

Reprinted from

Symposium on

Machine Processing of

Remotely Sensed Data

June 29 - July 1, 1976

The Laboratory for Applications of
Remote Sensing

Purdue University
West Lafayette
Indiana

IEEE Catalog No.
76CH1103-1 MPRSD

Copyright © 1976 IEEE
The Institute of Electrical and Electronics Engineers, Inc.

Copyright © 2004 IEEE. This material is provided with permission of the IEEE. Such permission of the IEEE does not in any way imply IEEE endorsement of any of the products or services of the Purdue Research Foundation/University. Internal or personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution must be obtained from the IEEE by writing to pubs-permissions@ieee.org.

By choosing to view this document, you agree to all provisions of the copyright laws protecting it.

PACIFIC NORTHWEST RESOURCES
INVENTORY DEMONSTRATION

J. D. Nichols

ESL Incorporated, Sunnyvale, California

I. ABSTRACT

The Pacific Northwest Land Resource Inventory Demonstration project is being carried out jointly by NASA, the U.S. Department of the Interior (USDI) and Pacific Northwest Regional Commission (PNRC) through the technical capability provided by NASA, USDI and contractor support. The project is designed to demonstrate to users from state and local agencies in Washington, Oregon, and Idaho the cost effective role that LANDSAT derived information can play in natural resource planning and management when properly supported by ground data and aircraft data.

II. INTRODUCTION

A Land Resource Inventory Task Force (LRITF) composed of representatives of the States of Washington, Oregon, and Idaho have been meeting since mid-1974 to discuss common problems related to land resources. This group was established under the sponsorship of the PNRC. The PNRC is a U.S. Department of Commerce funded organization composed of the governors of the three states together with a federal cochairman appointed by the President. The PNRC staff has offices in Vancouver, Washington. It is the Commission's responsibility to develop and establish projects and programs which will contribute to the economic development of the Pacific Northwest Region.

Through the efforts of the LRITF, the Commission has developed a strong interest in determining the applicability of information obtained from satellite, high-altitude aircraft, low altitude aircraft and ground crews to the solution of regional land resources problems. In response to inquiries made to Ames Research Center (ARC) by the PNRC, a number of meetings among representatives of ARC, the PNRC, and USDI's Earth Resources Observation Systems (EROS) and Geography Programs were held. As a result of these meetings, the three parties decided to jointly plan and perform a remote sensing demonstration project.

In order to achieve the above overall goal, the following key factors are being addressed:

1. The hardware, software, and experience in application techniques required to extract useful information from multispectral imagery is readily available.

2. The interests of diverse users has been merged into a common base of support within the region for the project.

3. The particular applications to be demonstrated during the project have been identified jointly by users and NASA/USDI applications experts to ensure that they are: a) related to real problems of importance to the users, and b) technically feasible.

4. Information products obtained from LANDSAT technology are being integrated with information from other more conventional sources to provide a total problem-solving capability.

5. The users will evaluate the utility of LANDSAT-based information products either separately or in combination with other types of information. The NASA/USDI participants will document the costs of producing useful information. This documentation will provide the basis for a cost-effectiveness assessment which will support recommendations to the region as to the installation of an operational LANDSAT-based Natural Resource Inventory System.

III. TECHNICAL PLAN

The efforts to be carried out during the proposed project have been organized into five main phases. The project has concentrated on well-defined applications in limited geographical areas, working with well-motivated users having some previous experience in remote sensing techniques.

A. Phase I: Maps and Overlays

The purpose of Phase I is to produce a set of 1:500,000 scale base maps for the entire Pacific Northwest region, together with a set of five overlays. The overlays will provide information concerning:

1. Land use determined by visual interpretation of LANDSAT imagery using the Level 1 categories of USGS Circular 671.

2. Soils information to a level of detail consistent with that of the Level 1 land use categories.

3. Federal, state and private land ownership.

4. Location and extent of drainage basins.

5. Energy-related information such as location of coal fields, power-line corridors, geothermal areas, pipelines, etc.

This phase of the project has been completed by the region's universities and state agencies on contract to PNRC.

B. Phase II: Early Digital Image Analysis

Phase II provides for initiation of digital image analysis work as a modest level of effort using existing ARPA-Network and Ames Research Center data analysis facilities and contract support. The purpose of this phase is two-fold:

1. Provide successful small-scale demonstration of digital analysis techniques resulting in tangible products (described below) to which users can react.
2. Provide additional technical experience in use of the existing data analysis system.

C. Phase III: Demonstration of Applications Using Interactive Image Analysis Equipment

The purpose of this phase is to carry out demonstrations of the utility of LANDSAT-based information products over a wider range of applications than in Phase II, making use of an upgraded user-oriented image analysis capability. In addition, new applications will be addressed during this phase, starting with preliminary analyses in localized areas and then expanding the coverage as analysis techniques improve and optimum product types become more completely defined. During Phase III, user personnel from the Northwest will be more directly involved in the data analysis effort, bringing to bear their knowledge of the problems and their access to ground truth information. They will be trained and assisted by NASA, USDI and contract personnel experienced in the operation of the data analysis system. For this purpose the users will come to Ames Research Center for periods of a few weeks. Emphasis will be placed throughout the project on extraction techniques which provide the most cost-effective results. A function will be established within the project to monitor the costs of system operations, and representatives from the Pacific Northwest Region will evaluate the utility of the products and the benefits derived from their use.

D. Phase IV: LANDSAT Products and Land Resource Information Systems

Many users in the Pacific Northwest Region believe that the greatest payoff from LANDSAT technology will arise from the synergistic use of LANDSAT based information in combination with information derived from other more conventional sources. The purpose of Phase IV is to evaluate that payoff by interfacing a LANDSAT based data analysis system and a geographically referenced information system or systems. The output of the former will be used as input to the latter, and the utility of such input will be evaluated.

E. Phase V: Documentation

During the course of the project, all procedures and techniques will be fully documented in order to facilitate the transfer of the technology to the user organizations at the completion of the project.

The PNRC states are shown in Figure 1 with the projects shown by discipline. Three of the projects that will be discussed further are: Washington Forestry, Oregon Tansy Ragwort, and Idaho Irrigated Lands. These three projects and the Oregon Forestry Project utilize multistage sampling procedures. Here, the satellite data is processed and used to allocate the photo interpretation effort which, in turn, is used to locate the specific points on the ground where detailed information is collected by field visit. The results of this data collection and information extraction effort provided the means for an objective estimation of the quantitative parameters of interest to the resource manager along with detailed in-place information on the resources through map overlays.

A. Washington Forestry Project

Project Area. The 20 million acres of Western Washington, with nearly 10 million acres of commercial forest land, is the project area. This is a logical study area because the total area is often considered as a single region, the forest resource is very important to the economy of the region, and the timber supply situation needs to be assessed with current resource data.

Project Objectives. The project objectives are to:

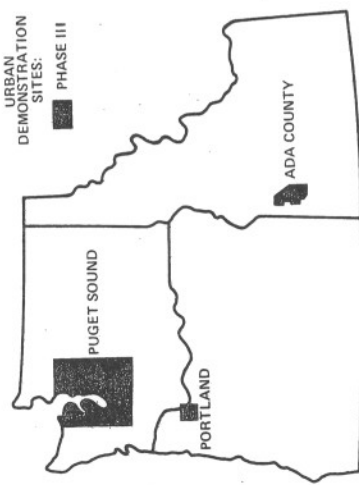
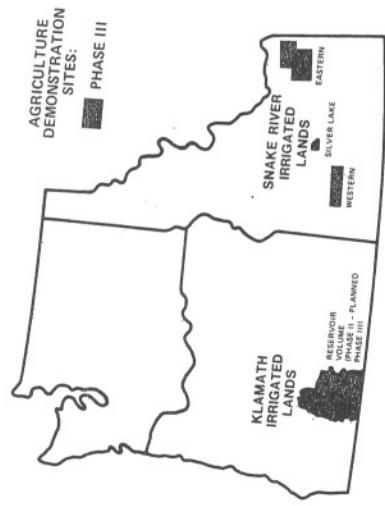
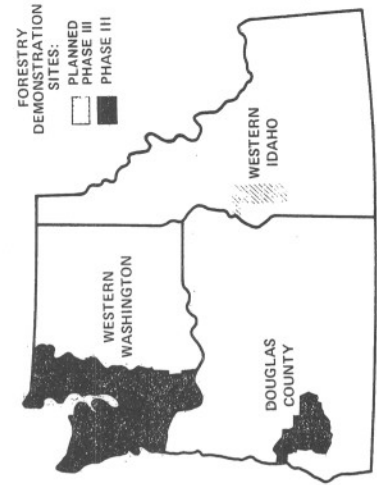
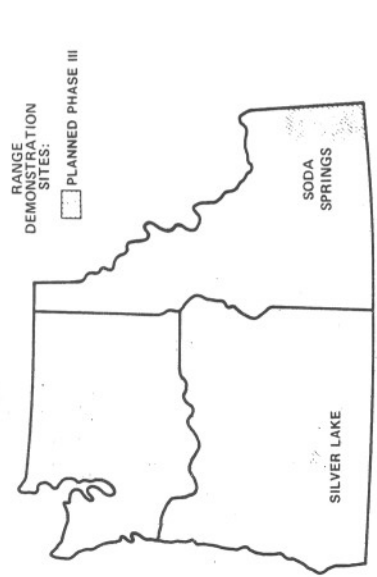
1. Complete a forest inventory for Western Washington with data reported for five ownership groups, Douglas Fir and Western Hemlock Zones, and for young and old growth conifer stands and hardwood stands.
2. Evaluate the value, cost and reliability of the remote sensing inventory system.
3. Provide the State of Washington's Department of Natural Resources (DNR) personnel with training and experience in the use of remote sensing inventory techniques.

Methodology and Products. The data is being generated for the Douglas Fir and Western Hemlock Zones and five ownership classes (State, National Forest, Other Public, Forest Industry and Other Private). The results will be presented in the table showing basal area per acre by age and site class. They will be estimated by using analysis of variance, analysis of covariance and regression analysis techniques on the LANDSAT photo interpreted and ground collected data.

Summary statistics (mean, standard deviation and standard error of the estimate) will be provided for each ownership class and zone as follows:

Young-Growth Conifer Stands

1. Basal area per acre by 10 year age class and site class for all conifer stands in age classes 30-100 (30 year age class is 26-35, . . . , 100 year age class is 96-105). Forest site classes are I, II, III, IV and V as



DEMONSTRATION SITE MASTER SCHEDULE

DISCIPLINE	DEMONSTRATION	1978												1977											
		J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
AGRICULTURE	SNAKE RIVER IRRIGATED LANDS, OREGON																								
	KLAMATH IRRIGATED LANDS, OREGON																								
URBAN	PORTLAND LAND COVER, OREGON																								
	PUGET SOUND, WASHINGTON																								
FORESTRY	WESTERN WASHINGTON, OREGON																								
	WESTERN IDAHO, OREGON																								
RANGE	SILVER LAKE, OREGON																								
	SODA SPRINGS, IDAHO																								
WEEDS	TANSY RAGWORT, OREGON																								
	LEAFY SPIRIG, IDAHO																								

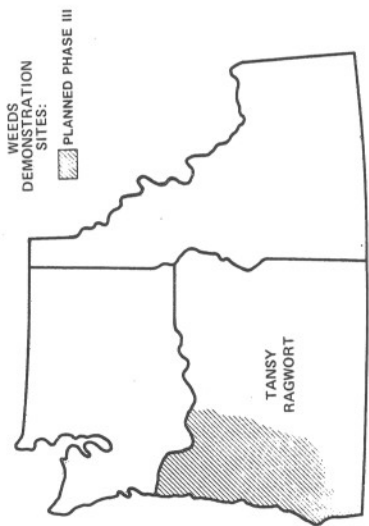


Figure 1. PNRC States.

conventionally noted for Douglas Fir and Western Hemlock.

2. Basal area by diameter breast high (DBH), 10 year age class and site class.

3. Acreage by 10-year age class and site class for ages "0" through 100.

Old-Growth Conifer Stands

1. Net cubic foot volume for the two older age classes (106-155, and 156 and older).

2. Acreage by site class for conifer stands above the 100 year age are to be grouped into 105-155 and 156 and older.

Hardwood Stands

1. Basal area per acre by 10 year age class and site class for all hardwood stands in age classes 30-100. Forest site classes are I through IV as defined by Alder Site Tables.

2. Acreage by 10 year age class and site class for ages "0" through 100.

B. Monitoring and Inventory of Tansy Ragwort In Western Oregon

Objectives. The objective of this study is to monitor the density, condition and area coverage of tansy ragwort in Western Oregon. To accomplish this an operational inventory, mapping and monitoring methodology has been developed from existing proven techniques. To be useful in the eradication program, the information is being summarized by environmental units, political boundaries and general ownerships.

The summer and fall of 1975 were used to develop the operational methodology and detailed implementation plan to be utilized during the winter and summer of 1976. Extreme care was taken to ensure that each level of data (LANDSAT, U-2, conventional aircraft, low altitude aircraft, and ground data) was utilized in a cost effective manner in the entire information collection process.

Potential For Success. There are a number of characteristics of tansy ragwort that make it possible to monitor, inventory and map characteristics pertinent to the eradication program. Tansy ragwort is a shade intolerant species; that is, it does not grow in areas where there is greater than 70% crown closure of trees or tall brush. This relationship with other dominant vegetation types allows the mapping of the areas where the weed does not exist in large quantities enough to pose a problem.

The seed spread and germination characteristics of the plant make it ideally suited for regeneration in clear cut areas after logging operations. Shortly after a clear cut is completed tansy ragwort will appear in the open area with disturbed soils. The infestation will increase until brush or forest regeneration begins to dominate the site to the point where shading occurs and the plant cannot compete. Because of the demonstrated potential for mapping of clear cut operations by age

class, the probable existence of tansy ragwort in these clear cut areas can be predicted through the analysis of remote sensing data.

There is significant correlation between grazing intensity and the presence or absence of tansy ragwort. Over-grazing of dry farmlands or dry pastureland predisposes the land to the invasion of tansy ragwort. Therefore, by mapping the cover type and associated land use type the potential for tansy ragwort invasion can be predicted and the intensity of the infestation estimated.

Because of its unique phenological, morphological and spectral characteristics, direct observation of the plant can also be used in the inventory and mapping procedure. Tansy ragwort has the ability to maintain a high level of biological productivity after many of the associated plant species have dried. This, along with the unique shape, size and blooming characteristics of the plant, make identification and measurement relatively easy using large-scale color aerial photography.

Operational Methodology. Following is a brief description of the operational procedure for the tansy ragwort project. It is based on information obtained during a number of LANDSAT I investigations in the agriculture, forestry and range disciplines.

1. Stratify the entire study area into environmentally similar types pertinent to the intensity, condition and spread rates of tansy ragwort.

2. Divide the entire study area into primary sampling units.

3. Utilizing mixed classification procedures, where supervised and unsupervised techniques are mixed, categorize all picture elements according to the probability or intensity of tansy ragwort presence.

4. Select a small number of PSU's (n_p) within each of the environmental strata for intensive photo interpreter and computer analysis.

5. Select a small number of secondary sample units (SSU's) proportional to the photo interpreter and computer predicted intensity of tansy ragwort.

6. Fly SSU flight lines at the appropriate scale to identify tansy ragwort, map its location, estimate crown closure and assess its condition.

7. Interpret the SSU data by actually identifying tansy ragwort and estimating its cover and condition.

8. Select tertiary sample units (TSU's) from the interpreted SSU data proportional to the interpreted intensity of the plant.

9. Visit the selected TSU's on the ground to make the final estimate of cover, intensity and condition of tansy ragwort.

10. Using the appropriate estimation procedures, provide the inventory data necessary for the project along with predictions of intensity adjusted by this procedure for the non-visited SSU's and TSU's.

11. Provide summary statistics for each of the environmental strata and political boundaries pertinent to the project.

12. Provide intensity maps for the entire West Side study area utilizing the appropriate prediction procedures.

13. Develop an analysis method and sampling scheme for use in the 1977 and later time frames for monitoring the change in tansy ragwort.

C. The Inventory of Water Related Parameters Over Southern Idaho

Introduction. As a result of the Phase III study in Ada and Elmore Counties in Idaho an operational methodology has been developed that will allow the inventory of water demand by five kilometer square nodal cells over Southern Idaho. After considering cost, accuracy, consistency, speed and information need, the methodology has been limited to a two-phase (double sample) of Southern Idaho. The first phase will be a complete enumeration of sample units within the study area in Southern Idaho using the LANDSAT digital data from a multispectral scanner. In this phase each sample unit will be analyzed with the digital data to determine the percent agriculture within the unit. This estimate of agricultural land will then be used as a basis for selection of a small number of sample units proportional to the acreage of agricultural lands within the sample units. The selected units will then be flown with a low altitude aircraft. The resulting photography will then be photo interpreted and ground checked to determine the acreage by crop type, irrigation type and irrigation source within each of the units selected.

The regression relationship between the photo/ground and LANDSAT results for the selected cells will be estimated. This regression relationship will then be used to predict water demand for the unvisited sample units. Confidence interval will also be provided for all estimates.

Objectives.

1. Inventory demand for surface and ground water over Southern Idaho by nodal cell.
2. Determine the source of irrigation and type of irrigation within each cell.
3. Provide estimates of acreage by crop type for each cell.
4. Provide a data base for long term monitoring of water use by source, irrigation type for each cell.
5. To the extent possible with the digital LANDSAT data, map rangeland, dry land farming and urban development over Southern Idaho.
6. Provide for the training of Idaho personnel in the operational procedures to the extent necessary to implement the baseline inventory and follow-on monitoring.

Procedures.

1. Complete the digital analysis of the LANDSAT data over Southern Idaho and map it to the UTM coordi-

nate system. This analysis will be as detailed as economically possible, but at a minimum should break the crop types into groups that are similar in consumptive use and crop calendar. This analysis should also break out rangeland, forested land and urban lands within the study area.

2. After the computer analysis is complete, summary statistics will be generated for each of the five kilometer cells within the study area. These statistics will include acreage by crop type or crop group, total area of agriculture, range, urban, and other.

3. The area will be further subdivided into sample units and the total acreage of agricultural land estimated from the computer analysis result. Tentative size for the flight line is 2.5 kilometers by .33 kilometers.

4. Each of the cells will be assigned to a generalized strata that separates the area by irrigation type, irrigation source, crop type and field size. This information will be obtained from historical data, U-2 data, LANDSAT hard copy data and personal knowledge. Approximately 20 such strata will be determined.

5. From the list of sample units a small number will be selected for each of the strata. This selection will be made proportional to the acreage of agricultural land within the sample unit. Note that there are approximately 30 sample units per nodal cell and approximately 47,000 sample units in the area of interest in Southern Idaho. It is anticipated that 50-70 sample units will be selected in Southern Idaho.

6. Each of the selected sample units will be flown at low altitude with light aircraft.

7. Each of the flight lines obtained will then be interpreted and measured to determine the area by crop type, the type of irrigation and the irrigation source if possible. When the information needed cannot be adequately obtained from the photography, ground checks will be made to determine irrigation type, irrigation source and crop type.

8. Using the regression model established in the 1975 study, the data obtained from the LANDSAT computer analysis and from the photo ground data will be analyzed. The coefficients for the regression equations to predict water demand and crop type will be estimated. Confidence bounds for the mean and for the individual observations will also be estimated.

9. Prediction of water demand and acreage by crop type will be made for each cell based on the regression equation provided in the previous stop. This will be accomplished by adding the values obtained for each of the sample units within a five kilometer nodal cell for the large cells. In special areas where the one half mile and one mile cells are used, the sample units will be subdivided the the computer analysis results used to provide estimates for these smaller cells.

10. Summary statistics will be generated by county, strata and administrative unit within the study area for crop type, irrigation demand, irrigation source and irrigation type.

11. A secondary study will be conducted to determine whether the end of the irrigation period can be determined from sequential LANDSAT hard copy data. This study is necessary to more precisely attune the water demand model.

NOTES

Mr. Nichols is currently the Manager of the Earth Resource Applications Department of ESL Incorporated, Sunnyvale, California.

The introductory portion of this paper was extracted and edited from Volume 1, Pacific Northwest Land Resources Inventory Demonstration Project. The technical portion is from work completed under contract to NASA Ames Research Center and the State of Washington Department of Natural Resources, in cooperation with the Idaho Department of Water Resources and the Oregon State Forestry Department.