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THEMATIC MAPPER WORKING GROUP PROGRESS REPORT 1

by
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with

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INTERPRETING FOREST AND GRASSLAND BIOME PRODUCTIVITY UTILIZING NESTED SCALES OF IMAGE RESOLUTION AND BIOGEOGRAPHICAL ANALYSIS

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PART I: INVESTIGATION AND TECHNICAL PLAN

A. SUMMARY

This initial progress report summarizes data acquisition, initial site characterization, image and geographic information methods available, and brief evaluations of first-year problems for NASA's Thematic Mapper (TM) working group.

A team of ecologists and remote sensing analysts is exploring how Thematic Mapper (TM) and other spectral data can be used to relate local, intensive ecosystem research findings to estimates of carbon cycling rates over wider geographic regions (Table 1). The two-year feasibility project attempts to utilize and complement related ecological and geoscience research sponsored by many organizations. We hope to develop a greater understanding of ecological interactions by applying new and emerging remote-sensing technologies, and to focus on opportunities to exploit this technology as an analytical tool. Our effort is to span environments ranging from dry to moist climate and from good to poor site quality using TM's capability, with and without the inclusion of geographic information system data, and thus to interpret the local spatial pattern of factors conditioning biomass or productivity.

Progress during the first experiments on project activities is summarized by study area in Table 2. Twenty-eight TM data sets have been acquired, archived, and evaluated. Replacement or supplementary data for a few images of inferior (cloudy) quality are being pursued. The ERDAS image processing and GIS system has been installed on our microcomputer (PC-AT) and project staff are investigating its capabilities. TM coverage of seven study areas have been exported via ELAS software on the PRIME to the ERDAS system. Statistical analysis procedures to be used on the spectral data are being identified. Ancillary data sets appropriate to each study area are being acquired in digital and/or map form as available. In several instances, map format data are being digitized. Coordination has begun with regional contacts for some study areas. And lastly, assistance with polygon to grid transformations has been pursued for purposes of GIS development.

B. INTRODUCTION

To maximize the scientific value of the Thematic Mapper, it will be necessary to take advantage of its capability for resolving ecosystem patterns at the landscape scale while using a nest of larger regions and coarser picture element (pixel) resolutions for regional studies and analyses of global change. The first goal of this project between the cooperating Illinois and Tennessee groups is to use high resolution data (30 m pixels) to quantify the extent of vegetation estimated to have high, low, and intermediate productivity levels. We are emphasizing forest research areas and subcounty regions exemplifying a wide variety of climatic and site conditions. The proposed locations have been chosen where long-term ecological records exist, where teams of researchers actively work, where U.S. Forest Service Inventory ground data exist and/or where other ground data will be available and cost-effective for project goals; i.e. for interpreting the meaning of ecological production and landscape-conditioning factors affecting carbon dioxide assimilation by plants. By using these sites and others in more extreme climates of the world, the broader goal of interpreting global habitability can begin to be evaluated.

HYPOTHESES, OBJECTIVES AND TASKS

Within the limitations of reduced funding and availability of image and ancillary data, our project attempts to address the hypotheses as presented on the left of Table 1. In brief we assume first (1A) that high resolution (30m) pixel data including thermal (band 6), middle-infrared (bands 5, 7), as well as short infrared (band 4) and visible (bands 1, 2, 3) wavelengths can be effective in resolving textures of ecosystem complexes in contrasting landscapes. Some information may be lost when coarser pixels and fewer wavelength bands are used for covering wide regions with more frequency and less cost. We hope to test the assumption (1B) that a combined study can have advantages, but regain part of the sacrificed information by sampling with TM.

Another working hypothesis (2) is that we can quantify the variability of spectral signatures, inferred biomass, and estimated productivity in a framework of components of variance.

In Table 1, Objectives and Tasks originally proposed are reworded. [Square brackets identify in Hypothesis 1A and Tasks (d, e, f) aspects curtailed by restricted funding.] Braces show how the objectives relate to more than one working Hypothesis and Task.

C. DATA ACQUISITION AND QUALITY CHECKING

1. TM Data

A total of 27 sites have been pursued for possible inclusion into this study of forest, and, to a minor extent, grassland productivity. The sites are located throughout the United States and represent many of the major forest community types found on the continent.

Four of the sites are described in the appendices, and all are depicted geographically in Fig. 1 and tabulated by state, county, site, and lat-long in Table 3. Descriptors for the study sites, upon which other tables are based, are also given in that table.

Photographic images of each TM scene were acquired to determine data quality over specific study sites. Areas obscured by excessive clouds and haze will either be dropped from the project or an attempt will be made to acquire better quality data. Table 4 summarizes the TM data quality by study area for each quarter scene.

2. Ancillary Data

Efforts are well underway to determine the availability, format, and quality of ancillary data sets appropriate for each study site. These data will be used to stratify the TM spectral data for improved analysis (such as vegetation, elevation, and soils information), extrapolate TM data to larger areas (AVHRR data), or provide benchmark forest productivity data for statistical comparisons (ground research data). Status of ancillary data acquisition is summarized by study area in Table 5.

D. EXPERIMENTAL SITES AND SURROUNDING (SUB)COUNTIES

As mentioned previously, 27 sites are currently being pursued as possible areas for forest (and grassland) productivity analysis (see Fig. 1, Table 3). In selecting sites, an effort was made to include those where adequate TM data existed, and where we could access ancillary data that would be of value to the project. Examples of data of specific interest were soils maps, vegetation maps, U.S. Forest Service Inventory Data, USGS Land Use-Land Cover (LUDA) Data, USGS Digital Elevation Models (DEM), and other ground truth information on biomass and productivity. The latter category includes sites where universities or agencies are gathering data on biomass and productivity routinely, such as the National Science Foundation Long Term Ecological Research (LTER) sites.

Background information is being accumulated for all of the sites where possible. USDA Soil Conservation Service Soil Survey reports have been collected as well as climatological, land-use, and major vegetation type information. The ancillary data acquisitions have been tabulated in Table 5. Specific details regarding four of the specific study sites have been summarized in Apendix D. For each of the semi-annual reports, background material on additional sites will be presented. For this report, sites selected for initial background material include Jackson, Lake, Konza, and Boulder.

E. RESEARCH APPROACH

1. Data Handling Problems and Progress

a. Thematic Mapper Data

One hundred eight quarter-scenes of TM data covering 27 potential study areas were selected and ordered in P-Type format. A TM tape data base file was developed on the INFO relational data base software, enumerating such things as path, row, quadrant, scene ID, acquisition date, comments on data quality, and storage locations of each tape. The file has proven to be very useful for managing the large number of tapes.

To extract the appropriate subset covering a study area from each TM quarter scene, a rectangular area was identified by the coordinates (initial line, initial element; last line, last element). This task proved to be extremely difficult because of poor documentation on the P-type quarter scene format, particularly concerning the number of leading and trailing zeros used to pad the lines of image data. Through trial and error, as well as with assistance from other TM data users who had encountered the same problems, we devised a mylar template to overlay the image prints for accurately estimating line, element coordinates. Topograpic maps (1:250,000 scale), borrowed on seven day loan from the University of Illinois library, were used to locate our areas of interest on the TM scenes. A set of these maps was ordered from U.S. Geological Survey and recently delivered (taking approximately 5 weeks).

The ELAS Thematic Mapper Image Processing System ("TIPS") module is being used to extract the study area subsets from 6250 BPI tapes to PRIME disk files. Because of heavy demand for the 6250 BPI tape drive, progress has been slow. Disk space limitation is another problem encountered; even with ca. 120 megabytes of disk space available for scene storage on the PRIME, one or two county study areas will exhaust the disk space.

If a study area spans two TM quads east to west, the ELAS "JTIP" module is used to strip leading and trailing zeros of the two study area files and merge them into one. These files are then written to 1600 BPI tapes. Two problems came about at this step. First of all, the system device address MT4 used for the 1600 BPI tape drive was not acceptable to ELAS. PRIME user services provided instructions for using an alias device address to get around this problem. Secondly, the ELAS module "COPY" will not recognize an end of file (EOF) marker on a tape if the file being copied is too large for one tape. In fact, from experience on three trials, it appears that if COPY runs off the end of a tape the whole tape is useless. To remedy the situation (though not a very satisfactory remedy) files are split into parts if they are too big for one 1600 BPI tape.

Once a study area's TM data is on 1600 BPI tape, we then use the ERDAS system in the Department of Geography to read the tape and write it to IBM-PC hard disk. This step is necessary because the INHS ERDAS system does not have a tape drive and is not currently linked to the PRIME system. Once the ERDAS display has been used to verify that the appropriate area was extracted, these data are written to a CIPHER-brand tape cartridge (23 megabytes, 1/4 inch). Problems encountered at this stage have been disk limitations on the Geography department's IBM-PC-AT and the extra time and coordination necessary to use the already heavily used Geography ERDAS system, across campus from INHS.

The CIPHER tapes are used for storage and back-ups of study area data on the INHS ERDAS system. Two small study areas can be stored at one time on the 20 megabytes hard disk of the INHS IBM-PC-AT. ERDAS's capabilities are currently being investigated.

b. Advanced Very High Resolution Radiometry (AVHRR) Data

The Geographic Resources Center at the University of Missouri-Columbia serves as a large repository for AVHRR data. They have agreed to loan INHS data and provide us assistance on using them. One 7 August 1983 LAC (1.1 km^2) data set covering the Eastern U.S. has been acquired. INHS will use ELAS module TIRO to export the LAC data to the ERDAS system. AVHRR images covering the Southern Appalachian and Adirondack sites were made available from NASA's L.B. Johnson Space Center, but have not been processed.

c. Geographic Information Systems

The geographic infomation system (GIS) component of the work is critical in our study for improving on the information base provided by TM. As mentioned in the facilities section of this report (Appendix C), INHS does have an extremely powerful GIS in its ARC/INFO software on a PRIME computer. This vector based system has the capability to convert polygon files to grid files. Environmental Systems Research Inc. (ESRI), the developers of ARC/INFO, have made an agreement with Earth Resources Data Analysis Systems (ERDAS) to make the two systems compatible. This compatibility development is currently underway and should be completed in the next few months. ESRI is developing software which converts their polygon files to ERDAS format, and ERDAS is developing software to allow acceptance of ESRI GRID files into ERDAS.

At present, INHS has the ARC/INFO system and the ERDAS PC-AT system, but the two cannot be integrated as yet. Attempts have been made to produce our own ERDAS-compatible GIS data, but as yet we have been unsuccesssful.

Soil association maps from several counties have been automated into ARC/INFO GIS files. These include Comanche County, Oklahoma; Leon County, Florida; Outagamie County, Wisconsin; and Grundy and Lake Counties, Illinois. Additionally, automated soil unit maps (to soil series level of about 3 acre resolution) are available, and some extractions have been made, from the Illinois GIS for Pope and Jackson Counties, Illinois. The ORNL is using a grid cell based system for soils in the Adirondacks. We are in pursuit of other automated data bases of soils (and other variables) from additional sites.

Jackson and Pope counties are in the region of intensive automated, high resolution mapping in Illinois. In addition to soils, automated data include vegetation (with 18 forest classes), slope, landform, hydrology, and wetlands. We expect these data to be very helpful in our analysis.

The Geoecology data base has very coarse, county resolution, yet it will be helpful in our broadening to regional perspective using AVHRR data. It has information on Kuchler's potential vegetation, climate, surficial geology, and soil associations.

The ADDNET data base, developed and maintained by ORNL, has 65 data files with 1200 variables for the Adirondacks. The most relevant data sets for this project include forest plot summary volumes, areas, forest plot remeasurements, soils information, slope, aspect, elevation, and bedrock.

2. Discriminant Analysis

Discrimination of forest biomass within an environmental gradient, such as a moisture regime, is dependent upon the spectral radiance contrast between vegetation and the surrounding soil surface. The initial objective of our research effort with Landsat TM data is to examine which spectral bands or band combinations (ratios and linear combinations) give the best discrimination of forest types along such an environmental gradient. We are evaluating Landsat TM within relatively homogeneous environments, and then comparing results between extreme environments, such as alpine (Boulder County, Colorado), arid and semiarid (Emery County, Utah), and humid temperate (Jackson County, Illinois) environments.

Within each environment, we are using discriminant analysis techniques to determine which forest units along an environmental gradient can be distinguished, and additionally, which of the TM bands or band combinations are best to distinguish these units. This analysis will help to determine what forest classifications we can hope to use in our analysis, and which TM bands are sensitive to variation between these classes. Discriminant analysis is a statistical technique that can be used to group observations by weighting and combining TM bands and band combinations in a linear model that best separates predefined groups. Unlike clustering and related unsupervised methods, discriminant analysis requires supervised selection of forest units along an environmental gradient. The discriminant analysis can be used to resolve the feature selection problem, i.e., which bands are best to discriminate this grouping. The relative importance of the reflectance indexes to discriminate between forest units and the overall accuracy of the group separation can be determined from this analysis.

Our procedure so far focuses on these two primary questions: 1) what are the environmental groupings that can be resolved in each of the three extreme environments, and 2) what are the best TM bands or band combinations to resolve these groupings in each of the extreme environments. Subsequently, we intend to use this information for selecting ground data and TM bands and band combinations that can be used in regression models to evaluate how effective TM data will be for predicting forest conditions at other sample sites in each environment.

3. Regression Analysis

We plan to use regression analysis extensively where ground truth information is available. In Illinois, Kansas, Wisconsin, and Minnesota, verbal approval has been given by the North Central region of the U.S. Forest

Service for release of specific ground plot locations and data collected during the last Continuous Forest Inventory (CFI). These locations will remain confidential, but will be valuable to us as ground truth and the dependent variable to be regressed against variations in TM spectral band data, various ratios and transformed vegetation indices, and the host of GIS variables entered for the area. In regions where USFS inventory data cannot be released, we hope to utilize other ground data for regression purposes.

F. BRIEF EVALUATION OF RESULTS AND FUTURE PLANS

We have summarized many of our activities by study site in Table 2. Thematic mapper scenes analyzed by each group continue to show two advantages over the multispectral scanner (MSS). Infrared channels and 30 pixel resolution reveal many details of landscape pattern that are otherwise missed. Yet we sometimes back off to cover larger areas by sampling one line and element out of two or three, e.g. when covering larger areas within which to select test areas. Then coverage reverts to a level similar to that of MSS, but without the optical averaging which is inherent in its 80 m pixels.

In general, we are very pleased with the amount of TM data we have obtained for the project, especially in light of cutbacks necessary since EOSAT commercialization. We are also very encouraged by the types and quality of ancillary data and AVHRR we have acquired or been given permission to acquire. We feel the integration of ARC/INFO and TM data will give us a tremendous tool for performing discriminant and regression analyses to help tie forest ecosystem productivity to TM information.

To cover the much wider areas of a continent, ca. 1 km pixel resolution can be attained by AVHRR at more frequent intervals than the LANDSAT overflights. Our plan is to place at least the Southern Applachian and Adirondack mountain areas, and some others if feasible, in a broader regional analysis (see Hypothesis 1B on Table 1). By analyzing the frequency distribution of reflectances within and between ecosystem categories, it should be possible to quantify the components of variance which are added as more heterogeneous categories of landscape are introduced, on progressively larger spectral scales (see Hypothesis 2).

In a related study, arrangements have been made at the Goddard Space Flight Laboratory (GSFL) to extend the nested spatial scale further, to the Global Area Coverage (GAC) now being processed by C.J. Tucker and colleagues. Sampling at spatial intervals averaging as much as 30 x 50 km per pixel makes it feasible to obtain multiple records for most areas, thereby allowing deletion of sampling times which happen to share unacceptible levels of clouds or haze interfering with the spectral signatures. Tucker has requested that Jerry Olson collaborate in the analysis and synthesis for global arrays 1280 pixels wide and 1024 high. An equal-area projection will complement the equal latitude-longitude grid cells associated with the Olson and Watts (1982) Map of Major World Ecosystem complexes. Having either these map categories or the Tucker greeness index classes (seasonal or annual integration) will provide upper hierarchy classes within which the TM (or MSS) scanner can be combined as samples.

PART II APPENDICES

A. Personnel/Agency Structure

This project has involvement by two major institutions, the University of Illinois (UI) and the Oak Ridge National Laboratory (ORNL). Within these two large institutions, there are organizations identified on this Progress Report's cover sheet. Drs. Louis Iverson (PI) and Paul Risser (co-investigator) are housed at the Illinois Natural History Survey (INHS) on the UI campus. Dr. Thomas Frank (co-investigator) is located in the UI Department of Geography. Mr. Colin Treworgy (co-investigator), formerly at INHS, has transferred to the Illinois State Geological Survey, which is in the same building as INHS.

The project is supporting two co-investigators at UI, Ms. Elizabeth Cook began as remote sensing specialist for the INHS in December, 1985 (2/3 time), and Ying Ke began as a graduate research assistant in the Department of Geography (Dr. Thomas Frank, adviser) in September 1985 (1/2 time).

Dr. Jerry Olson (co-investigator), the original principal from ORNL, took an early retirement October 1, 1985 from ORNL. As ORNL is not allowed to subcontract to an early retiree within 12 months of retirement, Dr. Olson was hired directly by the University of Illinois as a temporary off-campus employee. He operates out of his home, and is contributing the remainder of FY 1986 effort from his personal funds and (after May 15) The Swedish National Research Council while visiting two universities in Uppsala. Olson has managed collaborations with other ORNL investigators and NASA laboratories. ORNL responsibilities for this project were shifted to Dr. John Krummel, and Dr. David Shriner's Regional Research Analysis group, of the ORNL Environmental Sciences Division. As funds are short, the post-doctoral associate has not yet been hired at ORNL, but is expected shortly. Other ORNL efforts are being conducted by members of the Computer Science and Telecommunications Department, Section of Geographic Data and Image Processing

Systems, including Richard Durfee (analyst), Jerry Dobson (collaborator), and James Hines (University of Tennessee subcontract employee).

As can be deduced by the above narrative, the structure has involved many players (most unpaid by the project) providing many pieces to the overall scheme. The time required for preliminaries has contributed to delays, but has not prevented many early start-up steps for the project.

B. COLLABORATION

In this first semi-annual report we have just identified several people whose data analytic interests (and outside support) permitted early work on major sites (especially Great Smoky Mountains and Adirondacks Mountains). Peter White and others of the National Park Service (NPS) and John Rehder of the University of Tennessee have work underway with aircraft simulated Thematic Mapper (TMS) imagery which we expect to share in return for providing analysis of satellite scenes of the same area. Charlotte Pyle, of NPS Uplands Laboratory, Gatlinburg TN, has provided unique data bases of disturbance history for the Great Smokies; Virginia Dale and John Krummel of ORNL have used seed money funding from ORNL to start digitizing these data bases. Smoky Mountain and Adirondack (Whiteface Mt., Huntington Forest) test areas for Thematic Mapper classification have been related by Jerry Dobson and Richard Durfee of ORNL to disturbance histories (wind, avalanche, fire) in these mountains.

Mr. Terry Barney and Ms. Mary Lyon, staff of the Geographic Resources Center-University of Missouri (GRC) are assisting with acquisition of AVHRR data for the project study area. The GRC is a large repository for these data from their research on global vegetation indexes. GRC staff will also be available to consult on AVHRR data formats and analyses.

Many of our collaborators have visited study sites or made contacts with field site investigators, and we expect more contributions of information from ground research. This report will serve partly to thank them for early contributions and to inform them of our own progress. The collaborator list given after the title page is probably still incomplete, because of the large number of sites being studied and potential interaction with other investigators.

Likewise several NASA laboratory or contractor groups have expressed interest in comparing their methods or findings with ours. Within the Thematic Mapper Working Group Paul Glazer and Larry Strong foresee specific collaboration. Robert Waide of Puerto Rico and Armond Joyce of National Space Technology Laboratory (NSTL) have presented early analysis of Puerto Rican landscape images, which can be related to ecosystem data like those summarized by Ovington and Olson (1970). Because the Puerto Rican scene provided to us by EROS was heavily obscurred by clouds, we await further results from Puerto Rico before renewing the extension of our own methods to the tropics. NSTL work also includes other important studies of wetlands (grassy Everglades, Florida; forested wetlands) which may require even earlier coordination in order to aid our own analysis of southern study sites.

In the western states, we anticipate that Sierra Nevada sites from Sequoia-Kings Canyon National Park will become related to David Peterson and Pamela Mattson's research on geochemical cycling. Work initiated by Jerry Olson, Hans Jenny, Paul Zinke, and the University of California Space Sciences Laboratory has attempted to compare estimates of soil distribution for the mountain part of Fresno County using soil profile analyses and MSS image analysis.

Both Ames Laboratory and NSTL have contributed to remote sensing interpretation of ecosystems extending in several directions from the H.J. Andrews Experimental Forest in the Oregon Cascade Mts. Our own collaboration in that area will depend on their progress, and on previous work of Stephen Running in that area.

C. FACILITIES AND EQUIPMENT

The facilities of the institutions involved are adequate to achieve the objectives of the study, but there has been and will continue to be a large learning curve to establish protocols, software links, and hardware configurations for efficient data handling. The vast quantities of data alone have caused considerable difficulties in managing data storage. The protocol currently being utilized at UI for TM data handling is described in portions of the report. Over the next months, software/hardware links will further develop microcomputer methods especially using ERDAS (Earth Resource Data Analysis Systems). There is even a possibility that the UI's new super-computer may be accessed to process large jobs, so that large arrays can be treated at one time instead of in small steps.

1. INHS facilities

The INHS has a Prime 750 minicomputer, soon to upgrade to Prime 9950, with eight megabytes of main memory. Peripherals to the Prime include 3000 megabytes of disk storage (150 megabytes allocated to this project), a 800/1600 bpi and a 6250 bpi tape drive, Tektronics 4113B color graphics terminals, printer, digitizer, plotter, colorgraphics recorder, and numerous other terminals. The primary utility of the system is for geographic information system (GIS) work. Software for the system include ARC/INFO (state-of-the-art software for processing vector-type data), GRID, GRID-TOPO, and EPPL6 (raster data GIS manipulations), ELAS version 415 (NASA developed image processing software), Surface-II (contouring and spatial modelling), INFO (relational database management package), and MINITAB (statistical package). INHS has had an operational GIS for over two years. The system includes major files of both map and tabular data that has been and will be important sources of ancillary data for the project. This is one of the main reasons for selecting proportionately more study sites in Illinois. Approximately 75 parameters, including soils, vegetation, landform, surface hydrology, infrastructure, surficial geology, and administrative units, have been mapped for the entire state at a coarse resolution and in selected areas (including Jackson and Pope counties) at a high resolution of 1-4 ha. (3-10 acres). The USGS Land Use Land Cover data (LUDA) is also on line for the entire state. Tabular files, such as the Soils-5 information file, can also be linked to soils maps and used to code areas according to texture, drainage characteristics or other parameters.

INHS has also recently acquired (January 1986) an ERDAS image processing system on an IBM PC-AT. It is our intention to directly link the ERDAS machine to the PRIME such that ERDAS software can run on the PRIME for larger jobs and so that the GIS capabilities on the PRIME can be integrated with the ERDAS imaging capabilities.

2. UI Spatial Data Analysis Laboratory facilities

The UI Spatial Data Analysis Laboratory (in the Geography Department) has an extensive network of ERDAS image processing systems which predate the IHNS ERDAS System. It has four ERDAS systems, which include image training and classification, spatial filtering, and GIS functions. As peripherals, the Laboratory has a 1600 bpi tape drive, Anadex and IBM printers, a coordinate digitizer, and an electronic camera.

As backup, there is capability for utilizing the UI mainframe CDC Cyber 175 which has full image processing and GIS capabilities.

3. ORNL facilities

ORNL Computer Sciences Division has several major computer systems, including a new Cray computer, two IBM 3033s, two IBM 4341s, an IBM 360/195, a DEC PDP-10, and several DEC System 2060s. Full image processing capability exists on an I^2S instrument. Peripheral devices are numerous and include printers, tape drives, digitizers, disk drives, and an IBM Mass Storage Subsystem. The Environmental Sciences Division also has links to these computer systems as well as access to the I^2S image processing system.

ORNL has an extensive GIS database established for the Adirondacks (through acid rain research efforts). Variables include soils, vegetation types, elevation, MSS data, and an extensive database on the water quality of the lakes. Another large database developed at ORNL (and also residing at INHS) is the Geoecology database. It is an integrated, county-level compiliation of environmental data for the coterminous United States (Olson et al. 1980). Data include monthly precipitation and temperature norms, rainfall acidity and monthly distribution, chemical characteristics of soils, bedrock geology, river basin water quality, crop distributions and production, natural vegetation distributions, forest species distributions and volume, landuse, land ownership, natural areas, and wildlife distributions. Thematic or contour maps can be produced to aid in analysis and display of results.

D. RESEARCH SITE BACKGROUND

For purposes of this and subsequent reports, we will be selecting a few sites for provision of background information. We feel this is important since the project does focus on a large number of sites occupying widely varying landscapes. Information on the sites will be accumulated throughout the project.

1. Jackson County, Illinois

a. Geography

Jackson County, located in southwest Illinois (Fig. 1), has a wide diversity of habitat types. About three-fourths of the land is used for farming, especially the production of corn, wheat, and soybeans. On the rolling hills, large amounts of forage are produced for beef and dairy cattle. The county currently has 118,600 acres of forest (30.9%), but estimates based on original surveys indicate 94.2% forest. The elevation ranges from 100 to 260 m (330 to 850 feet) above sea level. A wide, relatively fertile floodplain lies between the Mississippi River and the rugged hilly area to the east. The latter rugged zone is a highly dissected region. Rocky bluffs, some nearly vertical, occasionally rise more than 200 feet above the floor of the floodplain. This hilly region occupies a band adjacent to the Mississippi floodplain which expands southward to occupy most of the southern part of the county. This is the region which is currently forested, and where one of our first test study areas (512 x 1024 pixels) is concentrated. The northeast part of the county is predominantly flat and in agricultural use at present.

b. Climate

The climate diagram (Fig. 2) shows that rainfall is fairly uniformly distributed across the year, with annual rainfall averaging 101 cm

(42.5 inches). The average temperature is 56.8°F, with an average high of 89.9°F in July and an average low of 23.8° in January. The average "growing season" length (days above 32°F) is 169 days. Fifty-five percent of the rainfall falls during the growing season, on average. Average annual snowfall is about 31 cm (12 inches), but amounts vary greatly from year to year at the station.

c. Soils

There are 10 major associations found in the county ranging from silty floodplain soils to upland rocky outcrops. The associations are briefly described in Table 6. The most prominent associations in the county are Hosmer and Alford-Wellston, which together account for 50% of the county. The study site of interest is located along a strip in the southern part of the county from the Mississippi floodplain in the west to the loess-capped uplands to the east. This area is dominated by associations 1 (Belknap-Wakeland), 3 (Darwin-Medway-Cairo), 7 (Hosner), 8 (Hosner-Wellston), and 9 (Alford-Wellston). Associations 1 and 3 represent the bottomland soil types and 7-9 represent upland soil types.

Many of the current bottomland forests in our study area are growing in Jacob clay and Piopolis silty clay loam, whereas the upland forests are generally on Alford-Wellston silt loams at slopes exceeding 15% or Neotoma-Wellston soils at slopes exceeding 18%. Intermediate forested areas are commonly found on Wakeland silt loam. The Jacob clay soil is nearly level, poorly drained and located on broad flats and in narrow channels on bottomlands. Water and air move through this soil at a very slow rate, and surface runoff is slow to ponded. The pH is normally acid and root development is restricted by the fluctuating water level. Much of the area called "Oakwood Bottoms" is on this soil, and is dominated by pin oaks. Piopolis silty clay loam is also bottomland but has a slightly coarser texture which improves its ability to support plant growth. The Wakeland silt loam is nearly level, somewhat poorly drained and exists along streams in the area. The Alford-Wellston silt loams exist on steep slopes, are well drained, and are primarily derived from loess. The Neotoma-Wellston complex has the Wellston loess soil but also the Neotoma soil which is derived from bedrock and is very steep and shallow. There is therefore a gradient of soils existing in the study area from wet to dry, fertile to infertile.

2. Lake County, Illinois

a. Geography

Lake County is in the northeastern corner of Illinois (Fig. 1). It extends about 24 miles from north to south and 20 miles east to west with an area of 292,480 acres. In general, it has gently sloping relief and poorly defined drainage patterns; many drainageways terminate in depressions and marshes (one main reason for the county name). The county was 63.4% forested at the time of the original land survey (ca 1840), but is now only 7.2% forested.

b. Climate

Lake County has a typical continental climate, characterized by frequent changes in temperature, humidity, cloudiness, and wind direction. The average monthly temperatures and precipitation are presented in the climate diagram (Fig. 3). Lake Michigan causes a lake effect of cooling near shore in summer afternoons and warming on occasional cold winter days, but this is usually confined to only a narrow strip along the lake. The average growing season length is about 155 days (May 7 -October 10); along Lake Michigan the growing season is about 10 days longer.

Precipitation average is about 84 cm (33 inches) a year, with more than half falling during the growing season. Average snowfall is 90 to 100 cm (35-40 inches) per year, mostly in December-February.

c. Soils

There are 11 soil associations present in Lake County (Table 7). By far the major association in the county is Morley-Markham-Houghton, which occupies 42% of the county. The study site of interest is located in northwestern Lake County, which is principally occupied by the associations 1 (Marsh-Fox-Boyer), 3 (Zurich-Grays-Wauconda), 5 (Miami-Montmorenci), and 8 (Morley-Markham-Houghton). This area has been glaciated several times, most recently during the late Wisconsinan advance. Much of the terrain is characterized by kettle holes and other depressional areas resulting from the melting of dead glacial ice. The most common soil of the area, Morley silt loam, as well as other common soils like Markham, Miami, and Zurich, occupy the higher parts of the landscape, and are generally quite well drained and often sloping. The bottoms of the landscapes are often occupied by Houghton (an organic soil) and Peotone (depressional mineral soil) soils.

Morley silt loam (18% of county) soils developed on calcareous glacial till occupied by hardwood forest whereas Houghton muck (6.1% of county) developed in kettle holes which were almost always wet. Much of the current forest in NW Lake County, however, is not growing on these major soils, but rather on some relatively minor soils like Fox loam (1.1% of the county), Rodman gravelly loam (0.4%), Zurich silt loam (3.0%) and Boyer sandy loam (0.6%).

Fox soils are level to rolling, well to moderately well drained soils that formed in 2-3 feet of loamy material over calcareous gravelly and sandy parent from glacial meltwater deposits. Hardwood trees are the native vegetation. The Rodman soils are hilly to very steep, excessively drained to well-drained soils that have loose, calcareous gravel and sand at a depth of less than 10 inches. They also formed in glacial outwash, with hardwoods and grasses as the native vegetation. The Boyer series consists of undulating to to rolling, well-drained soils that formed in 2-3 feet of sandy material over calcareous sand and gravel. These soils are moderately deep over sand and gravel, are on uplands, and had hardwoods as the native vegetation. The Zurich series consists of deep, fairly level, well drained to moderately well drained soils that formed in 2-3 feet of silty material and the underlying calcareous, stratified silt and sand. Again, these soils are on uplands with the native vegetation being hardwoods.

Using these four soils as examples, there is a gradient of fertility and water holding capacity apparent. The soils in decreasing order of plant growth potential are Zurich, Fox = Boyer, and Rodman soils. Our efforts here are involved with seeing if TM data can also detect differences among forest productivity across the landscape, with and without inclusion of GIS data.

3. Konza Prairie, Geary County, Kansas

Konza Prairie is an 8600 acre tallgrass prairie designated as a Biosphere Reserve and as a part of the National Science Foundation Long Term Ecological Research Network (LTER).

a. Geography

The area is located in northeastern Kansas (Fig. 1) about 10 km south of Manhattan, near the Kansas River. It is in the Central Loess Plains and Bluestem Hills major land resource areas, comprised of gently sloping uplands, moderate-sized alluvial valley floors, and highly dissected intermediate areas where drainages are often entrenched in narrow canyons. Elevation difference between highest and lowest points on the landscape is about 170 m (560 feet). In general, the area surrounding Konza is used for farming and ranching, although Fort Riley Military Area and Tuttle Creek Reservoir are important socioeconomic factors in the region.

b. Vegetation

Konza is typical tallgrass prairie, comprised largely of big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorahastrum nutans*), and switchgrass (*Panicum virgatum*). Similar prairie dominated the presettlement vegetation of this area, with forestland existing mostly in riparian situations. In a 1981 forest inventory, Geary County was 8 percent forested.

c. Climate

Geary County has a continental climate characterized by hot summers, cold winters, abundant sunshine, and moderate humidity. Average precipitation is 32 inches per year with a pronounced rainfall peak in late spring and early summer. Typically, late April to mid October is frost free.

d. Soils

Three soil associations dominate the area. The Reading-Kennekec-Ivan association is characterized as deep, nearly level to gently sloping silt loams occuring on terraces and flood plains. Clime-Sogn soils are moderately deep to shallow, sloping to steep silty clay loams on uplands. The Benfield-Florence association soils are deep, sloping to steep silty clay and cherty silt loams on uplands.

4. Boulder County Watershed

The Boulder County watershed study area is located 45 km west of Boulder, CO, in the southern Rocky Mountains and southern part of the North American tundra, an area of continental climate. The area is dominated by alpine tundra vegetation at higher elevations, grading into spruce and Douglas fir forest down slope from the continental divide. The area is known as the Green Lakes valleys, rising gently westward from about 2500 to 3750 meters s.m. Altitudinally the study area is limited by the alpine tree line and by scree slopes which surround the western part of the alpine zone. On an eastern transect from the Continental Divide, precipitation increases with altitude, but annual averge solar radiation totals show little or no change between 2590 and 3750 m s.m. The mean duration of the frost-free season decreases with increasing altitude. The diurnal temperature range is lowest at the highest elevation; differences of temperature between sites with different exposure diminish and mean wind speed increases with increasing elevation. South-facing slopes are significantly warmer than north-facing slopes. The period from January through April is wet while a dry period occurs in August through October.

Wind and snow distribution, influencing the moisture supply, are the major abiotic factors in determining the vegetation in this region. Substrate moisture, snow cover, and substrate disturbance are the major environmental factors controlling vegetation distributions.

E. RELATED MEETINGS, PRESENTATIONS, SEMINARS, VISITS, AND PUBLICATIONS

Cary, Diana L. and Cook, Elizabeth A. 1984. "Interpretation of Pheasant Habitat Using Satellite Imagery." Proceedings of PERDIX III: National Gray Partridge and Ring-Necked Pheasant Workshop. March 1983. Campbellsport, WI.: Wisconsin Department of Natural Resources. p. 148-157.

Cook, Elizabeth A. and Barney, Terry W. 1985. "Statewide Forest Iventory Using Landsat Thematic Mapper Data and Moss Data Base Techniques" Missouri Department of Conservation Working Paper (Unpub).

Frank, T. 1985. Army Corp of Engineers, Geographic Information System Workshop, (Invited presentation), Ft. Hood, Texas, November 6-10, 1985; "Image processing support for the Geographic Retrieval and Analysis Support System."

Frank, T. 1985. Western Great Lakes Region, American Society of Photogrammetry, (Invited presentation), Dekalb, Illinois, November 1-2, 1985; "Research Applications Using the ERDAS Image Processing System."

Frank, T. 1985. Louisiana State University, Department of Geography Colloquia Series, Baton Rouge, Louisiana, October 1985; "Classifying Alpine Tundra with Color IR Photogrphy and Topoclimate."

Frank, T. 1985. University of Hawaii, Department of Geography Colloquia Series, Honolulu, Hawaii, April 1985; "Classifying Alpine Tundra with Color IR Photography, Topographic Context, and Topoclimate."

Frank, T. 1985. Arid Lands Remote Sensing Conference, Arid Lands Remote Sensing Working Group, Salt Lake City, Utah, 1985; "Review of Methods to Monitor Changes in Semiarid Rangelands Using Landsat Data."

Frank, T. D., 1985. Differentiating semiarid environments using Landsat reflectance indexes, Professional Geographer, Vol. 37, No. 1, pp. 36-46.

Frank, T. D., 1984. The effect of change in vegetation cover and erosion patterns on albedo and texture of Landsat images in a semiarid environment, Annals of the Association of American Geographers, Vol. 74, No. 3, pp. 393-407.

Frank, T. D., 1984. Assessing change in the surficial character of a semiarid environment with Landsat residual images, Photogrammetric Engineering and Remote Sensing, Vol. 50, No. 4, pp. 471-480.

Frank, T. D. and S. A. Isard, 1986. Classification of alpine tundra using high resolution aerial imagery and topoclimatic index values, Photogrammetric Engineering and Remote Sensing, vol. 52, No. 3.

Frank, T. D., and C. E. Thorn, 1985. Stratifying alpine tundra for geomorphic studies using digitized aerial imagey, Arctic and Alpine Research, Vol. 17. No. 2, pp. 179-188.

Iverson, L. R. 1985. Presented paper entitled "The Illinois GIS: A tool to better manage the states natural resources." At the Midwest chapter of American Society of Photogrammetry and Remote Sensing in DeKalb, IL. October, 1985.

Iverson, L. R. 1986 Presented seminar at Indiana State University Department of Geography and Geology entitled, "Utilizing the Illinois Geographic Information System for Natural Resource Management." January 22, 1986.

Iverson, L. R., and E. A. Cook. 1985. Attended International ERIM conference at Ann Arbor, Michigan. October 21-24, 1985.

Iverson, L. R., J. O. Olson, Y. Ke, and T. Frank. 1985. Attended American Society of Photogrammetry and Remote Sensing in Indianapolis, Indiana. Also occurring at that time was the first TM Working Group conference. September 8-13, 1985.

Iverson, L. R., and L. G. Perry. 1984. Integration of biological pieces in the siting puzzle. pages 99-131. In: The Siting Puzzle: Piecing together economic development and environmental quality. Illinois Department of Energy and Naturl Resources, Springfield.

Iverson, L.R. 1985. Attended CERMA conference on Integration of Remote Sensed Data in Geographic Information Systems for Processing of Global Resource Information, May, 1985.

Koeln, G. T., and Cook, E. A. 1984. "Application of Geographic Information Systems for Analysis of Radio-Telemetry Data on Wildlife." Proceedings of the Pecora IX Symposium. October 1984. Sioux Falls, S.D.: IEEE Computer Society Press, pp. 154-158.

Olson, J. O. 1985. Attended Land Processes Research on Forests, Goddard Space Flight Center, December 17-18, 1985.

Olson, J. O. 1986. Attended workshop on Climate-Vegetation Interactions, Goddard Space Flight Center, January 27-29, 1986.

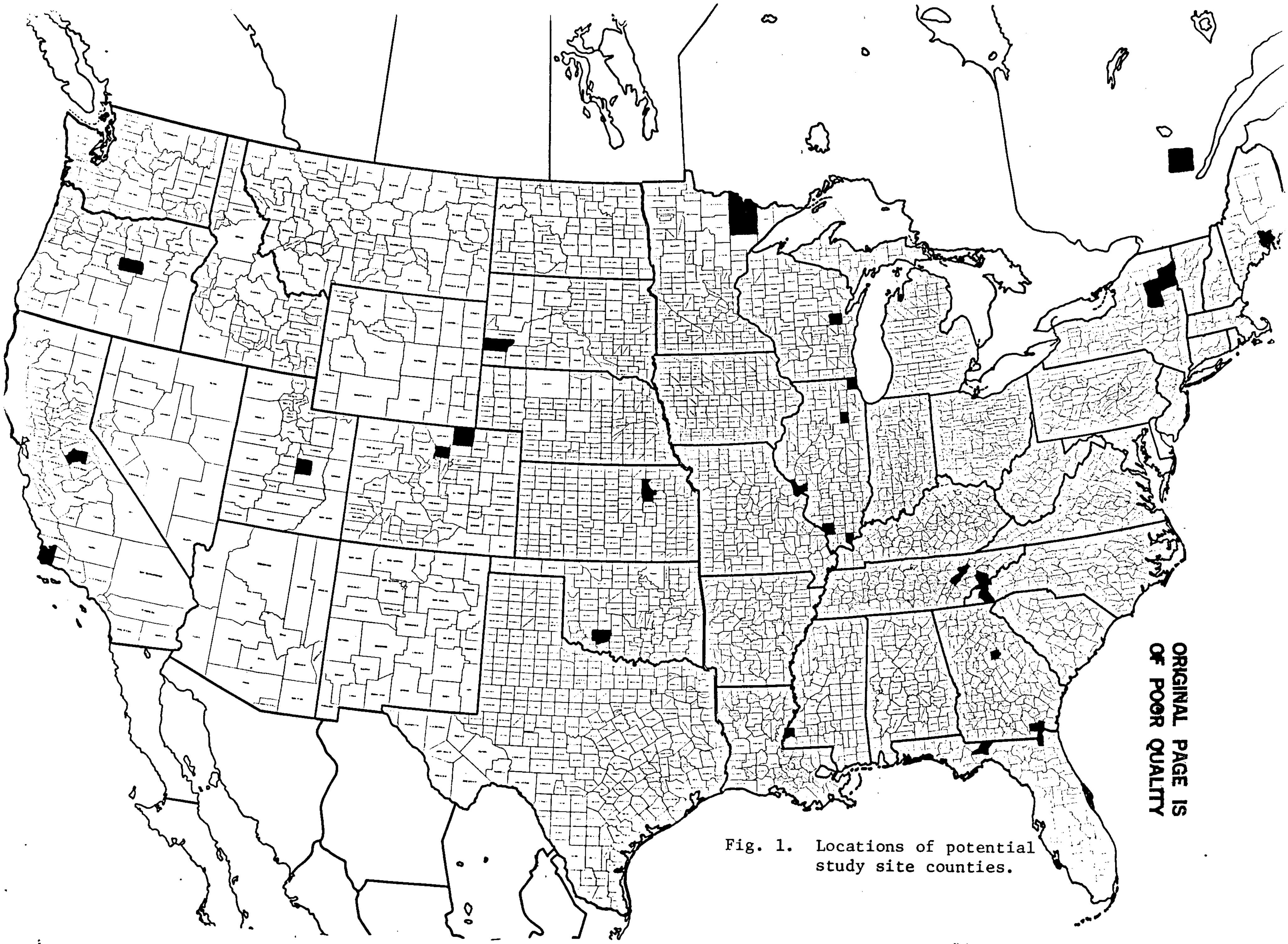

Fig. 1. Locations of potential study site counties.

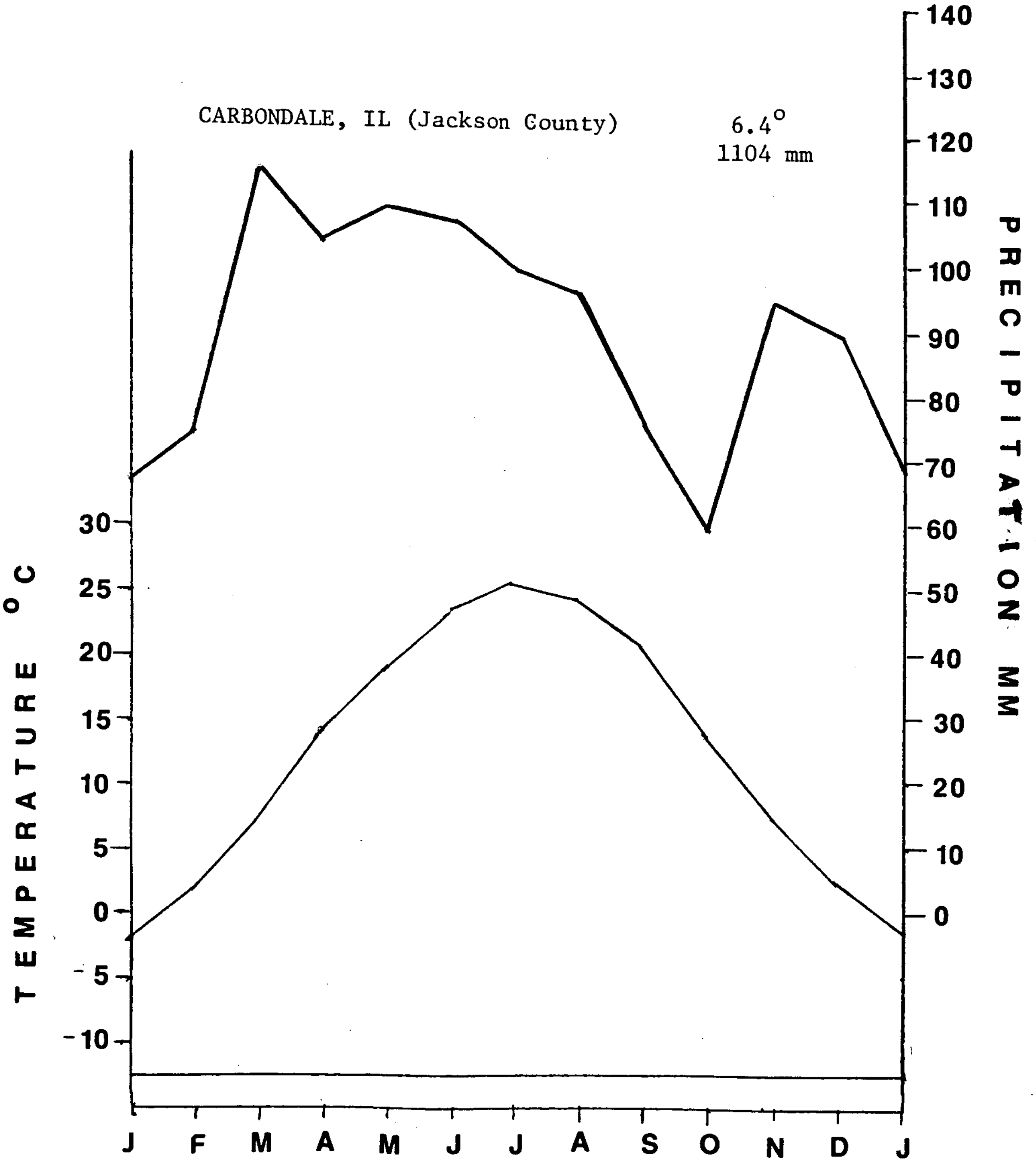

Fig 2. Climate diagram for Carbondale, Il station in Jackson County (thick line-precipitation, thin line-temperature).

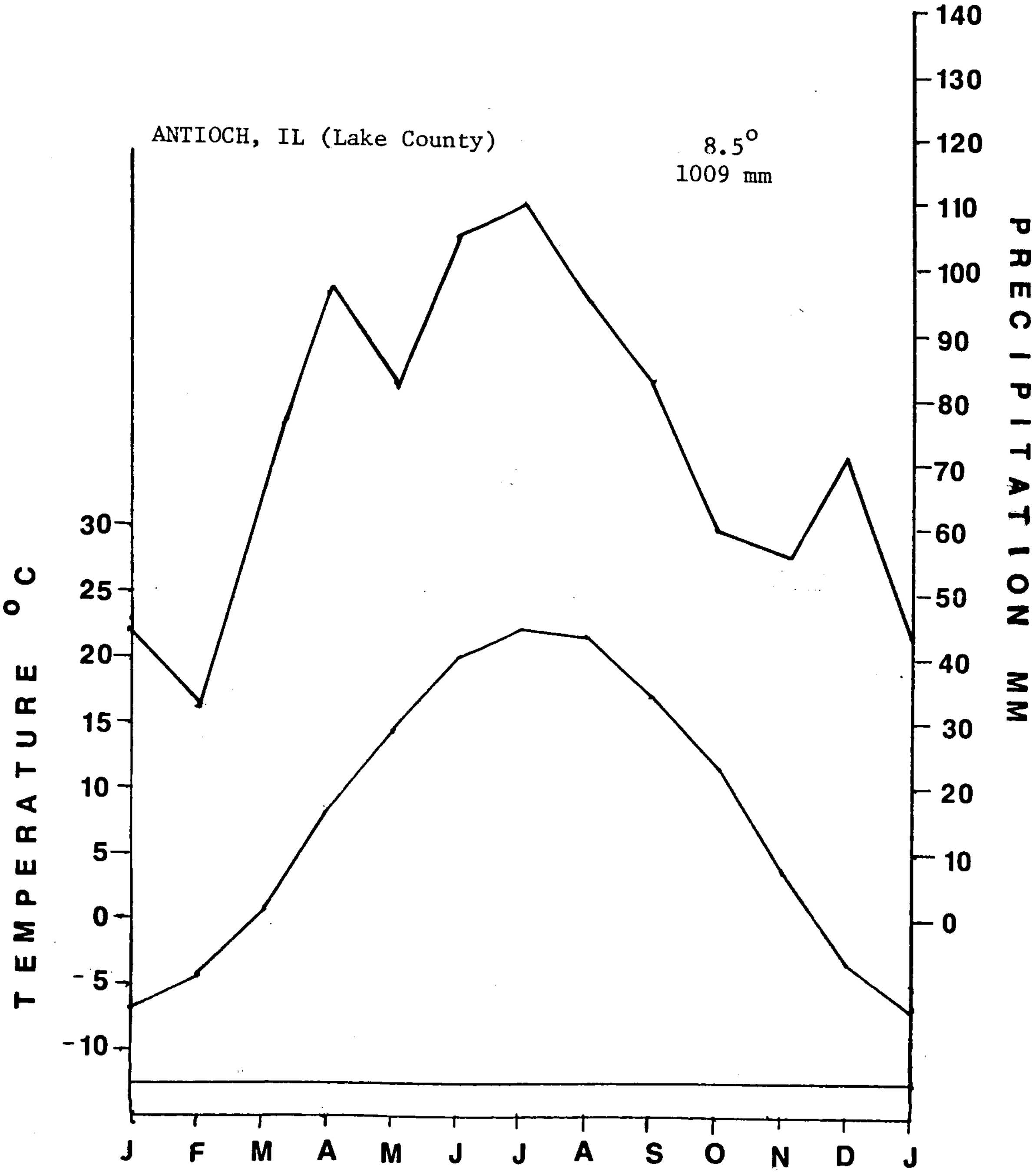

Fig. 3. Climate diagram for Antioch, IL station in Lake County, IL (thick line - precipitation, thin line - temperature).

Table 1. Hypotheses, Objectives, and Tasks for Interpreting Productivity

Hypotheses	Objectives	Tasks
1A. Local communities. Visible, infrared, and perhaps thermal bands of upward radiation from tree [and grass] canopies can be combined to rank local communities according to production. Further, it may become possible to derive weighted average production estimates for a specifically defined area from an ecological understanding of the differences in vegetation or landscape pattern.*	**1. PATTERN ANALYSIS: To stratify and subdivide ensembles of ecosystems	a. Evaluate how classification of ecosystem complexes can be improved, using TM data alone and then in combination with other geographic information systems (GIS) data. b. Bracket and model estimates of net primary production rates for three forest landscapes and other landscape areas using TM and GIS data.
1B. Regional Landscapes. When coarser pixels are used (as on AVHRR), information is sacrificed in order to cover wide areas. The hypothesis is that local TM sampling can compensate for some of this lost information. Then wide area coverage can be interpreted by understanding the meaning of landscape patterns typical of contrasting regions (e.g., diverse climate, terrain, disturbance history).	2. ECOSYSTEM ANALYSIS: To simulate and interpret differences in productivity	c. Identify the sphere of influence of climatic, geomorphologic, and other ecosystem-conditioning factors in 20 or more counties where TM classifications, geoecology dataset variables, and modern soil association maps can be combined for forests and other landscape areas. d. Map the zonation of forest complexes [and of grasslands] that can be resolved by stratifying regions broadly with AVHRR data and by calibrating and validating detailed patterns with TM and ground data.
2. Combined analysis of variance of productivity estimates within comparable-site quality classes, between classes within local landscapes, and between studied landscapes across a wide continental area will begin to provide a basis for estimation of fluxes and pools of carbon.	3. LANDSCAPE SYNTHESIS: To relate TM and AVHRR patterns on regional scales	e. Identify and map important factors conditioning productivity, [including storage capacity for waste and nutrients and the approximate rates of offsite transportation (as by erosion, burning, or harvest)]. f. [Analyze effects of burning forests and prairies on TM reflectance, thermal radiation, and primary productivity.] g. Prepare and submit to NASA semiannual progress reports and a detailed final report documenting the results of this investigation.

*Square Brackets [ ] indicate aspects of the original proposal which had to be restricted when funding was reduced. These will be addressed in a limited degree if supplementary funding allows

**Braces show how some tasks serve several objectives and some objectives are relevant to more than one hypothesis.

Table 2. PROJECT ACTIVITIES BY STUDY AREAS

Study Areas	Establish Data Archiving and Project Record Keeping System	Assess TM Data Availability and Quality	Assess Ancillary Data Availability and Format	Establish Regional Contacts Per Study	Literature Review	Extract Study Area TM Data	Export TM Data to ERDAS	Statistically Analyze TM Data	Export Ancillary Data to ERDAS	GIS and Statistical Analysis of TM/Ancillary Data	Results
Mt. LeConte and Cades Cove	1	1	2	1	1	2					
Oak Ridge	1	1	2	2	2						
Whiteface and Huntington	1	1	2	2	2	2					
Jackson	1	1	2	2	2	1	1	2	2		
Pope	1	1	2	2	2						
Calhoun	1	1	2	2	2	1	1				
Lake	1	1	2	2	2	1	1	2			
Grundy	1	1	2	2	2						
Outagamie	1	1	2								
Boulder	1	1	2	2	2	1	1	2	2		
Pawnee	1	1	2	2	2						
Maine	1	1	2								
Custer	1	1	2	2							
Minnesota	1	1	2								
Emery	1	1	2	2		1	1	2			
Konza	1	1	2		2						
Tall Timber	1	1	2		2						
Quebec	1	1	2	2	2						
Sierra Nevada	1	1	2	3	2						
Santa Barbara	1	1	2	2	2						
Natchez	1	1	2	2	2						
Oregon	1	1	2		2						
Coweeta	1	1	2	2	2	2	2				
Okefenokee	1	1	2								
Oconee	3	1	3	3	3						
Comanche	2	1	2	2	2						
Puerto Rico	3	1	3	3	3						

1 = completed   2 = in progress   3 = pending

Table 3. PROPOSED RESEARCH AREAS
(with acceptable TM data)

State	County	General Site	Specific Quadrangle(s)	Apr. Lat,Long	Descriptor
TN, NC	Sevlier Swain	Great Smoky Mountains National Park	Mt. LeConte, etc.	36,83	LeConte
TN, NC	Blount, Swain	Great Smoky Mountains National Park	Cades Cove, etc.	36,83	Cades
TN	Anderson, Roane	Oak Ridge Hardwood Forest	Bethel Valley, etc.	26,84	Oak Ridge
NY	Essex	Adirondack Mountains - Whiteface Mt.	Franklin Falls	44,74	Whiteface
NY	Essex, Hamilton	Adirondack Mountains - Huntington Forest	Newcomb	44,74	Huntington
IL	Jackson	Shawnee National Forest	Alto Pass	38,89	Jackson
IL	Pope	Shawnee National Forest	Eddyville	37,88	Pope
IL	Calhoun	Miss-Ill River Confluence	Pleasant Dale Valley	39,91	Calhoun
IL	Lake	Chain O'Lakes State Park	Fox Lake, Antioch	42,88	Lake
IL	Grundy	Goose Lake Prairie St. Park	Minooka, Coal City	41,88	Grundy
WI	Outagamie			44,88	Outagamie
CO	Boulder	Boulder County Watershed, including Niwot LTER		40,105	Boulder
CO	Weld	Central Plains Experimental Range LTER and foothills		41,104	Pawnee
ME	Waldo, Knox	Coastal		44,69	Maine
SD	Custer	Black Hills		44,103	Custer
MN	St.Louis, Itasca	Vermilion State Forest		47,92	Minnesota
UT	Emery	Manti-la-sal National Forest		39,111	Emery
KS	Riley, Geary	Konza Prairie LTER		39,97	Konza
FL	Leon	Tall Timbers Experimental Forest		30,84	Tall Timbers
Quebec	Montmorency	Laurentides Provincial Park		48,71	Quebec
CA	Fresno Tuolumne	Yosemite National Park (and/or Sequoia-Kings Canyon)		38,120	Sierra Nevada
CA	Santa Barbara	Vandenberg Air Force Base		34,120	Santa Barbara
MS	Adams	Natchez, Fayette		31,91	Natchez
OR	Cook, Grant	Ochoco National Forest		44,120	Oregon
NC	Macon	Coweeta LTER		35,83	Coweeta
		Other Possible Areas (questionable TM data)			
GA	Charltan	Okefenokee Swamp		31,82	Okefenokee
GA	Putnam	Oconee State Forest		33,83	Oconee
OK	Comanche	Wichita Mts		34,98	Comanche

Table 4 (cont). TM DATA QUALITY ASSESSMENT

Study Areas	Path	Row	Quad	Acquisition Date	Quality
Jackson	23	34	1	7/18/84	Good
	23	34	2	7/18/84	Good
Pope	22	34	1	5/24/84	Good
	22	34	3	5/24/84	Good
Calhoun	24	33	1	7/9/84	Good
	24	33	2	7/9/84	Good
Lake	23	31	1	7/18/84	Satisfactory
	23	31	2	7/18/84	Satisfactory
Outagamie	23	31	3	7/18/84	Good
	23	31	4	7/18/84	Good
Boulder	24	29	2	5/6/84	Satisfactory
	24	29	4	5/6/84	Satisfactory
Pawnee	34	32	2	6/29/84	Satisfactory
	34	32	4	6/29/84	Satisfactory
	33	32	1	6/22/84	Good
	33	32	2	6/22/84	Good
	33	32	3	6/22/84	Good
Maine	11	29	1	6/12/84	Good
	11	29	2	6/12/84	Good
	11	29	3	6/12/84	Good
	11	29	4	6/12/84	Good
Custer	33	30	1	7/8/84	Good
	33	30	2	7/8/84	Satisfactory
Minnesota	27	27	1	6/28/84	Good
	27	27	3	6/28/84	Satisfactory
Emery	37	33	1	6/2/84	Good
	37	33	2	6/2/84	Good

Table 4. TM DATA QUALITY ASSESSMENT

Study Areas	Path	Row	Quad	Acquisition Date	Quality
Mt. LeConte and Cades Cove	18	35	3	6/13/84	Excessive Clouds
	18	35	3	9/1/84	Good
	18	35	3	10/3/84	Good
	19	35	2	9/8/84	Good
	19	35	4	9/8/84	Good
	19	35	2	10/26/84	Satisfactory
	19	35	4	10/26/84	Satisfactory
	19	35	2	1/14/84	Good
	19	35	4	1/14/84	Excessive Clouds
	19	35	2	8/10/85	No Print Available
Oak Ridge	19	35	1	9/8/84	Good
	19	35	3	9/8/84	Good
	19	35	1	10/26/84	Excessive Clouds
	19	35	3	10/26/84	Excessive Clouds
	19	35	1	1/14/85	Good
	19	35	3	1/14/85	Satisfactory
Whiteface and Huntington	14	29	3	12/13/82	Good
	14	29	3	6/17/84	Satisfactory
	14	29	1	8/4/84	Good
	14	29	2	8/4/84	Satisfactory
	14	29	3	8/4/84	Satisfactory
	14	29	4	8/20/84	Satisfactory
	14	29	3	9/21/84	Excessive Clouds
	14	29	3	10/7/84	Excessive Clouds
	14	29	3	11/8/84	Satisfactory
	14	30	3	8/8/84	No print Available
	14	30	1	8/4/84	Excessive Clouds
	14	30	2	8/4/84	Excessive Clouds
	14	30	3	8/4/84	Excessive Clouds
	14	30	4	8/4/84	Excessive Clouds
	15	29	2	7/10/84	Good
	15	29	4	7/10/84	Good
	15	30	2	7/10/84	Satisfactory

Table 4 (cont). TM DATA QUALITY ASSESSMENT

Study Areas	Path	Row	Quad	Acquisition Date	Quality
Konza	28	33	1	8/6/84	Good
	28	33	2	8/6/84	Excessive Clouds
Tall Timber	18	39	1	10/3/84	Good
	18	39	3	10/3/84	Good
	18	39	1	1/23/84	Satisfactory
	18	39	3	1/23/84	Good
Quebec	13	27	1	6/10/84	Satisfactory
	13	27	3	6/10/84	Excessive Clouds
Sierra Nevada	42	34	1	7/7/84	Good
	42	34	3	7/7/84	Good
	43	33	4	6/8/84	Satisfactory
Santa Barbara	42	36	1	10/27/84	Good
	42	36	3	10/27/84	Good
Natchez	23	38	1	10/25/82	Good, But Not Received
	23	38	2	10/25/82	Good, But Not Received
	23	38	3	10/25/82	Good, But Not Received
	23	38	4	10/25/82	Good, But Not Received
Oregon	44	29	3	8/12/83	Good
	44	29	4	8/12/83	Good
Coweeta	18	36	1	6/13/84	No Print Available
Okefenokee	17	38	3	6/6/84	Satisfactory
	17	38	4	6/6/84	Excessive Clouds
	17	39	1	6/6/84	Excessive Clouds
	17	39	2	6/6/84	Excessive Clouds
Oconee	18	37	1	6/13/84	Satisfactory
	18	37	2	6/13/84	Excessive Clouds
	18	39	3	6/13/84	Satisfactory
Comanche	28	36	1	7/21/84	Satisfactory
	28	36	2	7/21/84	Good
	28	36	3	7/21/84	Excessive Clouds
	28	36	4	7/21/84	Good
Puerto Rico	5	47	4	6/2/84	Excessive Clouds

Table 5. ACQUISITION OF ANCILLARY DATA BY STUDY AREAS

Study Areas	Topographic Maps	AVHRR	Soils	DMA Evaluation	DEM Evaluation	Vegetation Mars	Forestry Ground Data
Mt. LeConte and Cades Cove	2	2	1A	4	0	1A	1A
Oak Ridge	0	2	0	1A	1A	1A	1A
Whiteface and Huntington	2	1A	2	4	0	2	1A
Jackson	3	1A	4	4	1B	4	2
Pope	3	2	4	4	1B	4	2
Calhoun	3	1A	1B	4	1B	4	2
Lake	3	2	4	4	1B	4	2
Grundy	3	2	4	4	1A	4	2
Outagamie	2	2	4	1A	1B	1A	2
Boulder	2	1A	3	1A	1A	3	0
Pawnee	2	1A		1A	0	3	0
Maine	2	1A	3	1A	1B	1A	0
Custer	2	1A	3	1A	0	1A	0
Minnesota	2	1A	0	1A	1B	1A	0
Emery	2	1A	3	1A	0	1B	0
Konza	2	1A	4	1A	1A	2	2
Tall Timber	2	2	4	1A	1B	1A	1A
Quebec	2	1A	0	1A	0	0	0
Sierra Nevada	2	1A	3	1A	1A	1A	0
Santa Barbara	2	1A	3	1A	1A	1A	0
Natchez	2	1A	3	1A	1B	4	0
Oregon	2	1A	0	1A	1B	1A	0
Coweeta	0	2		1A	0	1A	2
Okefenokee	2	2	1B	1A	1B	1A	0
Oconee	2	2	3	1A	1B	1A	1A
Comanche	2	1A	4	1A	1B	1B	0
Puerto Rico	2	1A	5	5	5	5	5

0 = not yet pursued; 1A = available; 1B = unavailable; 2 = ordered; 3 = inhouse, non-digital format; 4 = inhouse, digital format; 5 = will not be used

Table 6. Jackson County Soil Associations

Association	Topography	Drainage	Parent Material	% of County
1. Belknap-Wakeland	nearly level	somewhat poorly	floodplain silt	12
2. Darwin-Medway-Cairo	nearly level-sloping	somewhat poorly-v.poorly	clay-loam sediment	8
3. Jacob-Booker	nearly level-depressional	poorly-v.poorly	acid clay sediment	6
4. Hurst-Colp-St.Charles	nearly level-mod.steep	somewhat poorly-well	silt terraces	14
5. Alvin-Camden	nearly level-mod.steep	well-mod.well	loamy terraces	2
6. Bluford-Ava-Wynoose	nearly level-strongly sloping	mod.well-poorly	loess	
7. Hosmer	gently-strongly sloping	mod.well	loess	26
8. Hosmer-Wellston	gently sloping-v.steep	mod.well-well	loess,bedrock	2
9. Alford-Wellston	sloping-v.steep	well	loess,bedrock	24
10. Orthents	rugged ridges	well	stripmine spoil	1

Table 7. Lake County Soil Associations

Association	Topography	Drainage	Parent Material	% of County
1. Marsh-Fox Boyer	level-rolling	well-mod.well	sand and gravel	8
2. Mundelein-Pella-Barrington	level-gently sloping	well-poor	silt	2
3. Zurich-Grays-Wauconda	nearly level-mod.steep	well-somewhat poorly	silt-sand	11
4. Coswin-Odell	level-strongly sloping	well-mod.well	loamy till	4
5. Miami-Montmorenci	gently-strongly sloping	well-mod.well	silty till	7
6. Elliot-Markham	level-strongly sloping	well-somewhat poorly	silty till	10
7. Morley-Beecher-Hennepin	nearly level-v.steep	well-somewhat poorly	silt	3
8. Morely-Markham-Houghton	gently sloping-steep	well-v.poorly	silt-organic	42
9. Del Rey-Saylesville-Peotone	level-mod.sloping	well-v.poorly	silty till	2
10. Frankfort-Montgomery-Wauconda	level-gently sloping	somewhat poorly-v.poorly	loamy till	4
11. Nappanee-Montgomery	level-moderately sloping	somewhat poorly-v.poorly	loamy till	7