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ANNUAL REPORT - Year 2

NASA Grant No.: NAGW-3862

Title of Project:

"Toward Soil Spatial Information Systems (SSIS) for Global Modeling and Ecosystem Management"

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

2

Reporting Period: 01 January to 31 December 1995

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Introduction

This is a report of the activities and accomplishments of the SSIS (Soil Spatial Information Systems) Project in Year 2. For more than 20 years an interdisciplinary team of scientists at Purdue University has been conducting research on the applications of remote sensing for delineating soil variability and characterizing soil conditions. Only during the past decade as global change studies and global modeling activities have accelerated has the critical need for a credible, reliable global soils and terrain digital database at an appropriate scale for global change and modeling studies been enunciated widely.

The SSIS Project is designed to provide research support for the development of a world ***SO***ils and ***TER***rain (SOTER) digital database at a scale of 1:1,000,000. Although the SOTER Project within the past six years has developed operational procedures for translating and correlating soil maps from different classification systems to the universal legend and standardized procedures of SOTER, there are many scientific and technical problems which are yet to be resolved.

There are numerous limited efforts to improve on existing world soil information systems or to use the extant but extremely limited Soil Map of the World to model global soil carbon and other environmentally related phenomena. Locations of some of these efforts in the United States include work of W. Post (Oak Ridge National Laboratories), N. Bliss (EROS Data Center), R. Lozar (Construction Engineering Research Laboratories, CERL, U.S. Army Corps of Engineers), S. Waltman (World Soil Geography, Natural Resources Conservation Service, U.S. Department of Agriculture), and E. Levine (Goddard Space Flight Center).

The critical need for a credible, usable, accessible world soils and terrain digital database suggests that a strong research effort in support of the development of such a database is essential. This report describes a small but important effort being made to address some of the critical research issues related to the SOTER Project.

This effort at Purdue University is being supported directly by two faculty members, five graduate students, and an electrical and computer engineering technical support staff member. Indirectly numerous other faculty members and students at Purdue University, and Gödöllö Agricultural University (Hungary), and scientists at CERL, the EROS Data Center, the Research Institute of Soil Science of the Hungarian Academy of Sciences have contributed and will continue to contribute to this research effort.

During the first six months of 1995, Bruce Worstell, a Purdue graduate research assistant on this Project, worked as an intern with Dr. Norman Bliss at the EROS Data Center. It was an excellent work experience for Worstell, and their joint effort at EROS contributed immensely to the research under objective one of this project.

Another Purdue graduate student, Todd Helt, although not being supported within this Project budget, is contributing to both objectives one and two of the Project. He spent the first six months of 1995 at Gödöllö Agricultural University (Hungary) conducting research in collaboration with Hungarian soil scientists (Prof. E. Micheli, Prof. G. Varallyay, Dr. G. Buttner, and Ph.D. graduate student E. Dobos) in support of the development of a SOTER database for Hungary. His work there helped to catalyze the collaboration and exchange of data among scientists of Gödöllö Agricultural University, the Research Institute of Soil Science and the Institute of Geodesy and Remote Sensing of the Hungarian Academy of Science. Helt's work in Hungary has resulted in the naming of Hungarian Prof. Erika Micheli to the Purdue Graduate Faculty so that she can serve on Helt's Graduate Advisory and Examining Committee. Dr. Micheli has translated and correlated the Soil Map of Hungary to both the soil classification systems of the Food and Agriculture Organization of the United Nations and Soil Taxonomy (the U.S. system).

A Description of the SOTER Project and Its Status.

The critical need for a credible, uniform digital map of world soils continues to build. This need is driven by global modelers and many other scientists, planners and decision-makers who are concerned about what is happening to the land resources of the world. At what rate is prime agricultural land being removed from food production on a global basis? What is the rate of land degradation from a variety of causes on a continental and global basis? What is the quantitative relationship between the inequitable global distribution of human population and the food producing capacity of the lands they occupy?

The only available and relatively easy-to-access global soil map is the Soil Map of the World (scale 1:5M), a joint project of FAO (Food and Agriculture Organization) and UNESCO (United Nations Educational, Scientific and Cultural Organization) produced during a period of about two decades beginning in 1960.

In a sense the soils of an area "record" the climatic, geologic, hydrologic and biological history through their genetic processes and composition. Soils thus become a primary indicator in terrestrial ecosystems of the environmental conditions and their potential productive capacity. The FAO-UNESCO Soil Map of the World was an important step forward in our understanding of the vast differences in soils and soil properties. These differences, or soil variations, contribute significantly to the broad array of terrestrial ecosystems and their vast differences in carrying capacity or capacity to support human settlements.

Even with the limitations and the very severe lack of detail of the World Soil Map, a digitized version of this Map is being used by the scientific community, especially by global modelers with varying degrees of satisfaction and often with unsatisfactory results in characterizing the soil resources of the world. There is a critical need for a world soils and terrain digital database which will build on the FAO-UNESCO Map through improvement of cartographic and descriptive soils and terrain data generated at a scale of 1:1M or larger.

In 1986 the International Society of Soil Science (ISSS) initiated a program to develop a world ***SO***ils and ***TER***rain (***SOTER***) digital database at a scale of 1:1M. This is an ambitious project and one which by conventional means will require many years to complete. It is a project which must be done, but its implementation is fraught with many difficulties, and there is critical need for a program of research in support of the objectives of developing a uniform, credible, usable, accessible world soils and terrain digital database.

Since most soil mapping in the world was done prior to the development of the interfacing of disparate data sets related to a broad range of Earth system components and processes, the cartographic quality of soil maps was not a serious concern at the time of map generation. Now that scientific and resource management communities wish to combine many layers of different kinds of data into a cartographically acceptable spatial database, mapping accuracy becomes a serious concern. This means that all exsiting soil maps must be tested and corrected when necessary for geometric accuracy and appropriate map projection before such maps can be entered into an integrated database.

One of the most critical issues requiring continuous attention is that of integrating soil maps produced by different systems of soil classification into a unified, compatible world soils and terrain digital database with a universal legend and standard descriptive terminology and class limits for different physical, chemical and biological properties of soils. During the first years of the SOTER Project major attention was given to the development of a SOTER Procedures Manual to serve as a guide for translating and correlating soils maps from any classification system to a uniform SOTER cartographic and attribute database. After using and testing of this SOTER Manual in several countries, SOTER management has completed the 6th Version of the Manual which was recently published jointly by FAO, ISSS, ISRIC (International Soil Reference and Information Centre) and UNEP (United Nations Environment Programme). Even though the SOTER Manual is considered operational, it will continue to require upgrading and improvement as it is applied to more soils and terrain regions of the world.

Since 1988 SOTER digital databases have been implemented in portions or all of Argentina, Brazil, Canada, Hungary, Kenya, United States and Uruguay. In every country where the SOTER database is applied, new issues are identified where research would be helpful to improve the methods and guidelines for translating and correlating existing maps to the SOTER database.

Under this NASA grant, Hungary and Indiana are the primary sites where research is being conducted in support of the SOTER Project.

Implementation of Project Objectives during Year 2.

The general objective of this project is to conduct research to contribute toward the realization of a world soils and terrain spatial database, which can stand alone or be incorporated into a more complete and comprehensive natural resources digital information system. The soils and terrain spatial database must be compatible on a global basis and accessible and easily useable and relatable to a wide range of spatial scales by a broad community of users.

In order to achieve this general objective, research will focus on the following specific objectives:

Objective 1. To conduct research related (a) to translation and correlation of different soil classification systems to the SOTER database legend and (b) to the interfacing of disparate data sets in support of the SOTER Project.

Research aimed at addressing this objective has been pursued with a range of datasets in two sites of approximately 93,000 square kilometers each: Hungary and Indiana USA.

A. Developing a SOTER database for Indiana

Currently, 3 data sets have been used to develop the SOTER database for Indiana. The State Soils Geographic (STATSGO) database from the Natural Resources Conservation Service was the source of the soil map and attribute data. The 3 arc second Digital Elevation Models (DEM) available through the U.S. Geological Survey were used for deriving terrain information. The Soil Interpretations Record was used to derive parent material information. The development work has been performed using ARC/INFO in a UNIX environment and can be categorized into 2 phases:

Phase 1: Database Development. The SOTER database contains 76 attributes related to soil and terrain characteristics. Initially, tables were created according to the SOTER procedures manual and algorithms were developed to create linkages between the tables. Once, the database structure was established, more algorithms were developed to translate the attribute data from STATSGO to SOTER. Since STATSGO lacks many of the attributes included in the SOTER database, attributes were converted/derived where possible. Some of the attributes were derived with few problems. However, other attributes had classes that did not correlate or required assumptions or additional processing in order to populate the database.

Phase 2: Map Unit Development. Ideally, map unit development using the SOTER approach begins by identifying physiographic regions and subdividing these regions based on parent material. Unfortunately, STATSGO is deficient in both physiographic and parent material data. To overcome these deficiencies, the 3 arc DEMs and the Soil Interpretations Record were used to derive physiographic and parent material information respectively (Fig. 1a).

The SOTER procedures manual provides guidelines for slope and relief criteria associated with major landforms. These criteria were applied to the DEM but failed to provide any useful classification of major landforms. During the analysis, however, it was discovered that relief did a reasonable job of characterizing the landscape. Relief was computed for a pixel by computing the difference between the maximum and minimum elevation within a radius of 1 km of the pixel (i.e. 2km window diameter). Further processing was then done to determine the dominant relief class for a given STATSGO polygon. This layer was used to represent the physiography (Fig. 1b).

Deriving the parent material required a manual interpretation of data in addition to developing algorithms. Soil series descriptions in the Soil Interpretations Record were evaluated manually to determine the surface parent material. The STATSGO database was then coded according to this

Figure 1a. Physiography

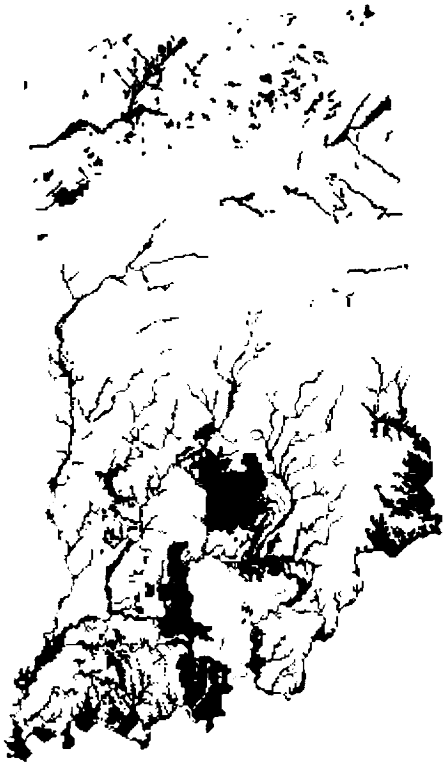
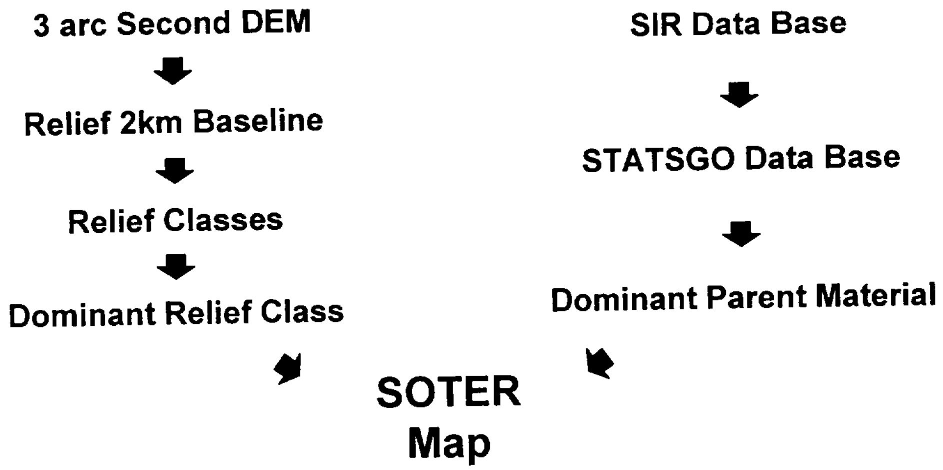


Figure 1b. Parent Material

Figure 1c. SOTER Map

description and analyzed to determine the dominant parent material for each map unit. This layer was used to represent the surface parent material. The layers for physiography and parent material were then combined to create combinations known as SOTER units (Fig 1c).

SOTER Map Unit Development



Future goals

Though the data have been converted into the SOTER format, the database is still not in an operational form. Links between database tables need to be tested to make sure that the linking strategy was implemented properly.

Using relief as an indicator of physiography may be sufficient but a more comprehensive description of landforms is necessary to meet the SOTER criteria. Developing algorithms that can be used to extract landform classes from DEMs would be a useful tool that could be applied to other areas where terrain information is lacking. However, there will still be desired terrain attributes in the SOTER database that cannot be filled from these data. Attributes of lower order in the database require more localized terrain information than at the terrain unit level. These attributes may remain empty or may be filled from other sources.

Although the SOTER Procedures Manual is now in its sixth revision in as many years and is now considered an operational manual, research results continue to suggest that other revisions and improvements should be made in the procedures. It is anticipated that one of the positive results from this Project will be a set of recommendations for improvement of the SOTER Manual.

Developing a SOTER Database for Hungary.

The first country in Central and East Europe to collaborate fully in the SOTER Project is Hungary. The Hungary SOTER Project was initiated and implemented by Prof. Gyorgy Varallyay, Director of the Research Institute of Soil Science and Agricultural Chemistry (RISSAC) of the Hungarian Academy of Sciences. One of the collaborators in the Hungary SOTER Project is Prof. Erika Micheli of the Gödöllö Agricultural University because of her expertise in soil survey and soil classification systems. Purdue University and Gödöllö Agricultural University (GAU) signed a Memorandum of Understanding in 1991 with the intention of building a long term program in faculty exchange, student exchange and collaborative research. One of Purdue's graduate students in soil science, Todd Helt, went to GAU for the spring semester 1993 under a student exchange program and became interested in the Hungary SOTER Project. As the SSIS Project has evolved since its initiation in 1994, research involving the Hungary SOTER project became a natural extension of the SSIS Project under the Purdue-GAU collaborative program.

During the past few decades, several different soil maps and land evaluation maps have been generated for Hungary, all of them using different classification systems and somewhat different approaches from those used in the United States. Since Indiana and Hungary represent areas of equal size and have many similarities in land use and agricultural practices, it seems appropriate under the SSIS Project to evaluate and compare SOTER maps and databases of Hungary and Indiana. In this process we can test SOTER procedures in an effort to improve and assess the uniformity and transferability of the technology.

In Hungary the SOTER methodology has been applied, and the detailed database has been developed for Hungary by experts at RISSAC and GAU. This existing "ground reference" database at 1:500,000 scale provides the opportunity to test the potential application of other types of data, in particular remotely sensed and digital terrain data, for the ability to delineate SOTER map units and/or their attributes, and for improving the existing SOTER database.

The objectives of the research related to the Hungary SOTER database are to develop quantitative methods for a) delineation of SOTER units and some attribute data for areas where current soil databases do not exist, are outdated, or otherwise lacking; b) "upward" and "downward" generalization of national SOTER databases, e.g., Hun-SOTER at 1:500,000, (Fig. 2a) to be compatible with global change database requirements (1:1,000,000), and meeting the needs of the local and national planners (<1:500,000); and c) validating, to some degree, parts of the SOTER databases. Currently, there is no cost effective method for such verification. A detailed database including remote sensing data (multi-temporal AVHRR and Landsat TM), soils information, digital elevation data, and planimetric/cultural features has been developed at 1:100,000. This database is being used for testing remote sensing and digital terrain based (Figs. 2b and 2c) SOTER approaches.

A major challenge of this Project is to attempt to answer some of the issues related to the question: How can multitemporal, multispectral, multispatial, multisource data sets be used to achieve the above objectives.

Fig. 2a SOTER Units of Hungary

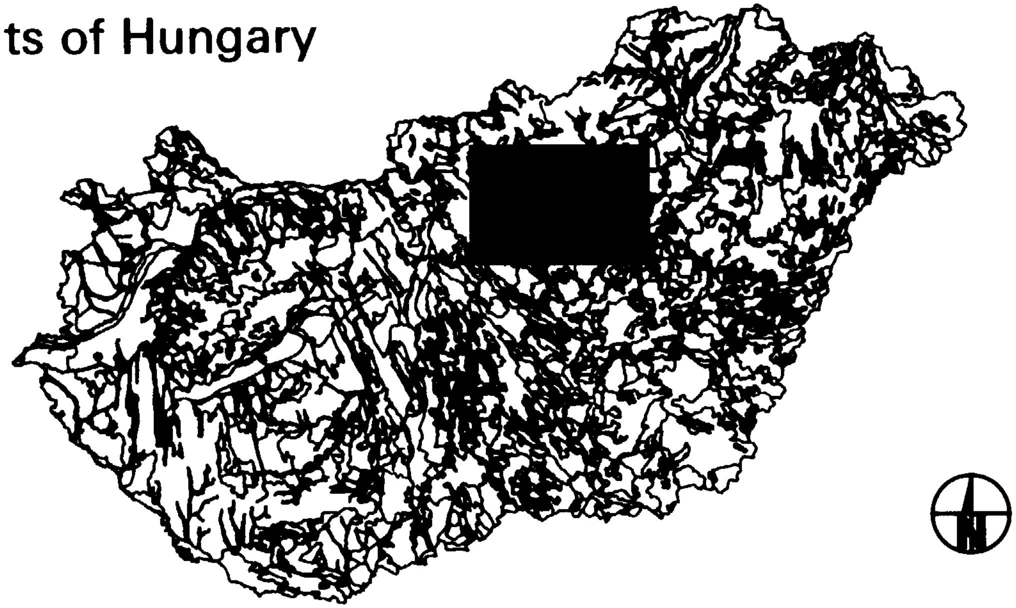


Fig. 2b Digital Elevation Model

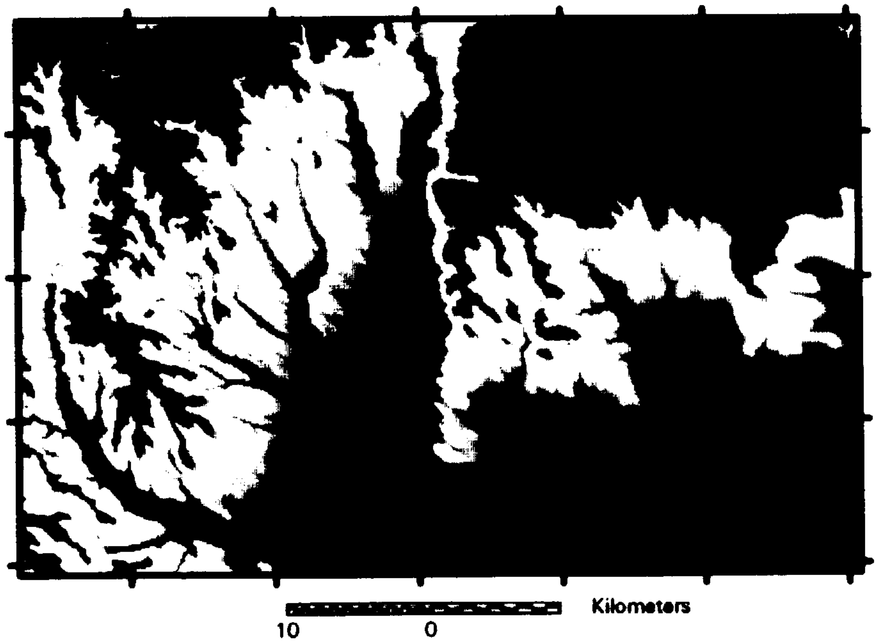
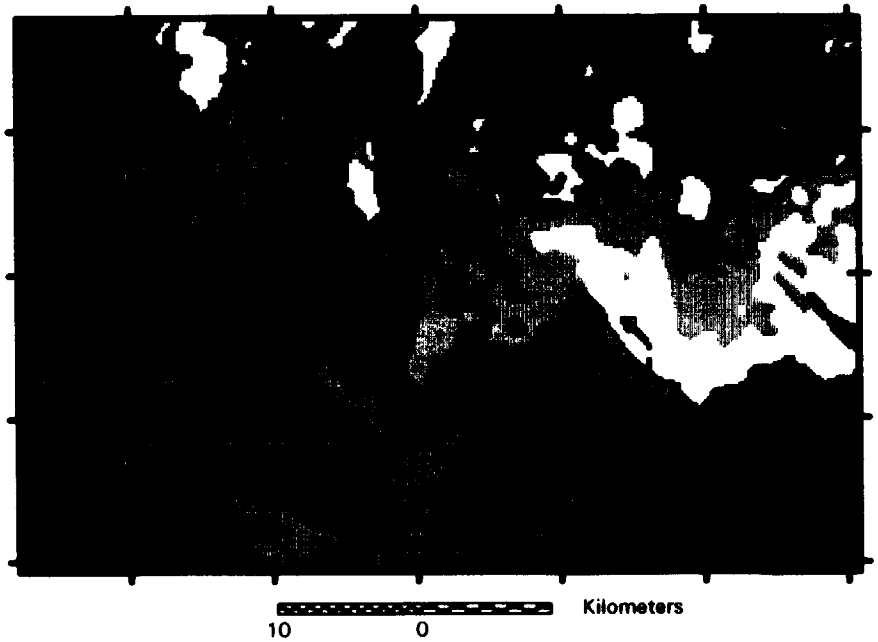


Fig. 2c Relief Intensity and Parent Material



Objective 2. To examine the potential use of AVHRR (Advanced Very High Resolution Radiometer) data for delineating meaningful soils and terrain boundaries for small scale soil survey (range of scale: 1:250,000 to 1:1,000,000) and terrestrial ecosystem assessment and monitoring.

AVHRR data were used efficiently and very effectively to compare land surface conditions for the state of Indiana during the growing seasons for 1987, a normal season for corn and soybeans, and 1988, a year of severe drought. The main objective of the study of the comparison of the AVHRR views of the landscape through the growing seasons of 1987 and 1988 was to determine the extent to which the drought was affecting green vegetation, especially the corn and soybean crops. However, it was quite revealing to observe the extent to which the severity of the effects of drought on the crops was related to eight different soil associations across the State. This stratification indicated that the landscape and the land-cover/land-use conditions have an important effect on the NDVI (normalized difference vegetation index) values.

AVHRR data provided an excellent tool for monitoring the effects of the 1988 drought in Indiana. By comparing NDVI values (as indicators of the development of photosynthetically active biomass) under different ecological conditions, it was possible to identify different patterns in vegetation development. Although no attempt was made in this study to quantize the relationship between the vegetation development patterns and the soil association patterns, a visual interpretation of the images and the soil association map indicated a seemingly significant relationship.

In the discussion of the Hungary SOTER research under *Objective 1* the point was made that AVHRR data are included in the many sources of data being used in the Hungarian study. During the forthcoming months a more complete assessment will be made on the possible contribution of AVHRR to the improvement of a SOTER database, both cartographic and attribute data, for Hungary.

Objective 3. To determine the potential use of high dimensional spectral data (220 reflectance bands with 10 m spatial resolution) for delineating meaningful soils boundaries and conditions for the purpose of detailed soil survey and land management.

The approach to this study has been to use high dimensional spectral data from both laboratory instruments and airborne imaging spectrometers. The laboratory instrument is a Perkin Elmer spectrometer. The primary source of airborne data is from the AVIRIS (Advanced Visible and Infrared Imaging Spectrometer) developed at the Jet Propulsion Laboratory.

The major obstacle in this study has been in the acquisition of AVIRIS data on appropriate dates for the test sites in Tippecanoe County, Indiana. Although AVIRIS data have been acquired over the test sites on 6 September 1991, 12 June 1992, and 13 July 1995, none of these dates is optimal for the study of soil patterns and the quantity and quality of crop residue on the soil surface. For each of these years requests were made for flights over the test sites in Tippecanoe County, Indiana, during the period 15 April to 1 June. However, it has not been possible to obtain AVIRIS data during this period. This is a time when there is minimum green vegetative cover and maximum exposure of surface soil patterns for observation.

During the past few years increasing numbers of aerospace industries have been investigating the potential for commercial Earth observing satellites for environmental monitoring and assessment. Some of these companies have obtained permits to launch and operate Earth observing satellites. In preparation for such ventures some of these industries are designing sensors and testing them on aerial platforms. Something completely new about some of these efforts is the spatial scale which some are using. There are apparently no military constraints now about sensors with 1 or 5 meter spatial resolution. One of the companies which recently acquired aerial sensor high dimensional data for the SSIS Project is TRW. See the specifications in the table below. Another source of high dimensional data obtained for the Project is the Office of Naval Research (the HYDICE sensor).

Imaging Spectrometer Data

Imaging Spectrometer data were obtained over designated soil test sites by three different systems during 1995. These include the Airborne Visible/Near Infrared Imaging Spectrometer (AVIRIS), the TRWIS-B and the HYDICE sensors. To date only the data from the TRWIS-B is available. The data from the other two sensors systems will be available after sensor calibration has been finalized. The specifications for the sensors follow:

Specification Item	AVIRIS	TRWIS-B	HYDICE
Spectral Range	400 - 2500 nm	460 - 880 nm	400 - 2500 nm
No. Spectral Channels	224	90	210
Spectral Rosolution	10 nm	4.8 nm	10 nm
IFOV	1 mrad	1 mrad	0.5 mrad
Cross Track FOV	30 degrees	13.75 degrees	9 degrees
Number of Bits	12	8	12

The dates in 1995 for data collection over sites in Tippecanoe County, Indiana were:

AVIRIS
Indian Pine (Line 1): 13 July at 18:07 GMT, 8% Cloud Cover
Stockwell (Line 2): 14 July at 16:23 GMT, 5% Cloud Cover

TRWIS-B
Indian Pine South (Line 1): 24 September, 0% Cloud Cover
Indian Pine North (Line 2): 24 September, 0% Cloud Cover
Stockwell (Line 3): 24 September, 0% Cloud Cover
(Other sites in Indiana outside Tippecanoe County)
Farmland (Line 4): 24 September, 0% Cloud Cover
Tipton (Line 5): 24 September, 0% Cloud Cover
Oakdale (Line 6): 24 September, 0% Cloud Cover

HYDICE
Indian Pine (Line 1): 12 October at around 16:00 GMT, 0% Cloud Cover

Research on Characterizing Soil Surface Conditions with High Dimensional Spectral Data.

Chang Woo Ahn, a Ph.D. graduate research assistant, is leading the research effort with high dimensional spectral data. His research includes the analysis of data from a newly acquired Perkin Elmer Model Lambda 19 UV-VIS-NIR spectrometer and airborne sensors, primarily AVIRIS. One of his preliminary studies is described here.

Crop residues play a critical role in controlling soil erosion. There are several practical ways of measuring the amounts of crop residues in the field, but these are rather tedious, inaccurate and somewhat subjective. The detection and classification of senescent dry plant material such as crop residues with remote sensing techniques have not been applied very successfully because, unlike green vegetation, crop residues do not have distinct spectral features.

Spectral measurements of crop residue components like lignin and cellulose are of little value in the middle infrared because of atmospheric water absorptions and a low signal-to-noise ratio. Another problem is that crop residues are not normally scattered uniformly on the fields. Therefore surface reflectance may be very variable and mixed. In this situation the statistically based classifiers are limited since they do not account for the prevalent case of mixed pixels and the resulting misclassifications of the residues. The advent of the high dimensional imaging spectrometer such as AVIRIS provides detailed spectral data for quantifying spectral categories of surface conditions.

Very preliminary measurements and interpretations have been made to study the possibilities of linear mixture models for more effective classification of crop residues and delineation from the soil background.

The use of hyperspectral data for studying soil spectral variations and in delineating meaningful soil boundaries has been severely limited because of the acquisition of AVIRIS over our test sites at times when soil surface patterns are severely masked by green vegetation and/or crop residue.

CERL Contribution to the SSIS Project

One of the projects in CERL's Environmental Compliance Division has focused on global analysis and modeling. Robert Lozar has focused his research interest in the development of methods which might improve the utility of a global map of soils and terrain. His approach is to incorporate the high confidence statistical characteristics derived from NASA's latest Mission to Planet Earth (MTPE) satellite imagery from the Pathfinder data sets with currently available digital map information.

The Pathfinder data (e.g. NDVI) will be used to extract statistical characteristics of the data, correlate that with the central portions of the mapping units of the FAO Soil Map of the World to determine if there are significant correlations. How the statistical characteristics change seasonally and annually will be examined. These changes, in combination with other data sets (soil maps, topography, terrain maps, water flow concentration, climatic characteristics) will be used to improve the interpretation and reliability of the uses of current soil maps and to provide a basis for continued improvement as more data in the Pathfinder and EOS platform series become available.

In collaboration with Purdue soil scientists, it is anticipated that CERL can contribute to the continuing development of methods for the interpretation of soils data by combining soils data from different sources (e.g. FAO Soil Map of the World, Soil Taxonomy, other) in a geographical information system. These efforts should contribute toward an improved soil spatial information system in support of the SOTER Project.

Supporting Project Facilities:

During the first year of the Project, a total rennovation project began in the Lilly Hall of Life Sciences at Purdue University, the location of the Spatial Data Analysis Laboratory (SDAL) where most of the image processing and spatial data analysis is done in this Project. During this period of rennovation the entire SDAL facility had to be moved to temporary quarters in another building on campus. This has caused some difficulties at times, but the SDAL facility will move into its newly rennovated laboratory in the Purdue Department of Agronomy in January 1996.

With the new facility will come improved networking and communications capabilities. This should greatly improve our ability to operate on Internet and the WWW more efficiently. The new facility will also provide a much improved work environment with more and better space for research and education.

Equipment in the SDAL includes a Sun SparcSystem 05 and a Sun SpacSystem 20, a Macintosh computer, two Calcomp digitizing tablets, two Epson printers and an HP DeskJet 1600CM color printer. Image processing systems include ERDAS IMAGINE 8.2, PC and Mac versions of MultiSpec, and IDRISI. ARC/INFO is available on the net under a University multiple site license.

World Wide Web (WWW) Distribution of SSIS Project Data and Results

The SSIS Project has a home page on the World Wide Web. This page, "Toward Soil Spatial Information Systems for Global Modeling and Ecosystem Management," provides a summary of the Project--background, research objectives and preliminary results. Users can access this information at the following address:

http://dynamo.ecn.purdue.edu/~biehl/SoilInfo/SSIS_Project/Index.html

Research Plans for 1996

Research in 1996 fill focus on completing the three objectives defined in the original research proposal to NASA.

Objective 1.

The major emphasis will be on the assessment of the quality and a careful comparison of the SOTER databases for Hungary and Indiana and to verify their validity by comparison with a variety of different soils, terrain, land use and other maps of various scales. We will seek to develop a repeatable methodology for assessing the validity and uniformity of the SOTER maps.

Objective 2.

Research under this objective will focus on two issues: 1) the integration of multitemporal AVHRR data into the the SOTER spatial database for Indiana and Hungary and a statistical assessment of the soil/surface patterns derived from multitemporal AVHRR data in comparison with STATSGO, SOTER, soil association maps, and other existing surface feature maps of Hungary and Indiana. A study will also include an examination of the correlation problems of the STATSGO maps for Illinois and Indiana along the border between the two states and to integrate AVHRR data into the STATSGO spatial databases for the two states to assess the use of AVHRR data as a tool for adjusting the map differences at the state boundary.

Objective 3.

This objective contributes to the support of SOTER indirectly. Most of the SOTER research relates to spatial scales of 1:500,000 or smaller (less detail). Research under this objective relates to spatial scales in much greater detail. The focus in year 3 will be on the analysis of existing high dimensional data for 1) delineating soil differences/boundaries for detailed soil mapping and 2) for characterizing soil surface conditions, with emphasis on the quantity and quality of crop residue.

APPENDIX A Personnel Involved in the SSIS Project

United States

Purdue:

Marion F. Baumgardner, P.I., soil scientist
Larry L. Biehl, electrical engineer
Chris J. Johannsen, Co-P.I., land use specialist
Chang-Woo Ahn, graduate student, Ph.D. dissertation research
Ilhami Bayramin, graduate student, Ph.D. dissertation research
Todd Helt, graduate student, M.Sc. thesis research
Bruce Worstell, graduate student, M.Sc. thesis research

CERL:

Robert Lozar, spatial analysis systems specialist

Hungary

Gödöllö University of Agricultural Sciences, Hungary

Erika Michéi, soil scientist
Endre Dobos, graduate student in soil science

Research Institute of Soil Science and Agricultural Chemistry, Hungarian Academy of Science

György Várallyay, soil scientist and director of the Institute

Institute of Geodesy and Remote Sensing, Ministry of Agriculture

György Büttner, soil scientist and remote sensing specialist

APPENDIX B Abstracts for Professional Meetings in 1995 and those Projected in 1996

17-19 Jul 95 Annual Meeting of North Central Branch, American Society of Agronomy. Grand Island, Nebraska. Theme: "Agricultural Management to Protect Water Quality"

ABSTRACT 1: "Using Soils and Terrain Digital Databases (SOTER) for Water Quality Assessment." Bruce B. Worstell (Purdue Univ.), Norman B. Bliss (EROS Data Center), and Marion F. Baumgardner (Purdue Univ.)

A methodology has been developed for creating a universal legend and mapping procedure for a world soils and terrain digital database (SOTER). In converting Soil Taxonomy (U.S. System of soil classification)to the SOTER database, SOTER terrain units were derived from STATSGO map units. STATSGO attributes were translated into the SOTER data structure. The 3 arc second DEM data were used to characterize the elevation and relief of the SOTER terrain units. This paper highlights the methods used in the development of SOTER and suggests some applications of this database for assessment of water quality.

ABSTRACT 2: "Water Quality Assessment--GIS Applications of the Soils and Terrain (SOTER) Digital Database in Hungary." Todd Helt, Chris J. Johannsen and Marion F. Baumgardner (Purdue University), Endre Dobos and Erika Michéli (Gödöllö Agricultural University, Hungary)

Consideration of terrain and soil factors which impact water quality is an essential component in decision-making at all levels of agricultural management. The role of soils in buffering and mediating the potentially negative effects of local agricultural management practices on regional water quality is related to numerous soil and terrain parameters. Easy access to a standardized spatial soils and terrain digital database (SOTER) offers regional decision-makers tools to manage and monitor the impacts of agriculture on water quality.

02-03 Nov 95 Annual meeting of Indiana Academy of Science, Indianapolis, Indiana

ABSTRACT: "Developing a Soil and Terrain (SOTER) Digital Database for Indiana" Bruce B. Worstell, Norman B. Bliss, and Marion F. Baumgardner

In 1986 a universal soil legend was developed for the purpose of preparing a world soils and terrain map at a scale of 1:1 M. At present the only global soil map is the FAO Soil Map of the World at a scale of 1:5 M, which was generated during the period 1960 to 1980. This map has serious limitations because of its small scale and because of the inadequacies in map quality during the time of the compilation of the Map. This paper reports research related to tools which have been developed to derive SOTER map units from existing data sets. In addition, constraints imposed by the existing data and the SOTER methodology are being documented. SOTER map units are essentially pyhsiographic classes that have been subdivided based on parent material. To develop Soter map units for Indiana, the 3 arc second digital elevation models (DEM) from the U.S. Geological Survey were analyzed with the State Soil Geographic (STATSGO) database from the

National Resources Conservation Service (NRCS). Physiographic classes were based on relief computed from the DEMs. Relief was determined using a 2km diameter moving window function. Within this window, the difference between the maximum and minimum elevation was computed and assigned to the center cell (i.e., processing cell). These relief values were then grouped into classes sized at 13m intervals. The STATSGO polygons were then overlaid onto the relief map to determine the dominant relief class for each polygon. Parent material information was extracted from the Soil Interpretations Record (SIR) database series description. These data were linked to the soil components in STATSGO and analyzed to determine the dominant parent material for each map unit. The physiographic and marent material maps were then combined to create a map containing SOTER map units for Indiana.

22-24 Apr 96	ASPRS/ACSM Annual Convention and Exhibition, Baltimore, Maryland

Three SSIS-related abstracts have been submitted to ASPRS for this meeting.

One SSIS-related abstract has been submitted or is being submitted for each of the following meetings:

21-23 May 96	2nd International Symposium on Spatial Accuracy Assessment, Colorado State University, Ft. Collins, Colorado
07-10 Jul 96	Annual Meeting of Soil and Water Conservation Society, Colorado USA
09-19 Jul 96	ISPRS International Congress, Vienna, Austria
04-06 Sep 96	2nd International Workshop on Sustainable Land Use Planning, Gödöllö, Hungary

Three separate SSIS-related abstracts will be submitted for this meeting:

03-08 Nov 96	Annual Meeting of American Society of Agronomy, Indianapolis, Indiana.

APPENDIX C Relevant Scientific Meetings Attended and Papers Presented by Project Personnel

Professional Meetings

Marion F. Baumgardner

13-20 Jan 95	Meeting of GTOS (Global Terrestrial Observing System) Planning Group, Rabat Morocco.
21-25 Jan 95	Discussions and planning of SOTER Project in Hungary, Budapest.
26 Feb-01 Mar 95	Annual Meeting of American Society of Photogrammetry and Remote Sensing, Charlotte, NC.
19-22 Mar 95	ERDAS Users' Group Meeting, Atlanta, Georgia.
29 Mar 95	GTOS Executive Committee Meeting with Sponsors (ICSU, FAO, UNESCO, UNEP, WMO).
09-10 May 95	Discussions with World Bank Officials, Environment Division, on use of SOTER for land quality assessment, Washington, D.C.
15 Jun 95	EARTHMAP Meeting, invitation from Office of Geographer and Global Issues, U.S. Department of State, Washington, D.C.

21-25 Jun 95	Mission to Hungary for discussions on SOTER Project in Hungary.
26-30 Jun 95	Meeting of GCOS Data Management Committee, Offenbach, Germany.
17-19 Jul 95	Annual Meeting of North Central Branch of American Society of Agronomy, Grand Island, Nebraska
27 Aug-05 Sep 95	Mission to Hungary. Discussion of SOTER Project in Hungary. Recipient of Honorary Doctors Degree, Gödöllö Agricultural University
11-14 Sep 95	GCOS-GTOS Inter-Programme Data Management Coordination Meeting, NASA Headquarters, Washington, D.C.
21-24 Sep 95	Meeting of Bits of Power Committee, National Research Council, Washington, D.C.
16-20 Oct 95	Member of Planning Committee, participant in Executive Workshop on "Preparing Hungary's Agricultural Universities for the 21st Century: Integrating Teaching, Research and Extension. Gödöllö, Hungary
29 Oct-01 Nov 95	Annual Meetings of American Society of Agronomy, St. Louis, MO. Special Symposium on "Sustainable Use of Terrestrial Ecosystems in the 21st Century." Paper by M.F.Baumgardner on "Anticipating 21st Century Life in the Global Village."
30 Nov 95	Bits of Power Meeting, National Research Council, Washington, D.C.
Chris J. Johannsen	
09 Feb 95	Invited presentation at Stennis Space Center on "Impact of Precision Farming on Remote Sensing."
07 Aug 95	50th Annual Meeting of Soil and Water Conservation Society, Des Moines, IA. Chair of Session on "Helping the Producer to Decide How to Conserve."
09 Aug 95	State Conservationists Meeting, Natural Resources Conservation Service, USDA, Des Moines, IA. Chair of Panel on "Information Management."
31 Oct 95	Annual Meeting of Soil Science Society of America, St. Louis, Mo. 1. Paper by C.J. Johannsen, J.P. Tandarich and D. Helms. "Some Aspects of the History of Soil and Water Conservation in Missouri." 2. Paper by J.P. Tandarich, C.J. Johannsen and R.D. Hammer. "C.F. Marbut, M.F. Miller, W.A. Albrecht and J.H. Krusekopf and the Development of Soil Science and Soil Survey in Missouri."
6-9 Nov 95	Geological Society of America Annual Meeting, New Orleans, LA Paper by T. Helt, E. Dobos, E. Micheli, M.F. Baumgardner, and C.J. Johannsen. "Factors Affecting Regional Water Quality--Applications of a Remote Sensing and GIS Enhancement of the Hungarian Soils and Terrain (SOTER) Database."
16 Nov 95	Town/City Conference, Kiwanis International, Indianapolis, IN. Invited Paper on "Agriculture in the Space Age."

APPENDIX D Relevant National/International Activities by Project Personnel

Marion F. Baumgardner, P.I.

Chair, SOTER Working Group, International Society of Soil Science, 1986-98.

Member, GTOS (Global Terrestrial Observing System) Planning Group, sponsored by ICSU, FAO, UNESCO, UNEP, WMO, 1993-1996.
Chair, GTOS Working Group on Data Management, Access and Harmonization, 1993-96.
Member, GCOS (Global Climate Observing System) Data Management Committee.
Member, CODATA (Committee on Data for Science and Technology), representing the International Society of Soil Science.
Member, Working Group on Terrestrial Ecosystems, American Society of Agronomy. 1994-96.
International Editorial Board, International Journal of Remote Sensing, 1980-96.
Distinguished Honorary Editorial Advisory Board Member, Encyclopedia of Life Support Systems, 1995-

Chris J. Johannsen, Co-P. I.
Chair, USDA Blue Ribbon Panel on Natural Resource Inventories and Perrformance Measurement, 1995.
Member, Committee on Earth Studies, National Research Council, 1995-98.
Member, Humanitarian Mine Clearance Committee, National Research Council, 1995-97.
Member, Pecora 13 Conference Planning Committee, 1995-96.
Member, Planning Committee for Site Specific Crop Management Conference, 1995.
Member, Steering Committee, Third Intl. Conference/Workshop on Integrating GIS and Environmental Modeling, 1995-96.
Member, Planning Committee for Congressional Hearing on Site Specific Farming, 1995.
Member, Organizing Committee of Alliance for Information Technology in Agriculture, 1994-95.
Member, Soil Survey 100th Anniversary Committee, 1991-97.
Member, Academic Advisory Council, SPOT Image Corp., 1990-present (Chair, 1991-93).
Member, ASPRS National Awards Committee, 1988-present.
Member, Agronomy Achievement Award, American Society of Agronomy, 1993-95.
Member, Council on History, Soil Science Society of America, 1989-95 (Vice chair, 1993-95)
Member, International Activities Committee, Soil and Water Conservation Society, 1992-96.

APPENDIX E Relevant Publications

Helt, T. and C.J. Johannsen. 1995. Book Review: Remote Sensing. J. Nat. Resour. Life Sci. Edu. 24:84.

Lozano-Garcia, D.F., R.N.Fernandez, K. Gallo, and C.J.Johannsen. 1995. Monitoring the droughts in Indiana, USA. Intl. J. Remote Sensing 16:13271340.

NRC. 1995. Finding the forest in the trees: the challenge of combining diverse environmental data. (Report of the National Academy of Sciences Committee for a Pilot Study on Database Interfaces, M.F. Baumgardner member). National Academy Press. Washington, D.C.

Zhuang, X. B.A. Engel, X. Xiong and C.J. Johannsen. 1995. Assessing spatial accuracies using visualization tools. Photogr. Eng. Remote Sensing 61:427-423.

APPENDIX F

Ph.D. Thesis Proposal by Chang Woo Ahn

HYPERSPECTRAL REMOTE SENSING DATA ANALYSIS FOR CHARACTERIZING LAND SURFACE CONDITIONS

I. INTRODUCTION

The parameterization of the land surface has been a most critical issue in developing a reliable and robust global model. In particular, adequate information about soils is one of the essential data sets for initializing and validating global models since soil is an essential component of the terrestrial ecosystem and is an important source and sink of organic and inorganic solid and fluid constituents within the Earth system. Therefore, mapping of resources, monitoring of changes, and modeling of processes of the geosphere-biosphere require reliable information about soils.

Remote sensing is a useful and powerful tool for providing necessary information for characterizing soil surface conditions. Reflectance measurements from a soil surface are an expression of the inherent spectral properties of the soil and of environmental conditions, including non-soil cover on the soil surface. Soil organic matter and type and amount of iron oxides are examples of soil components which provide a soil with its inherent spectral properties. Surface roughness, green vegetation and crop residues are examples of environmental factors which affect the reflectance from the soil surface. Some of factors that affect the reflectance of the soil such as iron oxides and silica have absorption features that are more narrow than are the spectral bands of spectral sensors that have been used in the past.

Considerably less research has focused on the senescent plant components, though these can represent a significant portion of the biomass within a canopy or a vegetation community. Especially for agricultural land surface conditions, crop residues play a critical role in controlling soil erosion. Even though there are a few practical methods to measure crop residue cover in the fields, these are rather tedious and somewhat subjective. A more rapid, accurate and objective approach with remote sensing techniques is needed to evaluate quantitatively the amount and type of crop residues. One of the main reasons for the lack of research pertaining to senescent materials is the similarity between spectra of dry plant material and soils. Dry plant materials lack the pronounced spectral contrast between near-infrared and red wavelengths that distinguish green plant materials from soil. Thus, with the use of broad band sensors such as Landsat TM or SPOT, it may be impossible to distinguish senescent material from soils.

Consequently, current spectral-spatial resolution sensor systems do not adequately provide these types of specific information because of their coarse resolution. On the other hand, the advent of the hyperspectral imaging spectrometer provides a remarkable amount of narrow band data, providing the possibility of extracting more specific information about Earth surface features and conditions. This proposal is designed to assess the potential use of hyperspectral data and provide a better understanding of land surface conditions.

II. PROPOSED RESEARCH

Imaging spectrometer data from NASA/JPL's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) system were acquired on 12 June 1992 over Tippecanoe County, Indiana. A large volume of ground observation data were collected within AVIRIS flight lines on the two days of the AVIRIS data acquisition. Other new AVIRIS data acquisition missions have been requested for the study sites in Tippecanoe County, Indiana, during Oct./Nov., 1995 and April/May, 1996. The possibility of other prototype hyperspectral imaging spectrometers is being considered. This research will consist of five parts as follows:

1. Simulation of Broad Bands with Hyperspectral Data

To compare the TM broad band performance of crop residue detection and classification to the narrow band AVIRIS, the simulated TM will be created by interpolating the spectral response values to the real TM spectral response characterization. These interpolated data will be used as weighting coefficients to lump the AVIRIS data. The weighting process for each band is defined as

$$\mathrm{Cs}(\mathbf{k}) = \frac{\sum_{i=1}^{\mathrm{Na(k)}} \mathrm{A_{TM}}(\mathbf{i})\mathrm{C_A}(\mathbf{i})}{\sum_{i=1}^{\mathrm{Na(k)}} \mathrm{A_{TM}}(\mathbf{i})}$$

where

k=1,2,3,4,5, and 6, the channel index for the simulated TM data

Cs(k) refers to a simulated TM channel

Na(k) is the number of AVIRIS bands falling into k-th TM spectral channel

$\mathrm{A_{TM}}(i)$ is an interpolated value from the tabulated TM spectral response data for the i-th AVIRIS band in the k-th TM spectral channel

$\mathrm{C_A}(i)$ refers to the i-th AVIRIS spectral band to be weighted.

2. Spectral Measurements of Soil-Crop Residue Mixtures

This laboratory experiment is to identify unique spectral features and determine endmembers in soils and crop residues for efficient image classification.

Laboratory soil spectra database (246 soil series) of the Laboratory for Applications of Remote Sensing(LARS) at Purdue University using Exotech Model 20C spectrometer with a spectral resolution of 0.01 µm for the spectral domain 0.52-2.32 µm will be used for this analysis procedure.

Different types of crop residues with different weathered conditions will be collected and analyzed with a range of different soil backgrounds with the Perkin-Elmer Lambda 19 spectrometer with the same spectral domain as the hyperspectral imaging spectrometer. Spectral decomposition techniques and derivative algorithms will be employed for identifying some unique band features and for spectral separation of crop residue from soil-crop residue mixtures. The mixture model presented here is that measured spectral response is equal to the weighted sum of unique reflecting ground features.

$$d_{ik} = \sum_{j=1}^{n} r_{ij} c_{jk}$$

where d_{ik} is the measured response of spectral mixture k in waveband i, n is the number of independent reflecting features in the mixture, r_{ij} is the response of feature j in waveband i, and c_{jk} is the relative contribution of feature j in spectral mixture k. This equation can be expressed as a matrix notation in the following form;

$$[\mathbf{D}] = [\mathbf{R}]\,[\mathbf{C}]$$

where [D] is the experimental spectral data matrix, [R] is the response matrix of independent reflecting features, and [C] is the eigenvector matrix consisting of the relative contributions of the reflecting features in the spectral mixtures. Basically, principal component analysis is used to decompose a spectral data matrix [D] into an abstract eigenspectra $[R]_A$ and abstract eigenvector matrix $[C]_A$ such that $[\mathbf{D}] = [\mathbf{R}]_A[\mathbf{C}]_A$. The abstract eigenspectra matrix can be derived from the eigenvector matrix as follows:

$$[\mathbf{R}]_A = [\mathbf{D}]\,[\mathbf{C}]_A^T$$

The final step is to transform the uncorrelated, abstract factors into physically-based, real factors by utilizing the spectral signatures of suspected reflecting components as follows:

$$\mathbf{T}_l = [\lambda]^{-1}[\mathbf{R}]_A^T \mathbf{R}_l$$

where T_l is a least squares column vector transformer for each of the n components , and R_l is the associated target test column vector, containing the spectral signature of the suspected component and $[\lambda]$ is a diagonal matrix of eigenvalues. Transformation matrix, [T] , can be constructed by these column test vectors. The data matrix, [D], can be regenerated by the transformed $[C]_A$ and $[R]_A$ according to

$$[\mathbf{D}] = [\mathbf{R}]_A[\mathbf{T}]\,[\mathbf{T}]^{-1}[\mathbf{C}]_A$$

Multiplying the eigenvector loadings of a particular component by the corresponding real eigenspectrum produces the spectral contribution of that component toward the overall mixture response.

3. Classification of Hyperspectral Data through a Linear Spectral Mixture Model

The small classes may not have enough training pixels available for developing reliable estimates of the maximum likelihood statistics since it is estimated that a minimum of 10 times the number of channels per training class is necessary, with desirably as many as 100 times. Therefore, we need some kinds of pre-processing for analyzing hyperspectral data to reduce the dimensionality without any significant loss of information.

This study is to test the possibilities of a linear mixture model for the efficient classification of crop residues and soils with hyperspectral remote sensing data. A factor analytic inversion model was tested in the laboratory and found to be too computationally intensive because this model is based on the inversion of each pixel. It is not practical to apply this model for processing of an entire image. Therefore, this model needs to be slightly modified to compute only for endmember eigenspectra using a small number of training pixels. The linear mixture model assumes that x_i, the pixel's response sensed by AVIRIS in band i, can be written as:

$$\mathbf{x}_i = \sum_{j=1}^{c} \mathbf{f}_i \mathbf{m}_{ij} + \mathbf{e}_i$$

where f_i is the proportion of component j in the pixel, m_{ij} is the spectral response of component j in the band i and e_i is the error term for band i. Since we are dealing with proportions, the following two restrictions should be also considered:

$$\sum_{j} \mathbf{f}_j = \mathbf{1}$$

and $f_j >= 0$ for all j components. In addition, the root mean square(RMS) error image for each spectral band and the average error (ARMS) image can be generated as follows:

$$\mathbf{RMS} = \left[(\mathbf{x}_i - \sum_{j=1}^{c} \mathbf{f}_i \mathbf{m}_{ij})^2 \right]^{1/2}$$

$$\mathbf{ARMS} = \left(\sum \mathbf{RMS} \right) / \mathbf{b}$$

where b is the number of spectral bands. In order to control the computational demand with hyperspectral data, the entire image(145 by 145) will be segmented into a 36 by 36 subset smaller image.

4. Spatial Variability of Hyperspectral Data with Fractal Dimensions

One method of improving the classification performance of crop residues is to use public available ancillary data sources such as a topo maps, ownership boundary maps, and spatial roughness information . These GIS enhanced data are helpful in improving accuracy but rather expensive and time consuming to implement. Our procedure has been to extract information from hyperspectral data for improving the classification accuracy and deriving meaningful map layers for further spatial analysis. Fractals are a means of describing complicated, irregular features of variation and can be used to quantify "roughness" of several types of objects. It is reasonable to expect that different amounts of crop residues could be expressed in terms of different fractal dimensions. This research is to study the spatial variability of hyperspectral imaging for the classification of crop residues using fractal dimensions.

The 'Triangular Prism Surface Area' (TPSA) method will be used in computing fractal dimensions. This is a three-dimensional geometric method proposed by Clarke. The method takes digital numbers at the corners of a square, i.e., the center of a pixel, interpolates a center value of the square by averaging, divides the square into four triangles, and then uses Heron's formula to compute the area of projected upper surface. A proper size of kernel window will be designed for the entire image processing.

5. Integration of Hyperspectral Processed Data with GIS

These processed data and result map layers will be integrated with GIS for making an improved graphic final product and creating possibilities for further GIS applications.

III. EXPECTED RESULTS

The results from this study should make a significant contribution to our understanding of contributions which high dimensional spectral data can make in the identification and delineation of subtle variations in surface soil conditions related to vegetative senescence and plant residues. The study will also contribute to our capability to use most efficiently narrow spectral bands for specific objectives in determining land surface conditions.

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