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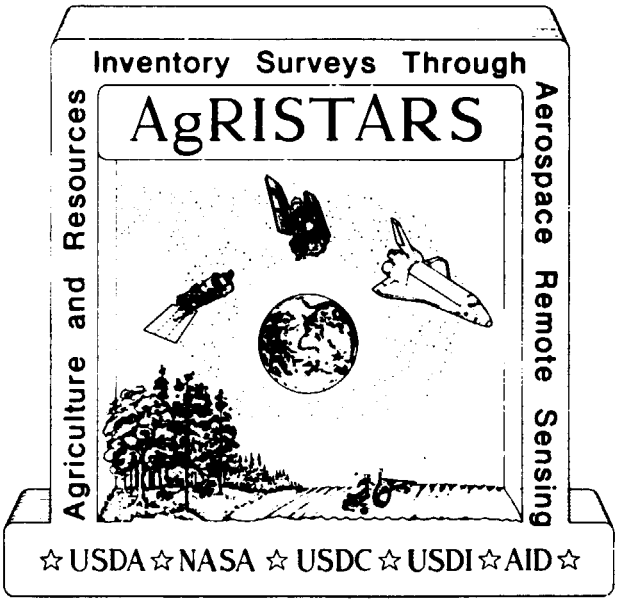
AgRISTARS MINISYMPOSIUM

DECEMBER 1-2, 1982



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

FORWARD

Welcome to the AgRISTARS Mini Symposium.

AgRISTARS is a cooperative research effort led by the U.S. Department of Agriculture and supported by the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, the U.S. Department of the Interior, and the Agency for International Development of the U.S. Department of State.

The goal of AgRISTARS is to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions.

The AgRISTARS program has been underway for three years now and a great deal of fine technical work has been accomplished. While this work has been documented in AgRISTARS reports and, to some extent, reported in literature and other symposia, a need was perceived to provide an opportunity for a general technical interchange. This Mini Symposium addresses that need. The papers you will be hearing cover a good cross-section of the work going on in the AgRISTARS projects. There are also some very informative posters available in the lobby of building 30 and in building 17, room 2026. We hope that you will take time to visit these displays.

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POSTER DISPLAY 30-33

Poster displays are available in the lobby of building 30 and in building 17, room 2026. We hope that you will take time to visit these displays.

1-1

CROP STRESS INDICATOR MODELS FOR LARGE AREA ASSESSMENT

Terry W. Taylor, USDA/ARS, and
Frank Ravet, USDA/FAS

A prime objective of the EW/CCA project is to provide a capability to monitor and assess crop condition over large area and respond in a timely manner. A series of crop stress indicator models were developed to alert a commodity analyst of potential problem areas. The models function as filters to eliminate the necessity of devoting time and resources to examine in-depth large data streams. Concentration is allowed on areas which are alerted as having a high probability of stress occuring. Subsequent analyses can then be made using ancillary, meteorological and spectral information. First iteration models for wheat (spring and winter), maize, sorghum, and sugarbeets have been developed. These are in various stages of testing and modification and have a similar structure consisting of three major components: 1) a phenology model, 2) a soil water budget model and 3) a hazard routine for stress definition. The maize stress model has been tested with foreign (USSR) and domestic (Missouri) meteorological and ground truth data. These results will be presented.

1-2

WATER DAMAGE TO RIPE HARD RED SPRING WHEAT

Armand Bauer and A. L. Black
USDA/ARS, Mandan, ND

Grain damage and/or yield loss can occur when threshing of ripe hard red spring wheat is delayed by rainfall or a combination of rainfall and high humidity. A knowledge of the effect of intensity and persistency of water related environment factors on sprouting is required to develop a capability to predict its impending onset in either standing or windrowed crops.

Misting at 1.97 cm/hr increased spike water concentration 35 percentage units the first 10 minutes and 0.75 percentage units per minute thereafter. Water imbibition by grain occured linearly at a rate of 1.9 percentage units per hour (Gordon et. al 1977). Spikes saturate at about 150% water concentraction and grain at about 100%. These equilibrated threshold spike water concentrations affecting sprouting is 42 to 45% of oven dried basis. Water held in the clumes and interstitial area of the spike evaporate more rapidly than water imbibed in the grain. Conditions which depress evaporation after rainfall enhance water imbibition by the grain.

Germination mechanisms in ripening grain is not triggered until spike water concentrations is reduced to 14% or less. Sprouting could not occur in spikes removed from sealed-growing wheat which had higher than 14% water concentration before wetting to 100% water concentration.

Post cutting susceptibility to sprouting differs with cultivars as does the time interval after cutting when cultivars become susceptible. In the most spout susceptible cultivars 10% sprouting occured within 7 days after cutting and in the least susceptible more than 35 days after cutting.

Seeds which have taken up water and then dried imbibe water faster with subsequent wetting and also increase in susceptibility to sprouting. Sprouting is more rapid

at 13°C than at 24°C. Field grain yield losses on 10 cm stubble were 15% and 20% less than 23 and 26 cm stubble respectively as rainfall forced larger portions of the windrow through the taller stubble to effect soil contact.

1-3

NORMALIZATION OF NOAA AVHRR DATA FOR ANGULAR ANISTROPHY

M. H. Duggin, D. Piwinski,
State University of New York
G. Ryland, Lockheed Engineering and Management Services Company, Inc.
and V. Whitehead, NASA/JSC

Empirical studies have demonstrated beyond a doubt that target radiance depends on view zenith (scan) angle in a systematic manner. The dependence is modulated by variations in haze and cloud across an image. Similar studies show that, while angular anistrophy in recorded radiance can probably be calibrated out of the data (a hypothesis supported by empirical studies) variation in haze and cloud target radiance can cause random fluctuations in target radiance. This cannot only cause problems in the identification of a target, but also can cause uncertainties in target discrimination.

Results demonstrating the angular variation of target radiance, the form of the dependence on view angle and the effect of unresolved cloud are presented and the course of present and future research discussed.

1-4

USE OF NOAA-6 SATELLITES FOR LAND/WATER DISCRIMINATION AND FLOOD MONITORING

T. Engman, USDA; D. W. Goss, USDA;
and N. C. Horvath,
Lockheed Engineering and Management Services Company, Inc.

A tool for monitoring the extent of major floods has been developed using data collected by the NOAA-6 Advanced Very High Resolution Radiometer (AVHRR). A basic understanding of the spectral returns in AVHRR Channels 1 and 2 for water, soil, and vegetation has been reached using a large number of NOAA-6 scenes from different seasons and geographic locations. A look-up table classifier was developed based on analysis of the reflective channel relationships for each surface feature. The classifier automatically separated land from water and produced classification maps which were registered to a global coordinate system. Testing of the classifier was completed for a number of acquisitions, including coverage of a major flood on the Parana River of Argentina.

1-5

AVHRR DATA EVALUATION AND INFORMATION CONTENT

Nicholas C. Horvath,
Mike L. Mathews
Lockheed Engineering and Management Services Company, Inc.

Data from the National Oceanic and Atmospheric Administration satellite system (NOAA-6 Satellite) have been analyzed to study their nonmeteorological applications and determine their useful limits. A file of charts, graphs, and tables was created from the products generated in this study. Analysis of these products indicates that the Gray-McCrary Index can discern

vegetation and associated daily and seasonal changes. It was found that the most useful data lie between pixel numbers 400 and 2000 on a given scan line. However, the data were still considered quite variable, so a new method of analysis was performed which identified procedures to stabilize most (~80%) of the variation in the index. This has been accomplished by examination of the solar correction coefficients originally used and the identification of clouds. These procedures can be easily implemented. The metsat system seems best suited for providing large-area analyses of surface features on a daily basis.

1-6

EVALUATION OF A NATIVE VEGETATION MASKING TECHNIQUE

Margaret C. Kinsler
Lockheed Engineering and Management Services Company, Inc.

Foreign Crop Condition Assessment Division (FCCAD) has utilized a crop masking technique based on Ashburn's Vegetative Index (AVI). Early Warning Crop Condition Assessment (EW/CCA) chose to use this technique in the evaluation of native vegetation as an indicator of crop moisture condition. A mask of the range areas (native vegetation) was generated for each of 13 Great Plains LACIE segments. These masks were compared to the digitized ground truth and accuracies were computed. An analysis of the types of errors indicates consistency in errors among the segments.

1-7

FUNCTIONAL EQUIVALENCE OF SPECTRAL VEGETATIVE INDICES

Charles R. Perry, Jr., USDA
Lyle F. Lautenschlager, USDA

Numerous formulas, vegetative indices, have been employed to reduce MSS data to a single number for use in assessing ground cover characteristics such as plant type, plant leaf area, plant stress, total biomass, etc. There has been much discussion in the literature about which index is superior. The idea of two vegetative indices being equivalent is formulated in terms functional equivalence: Two vegetative indices are taken to be equivalent for making a certain set of decisions, if the decisions made on the basis of the output of one index could have equally well been made on the basis of the output of the other index. The utility of these ideas are demonstrated by showing that several widely used indices are equivalent.

2-1

EARLY SEASON SPRING SMALL GRAINS PROPORTION ESTIMATION

D. E. Phinney
Lockheed Engineering and Management Services Company, Inc.
M. C. Trichel, NASA/JSC

The value of information from a crop inventory system is determined by its cost, accuracy, and when in the growing season the information becomes available. The Inventory Technology Development (ITD) project of the Agricultural and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) program has developed an accurate, automated technology for early season estimation of spring small grains from Landsat

MSS data. The technique is based on a constrained linear model in which the observed spectral response of a scene is estimated as a linear combination of the major elements in the scene. The procedure was evaluated over 100 sample segments collected for crop years 1975 through 1979 in the U.S. Northern Great Plains. Analysis of the test results indicated performance that was substantially better (n=100, mean error 1.04%, standard deviation = 7.47%) than the automated at-harvest technologies tested during the FY81-82 AgRISTARS Spring Small Grains Pilot experiments or previous analyst-intensive at-harvest technologies. Further advantages include major relaxations in requirements for multitemporal registration (none), data storage and transmission, and computation which are important in the design of smart sensor systems.

2-2

A CROP AREA ESTIMATOR BASED ON THE CHANGES IN THE TEMPORAL PROFILE OF A VEGETATIVE INDEX

J. H. Smith and D. B. Ramey
Lockheed Engineering and Management Services Company, Inc.

Most current crop area estimators, based on remotely sensed data, require the classification of either fields or picture elements (pixels) into crop types. This paper details current research into methods which estimate the change in crop proportion in a scene from one year to another, without requiring that individual fields or pixels be labeled as crop types. Instead, pixels are classified as vegetated or not vegetated, and the proportion of vegetated pixels in the scene is plotted as a function of time for each of two years. The plots are smoothed via polynomial regression, and the vertical distance between the curves (profiles) forms the basis of profile change methodology. Results demonstrating the feasibility of using the technique will be presented.

2-3

UPDATE ON A SYSTEM FOR LARGE AREA CROP INVENTORY FROM REMOTELY SENSED DATA

T. C. Baker, J. H. Smith, J. T. Malin
Lockheed Engineering and Management Services Company, Inc.

This paper presents an update on the state of the art in large area crop inventory from Landsat multispectral image data. In particular, it describes progress with and improvement to the estimation system developed during the Large Area Crop Inventory Experiment (1975-77) and its follow-on Transition Year project (1978-79). Both were jointly sponsored projects of the National Aeronautics and Space Administration, the U. S. Department of Agriculture, and the National Oceanic and Atmospheric Administration of the U. S. Department of Commerce. The improved large area estimation technology is a product of and research tool for the current joint venture of these three agencies in conjunction with the Agency for International Development of the U.S. Department of State and the U.S. Department of the Interior, known as the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing program. Several candidate technologies under development as possible improvements to the system are also presented.

2-4

THE AGRICULTURAL INFORMATION SYSTEM SIMULATOR: AN OVERVIEW AND AN APPLICATION

D. B. Ramey and J. H. Smith
Lockheed Engineering and Management Services Company, Inc.

A major application of remotely sensed data is the estimation of agricultural production in foreign areas. The evaluation of such production estimates is difficult due to the lack of ground-verified crop inventories for foreign areas. This paper describes simulation software designed to test the effect of sample design, cloud cover, local area estimation bias and variance, and other factors on the performance of Landsat-based large area agricultural estimators in foreign (and domestic) areas. Results of a simulation comparison of the effects of Landsat 4 orbital characteristics with those of earlier Landsats on a specific large area aggregation system configuration are presented.

2-5

INVESTIGATIONS OF THEMATIC MAPPER DATA DIMENSIONALITY AND FEATURES USING FIELD SPECTROMETER DATA

Eric P. Crist, Richard C. Cicone
Environmental Research Institute of Michigan

Features derived from the four MSS channels on Landsat 1, 2, and 3 have proven to be of great value in detection of the cover type and condition of agricultural fields. The Tasseled-Cap Transformation has been widely used to capture the vast majority of data variability over agricultural scenes in two features with direct physical interpretation: Greenness, which corresponds to the amount of green vegetation in the field of view, and Brightness, which is related to albedo or soil brightness. Other features such as the 7/5 ratio and the Normalized Difference have been found useful in particular applications.

The Thematic Mapper on the recently launched Landsat-4 includes detectors sensitive to different wavelength intervals and/or different bandwidths than those in the MSS. In particular, TM Bands 1, 5, and 7 are located in regions of the spectrum unsampled by the MSS (TM Band 6, the thermal band, is not considered here since its characteristics are substantially different from those of the other bands and previous sensors). These new bands, and narrower bandwidths in previously sampled spectral regions, suggest that new features may be available in TM data. Furthermore, the likelihood of strong correlations between at least some adjacent band pairs suggests that a dimensionality-reducing transformation like the Tasseled-Cap Transformation would be of value for the TM as well.

This paper presents the results of analyses aimed at determining, by means of simulation, the dimensionality of TM data over agricultural scenes, and the response of TM data features (bands or combinations of bands) to the physical characteristics of crop canopies and soils. Field-measured crop spectra, and field and laboratory-measured soil spectra are used, along with Dave atmospheric model data and prelaunch sensor calibration information, to simulate Landsat-4 MSS and TM inband reflectances, top-of-atmosphere radiances, and digital image signal counts for wheat, corn, and soybean plots.

The equivalency of TM Bands 2, 3, and 4 with MSS Bands 1, 2, and 4, and the resulting "Tasseled-Cap-equivalent" transformations of each, is demonstrated. Also shown is the increase in complexity, in terms of physical interpretation, associated with the principle components derived from all 6 TM bands (again, excluding the thermal band). The responses of TM spectral features to canopy characteristics such as percent cover, percent green leaves, etc. and to soil characteristics such as particle size distribution and organic matter are described. The results illustrate both the continuity between the MSS and TM sensors, and the added benefits potentially available through use of the extra TM bands.

2-6

DEVELOPMENT OF A QUANTITATIVE BASIS FOR FEATURE EXTRACTION IN A VEGETATIVE MONITORING SYSTEM

D. E. Phinney, J. H. Smith,
Lockheed Engineering and Management Services Company, Inc.
and M. C. Trichel, NASA/JSC

The development of an objective methodology for evaluation of alternative Landsat data pre-processing options, spectral transforms, and feature extraction algorithms is presented. Based on estimates of spectral separability between a target class and its confusion, analysis of variance techniques are used to evaluate potential design options for large scale vegetation monitoring systems. Case studies are presented for early season spring small grains separation and for barley/other spring small grains separation. It is concluded that the basis for efficient, objective selection among alternative feature extraction approaches has been established.

2-7

AN AUTOMATED SPRING SMALL GRAINS PROPORTION ESTIMATOR

T. B. Dennis, R. B. Cate,
M. E. Smyrski, T. C. Baker
Lockheed Engineering and Management Services Company, Inc.
C. V. Nazare
Intergraph Corporation

This paper describes a totally automated system for estimating spring small grains acreages within 5- by 6-nautical-mile sample segments as recorded in Landsat data. This procedure was developed for and tested in the fiscal year 1981 U.S./Canada Spring Small Grains Pilot Experiment conducted at the Lyndon B. Johnson Space Center as part of the Foreign Commodity Production Forecasting project of the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing program. The system was derived from attempts to model some of the human functions performed in the image analysis of Landsat data which was routinely carried out during the Large Area Crop Inventory Experiment.

2-8

SAMPLING UNIT SIZE CONSIDERATIONS FOR REDUCING DATA LOADS IN LARGE AREA CROP INVENTORYING USING SATELLITE-BASED DATA

Cecil Hallum
University of Houston at Clear Lake City
Charles Perry, USDA

Crop inventorying personnel who use synoptic information from satellite-acquired data must contend with large data sets. This paper reports on an approach for minimizing these data loads while

improving the efficiency of global crop area estimates using remotely-sensed, satellite-based data. Results of a sampling unit size investigation are given that includes closed-form, modeled allowances for, both, non-sampling and sampling error variances. These models provide estimates of the sampling unit sizes that effect minimal costs. A conservative non-sampling error variance model is proposed that is realistic in the remote sensing environment. This approach, in conjunction with the sampling error variance model, permits a closed-form and viable determination of the sampling unit sizes.

2-9

AN AUTOMATED APPROACH TO LARGE AREA CROP INVENTORY BASED ON COLOR AND TOPOLOGY

H. G. Smith, R. B. Cate, and T. B. Dennis
Lockheed Engineering and Management Services Company, Inc.

The concept of an automated approach to crop inventory using a color space representation (hue, value, and chroma) of multidate MSS data, combined with a spatial clustering technique for mid-summer estimates of winter and summer crop group wall-to-wall inventory has been outlined, implemented, and tested. The results of the concept feasibility test compared favorably with the results achieved in the Large Area Crop Inventory Experiment (LACIE) Phase III 1977 winter wheat inventory for 11 sites in the same area. Extension of the concept to different crops and different land surface cover types is underway.

2-10

AUGMENTATION OF LANDSAT MSS DATA BY SEASAT SAR IMAGERY FOR AGRICULTURAL INVENTORY

Daniel R. Nuesch, Dept. of Geography, University of Zurich, Switzerland; Quentin A. Holmes, Applied Intelligent Systems, Inc., Ann Arbor, Michigan; and M. D. Metzler, Environmental Research Institute of Michigan, Ann Arbor, Michigan

This paper explores the potential of joint use of Landsat MSS and SEASAT SAR for agricultural inventory. We combine information from sensors which respond to different crop canopy characteristics. Landsat MSS is a passive sensor which is responsive to the presence of vegetative biomass and chlorophyll absorption. SEASAT SAR is an active sensor in the microwave region which is responsive to canopy structure and its dielectric constant as determined by moisture conditions. The joint spectral attributes of these sensors affords an intriguing view of the agricultural scene. The high resolution of the SEASAT SAR brings with it the possibility of refined definition of the boundaries of agricultural fields.

SEASAT SAR data collected over Jasper County, Indiana, was optically processed, digitized and registered to Landsat Segment 844 consisting of seven MSS acquisitions. Digital SEASAT radar data was preprocessed using a non-linear isotropic filter which removed speckle noise without loss of spatial resolution or spectral information as occurs with conventional smoothing algorithms. The process developed resulted in the creation of two image features dubbed "tone" and "texture". The texture image was in fact the extracted speckle noise and was

found to contain information pertinent to crop canopy identification.

Results of this investigation revealed that the finer spatial resolution of SEASAT provides a better definition of field boundaries than Landsat and that the features called tone and texture can be used to improve corn from soybean labeling accuracies.

2-11

DEVELOPMENT, TEST AND EVALUATION OF A COMPUTERIZED PROCEDURE FOR USING LANDSAT DATA TO ESTIMATE SPRING SMALL GRAINS ACREAGE

K. R. J. Mohler, W. F. Palmer,
M. M. Smyrski, T. C. Baker
Lockheed Engineering and Management Services Company, Inc.
C. V. Nazare
Intergraph Corporation

This paper describes the development, test and evaluation of CAESAR, a computerized area estimation technique recently tested at the NASA Johnson Space Center.

The technique utilizes decision logic to test for characteristics determined by analysts to be important for crop identification. Registered Landsat multispectral scanner data which have been transformed into Kauth-Thomas greenness and brightness are required.

The accuracy of proportion estimates obtained using CAESAR was comparable to earlier results using manual techniques which were very labor-intensive. The primary sources of error were the selection of acquisitions and the designation of biowindows. With correct acquisition selection/designation, the mean error was reduced from 3.01 percent to 1.36 percent, and the standard deviation was lowered from 11.31 percent to 6.19 percent. These results are similar to those observed during development and serve to illustrate the potential of the technique.

2-12

EXPERIMENTS WITH AN EXPERT-BASED CROP AREA ESTIMATION TECHNIQUE FOR CORN AND SOYBEANS

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Richard C. Cicone,
Karen I. Johnson
Environmental Research Institute of Michigan, Ann Arbor, Michigan
Julie Odenweller
Space Sciences Laboratory,
University of California,
Berkeley, CA

Large area crop inventory using space remote sensing has been a major focus of the AgRISTARS program with special emphasis given to small grain, corn, and soybean production forecasting. To satisfy the need for timely estimates of crop production in foreign areas, ground based observations must not be required by the crop inventory procedure. Several approaches to addressing this problem have been pursued by various investigators. This paper describes an expert-based approach to the inventory of corn and soybeans.

In the analysis of data for crop production forecasting, an expert analyst has available satellite data in either numerical or image format, weather data, historical data, and years of experience. This expert can often produce very credible results, though they are not easily repeated and can be time consuming. In addition, transferring this expertise to others is not a trivial task. To take advantage of this expertise while introducing greater efficiency, objectivity, and

repeatability, an attempt was made to proceduralize the expert methodology in such a manner that a non-expert, and eventually a machine, could emulate the expert's analysis.

Achieving this proceduralization required a thorough understanding of both the expert's methodology and the physical basis for the phenomena seen in the satellite data used in the analysis. This led to the development of a structured, hierarchical decision logic for crop identification which would guide a non-expert analyst along a path followed by the expert. Supporting technology to enable the expert approach was developed as well, including the features to be utilized in the logic, data normalization techniques to maintain temporal and spatial consistency in those features, and methods of presenting the data that would convey maximum information.

The crop inventory procedure thus developed demonstrated the capability for making accurate estimates of crop acreage using non-expert analysts, but in an inefficient, time consuming manner. Overcoming this lack of efficiency required mechanization of many of the tasks which remained in the domain of the analyst due to their judgemental nature.

The solution to this difficult problem lay in the choice of a staged approach to crop identification. In this approach, the machine would make progressively more difficult decisions, with each stage of the process building on the accumulated learning of the previous stages. A total of four stages were developed with the first stage being simply an automation of the totally objective portions of the analyst's crop identification logic, and the succeeding stages designed to handle the more judgemental of the analyst's decisions.

The results of tests of the procedures validate the concept ofan expert-based system, and demonstrate the success with which an objective, proceduralized expert-based system may be automated to achieve both accuracy and efficiency. The challenge ahead is in adapting this approach to agronomic conditions which are considerably different from those in the U.S. Corn Belt.

3-1
LARGE AREA YIELD ESTIMATES DERIVED FROM PLANT SIMULATION MODELS

Sharon LeDuc
Center for Environmental Assessment Service
Tom Hodges
University of Missouri-Columbia

Plant simulation models are conceptual hypotheses on the growth and development of a crop. These processes are expressed as a system and are the basis of a computer program to output these ideas quantitatively. The goal is to use these models to provide estimates of the yield over a large geographic area. The effort was started during 1982 and is being extended to other geographic areas, other models and other crops. The results presented will be for estimating the spring wheat yield for North Dakota using the Texas A&M Wheat (TAMW) model. Variations in the application of the model were tried. Summer fallow and continuous cropped conditions were considered. Planting density was changed. Two different methods of summarizing the climatic data for input were tried.

Results show the simulated yield estimates follow the annual changes in observed yield. Statistical adjustment done objectively may be used to improve the accuracy of the yield estimate for the large area. Resources required to provide these estimates for a number of locations are significant. Quality control and summarization of climate data for input to the model requires computer and human resources. Daily temperatures, precipitation and solar radiation are required. Operation of the models and objective statistical adjustment may be accomplished with the main resource being computer time. Quality of the yield estimates will be examined and compared to the yield estimates from the simple crop yield regression models requiring monthly temperature and precipitation as input.

Value of these models is the capability to operate them and get a yield estimate for areas where unusual crop conditions are suspected. Also, they can be used for a large number of areas and at many different time periods.

3-2
APPLICATION OF SATELLITE SPECTRAL DATA IN ESTIMATING WHEAT YIELDS

Tom Barnett, NASA-JSC/Columbia, MO.

Using Landsat segment-averaged values of greenness (Kauth and Thomas, 1976) for wheat in the U.S. Great Plains, 1978 and 1979, a consistent linear relation was established between greenness at heading and end-of-season yield. Both winter wheat and spring wheat across the Great Plains appear to exhibit identical values of slope with slightly different intercepts. Tests at a smaller scale on field-average spectral and yield data for 1975-1978 confirm the value of the slope. Application of the winter wheat yield: greenness relation to 1981 spectral data from the NOAA-6 AVHRR sensor for 25 mi grid cells over Texas, Oklahoma, and Kansas gave very satisfactory estimates of final yield at CRD level.

3-3

INTENSITY, HUE, SATURATION (IHS) DISPLAY OF THREE CHANNEL INPUT

Russ Ambroziaak, NOAA

Past work in color display has used the direct assignment of red, blue, and green to three channel impact. The two channel displays, green = blue and red, now used by several groups, can be shown to be the least effective way of displaying the information. More effective ways need to be developed and tested in an operational environment. Several possible choices of candidates are:

- o Index presentation - B & W, false color
- o Spectral - IHS, RBG
- o Revised coordinate system - IHS, RBG

Initial tests indicate that the most effective method is a modified polar coordinate display in hue (H) and intensity (I) of the IHS system.

4-1

DEVELOPMENT OF CROP SPECTRAL TEMPORAL PROFILES APPLICATIONS TO CORN-SOYBEAN SEPARATION

G. D. Badhwar, NASA/JSC

The temporal development of a biological system is a key to its identification. In case of crops, this development manifests in temporal change in the spectral properties. A model has been formulated that describes the change of spectral properties as a function of time in terms of known biophysical properties of crops. Features extracted using this model have been applied to separate corn-soybean in both full season and in early season work.

4-2

SUPPORTING RESEARCH IN PATTERN RECOGNITION-INTRODUCTION

R. P. Heydorn, NASA/JSC

This paper discusses some of the research issues related in the use of remotely sensed data for land cover identification and inventory. These issues are discussed in terms of questions related to data representation and inference. In data representation one is trying to transform a given set of measurements to values which bring out properties that discriminate between land cover categories while surpressing unwanted background effects. Inference covers questions related to the classification of cover types given a specific representative of the measurements or questions related to the quantity of cover type material in an area.

Since much of the research has concentrated on estimating the quantity or proportion of a material, most of this paper will deal with inference issues related to the use of classifier based proportion estimators or direct proportion estimators. These issues are discussed in terms of the bias and variance of the estimators. When the "spectral separation" between crops is reasonably large, as is generally the case between corn and soybeans when several measurements are available throughout the growing season, classification methods have shown to perform well. However, when this separation is low, as is the case between individual small grains (e.g., between spring wheat and spring barley) other somewhat more complex methods are suggested. For these cases a method based on the "decomposition of mixtures" is being studied. In this approach each crop is represented by its spectral probability distribution

and the total probability distribution of the scene as a mixture of these crop distributions. The mixing proportions are taken to be the estimates of the amounts of the individual crops in the scene. If the crop distributions are members of a known (and identifiable) family of probability distributions, then these estimates are theoretically unbiased.

4-3

ESTIMATION AND IDENTIFICATION OF A VEGETATIVE COVER TYPE USING MIXTURE DISTRIBUTION DECOMPOSITION AND LABELING

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A fundamentally important problem in the analysis of remotely sensed data has been the characterization of the distribution of spectral measurements for cover types of interest. Such a characterization is an implicit or explicit part of the training of any classifier based on multispectral measurements. It also forms the basis for most unsupervised classification or clustering such data. Proportions of cover types of interest may be directly estimated as the prior probability of distributions identified as characterizing each cover types.

For these and other reasons, it appears natural to formulate the proportion estimation problem in terms of a mixture of underlying distributions. This mixture describes the whole image and is composed of a sum of simpler distributions, each with some specified proportion. The usual assumption has been that these underlying simpler distributions are multivariate normal. For agricultural applications, the real questions in such a formulation are whether crop categories of interest may be well represented by a small number of such underlying distribution, whether the underlying distributions themselves may be resolved from the overall mixture distribution, and whether the resolved distribution may be identified or labeled.

This paper describes recent work devoted to examining these questions for Landsat data. Mixture distribution resolution was accomplished using the CLASSY clustering algorithm developed by Lockheed at the Johnson Space Center. The features used were derived from parametric curves fitted to multitemporal greenness data and the pixels examined were restricted to those that are reasonably pure.

We show that small grains distributions may be well represented by a set of mixture component distributions. Direct proportion estimates for small grains as computed from ground truth labeled component distributions are presented for 18 Landsat segments. These proportion estimates are compared to the ground observed proportions of small grains in these images. In addition, evidenced that mixture distributions components may be identified by predicting the feature distributions associated with small grains is presented.

4-4

THE EFFECTS AND TREATMENT OF "MIXTURE" PIXELS IN PROPORTION ESTIMATION OF VEGETATIVE COVER TYPE

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From the viewpoint of spectral signatures of a vegetative cover type and its proportion estimation in a segment, "mixed" pixels present an unidentifiable problem. Due to lack of understanding of their spectral characteristics, these have been treated in the past like pure pixels when clustering and classifying the segment data. It has been seen empirically that this approach causes higher mean square error in the proportion estimation of vegetative cover type.

Background radiation and atmosphere may cause substantial adjacency effect on the spectral measurement of a pixel. It has been argued that the spectral measurement of a mixed pixel can be considered as a linear combination of spectral measurements representing the vegetative cover type components of the mixed pixel. Based on this model, we have investigated the effect of mixed pixels on the proportion estimation of a vegetative cover type. Under certain assumptions for the spectral class distributions, it is shown analytically that the treatment of mixed pixels as if these are pure can increase the bias and the mean square error of a proportion estimate considerably.

Several edge detection techniques have been investigated for the determination of boundary pixels. A method based on the spatial approach has been developed to detect boundary pixels and then, to allocate each such pixel to the homogeneous class of pixels that are spectrally closest to it. The method has been applied to a number of segments and is seen to effect improvement on the proportion estimation of vegetative cover type.

In addition, another proportion estimation method has been proposed and is being investigated. If certain underlying assumptions hold true, this method would provide a direct proportion estimation procedure that does not require detection and hence, any special treatment of mixed pixels in a segment.

4-5

PRELIMINARY EVALUATION OF THEMATIC MAPPER DATA FOR AGRICULTURAL INVENTORYING APPLICATIONS

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NASA/JSC
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In order to gain familiarity with the Landsat-D Thematic Mapper (TM) data, and to get some preliminary indications of how this data can be used in agricultural inventorying applications, evaluations were performed on initial TM data sets produced by GSFC. The evaluations used TM data acquired over Webster County, Iowa, on August 2, 1982, and over Mississippi County, Arkansas, on August 22, 1982.

As part of the evaluation, the JSC registration processor was used to evaluate the band-to-band registration accuracy. The accuracy was better than one pixel for all bands. As expected, the registration accuracy among the first four bands and bands 5 and 7.

by comparing a TM image with a USGS 7-1/2 quadrangle sheet map, the geometric fidelity of the TM image was found to be excellent.

Principal components analysis was performed on the TM data to get an indication of the information content in the data. The results indicated that the six bands in the visible through mid-infrared can be converted into three principal components which account for essentially all of the variability in the data. This confirms an earlier result obtained using field measurement data.

Evaluation of band count distributions for corn and soybeans showed that data in TM band 4 may produce better corn/soybeans separation than MSS data. The TM distributions were less skewed than distributions using MSS data. This should produce improved classification results.

In order to evaluate the effect of increased resolution on classification, an unsupervised clustering algorithm (CLASSY) was applied to the TM data and to simultaneously acquired MSS data. By observing features which were not resolved into separate clusters using TM data, an indication of how the increased TM resolution would affect classification was obtained. The results of this evaluation indicated that using TM data would produce separate classes for small features such as roads and homesteads, while using MSS data would not separate these small features.

4-6

MULTI-SENSOR REGISTRATION OF EARTH RESOURCE DATA

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P. Anuta, ERIM
and S. Ungar, GISS

The effective utility of the remotely sensed earth resources data gathered by satellites and aircraft can increase many fold if acquisitions over the same ground areas at different times can be precisely spatially aligned. Two processors are used to accomplish this task. The JSC registration processor is used to register Landsat multispectral and Thematic Mapper data, while the Goddard Institute for Space Study (GISS) Processor is used to accomplish aircraft Thematic Mapper Simulator (TMS) data registration.

The JSC registration processor builds upon the technology developed for both the Goddard Space Flight Center's Master Data Processor (MDP) and the LACIE processor. It accepts both the MDP "P" formatted as well as "A" formatted tapes as input. It makes use of all the available ancillary information for a pair of acquisitions in accomplishing the image-to-image registration. The output images can be resampled into different pixel sizes as well as placed into a variety of map projections. Subpixel registration accuracies are achieved by cross correlating edge image patches from both the reference and the registrant images and iteratively locating the correlation peak offsets to a fraction of a pixel.

The GISS processor makes use of the aircraft navigation and attitude information to correct the distortions caused by aircraft yaw, pitch and roll variations. Control points are used to tie the imagery obtained to the desired map coordinates.

In this paper, the details of the registration methods for both processors are described. Also, performance evaluations and representative operational characteristics are given.

4-7

MEASUREMENTS AND SCENE ANALYSIS OF CORN-SOYBEANS AND SMALL GRAINS FOR IDENTIFICATION, DEVELOPMENT STAGE ESTIMATION AND CONDITION ASSESSMENT

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University of Nebraska
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South Dakota State University

The goal of the measurements and scene analysis research is to provide quantitative information and models on the distinguishing biophysical and radiometric characteristics between crop classes (e.g., corn-soybeans, spring wheat-barley) and crop attributes within classes (e.g., development stage, leaf area index or moisture stress of corn). The approach is to first identify the key cultural and biophysical features which enable crop type, stage and condition to be identified using remotely sensed spectral measurements and then to determine, by empirical characterization and modeling, how the biophysical-agronomic variables are manifested in the spectral response. In this step, the functional relationships between biophysical and spectral variables are being determined. This is followed by development of models utilizing spectral inputs, particularly Landsat MSS and TM data, and determination of the sensitivity of the models to soil, crop and environmental factors.

The approach includes measurements of cultural practice experiments at ten agricultural experiment stations in the Corn Belt and Great Plains states, along with measurements of commercial fields at test sites in Iowa and North Dakota. The experiments include treatments of soil type, planting date, plant population and row spacing, species and cultivar, fertilization and moisture level. Agronomic data include development stage, leaf area index, and other canopy descriptors. the primary spectral measurements are made with an eight-band radiometer with the TM spectral bands; other sensors include radar and airborne multispectral scanner.

The primary objectives, experiment designs, measurements, and key analysis results of experiments being conducted by several universities including Purdue, Kansas State, Nebraska, and South Dakota State will be described. The results include use of the data in spectral-temporal profile models for crop identification and development stage estimation, relationships of spectral variables to canopy leaf area index and light interception, effects of nutrient and moisture stress on spectral response, and spectral characteristics of different species as function of develoment stage, cultural practices and environmental factors.

4-8

USES OF VEGETATIVE CANOPY REFLECTANCE MODEL

Narendra Goel, ASTER Consulting

Several potential uses of the Vegetative Canopy Reflectance Model, in conjunction with atmospheric scattering models for vegetative mapping will be discussed. They include the determination of agronomic variables like leaf area index and leaf angle distribution from canopy reflectance data, and the quantification of "distortion" caused by the atmosphere in the reflectance as measured by satellite-borne sensor.

Recent progress made in these areas will be highlighted.

4-9

SPECTRAL ESTIMATION OF LEAF AREA INDEX AND LIGHT INTERCEPTION BY CROP CANOPIES

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If agronomic variables related to condition and yield could be estimated from multispectral satellite data, then crop growth and yield models could be implemented for large areas. The objective of research at Purdue and Kansas State Universities has been to develop approaches for combining spectral and meteorological data in crop models. Leaf area index (LAI) is a key variable related to growth and infrared reflectance of crop canopies; it in turn is directly related to the light interception of canopies, a fundamental parameter photosynthesis, evapotranspiration and yield of canopies.

Reflectance data have been acquired over several growing seasons of corn, soybean, and wheat canopies. Treatments included planting date, row width, plant population, cultivar, and soil type. Agronomic data included leaf area index (LAI), percent soil cover, biomass development stage, and grain yield.

The spectral variable greenness explained 78% of variation in LAI over all treatments of corn. Single date observations of LAI or greenness had little value in predicting yields. The proportion of solar radiation intercepted (estimated from reflectance data) when accumulated over the growing season accounted for approximatelyy 65% of the variation in corn yields. Similar results have been obtained for soybeans and wheat. The concept of estimating intercepted solar radiation using spectral data represents a viable approach for merging spectral and meteorological data in crop yield models. We are currently assembling the necessary data to evaluate the concept using Landsat MSS data, as well as obtaining direct measurements of canopy light interception.

In assessing the capability of remote sensing to estimate LAI, it is critical to address the ability to make accurate in situ measurements since remote sensing experiments can be no more conclusive than the ground observational data on which they are based. The natural variability in LAI and the accuracy and precision of direct measurements are being assessed. Additionally, we are developing and evaluating indirect, non-destructive methods of estimating LAI. These methods offer a more rapid means of gathering this information, may provide additional information (e.g., leaf angle distribution),

and may improve the accuracy of estimates. The leading example of this approach is the work by Norman who has inverted a model of radiation in plant canopies to estimate canopy structure variables from ground data. The model inversion can be driven by either percentage of sunfleck area as a function of solar elevation or the proportion of canopy gap as a function of zenith angle which can be acquired from hemispherical photographs.

4-10

MICROWAVE PROPERTIES OF AGRICULTURAL CROPS AT LONG WAVELENGTHS

Jack F. Paris, NASA/JSC

The microwave properties of agricultural crops at short wavelengths (less than 4 centimeters) are well understood as the results of extensive research in the 1970's by investigators at the University of Kansas. In general, it is known at these wavelengths that the wet biomass of the crop canopy is a dominant parameter. Also, the use of cross polarized radar was found to be minimal for the shorter wavelengths. Row structure and row direction effects and soil moisture effects have been found to be small for the short wavelengths. At longer wavelengths, little was known about the active microwave properties of crops before 1980. In the present paper, the results of experiments conducted in 1980 and 1981 over bare, plowed fields (row structure and row direction experiments) and over corn, soybeans, wheat, barley, and sunflower fields (vegetation canopy experiments) by the presenter are given. In general, many of the results noted by previous investigators in the short wavelength portion of the microwave region did not hold true in the long wavelength portion. Row structure and row direction effects can be quite large (up to 20 db), especially at L-band (20 cm) for fields that have been prepared for flood irrigation. Also, the usefulness of cross polarized radar measurements is much greater for long wavelengths than for short wavelengths. Indeed, the separation of mature corn from mature soybeans was possible at C-band only with the use of the HV channel (horizontal transmit - vertical receive). Examination of the frequency dependence of the radar backscattering coefficient for corn and soybeans revealed an apparent resonance effect probably affected by the closeness of the size of scattering elements in the canopy (leaves, stems, and fruit) to that of the microwave radiation. Such unique scattering properties could lead to the development of a robust, single-date crop classification procedure using multifrequency and multi-polarization radar data.

4-11

DEVELOPMENT OF THE JSC THEMATIC MAPPER (TM) QUICK-LOOK IMAGE PROCESSOR

J. Gilbert, NASA/JSC

With the launch of Landsat-D in July 1982, the remote sensing community has been provided a new earth orbiting multi-spectral sensor which has increased spatial resolution and superior spectral discrimination than any previously launched Landsat instrument. This new instrument, the Thematic Mapper, is a forward step in the progression of remote sensing

technology, incorporating the knowledge and experience gleaned from early scanning instrument endeavors as well as utilizing the latest available satellite stability and pointing capability.

The immediate concern of Landsat ground processing segments became the accommodation of a data volume output from the Thematic Mapper which is seven times as great as multi-spectral scanner output for the same scene coverage. Often, existing multi-spectral scanner processors were in place since the early 1970's and were not capable of handling such volumes of data. The problem consequently became a manifestation of the adaptation of existing systems, wherever feasible, and in many instances, the implementation of new processors designed for increased data volume handling.

This paper presents the development of the Thematic Mapper ground pre-processing capability of the Earth Observations Data Laboratory (EODL) at the Johnson Space Center. The implementation of new processing elements and the utilization of existing syystems in the EODL to handle Thematic Mapper data are reviewed in detail. The EODL Thematic Mapper Pre-processor has been designed to provide AgRISTARS researchers with satellite imagery data over selected areas of interest in data sets which are sized to be computationally manageable. In addition, the EODL Thematic Mapper Pre-processor includes the capability to provide image products in support of research activity.

4-12

EVOLUTION OF A REMOTE SENSING RESEARCH DATA SYSTEM AND DATA MANAGEMENT

M. Alexander, NASA/JSC

The United States Space Program has greatly enhanced man's ability to monitor and examine the earth, its weather, and its oceans through the collection of synoptic data from orbit. The technology to manage and analyze this remotely sensed data has not kept pace with the amounts of data available nor with the ever increasing demands of the researcher for ready access to the data and data processing facilities. As the quantity and variety of data have increased dramatically, so have the problems of data archival, analysis, and communications.

This paper presents the evolutionary development of the Earth Observations Data Laboratory (EODL) data systems 1980-1982 as a means of solving these research related problems. This transition occurred during a period of rapid technological change accompanied by budget, program, and personnel reductions.

The choice of commercially available off-the-shelf IBM plug-compatible hardware; VM370/CMS/-OS/RSCS-Networking/ADABAS system software; SAS/IMSL applications software; as a the keystone data system in the EODL, has been essential to the success of the EODL transition.

In addition, the Earth Resources Research Division (ERRD) maintains a large collection of data sets and data bases. Although these data bases are related in that they are all earth observations, the data are almost exclusively independent with no shared software capabilities or electronic data linkage.

In order to provide basic data management requirements in addition to providing the capability of managing the above mentioned disparate data sets, a Data Base Management System (DBMS) was installed in the EODL. The logic and selection criteria of the DBMS areas are discussed in this paper.

4-13

COMPARISON OF MINIMUM DISTANCE AND MAXIMUM LIKELIHOOD TECHNIQUES FOR PROPORTION ESTIMATION

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A common objective in agricultural remote sensing is the estimation of the crop proportions $a_1,\ldots a_m$ in the mixture density

$$f(\underline{x}) = \sum_{k=1}^{m} a_k \; f_k(\underline{x})$$

where m is the number of crops and for each crop, $f_k(\underline{x})$ has been taken to be the reflected energy in four bands of the light spectrum, certain linear combinations of these readings, or other derived "feature" variables. We have examined minimum distance estimation of the mixture proportions as an alternative to the maximum likelihood procedures currently employed, and the performance of the MDE and MLE on both normal and non-normal data has been investigated.

5-1

IMPROVEMENT OF MOISTURE ESTIMATION ACCURACY OF VEGETATION-COVERED SOIL BY COMBINED ACTIVE/PASSIVE MICROWAVE SENSING

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The measured effects of vegetation canopies on radar and radiometric sensitivity to soil moisture are compared to first-order emission and scattering models. The models are found to predict the measured emission and backscattering with reasonable accuracy for various crop canopies at frequencies between 1.4 and 5.0 GHz, especially at $0 \leqslant 30°$. The vegetation loss factor, L(0), increases with frequency and is found to be dependent upon canopy type and water content. In addition, the effective radiometric power absorption coefficient of a mature corn canopy is roughly 1.75 times that calculated for the radar at the same frequency. Comparison of an L-band radiometer with a C-band radar shows the two systems to be complementary in terms of accurate soil moisture sensing over the extreme range of naturally occurring soil moisture conditions. The combination of both an L-band radiometer and a C-band radar is expected to yield soil-moisture estimates within +/-25% of true soil moisture even for a soil under a "lossy" crop canopy such as corn.

5-2

PRELIMINARY RESULTS OF THE COLBY AGRICULTURAL SOIL MOISTURE EXPERIMENT

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Lockheed Engineering and Management Services Company, Inc.
Jack F. Paris
NASA/JSC

NASA conducted a major soilmoisture experiment in the summer of 1978 in a test site near Colby, Kansas. Aircraft radar scatterometers measured the backscattering coefficient of about 40 fields at several wavelengths, look angles, and polarizations on six dates. On each flight date, ground truth teams collected data on the distribution of soil moisture in each field with depth and over the horizontal extent of the fields. They noted or measured other field properties as well as vegetation cover type and amount, row direction, row structure, and surface roughness.

To increase the quality of the data to be analyzed, we designed and implemented software packages on the AS3000 computer system at the NASA Lyndon B. Johnson Space Center to locate accurately the horizontal position of each area viewed by the sensors during the flights for each radar configuration. Also, we included checks on signal-to-noise ratios and other engineeering coefficients. Having access to low altitude photography taken during the flight line runs, we were able to locate the sensor footprints more accurately than other investigators who have been analyzing the same data.

The best single radar configuration for sensing soil moisture (given as the average volumetric moisture content in the upper 5 cm of soil) was in the C-band with a polarization combination of horizontal transmit and horizontal reception (HH) at a sensor look angle of 15 degrees with respect to the nadir. This result confirms the findings of several other research groups, however, the coefficient of determination R^2, was quite high (0.85) as compared to a value of 0.65 obtained on the same data set by previous investigators. This significant difference in results was due to the data handling procedures used in the present analysis.

5-3

PASSIVE MICROWAVE SENSING OF SOIL MOISTURE UNDER VEGETATION CANOPIES

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U. S. Department of Agriculture
Thomas J. Schmugge, and
James R. Wang
NASA Goddard Space Flight Center

Vegetation cover has a significant effect on the ability of passive microwave radiometers to detect changes in near surface soil moisture. A quantitative technique for isolating the effect of vegetation was developed using a theoretical model as the basis of a parametric approach. This approach was evaluated using data collected by truck mounted sensors over experimental plots. Results show that a microwave radiometer operating at a 21 cm wavelength can provide volumetric surface soil moisture estimates to approximately 5% of accuracy for fields covered with moderate vegetation. In addition, all of the data required for applying the parametric model can be measured using remote sensing.

5-4

A MICROWAVE SYSTEMS APPROACH TO MEASURING ROOT ZONE SOIL MOISTURE

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The current availability of water for agricultural purposes has become a severe problem in the last few years especially in Texas and Oklahoma. Development of efficient and effective methods of regulating, monitoring and utilizing the remaining water resources are crucial to taking action to minimize the problem. This document describes an approach to developing a technique of monitoring soil water conditions over large areas for potential use to agricultural managers. This approach utilizes an orbiting passive microwave remote sensing system to estimate near surface moisture and a deterministic soil water model to predict the moisture at root zone depth based on the near surface soil moisture estimate.

This microwave systems approach to remotely measuring large area soil water information is currently in the development and evaluation stage. This issue has been addressed thus far by dividing the problem into two issues. One is the evaluation of the ability to make a large area surface soil moisture estimate using an orbiting passive microwave system (Newton et al., 1979). The second is the development and evaluation of the model that is capable of utilizing the near surface soil moisture estimate as an input along with soil characteristics to predict the moisture within the root zone depth. The problem has been approached by developing computer simulation models to evaluate the approach and to validate these results where possible with actual field experimentation.

Experimental microwave and ground field data have been acquired for developing and testing a root zone soil moisture prediction algorithm. The experimental measurements have demonstrated that the depth of penetration at a 21 cm microwave wavelength is not greater than 5 cm. Previous work by Jackson (1980) indicates that the moisture in the lower profile (below five cm) can be estimated with a 0.06 standard error by using surface soil moisture for the top 5 cm. This document presents simulations of brightness temperature over bare soil conditions that can be utilized to test the lower profile prediction scheme of Jackson (1980). In addition, field experimental measurements exist to validate this work.

5-5

REMOTE SENSING OF SOIL MOISTURE: RECENT ADVANCES

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In the past few years there have been many advances in our understanding of the microwave approaches for the remote sensing of soil moisture. These include a method for estimating the dependence of the soil's dielectric constant on its texture; the use of percent of field capacity to express soil moisture magnitudes independent of soil texture; experimental and theoretical estimates of the soil moisture sampling depth; models for describing the effect of surface roughness on the microwave response in terms of surface height variance and the horizontal correlation length; verification of the ability

of radiative transfer models to predict the microwave emission from soils; experimental and theoretical estimates of the effects of vegetation on the microwave response to soil moisture; and simulation studies indicating how remotely sensed surface soil moisture may be used to estimate evapotranspiration and root zone soil moisture.

6-1

1981 AGRISTARS DCLC FOUR STATE PROJECT

James W. Mergerson
Charles E. Miller
Martin Ozga
Martin Holko
Sherman Winings
Paul Cook
George A. Hanuschak

This paper summarizes the work performed under the major crop area estimation element of the 1981 AgRISTARS (Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing), DCLC (Domestic Crops and Land Cover) Project.

The DCLC objective of providing timely, more precise year-end state and sub-state crop area estimates for SRS was accomplished. Corn and soybeans planted area estimates were provided for Missouri and Iowa. Harvested winter wheat estimates were provided for Kansas and Oklahoma.

6-2

KANSAS LAND COVER SURVEY

George May, USDA
Gregory S. Burns,
Marty Holko,
Jim Anderson, ERL

During FY81 a state level land cover study was conducted in Kansas. This survey utilized the area sample frame and methodology currently used by USDA, Statistical Reporting Service to provide probability estimates of crop acreages. All land within the 435 June Enumerative Survey segments was enumerated into 17 cover types. These ground data were used in classifying Landsat data to produce a land cover classification for the entire state. Statistically based, acreage estimates were obtained by developing regression relationships between the ground and classified data. Regional land cover maps and associated regression acreage estimates were also produced. A presentation on the results of this study was given to various state and federal agencies in an effort to provide land cover information that could benefit resource managers.

6-3

THE USE OF LANDSAT FOR COUNTY ESTIMATES OF CROP AREAS

Gail Walker
Richard Sigman
Statistical Reporting Service
USDA

The purpose of this report is to develop and compare estimators which use Landsat data to estimate crop areas at the county level. This report extends the Battese-Fuller estimator to a stratified sample design and evaluates the Huddleston-Ray estimator and variations of the Battese-Fuller estimator on a six-county area in South Dakota.

For SRS Landsat studies, the authors recommend replacing the Huddleston-Ray estimator with one of the favorably evaluated estimators in the Battese-Fuller family.

6-4

AUTOMATED SEGMENT MATCHING ALGORITHM

Maria Kalcic, NASA/NSTL/ERL

The USDA/Statistical Reporting Service uses two stages in the registration of digitized sample segments to Landsat MSS data. The first stage uses a control point-based transformation applied to the entire area of study. Since the first stage, or global registration, does not produce accuracy within a required one-half pixel, on a per segment basis, a second stage registration is required.

This second stage, or local segment shifting, has been performed manually by overlaying plots of the digitized segment and field boundaries to grey-scale plots of the Landsat MSS data, and then shifting the plots to produce the proper line up. The second stage registration has been automated as a result of the Domestic Crops and Land Cover/Scene-to-Map Registration Task. The Automated Segment Matching Algorithm (ASMA) uses edge-enhancement and within field variability as inputs to compute the necessary adjustment to each segment's computed location.

The algorithm results were compared to the manual shifting results and produced root mean square errors of 18.86 and 25.21 meters in the line and element directions, respectively. These errors meet the USDA/SRS requirement for a one-half pixel registration accuracy.

6-5

CLASSIFIER DESIGN FOR REGRESSIONS OF GROUND GATHERED WITH COMPUTER CLASSIFIED DATA

R. P. Heydorn, NASA/JSC

An estimator which is based on a regression of June Enumerative Survey (JES) data with computer classified Landsat data is being applied by SRS to estimate state crop acreages. The purpose for using the Landsat data is to increase the precision of the estimates based on the JES data alone. Recently, regression methods have also been considered for again using the Landsat data to improve the JES estimates at the county level. In each of these methods regression parameters are estimated using not only data from the county of interest but also from surrounding counties. Due to county-to-county differences, data from one county need not have the same statistical properties as does the data from the collection of counties. To minimize bias in the county estimates it is important that the data fits any assumed regression model.

This paper discusses the results of a NASA/JSC study to investigate the properties of various classifier designs that can influence the shape of the regression function. Some classifier designs which can lead to linear regressions in certain cases are discussed. The paper also presents a relationship between the R^2 of a regression and the omission/commission error rates of the classifier.

6-6

STRATIFICATION OF SAMPLED LAND COVER BY SOILS FOR LANDSAT-BASED AREA ESTIMATION AND MAPPING

E. R. Stoner, NASA NSTL

The distribution of agricultural crops and other land cover types frequently is closely associated with certain soils and land forms. One implication for Landsat-based area estimation and mapping is that a given pixel occurring within a certain soil unit does not in fact have an equal probability of falling into any one of the land cover classes. For example, 99% of all tobacco fields in Robeson County, North Carolina occur on well or moderately well drained sites, leaving 46% of the county land area on which tobacco is unlikely to occur.

Another implication of soil/land cover relationships for spectral discrimination of land cover types is the possibility of soil-induced spectral variations related to soil-specific management practices and background reflectance characteristics. In the Robeson County site, crop development cycles can be expected to differ between soybeans grown on well drained uplands and poorly drained depressional bays. Other crops such as tobacco, are grown in wide rows and achieve only partial ground cover, with the result that soil reflectance predominates over the response of green vegetative cover.

Sampled land cover can be stratified using mapped soil information available in typical county soil surveys. For the purpose of the Robeson County land cover study, soil information was simplified into 5 general soil classes whose characteristics of natural drainage, physiographic position, organic matter content, and surface color are homogeneous in regards to properties that would be expected to influence Landsat MSS response. Individual fields within June Enumenative Survey (JES) segments were coded by soil class grouping to effect the stratification of sampled land cover by soils. Cover type information was available for corn, soybeans, cotton, tobacco, hay, pasture, and forest. A multidate set of Landsat MSS data from the 1980 growing season was used in the analysis.

6-7

A CORRELATION ANALYSIS OF PERCENT CANOPY CLOSURE VS. TMS SPECTRAL RESPONSE FOR SELECTED FOREST SITES IN THE SAN JUAN NATIONAL FOREST, COLORADO

M. K. Butera
NASA/NSTL/ERL

This investigation tested the correlation between canopy closure which is an indicator of forest biomass, and individual Thematic Mapper Simulator (TMS) bands for selected forest sites in the San Juan National Forest, Colorado. Percent canopy closure was determined for 30 sites, each 25 acres in area, from aerial photo-interpretation and ground survey. The sites were selected to represent a range of canopy closure from 0 to 100%. They were also selected from plateaus with slope $\leq 10\%$ at an elevation of approximately 9,000 ft. This condition minimized the effect of slope as a variable in the analysis. The forest communities were dominated primarily by ponderosa pine and aspen. For each site, the mean response per band was calculated from TMS data acquired over the study area on September 18, 1961. A linear correlation and regression analysis

was performed on mean TMS response per band per site versus % canopy closure. Correlation coefficients for TMS bands 1-7 were -.757, -.663, -.666, -.088, -.797, -.579, and -.763, respectively. Using band 5 data, a model regression in the form of

$$\arcsin \sqrt{\%\ \text{canopy closure}} = y = 114.69 - 2.363\ \text{ch}\ 5$$

was applied to the data, creating a map of predicted % canopy closure for the study area. The following conclusions were made:

1. TMS bands 1, 5, 7, essentially wavelength intervals not covered by MSS data, proved most significant in relating % canopy closure to spectral response.

2. The negative correlations were probably caused by a spectral contribution from the background (dry soil, senescing grasses) with higher reflectivity response than the forest canopy.

3. For a given ecosystem the best predictive model is achieved when conditions of greatest spectral contrast between background and forest vegetation exist.

6-8

THE SIMULATION OF USDA SEGMENTS, FIELDS, AND PIXEL SPECTRAL VALUES

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Lockheed Engineering and Management Services Company, Inc.

The evaluations of procedures which use classification of Landsat spectral data to estimate crop proportions have been inconclusive in some cases due to an inadequate data base. Furthermore, our understanding of the classification process could be greatly improved with a larger data base.

A simulation procedure has been developed which could create such a large data base by simulating random segments, fields, and pixel spectral values. This procedure attempts to create simulated values which are similar or equal to the actual values found in our 1979 set of 33 Missouri segments. It simulates segment sizes, field sizes, crop proportions, and a percentage of edge pixels which are similar to the actual data.

The procedure simulates four-channel spectral values at the pixel level and the two acquisitions found in our Missouri data set. It simulates a within field variation of pixel spectral values, a between field (within segment) variation, and a between segment variation. Correlations among the channels and between acquisitions are simulated through the use of principal components. Spectral values for edge pixels are simulated through a linear mixing of adjacent field effects.

This paper also presents a preliminary comparison of simulated and actual data.

6-9

USDA SMALL AREA CROP ESTIMATION USING LANDSAT- AND GROUND-DERIVED DATA

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The USDA approach to crop estimation for large areas such as a state or a crop reporting district is to regress survey data (ground truth) onto Landsat classification results. This estimator can produce unbiased estimates with measurable precision

for such areas. However, the possible lack of adequate survey data in a single county or small group of counties requires the use of sampling units from the entire state or analysis district in order that the regression model may be applied to these smaller areas. Within this context, the regression estimates can be biased.

This paper summarizes the philosophy, evaluation, and results of three approaches to small area estimation; the problems intrinsic in these approaches; and the research directions in which these difficulties led.

6-10

EVALUATION OF USDA LARGE AREA CROP ESTIMATION TECHNIQUES

Sylvia Shen
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This paper describes the results of the Domestic Crops and Land Cover Classificaion and Clustering study on large area crop estimation using Landsat and ground truth data. The USDA's EDITOR system registers and digitizes the ground truth and raw Landsat data. It clusters, classifies, and develops area estimates by regressing the ground truth hectarage for a given crop onto the number of pixels classified into that crop for each segment. A research program was conducted to evaluate the performance of EDITOR and make selected improvements to components of EDITOR. In was found that the use of multitemporal data, over unitemporal, significantly improved crop hectarage estimates. Performance measures on an independent test set and a jackknifed test set decreased, indicating that the EDITOR procedure of using a single data set for training the classifier, developing the regressions, and evaluating the results leads to overoptimistic performance estimates. An alternative clustering algorithm, CLASSY, when substituted for the EDITOR clustering method, produced improved estimates. Use of a simpler classifier, namely Mean Square Error Classifier, did not produce significantly better hectarage estimates but showed more extendibility of the regression lines to an independent test set.

7-1

MAPPING FOREST RESOURCES USING THEMATIC MAPPER SIMULATOR (TMS) DATA

Stephen D. Degloria
University of California-Berkeley

A quantitative evaluation of TMS multispectral data is required to determine the extent to which TM data will serve as a framework for the spatial estimation and mapping of resources critical to forest management and planning. TMS data were acquired by the U-2 aircraft over the Plumas National Forest (PNF), California, during October 1981 through August 1982 coincident with systematic ground data collection efforts. The October 1981 mission focused on development and evaluation of day-night temperature difference images for the spatial estimation of soil temperature regimes. The August 1982 mission focused on determining (1) the ability of these data to detect and identify critical forest resources, and (2) the spectral variability of TMS data over diverse terrain. Relationships between the spectral data from the seven bands of the TMS and several forest resource variables include tree and brush species composition; basal area of commercial conifers; height, age and DBH of dominant

tree species; average stand crown diameter; average stand density; timber site; soil family; O horizon thickness; soil temperature (surface and 50 cm depth); and the topographic variables of elevation, slope, and aspect. Based on this and previous work, a multivariate soil temperature mapping function is being developed and applied in support of the PNF Soil Resource Inventory (SRI). Future activities include the integration of Landsat-4 TM and MSS data into the multi-dimensional data base for evaluating the spectral, spatial, radiometric, and geometric characteristics of these data in forest and rangeland environments.

7-2

DETECTING FOREST CANOPY CHANGE USING LANDSAT

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Goddard Space Flight Center

Multitemporal Landsat multispectral scanner data were analyzed to test various computer-aided analysis techniques for detecting significant forest canopy alterations. Three data transformations, differencing, ratioing, and a difference of ratios, were tested to determine which best delineated gypsy moth defoliation. Response surface analyses were conducted to determine optimal threshold levels for the individual transformed bands and band combinations. Results indicate that, of the three transformations investigated, a difference of ratios (band 7/band 5) transformation most accurately delineated forest change due to gypsy moth activity. Band 5 (0.6-0.7 micrometers) ratioed data did nearly as well, however, other single bands and band combinations did not improve upon the band 5 ratio results.

7-3

HIGH-ALTITUDE RADAR ASSESSMENT OF THE DAMAGE CAUSED BY THE VOLCANIC ERUPTION OF MOUNT ST. HELENS

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R. E. Hinkle
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Following the volcanic eruption of Mount St. Helens on May 18, 1980, the surrounding area was obscured by varying amount of clouds and ash for 30 days. A total view of the damaged area was needed immediately. This need was met within 3 days by acquiring high-altitude side-looking radar imagery. This imagery was analyzed using only the characteristics of the radar returns in conjunction with preeruption high-altitude photography. The analyst was able to establish the areal extent of the changes in lakes, topography, and damage to timber caused by the eruption. The three radar condition maps were compared to posteruption photography collected on June 19, 1980, and other damage condition maps. These comparisons show good agreement for both the boundaries between classes of damage and the types of damage defined by the radar imagery. A major factor in the total exploitation of the radar imagery was the availability of image analysts trained and experienced in interpreting the characteristics of radar returns from natural vegetation. This study shows that high-resolution radar data can provide important information on the damage to large areas when obscuration prevents the use of other types of imagery.

7-4

OKLAHOMA MID-CYCLE TIMBER INVENTORY PILOT TEST

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A large scale demonstration of a forest survey technology which uses high altitude panoramic photography in conjunction with two-phase sampling was conducted in Oklahoma during the 1981 mid-cycle timber inventory update. The results indicated that 4.3 of the 10.5 million acres of eastern Oklahoma are in commercial forest land. The total growing stock volume was estimated to be 2.0 billion cubic feet.

The fact that the growing stock volume estimate has a standard error (4.6 percent) only 2.2 percent larger than that of the full-cycle survey with only ten percent of field work is an indication of the efficiency of the system.

This project demonstrated that high altitude panoramic photography in combination with two-phase sampling can be used to efficiently satisfy the requirements for mid-cycle timber inventory updates.

8-1

INVENTORY OF SOIL CONSERVATION PRACTICES USING REMOTE SENSING

R. H. Griffin, II
NASA/NSTL/ERL

An examination of the size and shape of the 119 soil conservation practices listed by the USDA/SCS in the National Handbook of Conservation practices was made. This investigation revealed that about 20 could be detected by a scanner with the resolution of the thematic mapper. Although there are 22 practices that cannot be detected using remotely sensed data, it is likely that the majority of the remaining practices (77) could be detected with a scanner with an Instantaneous-Field-of-View (IFOV) of about 15 meters.

Another area of investigation has focused on the use of remotely sensed data and other mapped information to identify potential erosion hazards. For the study areas that have been investigated to date, elevation information obtained from the NCIC tapes (1:250,000 topography maps) have not been adequate for determining slopes zones for erosion hazard assessment. However, the use of digitized soil survey data along with Landsat MSS data have been used to identify areas where potential erosion hazards exist.

8-2

BUILDING A BRIDGE BETWEEN REMOTE SENSING AND HYDROLOGIC MODELS

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Hydex Corporation
Edward R. Johnson
Georgia Tech
Thomas N. Keefer
Sutron Corporation

Remote sensing technologies provide indirect measurement of land characteristics, vegetative cover, and the states of water in the hydrologic cycle. However, the use of this valuable information for modeling the hydrologic cycle has been very limited. This limited use is a result of two factors. First, there is not a one-to-one correspondence between parameters and states of hydrologic models and

common remotely sensed variables. The second, is our inability to effectively combine remotely sensed information with standard measurements to improve estimates of mean areal values of hydrologic variables.

The above limiting factors are the subject of completed and on-going NASA contracted research and are reported here. The studies have been accomplished in four parts:

- o Review of Hydrologic Models for Evaluating Use of Remote Sensing Capabilities
- o Strategies for Using Remotely Sensed Data in Hydrologic Models
- o Combining Remotely Sensed and Other Measurements for Hydrologic Areal Averages, and
- o Updating of Hydrologic Models Using Remotely Sensed Measurements

Objectives of the research are discussed and include development of techniques for (1) improvement in operational hydrologic forecasting, (2) enhanced knowledge of the states of water in the lithosphere for drought and crop yield studies, and (3) improved estimates of mean areal average values of hydrologic variables for wide agricultural application.

8-3

THE STRUCTURING OF A REMOTE SENSING BASED CONTINUOUS STREAMFLOW MODEL

J. R. Groves and R. M. Ragan
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Landsat remote sensing has been successfully used to provide land cover parameters for single event hydrologic models. The potential of space platform remote sensing to provide other data for the synthesis of continuous hydrologic processes is rapidly advancing, but applications are limited by the absence of models structured to accept the newly available or anticipated remotely sensed data.

The paper describes the development of the structure and testing program for a physically based continuous streamflow model specifically designed to incorporate information obtained from space platform sensor systems. The linkage and operating concepts are similar to those of the established Stanford Watershed Model family in that the objective is to route the incoming rainfall through a series of submodels that simulate individual hydrologic processes to produce estimates of the daily or hourly streamflow and the redistribution of moisture storage within the drainage basin. Too many of the components in the Stanford Model family are based on regression analysis and cannot be estimated in terms of measurable quantities. Each component in the proposed model is physically based and optimized to interface with remote sensing capabilities. All input data, both satellite and ground based, are incorporated into the model through a grid cell geographical information system. The data base, designed to be developed from digital imagery from Landsat, TIROS-N, and GOES satellite systems is to include land cover, solar radiation, snow cover, vegetative stress, cloud cover, temperature estimates, and other physical quantities relative to the synthesis of streamflow from precipitation. The strategy in the development of the components used to simulate individual hydrologic processes is to use extensive numerical experiments with complex highly theoretical models to evolve computationally efficient functional relationships that will stimulate the individual.

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R. R. J. Mohler, D. B. Ramey, and C. L. Dailey
Lockheed Engineering and Management Services Company, Inc.

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SPECTRAL WAVELENGTH CHARACTERISTICS OF TM, MSS, AVHRR
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C. R. Quinones
Lockheed Engineering and Management Services Company, Inc.

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M. M. Smyrski, H. G. Smith, E. R. Magness
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W. F. Palmer
Lockheed Engineering and Management Services Company, Inc.

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K. S. Nedelman, R. B. Cate,
Lockheed Engineering and Management Services Company, Inc.
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K. S. Nedelman and R. B. Cate
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K. S. Nedelman and R. B. Cate
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K.S. Nedelman and R. B. Cate
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A NON-PARAMETRIC CLUSTERING TECHNIQUE
D. B. Ramey
Lockheed Engineering and Management Services Company, Inc.

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T. Hodges, University of Missouri Columbia, Missouri

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T. Jackson, USDA/ARS, P. O'Neill, and T. J. Schmugge, NASA/GSFC

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James A. Brass,
NASA/Ames Research Center;
Michael A. Spanner,
Technicolor Government Services/ Ames Research Center;
David L. Peterson,
NASA/Ames Research Center; and
Joseph J. Ulliman,
College of Forestry, University of Idaho