson Water's peak water demand reduction effort 2. Direction for future water conservation program design	Savings of $4,000 in efficacy-evaluation reporting	Establishes baseline data to minimize subsequent conservation evaluation studies	1. Water conservation education program funded by EPA for public school institutions 2. Detailed study by USDI OWRT on conservation policies and public policy
Completed	1. Updated land use map 2. Land use history report	Baseline land use data for water quality - surface activity interaction model	Savings of $5,000 field research for current land use update	Baseline land use data to minimize subsequent update expenditures	Land use history report for study area
All Landsat scenes have been acquired, preprocessed and registered		Provides a method whereby the state can comply with OSM regulations	Potential $40,000 savings in salaries and travel		
Preliminary report preparation	1. Estimates of irrigated acreage 2. A comparison of costs and accuracies of manual & digital techniques	DWR will develop a capability to use Landsat data The decision will be based on data produced by ARSP			Possible state facility for remote sensing
Completed	1. 1:24,000 microinventory of TSP sources 2. 1:125,000 map of regional land use	Maps will support PAG's argument to EPA that sampler data is not representative New emissions controls will not be required for town of Rillito and Portland Cement Plant	Up to $1 million in additional controls	Up to $140 million in suspended federal funds	
Classification scheme is being developed and control data gathered	1. A method for mapping mesquite vegetation and some of its characteristics at a regional scale, 2. a demonstration of a technique for detailed inventory	Based on the application of techniques developed, a more [illegible]tive and profitable plan for managing state land will be developed	Up to $1 million in increased revenues		

Serial No.	Project Title	Cooperating Agency/s	Funding Source	Code	Amount	Project Purpose	Source of Data	Began
XLII	Remote Sensing Workshops for Resource Managers	Bureau of Land Management (BLM)	BLM	F	$30,000	To present a series of basic courses in remote sensing techniques to BLM resource managers.	1. Low medium and high aerial photographs 2. Landsat imagery	8/79

*NASA Grant 1979-80 $125,000.00 51%
Other Sources 122,949.50 49%
Total Funding 247,949.50 100%

Current Status	Final Products	Impacts	Economic Benefits		Spinoffs
			Direct	Indirect	
Completed	1. Comprehensive syllabus for attendees 2. Formal course presentation in Albuquerque, New Mexico; Corpus Christi, Texas; and Washington, D.C.				