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APPLICATIONS OF REMOTE SENSING IN RESOURCE MANAGEMENT IN NEBRASKA

Semiannual Progress Report, January-June, 1974

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1. Project Title:

Application of Remote Sensing in Land Use Classification and Delineation of Major Tectonic Lineaments in Nebraska.

2. Investigators

Dr. M. P. Carlson, Assistant Director and Principal Geologist, Conservation and Survey Division, University of Nebraska

Dr. Rex M. Peterson, Remote Sensing Coordinator, Conservation and Survey Division, University of Nebraska

Mr. J. B. Swinehart, Research Geologist, Conservation and Survey Division, University of Nebraska

Mr. James Barr, Resources Coordinator, State Office of Planning and Programming

Mr. Donald Buckwalter, Cartographer, Conservation and Survey Division, University of Nebraska

3. Purpose

To test and evaluate ERTS-1 imagery and other forms of remote sensing (1) in terms of a land use classification system for Nebraska and (2) in delineation of major tectonic lineaments within the state.

4. Scientific Results

No direct scientific research is included within the objectives of this project. However, some of the techniques and facilities developed for the applications objectives are being utilized by associated research projects. Continuing effort is being made through travel, publication and library collections to increase the level of expertise available to encourage the use of remote sensing in interdisciplinary projects.

As new image enhancement facilities became available, new impetus has been added to our lineament project. In addition to the major lineaments recognized, numerous curvilinear elements are expressed by topography, drainage, vegetation patterns, soils and other phenomena. Research is particularly aimed at the patterns created by the intersection of circles, ellipses, arcs, and straight lines.

5. Applications Results

Applications have been achieved through the Remote Sensing Center which serves as an interface between state and local agencies and units of the University. Current activity has also been supported by the State Office of Planning and Programming and the Nebraska Natural Resources Commission. A photomosaic and a seven color, Level I land use map of Nebraska, both derived from ERTS-1 imagery, have been published at a scale of 1:1,000,000.

A Level II land use map of Lancaster County is ready to be printed at a scale of 1:62,500 and the inventory is complete for a Level II map of the Lower Platte South Natural Resources District. Land use maps, based on dominant land use in each ten acre cell, are being prepared for Lancaster County for 1940, 1949, 1955, 1959 and 1965 to assess the historical patterns prior to our current publication.

A workshop-briefing was presented for twenty-three key staff of the Nebraska Game and Park Commission. Specific applications and facilities were reviewed and potential projects discussed. A cooperative agreement was signed to inventory and classify wetlands in Nebraska with the assistance of ERTS imagery. Other agencies have been furnished imagery for project assessment.

6. Work Planned

Approval has been received to realign the objectives of this project into three areas with more obvious applications potential.

The first of these, "Application of Remote Sensing in the Delineation of Major Tectonic Lineaments in Nebraska," had been scheduled for completion during the next reporting period. However, new staff expertise and the availability of image enhancement equipment may considerably increase the economic implications of continuing this project.

The second redefined area is "Application of Remote Sensing in Land Use Classification and Inventory and in the Delineation of Critical Environmental Areas." This project, in cooperation with state and local agencies, will continue the level II studies. As selected areas of Nebraska are completed, the ERTS imagery will be reassessed for further definition of our statewide effort. The unique perspectives of ERTS imagery will assist in the development of a process by which critical environmental areas can be determined.

The third area is "Application of Remote Sensing Technology to Accelerate Data Utilization and Graphic Product Distribution for the User Audience." The major effort to provide general service to the public will continue both through direct contract and general publications. Additional workshops for key personnel in user agencies will be held both inhouse and packaged for mobility. The cartographic-editorial capability will be expanded to accelerate distribution of our results.

1. Project Title:

Application of Remote Sensing to an Inventory of Irrigated Land in Nebraska

2. Project Personnel

Donald M. Edwards, Ph.D., Project Leader, Assistant Dean, College of Engineering and Technology, University of Nebraska, Lincoln, Nebraska 68508

Richard O. Hoffman, Ph.D., Co-Project Leader, Assistant Professor, Department of Industrial and Management Systems Engineering, University of Nebraska, Lincoln, Nebraska 68508

William E. Splinter, Ph.D., Professor and Chairman of Agricultural Engineering, University of Nebraska, Lincoln, Nebraska 68508

John E. Lagerstrom, Ph.D., Director of Engineering Extension, University of Nebraska, Lincoln, Nebraska 68508

Leslie F. Sheffield, Ph.D., Coordinator, Irrigation Development Program, Assistant Director of Agricultural Extension Service and Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska 68508

Gerald P. Wallin, Head, Comprehensive Planning Section, Nebraska Natural Resource Commission, State Capitol, Lincoln, Nebraska, 68509

Carmen Eucker, Water Resource Planner, Natural Resource Commission, State Capitol, Lincoln, Nebraska 68508

Mark David, Remote Sensing Technician, Department of Electrical Engineering, University of Nebraska, Lincoln, Nebraska 68508

Thomas Burton, Research Assistant, University of Nebraska, Lincoln, Nebraska 68508

3. Purpose of the Investigation and Work Accomplished

3a. Purpose

To evaluate use of aircraft and satellite imagery in detecting and estimating the acreage of irrigated land in Nebraska.

3b. Introduction

During the past year several accomplishments have been achieved in the data gathering phase, the scientific area and the application area. In Sections 4 and 5 these accomplishments are summarized This section describes these results in more detail.

During the past year an advisory team was formed, three specific projects were defined and started, ground truth data was gathered for a complete crop growing season, and the analysis of a complete crop growing season was started. Through pilot studies on five counties it has been concluded that ERTS-1 imagery can be used for detecting and estimating the acreage of irrigated land in Nebraska. These pilot projects have generated significant interest and requests for information from state planning agencies, natural resource districts, electric utility companies and irrigation manufacturing firms.

The advisory team is composed of representatives from the Nebraska Natural Resource Commission, the Nebraska State Office of Planning and Programming, the Nebraska Game and Park Commission and the University of Nebraska Departments of Agricultural Engineering, Industrial and Management Systems Engineering, Irrigation Development Program, and Conservation and Survey Division. These agencies were brought together in order that the results of the project could be used immediately. The three projects selected by this advisory team were the Irrigation Project, the Center Pivot Project, and the Remote Sensing Center Project.

3c. Irrigation Project

The purpose of the Irrigation Project was to identify land which is irrigated by gated pipe, siphon tube systems, gravity flow from streams, and sprinkler systems other than center pivot systems. This type of irrigated land is difficult to identify with ERTS-1 satellite imagery because identification must be based on crop stress. In order to assist in developing a procedure and an algorithm for identification of irrigated land, one hundred and twenty-four test sites were established in Dawson and

Phelps Counties. Between May and October of 1973, ground truth was gathered on each of these sites during each overpass of ERTS-1. Parameters on irrigation conditions, crop conditions, and weather conditions were collected on each test site, coded and stored in a data bank. The field patterns for Dawson County have been outlined and some crops identified. At this point in the project, all irrigated alfalfa has been identified and limited success has been achieved in identifying irrigated cornfields. In Dawson County preliminary estimates from ERTS-1 imagery indicate 256,000 acres of cropland, with 115,000 acres in alfalfa, and 12,000 acres of alfalfa being irrigated.

Using ERTS-1 imagery and other sources, preliminary estimates indicate that over 5 million acres of Nebraska's 16 million acres of crops and hay are irrigated. However, current monitoring methods do not provide an accurate measure of this acreage. To use effectively the water resources and energy resources in Nebraska, an accurate measure of the amount of water used for irrigation must be obtained. Nebraska state agencies involved in water resource development are very interested in using results from ERTS-1 imagery to expand the Dawson County studies into other counties in order to obtain an accurate measure of irrigated land on a county-by-county basis. The ERTS-1 imagery is the best means currently available for state-wide monitoring on a set time schedule.

The irrigated estimates are important parameters in estimating crop yields, river levels, water table levels, wind erosion, beef production yields, and energy needs. For example, in western Nebraska, corn planted on non-irrigated land may yield only 30 bushels of corn per acre, but the same land irrigated may yield 150 bushels per acres. Since water for irrigation comes from rivers, reservoirs, or wells, the effect on river levels and water tables can be drastic. If too much water is removed from a river by an irrigation ditch, the rivers can dry up, leaving city water and sanitary facilities in desperate need, killing wildlife habitat, and causing flooding because of high water tables. If irrigation wells are used too extensively, the water table is lowered, thus increasing cost and energy needs for withdrawing the water.

Energy availability for irrigation systems are critical factors in crop production and yields. It is estimated that the average gated pipe or siphon tube system operates at 80% efficiency at the pumping plant, lifts the water 100 ft. out of the well against a 20-foot pressure head in the system, has a capacity of 900 gallons per minute and applies 20-acre-inches of water per year. On this basis, this method of irrigation requires 30.9 gallons of Diesel fuel per acre per year or its equivalent. About 2.7 million acres are irrigated with gated pipe or siphon tubes. Current rough estimates place the need at 68 million gallons of Diesel equivalent fuel for surface irrigation. If the project is continued at the current level, an accurate measure of the number of acres under surface irrigation will be obtained and exact energy requirements will be calculated.

3d. Center Pivot Irrigation Project

The second project was to identify the location of all center pivot irrigation systems in each Nebraska county. This type of system uses wells as its main source of water. Because of their geometric shapes, these systems are relatively easy to identify on ERTS-1 imagery.

Five counties were selected as a test site. Once each center pivot irrigation system was identified, the number of acres irrigated was calculated and the type of crop identified. Figure 1 illustrates the type of analysis being conducted. Each circle indicates a center pivot irrigation system in Box Butte County. One hundred sixteen center pivots were identified in the August 1973 ERTS-1 imagery. In August 1972 only 54 center pivot irrigation systems were identified. This is a 115 per cent growth in center pivots in one year. From a water and energy management program this is a critical piece of information. It is estimated that an average sprinkler system (center pivot or skid tow) operates at 80% efficiency at the pumping plant, lifts the water 100 feet from the well against a 173 foot pressure head, has a capacity of 900 gallons per minute and applies 15 acre-inches of water per year. On this basis, this method requires 53.4 gallons of diesel equivalent fuel per acre per year. About 1.3 million acres are irrigated with center-pivots or skid-tow systems. Therefore, sprinkler systems consume 53.3 million gallons of diesel equivalent fuel. From preliminary analysis of ERTS-1 imagery, it is estimated that 5,500 center pivot irrigation systems exist and that 2,000 new systems will be installed in 1974.

The farmers would prefer to use electricity to power their center pivot systems, but Power Districts have not allowed hookups. The high peak load imposed by electrically powered irrigation systems, together with air conditioners and electrical demands by other users such as industry, creates a serious demand problem for electrical power suppliers. An electrical district in Nebraska must pay for a base of

FIGURE ONE

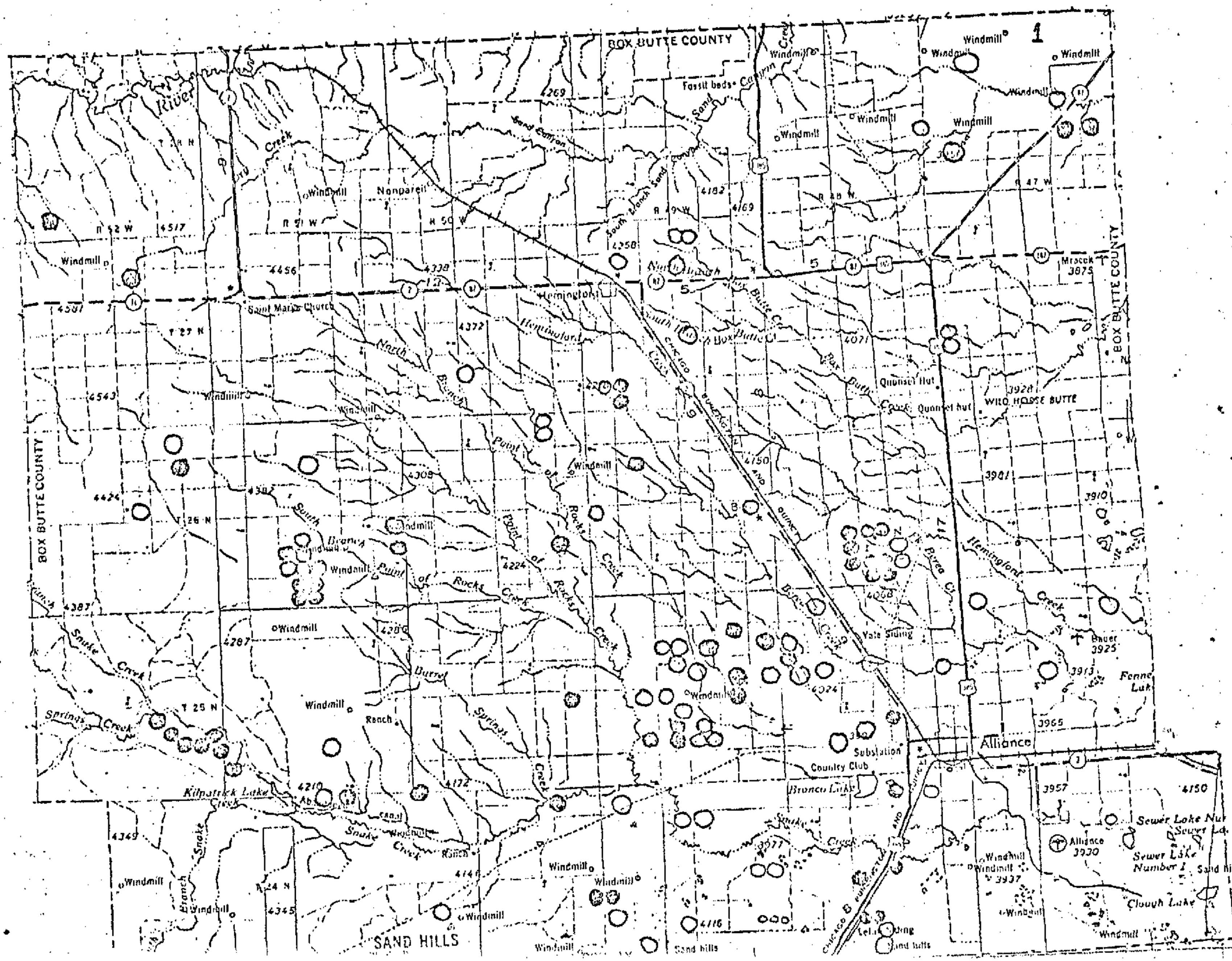
BOX BUTTE COUNTY CENTER PIVOT GROWTH RATE

54 existed August 1972

62 installed by August 1974

Burton, Thomas

November 1973



6.

65% of peak load throughout the year. The demand during the winter months drops considerably below that, thereby forcing the District (and the farmer) to pay for unused electricity.

A test last summer with the Custer County Public Power District with 22 center pivots, in which the times on and off were scheduled, not only reduced the peak (normally at 7:00 p.m.) but reversed the load cycle to a maximum at about 6:00 a.m., with a minimum at 7:00 p.m. This idea is very attractive to the power suppliers and will be attempted in several areas this summer. The expansion of this type of program has generated several requests by power districts for information from the ERTS-1 data on the location of the center pivot locations. If funding is continued at the current level, this area will be explored.

If proposed center pivot systems do not receive the necessary energy to operate, then large sections of land will be lost to wind erosion and crop and beef output will decrease. The State Bureau of Business Research has shown for every $1 invested in irrigation development, $13 are returned to the economy of the State. The average cost of a center pivot system is $35,000 installed. If 2000 units cannot be installed because of lack of energy, several hundred thousand dollars will be lost to the State. In order for the state agencies and private industries to take appropriate action, information on the location and number of center pivot systems and projected areas of installation is necessary.

In Nebraska all irrigation wells are required to be registered with the county. This information has been gathered and plotted on a Nebraska map at a 1:125,000 scale. This provides a good ground truth source for determining the number of center pivots missed and the number of non-registered wells. This information has been used to better plan water use in certain parts of the State.

Another phase of the center pivot irrigation project is the identification of crop type. Figure 2 illustrates the work being done in Box Butte County on this phase. The dark circles are center pivots which are irrigating alfalfa or pasture. This type of program will be continued for other counties.

3e. <u>Remote Sensing Center Project</u>

The third project was the establishment of the Nebraska Remote Sensing Center. In order to assist in accomplishing the remote sensing projects and give state agencies a central place to contact, the Center was established. The Center contains the equipment, personnel and facilities needed to conduct remote sensing research and application studies. The personnel have been trained in the use of the equipment and the interpretation of imagery. The Center is now reaching full operational status and has been expanded into a major project of its own.

4. <u>Scientific results obtained during report period</u>.

a. A full growing season of ground truth data for 124 test sites in Dawson and Phelps Counties has been gathered.

b. The technical procedures for identifying center pivot irrigation systems with ERTS-1 imagery has been established.

c. The technical procedures for identifying boundaries of agricultural fields with ERTS-1 imagery has been established.

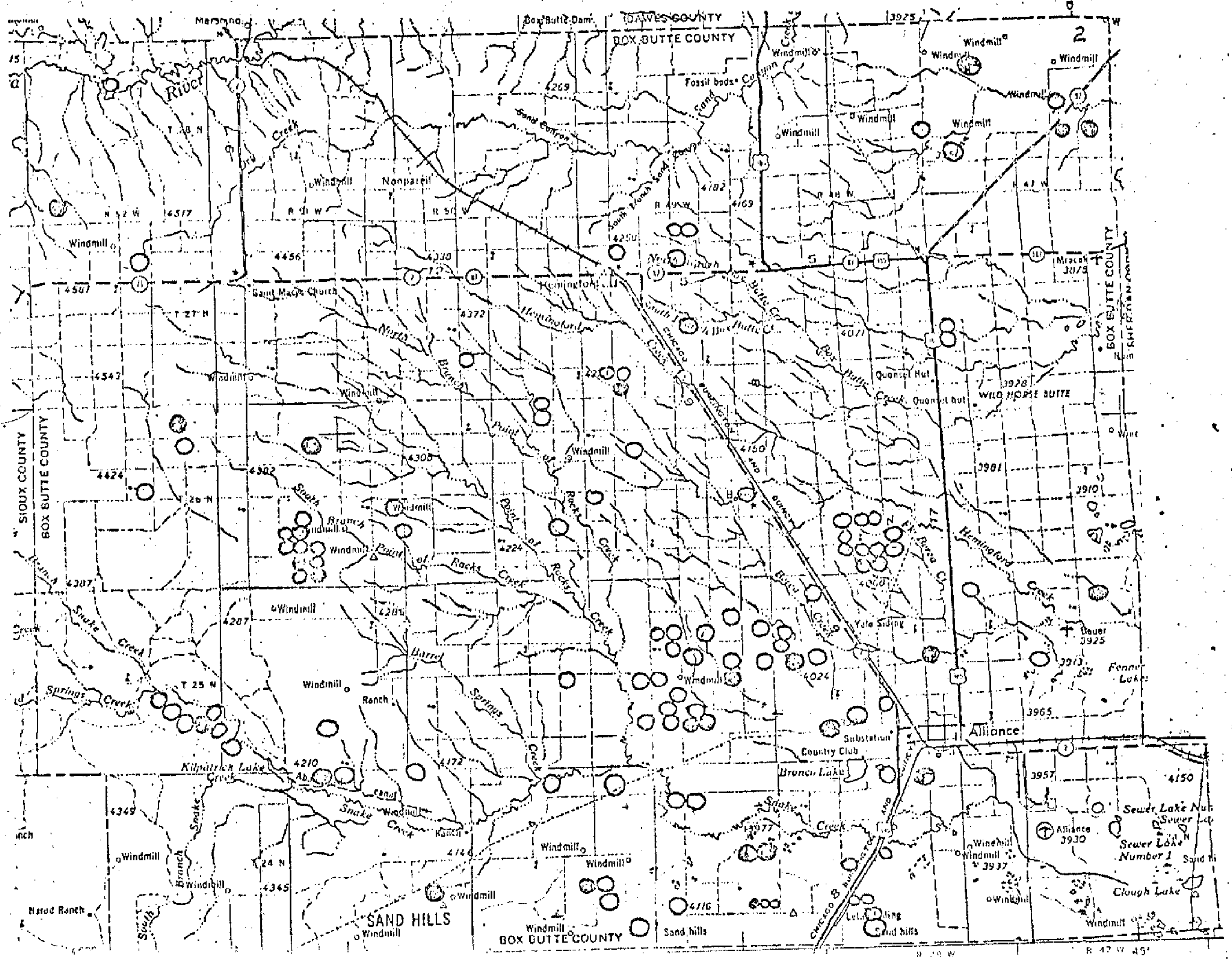
d. The technical procedures for identifying the crop type in the agricultural fields with ERTS-1 imagery has been established.

FIGURE TWO

BOX BUTTE COUNTY CROP TYPE

20 forage crop   O 96 row crop

Burton, Thomas   November 1973



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e. The technical procedures for identifying certain irrigated fields using ERTS-1 imagery has been established.

f. It has been shown that the growth rate of center pivot irrigation systems can be measured, using ERTS-1 imagery, and is 115 percent in Box Butte County.

g. The following presentations and publications dealing with remote sensing and irrigation using ERTS-1 imagery have been presented:

1. Edwards, Donald M., Application of Remote Sensing to Irrigation, Nebraska Academy of Science Annual Conference, Lincoln, Nebraska, April 1973.

2. Hoffman, Richard O., ERISTAR, Information Division, Session 3500, American Society for Engineering Education, Annual Conference, Ames, Iowa, June, 1973.

3. Hoffman, Richard O., Application of ERTS imagery in Nebraska, Nebraska Chapter, American Society of Quality Control, Fremont, Nebraska, July 1973.

4. ERTS: A Far-out planning device, Planning, the American Society of Planning Officials Magazine, August 1973.

5. Edwards, Donald M., Irrigation Inventory, Nebraska Remote Sensing Center News, Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska, September 1973.

6. Edwards, Donald M., ERTS-1 Interpretation, Nebraska Academy of Science, Science Teachers Workshop, Halsey National Forest, October 1973.

7. Biles, William, Richard O. Hoffman, et al, The Industrial Engineer in Environmental Information Systems, Proceedings of the First Annual Systems Engineering Conference, New York, American Institute of Industrial Engineers, Norcross, Georgia, November 1973.

8. Carlson, Marvin, Rex Peterson, Richard O. Hoffman, Donald M. Edwards, etc. Applications of Remote Sensing in Nebraska, Ninth International Symposium on Remote Sensing, Ann Arbor, Michigan, April 1974.

9. Hoffman, Richard O., and Donald M. Edwards, Talks on ERTS-1 imagery use to classes, service organizations and other interested groups.

h. The following presentations and publications dealing with remote sensing and irrigation using ERTS-1 imagery are scheduled:

1. Eucker, Carmen C., Richard O. Hoffman, Donald M. Edwards, and Gerald Wallin, Applications of remote sensing to crop identification and water use, International Seminar and Exposition on Water Resources Instrumentation, Internation Water Resource Association and the American Society of Civil Engineers, Chicago, June 5, 1974.

2. Hoffman, Richard O., Donald M. Edwards, Gerald Wallin, Thomas Burton, Applications of remote sensing for identification of center pivot irrigation systems and estimating water usage, International Seminar and Exposition on Water Resources Instrumentation, International Water Resource Association and the American Society of Civil Engineers, Chicago, June 5, 1974.

3. Hoffman, Richard O., Donald M. Edwards, Carmen C. Eucker, Gerald Wallin, Measuring and monitoring irrigated land with ERTS-1 imagery, Sixty-seventh Annual Meeting of the American Society of Agricultural Engineers, Stillwater, Oklahoma, June 25, 1974.

5. Application of results obtained during the reporting period.

5a. Direct applications already achieved.

1. Three projects of primary interest to the Nebraska State Office of Planning and Programming and the Natural Resources Commission were identified and started.

2. The location of 39,469 registered irrigation wells has been mapped at a 1:125,000 scale for the 91 counties in Nebraska. This allows the comparison of registered irrigation wells with center pivots. The irrigation well registration is one of the prime bases for estimating the number of irrigated acres in Nebraska.

3. The locations of center pivot irrigation systems have been mapped at a scale of 1:125,000 using ERTS-1 imagery for the 93 counties in Nebraska.

4. In Dawson County, 2,013 fields have been mapped at a scale of 1:125,000 using ERTS-1 imagery. In Phelps County, 4,500 fields have been mapped at a scale of 1:125,000 using ERTS-1 imagery.

5b. <u>Potential application to local programs.</u>

1. Development of a more accurate forecast of the amount of diesel equivalent fuel needed to run irrigation systems.

2. Development of a more accurate estimate of the amount of water to be removed from the ground water reservoirs due to well irrigation.

3. Development of a more accurate prediction of the water table level.

4. Development of a more accurate prediction of the types of crop acreage in Nebraska.

5. Development of irrigation management techniques.

6. Development of an accurate measure of irrigated lands for use in State water use planning.

5c. <u>Potential application to federal programs.</u>

1. Basic data for development of a more accurate prediction of crop yields.

2. Basic data for development of the amount of water available for exporting out of Nebraska or for use in Nebraska for imported energy and manufacturing developments.

3. Basic data for developing energy allocation policy and needs for the U.S.

4. Basic data for developing water resource policy and needs for the U.S.

6. <u>Work Planned for the Future</u>

Figure 3 illustrates the time schedule for the Surface Irrigation Project and the Center Pivot Irrigation Project.

6a. Center Pivot Irrigation Project

From the ground truth and the ERTS-1 imagery gathered during the summer of 1973, it has been shown that center pivot irrigation systems can be identified, the amount of land irrigated measured, the class of crops irrigated identified, and the growth rate calculated. This has been accomplished for five counties. Work on the above project will be continued for the remaining 88 Nebraska counties. The final product will be a Nebraska state map showing the location of land irrigated by center pivot systems, indicating the type of crop irrigated, the amount of land irrigated, and the growth rate of center pivots. This information has been requested by the Nebraska State Natural Resource Commission, the Nebraska State Office of Planning and Programming, several Natural Resource districts, and the Nebraska Irrigation Program, and several electrical power districts.

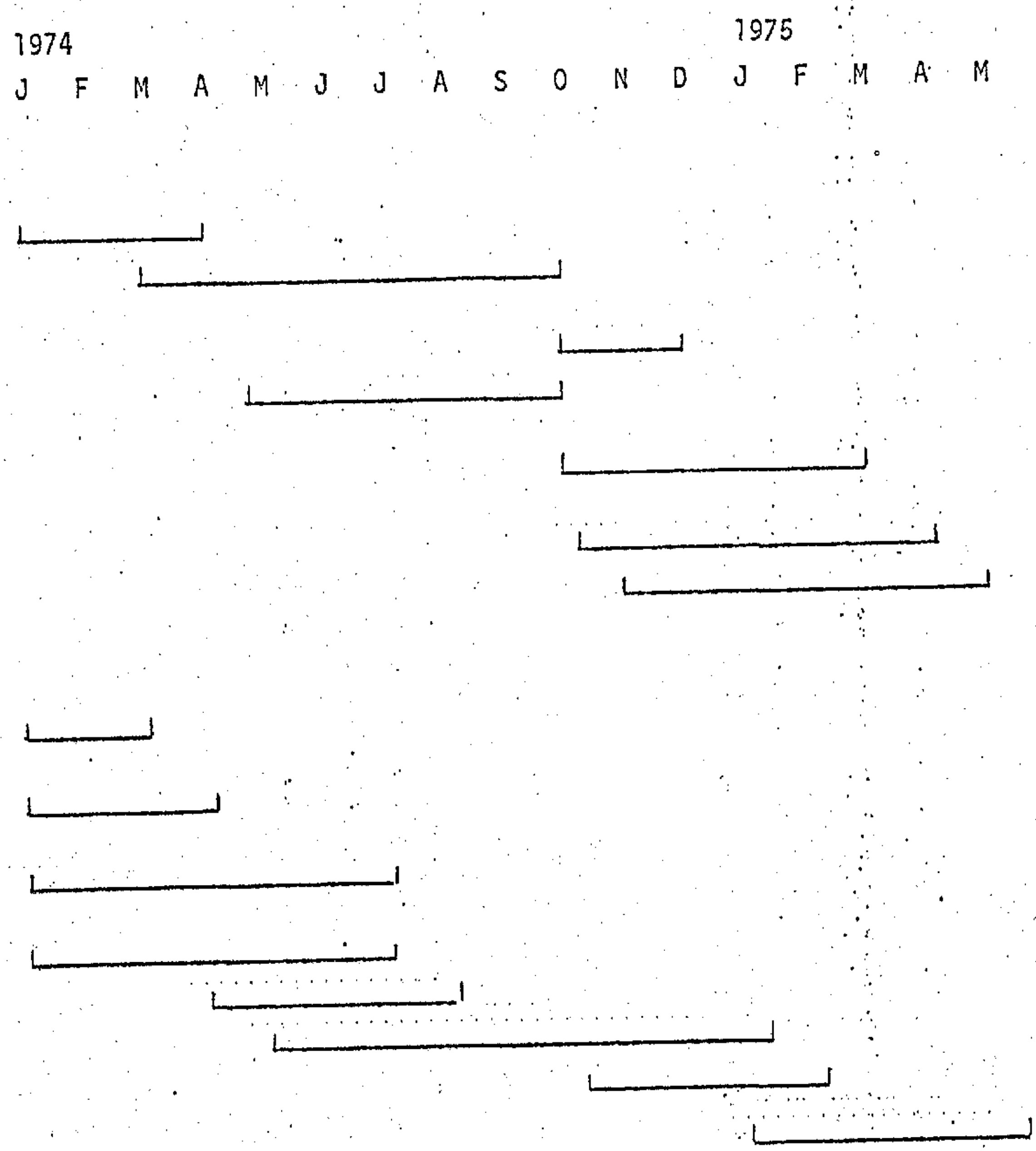
If funding is continued at the present level, we will be able to meet the request from the above agencies for information related to water usage and energy requirements.

6b. Irrigation Project

Work on the Irrigation Project of identifying land by other than center pivot systems includes additional development and refinement of the identification procedures. This will include developing procedures which will identify more reliably surface irrigated land and the type of crop being raised. To accomplish this, use of more sophisticated electronic equipment and photographic enhancement procedures will be necessary. These procedures and algorithms are being developed for

Figure Three

TIME SCALE FOR IRRIGATION PROJECT



1. Irrigation Project
   a. Develop algorithms for identifying irrigated land and crops
   b. Apply algorithms to counties 1973
   c. Calculate water and energy needs for 1974
   d. Gather ground truth data
   e. Apply algorithms to counties for 1974
   f. Statistically test validty of algorithms
   g. Prepare new maps and report

2. Center Pivot Irrigation Project
   a. Document procedure for locating center pivots
   b. Document procedure for determining crop type
   c. Locate all center pivots for each county
   d. Determine crop type for each center pivot
   e. Publish report and maps for 1973
   f. Calculate energy and water needs
   g. Test procedures for 1974 season
   h. Publish new maps and report

Dawson County and Phelps County. The remaining 91 counties will then be analyzed and a Nebraska state map developed which shows all the surface irrigated land and the type of crop identified.

If funding is continued at the current level, it is planned next summer to gather additional ground truth data in Dawson County, Phelps County and three other counties. This will allow the testing of the algorithms.

6c. Remote Sensing Center Project

Work on the Remote Sensing Center project has been completed. Its purpose was to start the development of a remote sensing center where all ERTS-1 imagery and analysis equipment could be housed, with supporting technicians. This has been accomplished. The Nebraska Remote Sensing Center is now a separate project, supported in part by this University Affairs Grant and several Nebraska state agencies. Its facilities will be used by this project for analysis of the irrigation data and ERTS-1 imagery.

PROJECT TITLE:

Application of Remote Sensing in Estimating Evapotranspiration in the Platte River Basin.

INVESTIGATORS:

Blaine L. Blad, Assistant Professor of Agricultural Climatology, Department of Horticulture and Forestry, University of Nebraska.

Norman J. Rosenberg, Professor of Agricultural Climatology, Department of Horticulture and Forestry, University of Nebraska.

PURPOSE OF INVESTIGATION:

Primary objectives of this study are: (1) to develop and test evapotranspiration (ET) models based on crop temperature and (2) to determine the feasibility of using remotely sensed thermal imagery to supply data on crop temperature for use with these models.

SCIENTIFIC RESULTS OBTAINED:

The field data collected during 1972 and 1973 have been computer converted into a usable format and analyzed to evaluate the performance of the mass transfer and crop resistance models in estimating ET. The Bowen ratio-energy balance (BREB) model had previously been calibrated against lysimeters and was found to be acceptable as a field standard. (Blad and Rosenberg, 1974a). BREB results were used in evaluating the constants required to apply the mass transfer and crop resistance models and as a standard against which the two crop temperature based ET models could be tested.

The mass transfer model may be written as:

$$LE = f(u)\ (e_s - e_a) \qquad (1)$$

where LE is latent heat flux, f(u) is a constant related to windspeed, e_s is the saturation vapor pressure at the evaporating surface (determined from the crop temperature) and e_a is the vapor pressure of the air at a fixed height (200 cm in this study). Crop temperatures determined with an infrared thermometer were used to evaluate f(u). For 1972:

$$f(u) = 2.95 \times 10^{-2} + 7.42 \times 10^{-5}\ u_2 \qquad (2)$$

and for 1973 the relationship was:

$$f(u) = 3.30 \times 10^{-2} + 5.95 \times 10^{-5} u_2 \qquad (3)$$

where u_2 is the wind speed in cm sec^{-1} at 2 meters above the surface. Some problems associated with changing calibration of the IR thermometer were encountered during these studies. Differences in the f(u) relationships for these two years may be related to these problems, and also to variation in the aerodynamic roughness of the alfalfa crop during the two years.

The relationships determined using leaf thermocouple data were in better agreement for the two years but because of difficulties associated with accurate measurement of crop temperatures using thermocouples there is no reason to accept these relationships as more accurate than those determined for the IR thermometer. The f(u) equations derived from thermocouple data are:

$$f(u) = 2.70 \times 10^{-2} + 6.22 \times 10^{-5} u_2 \qquad (4)$$

for 1972 and

$$f(u) = 2.44 \times 10^{-2} + 6.46 \times 10^{-5} u_2 \qquad (5)$$

for 1973.

These f(u) relationships were used in equation (1) to estimate LE during several days in 1972 and 1973. The daily pattern of LE estimated by the mass transfer model using f(u) derived from equation (2) is compared to BREB estimated LE in Fig. 1a for July 8, 1972. As illustrated in Fig. 1a LE calculated by the BREB and mass transfer methods generally agrees very well throughout the day. Agreement between the two methods was generally good irrespective of whether or not the day was sunny or cloudy. The mass transfer method likewise gave reliable ET estimates during periods of advection and non advection.

The crop resistance model is a modification of a model proposed by Brown and Rosenberg (1973) and may be written as:

$$LE = C_p \, \rho \left(\frac{T_a - T_c}{r_a}\right) + (Rn - S) \qquad (6)$$

where C_p is the specific heat of air, ρ is the density of air, T_a is air temperature, T_c is crop temperature, r_a is boundary layer resistance, Rn is net radiation and S is soil heat flux. All terms in this equation except r_a can be easily measured. Data on crop temperature obtained with the infrared thermometer were used to evaluate r_a as a function of wind speed. For 1972:

$$r_a = 10.0\ u_2^{-0.72} \tag{7}$$

and for 1973:

$$r_a = 102.0\ u_2^{-1.11} \tag{8}$$

These equations appear to be rather different, however, both equations give values of r_a that are very similar, especially in the wind speed range from 200-800 cm sec^{-1}. r_a values are also in good agreement with those calculated from other r_a vs windspeed expressions reported in the literature for crops of similar height.

The crop resistance model was used to calculate LE rate on a 15 min basis. Results were compared with BREB estimated LE rates. An example of this comparison for one day is given in Fig. 1b. The BREB and crop-resistance model estimates agree very well. On a daily basis agreement between the two methods was within 10% or better on each of the 6 days for which data are available. Sunny and cloudy and advective and non-advective days were included in the test.

Our results, shown above, suggest that both the crop resistance model and the mass transfer model are fundamentally sound and with the necessary refinement, can provide reliable estimates of ET. Thus, Objective 1 stated above has been realized. Further refinement of these models and testing of them on crops other than alfalfa will be accomplished by a major grant received from the Office of Water Resources Research.

We have not been as successful in accomplishing Objective 2. A few successful thermal scans were obtained over our experimental site during 1972.

The analysis of these scans has been delayed, however, due to the lack of a needed densitometer at the University of Nebraska. Thermal scans over our experimental site in 1973 were unsuccessful except for a single scan obtained for us by the Nebraska National Guard

Preliminary analysis of those thermal scans obtained thus far do reveal, however, that alfalfa fields were cooler than corn and pasture during periods of sensible heat advection. This suggests that corn consumes less water than does alfalfa under the same conditions and that pasture, the warmest crop, consumes least. This corroborates findings in 1971 showing that pastures used 20-25% less water than alfalfa (Blad and Rosenberg, 1974b).

APPLICATIONS OF RESULTS:

The findings of this study can be usefully applied in the proper management of water resources. If water management is optimized we expect a concommittent conservation of fuel and energy, conservation of natural resources, and improved efficiency in food production.

The methods developed in this study can be used to aid farmers in the Great Plains region to properly schedule irrigation so as to maximize the efficiency of irrigation and reduce the all too common and wasteful practice of applying too much water. Study results should also be valuable to the U. S. Geological Survey and state agencies which require ET data for hydrologic studies.

WORK PLANNED:

A report, showing (1) the performance of temperature based ET models, (2) comparison of crop temperatures measured with infrared radiometers and thermocouples, and (3) the feasibility of measuring crop temperatures with remotely sensed thermal imagery, is presently nearing completion. The newly acquired densitometry equipment will be used to analyze the available thermal imagery.

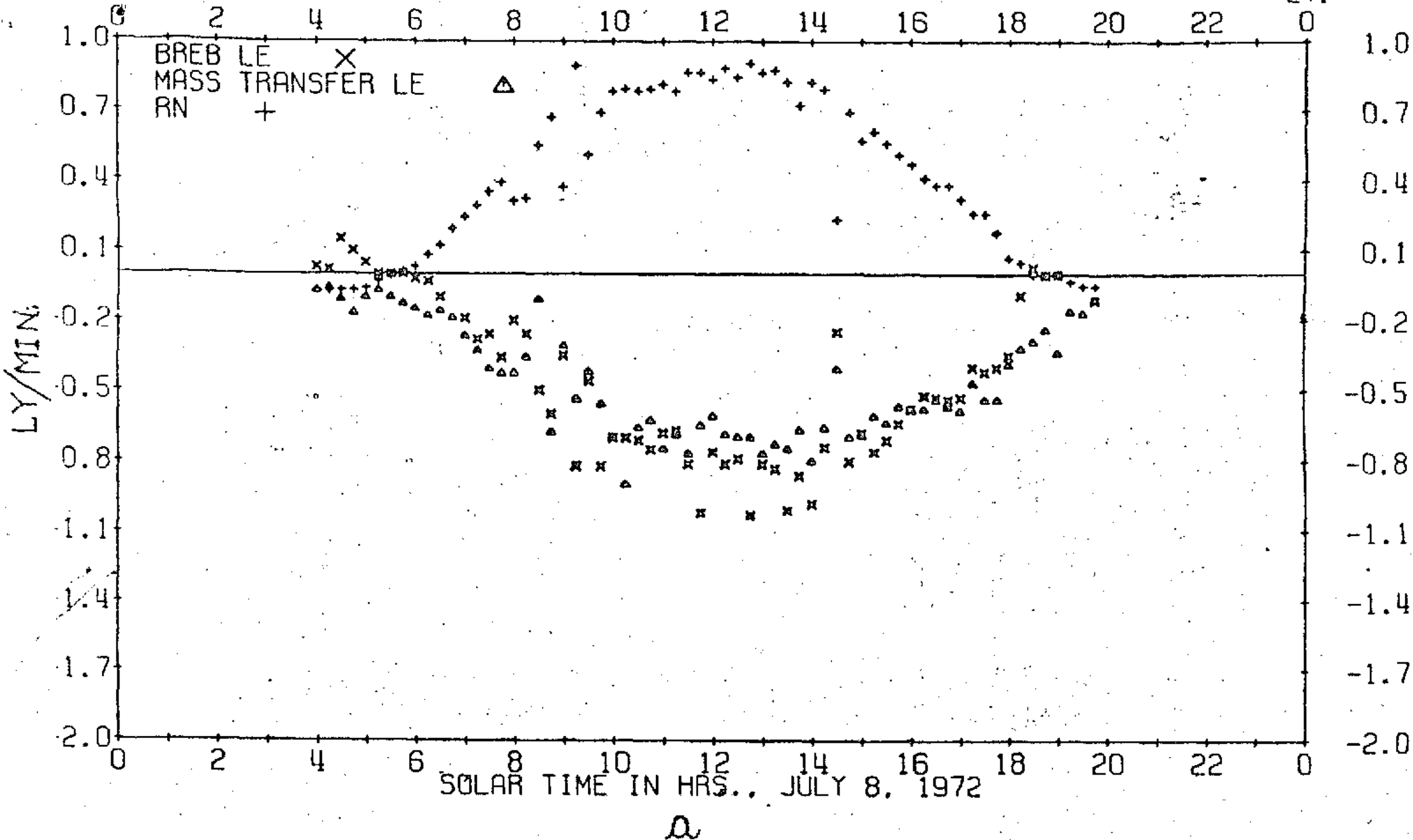
Additional field work, supported primarily by the Office of Water Resources Research, will be conducted this summer at Mead and Scottsbluff, Nebraska, and at Manhattan, Kansas in a cooperative project with Kansas State University to further test the temperature based ET models on a regional basis.

REFERENCES:

Blad, B. L. and N. J. Rosenberg. 1974. Lysimetric Calibration of the Bowen Ratio-Energy Balance Method for Evapotranspiration Estimation in the Central Great Plains. J. Appl. Meteor. 13:227-256.

Blad, B. L. and N. J. Rosenberg. 1974. Evapotranspiration by Subirrigated Alfalfa and Pasture in the East Central Great Plains. Agron. J. 66 (in press).

Brown, K. W. and N. J. Rosenberg. 1973. A Resistance Model to Predict Evapotranspiration and Its Application to a Sugar Beet Field. Agron. J. 65:341-347.



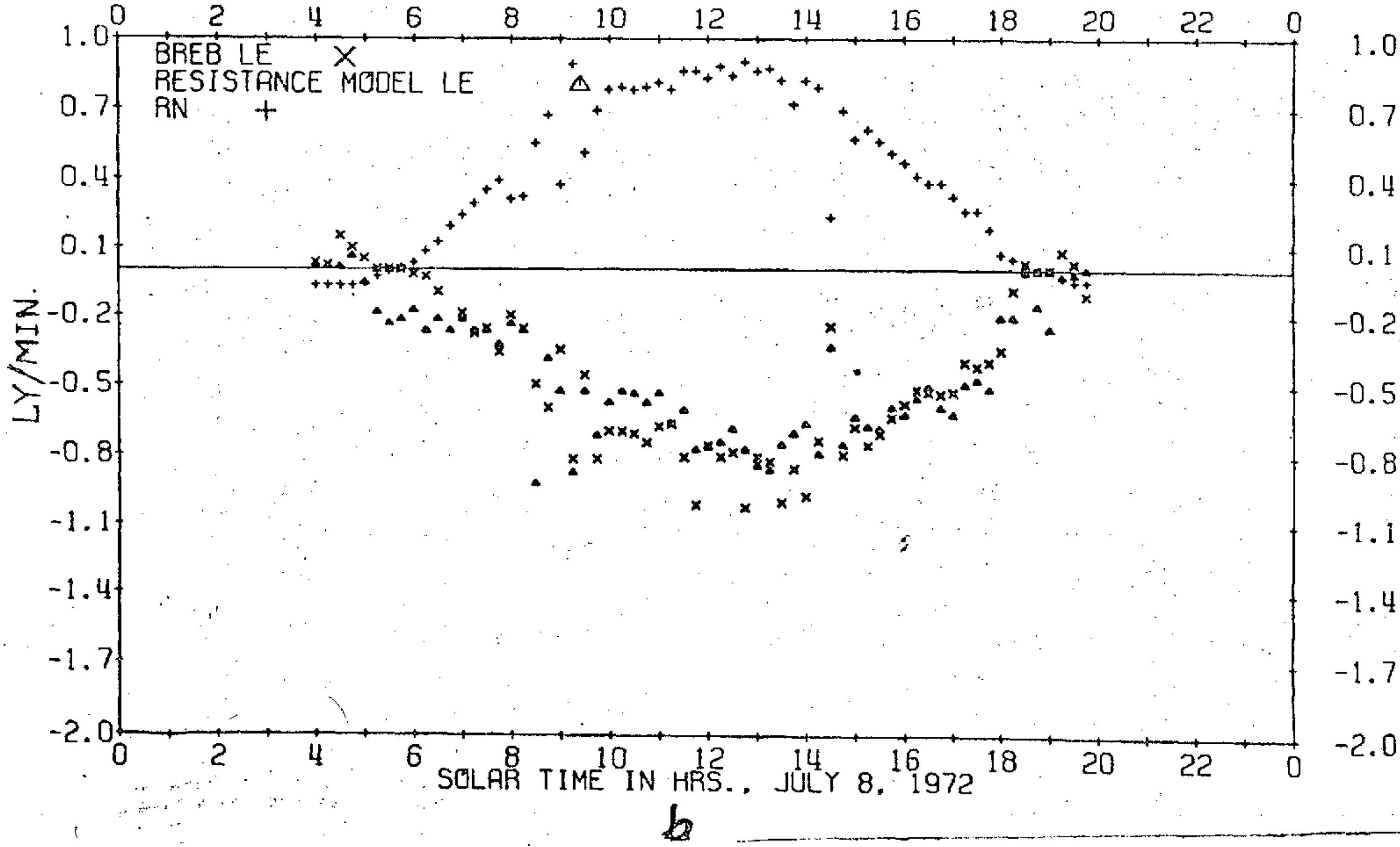


Figure 1; a) Estimates of LE rates calculated by the mass transfer model and the BREB model and measured net radiation on July 8, 1972.
b) Same as a except that crop resistance model LE is compared with BREB LE.

1. Project Title

Application of Remote Sensing in the Determination of Water Quality in Nebraska Reservoirs

2. Investigators

Dr. Gary L. Hergenrader, Chairman, Organismic Biology, School of Life Sciences, University of Nebraska

Mr. Kelly White, School of Life Sciences, University of Nebraska

3. Purpose

The purpose of this research is to determine the feasibility of measuring selected aspects of water quality in Nebraska reservoirs by remote sensing. Specifically, can concentrations of chlorphyll and inorganic turbidities be quantified by remote means? In addition, can the spectral signatures of the rooted macrophytes and major classes of phytoplankton that occur in reservoirs be recognized through the use of different filter - film combinations? If it is possible to measure these parameters of water quality remotely, then remote sensing will provide a powerful new tool for monitoring eutrophication in Nebraska waters.

4. Work Accomplished to Date

Up to now our effort has mostly been directed toward the acquisition of large amounts of remotely-sensed data from our study reservoirs. From the outset we have operated upon the premise that the most useful information for our project would come from low altitude flights made in small airplanes. Furthermore, it was necessary to make these flights mainly during summer, the period of maximum growth of aquatic macrophytes and algae. We have experienced considerable difficulty in completing the number of underflights we had scheduled, mainly due to poor weather and problems with commercial aviation firms. During the past growing season three low-altitude flights using multi-spectral photography were completed for us by the Remote Sensing Center, University of Kansas. An additional flight by them has been made for us this year and four more have been scheduled. Infra-red and color Ektachrome imagery was also obtained from small aircraft leased from a local aviation firm. Several hours of flight time have been contracted for during this growing season and several more of these flights will be completed.

Concurrent with all over-flights ground truth was collected to determine secchi depth, wave conditions, dissolved solids, suspended solids, chlorophyll concentrations, inorganic turbidites, and location and identity of patches of rooted macrophytes. White styrafoam panels were floated on the lake surface to provide a reference which could be used to standardize variations in light intensity between days and between lakes.

Film densities were initially evaluated with a Macbeth Quantalog densitometer with a 2mm viewing slot. It soon became obvious that this instrument failed to provide the necessary resolution because the slot size was too large. A 1mm aperature was fabricated, the machine recalibrated for the new aperature, and some preliminary measurements were obtained. In addition, we evaluated other pieces of hardware for their usefulness to our analysis of film density. Two line scanning microdensitometers, the I^2S, IDECS, and our recently acquired Spatial Data System were tested. Our own microdensitometer and the Spatial Data System seem to give the most reliable and consistent output. Table 1 presents some of the preliminary correlations obtained between water quality parameters and film density of color imagery obtained from light aircraft.

Table 1. Correlation coefficients (r) between film density and water quality parameters for different filters.

	Density vs Suspended Solid	Density vs Formazin Turbidity Units	Density vs Chlorophyll	Density vs Dissolved Solids
yellow filter	r = +.06	r = +.845	r = +.71	r = -.16
green filter	r = +.02	r = +.82	r = +.68	r = -.12
red filter	r = +.11	r = +.87	r = +.745	r = -.21
Green-Yellow			r = -.97	

The preliminary correlations in Table 1 suggest that chlorophyll and turbidity might be accurately quantified by remote sensing. Rather good correlations are observed in the red band and the green minus yellow gives a surprisingly high correlation. It should be noted, however, that these values are preliminary and tentative.

5. Work Planned for Future

As indicated above some of the flights that we have contracted for with other agencies remain to be made. These will be completed during the current growing season. Especially critical are those flights to be made in the aircraft with multi-spectral capability. In addition to completing those flights, most of our effort will be concentrated on the analysis of data we have acquired. Recently obtained analysis equipment in the Nebraska Remote Sensing Center will be utilized to quantify correlations between water quality parameters and film density. When we have reached the stage where the degree of eutrophication in Nebraska reservoirs can be quantified accurately by remote means, then direct applications of the technique, as for example, assisting the Nebraska Department of Environmental Control in meeting the requirements of the 1972 Federal Water Pollution Control Act related to eutrophication, will follow.