E83-10120
CR-169723

SEMI-ANNUAL STATUS REPORT

of the

NASA-sponsored

Cornell University Remote Sensing Program

1 June - 30 November 1982

(E83-10120) REMOTE SENSING PROGRAM Semiannual Status Report, 1 Jun. - 30 Nov. 1982 (Cornell Univ., Ithaca, N. Y.) 261 p HC A12/MF A01 CSCL 05B

N83-15790

Unclas
G3/43 00120

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January 1983

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10 January 1983

NASA Scientific and Technical
Information Facility
P.O. Box 8757
Baltimore-Washington International
Airport
Maryland 21240

Re: NASA Grant
NGL 33-010-171

Dear Sir/Madam:

In accordance with the provisions of the subject grant, we are submitting two (2) copies of our 21st Semi-Annual Status Report, which covers the period 1 June to 30 November 1982. In addition, three (3) copies of this report are being sent directly to Dr. Alexander J. Tuyahov at NASA Headquarters.

Sincerely,

Warren R. Philipson
Associate Professor and
Principal Investigator

cc: A.J. Tuyahov, NASA Hdqts.
D.A. Douvarjo, NASA Hdqts.
Deans T.E. Everhart & W.B. Streett
T.R. Rogers & F.J. Feocco
Director R.N. White

INTRODUCTION

The primary objective of the NASA-sponsored, Cornell University Remote Sensing Program is to promote the application of aircraft and satellite remote sensing, particularly, in New York State. In accordance with NASA guidelines, this is accomplished through conferences, seminars, instruction, newsletters, news releases, and most directly, through applied research projects. Each project must be, in some way, unique; essentially noncompetitive with commercial firms; and, potentially, benefit- or action-producing. Relatively little emphasis is placed on technology transfer, per se.

The activities of the Remote Sensing Program staff, from 1 June to 30 November 1982, are reviewed in this Semi-Annual Status Report, the 21st to be submitted to NASA since the Program's inception in June 1972.

COMMUNICATION AND INSTRUCTION

Contacts and Cooperators

The Program staff regularly spends many hours discussing remote sensing activities, capabilities, projects and research, with representatives of various local, county, regional, state, national and international agencies, public and private organizations, foreign countries and the academic community.

During the past six months, Ta Liang, Program co-investigator, spent five weeks on a soil mapping project in the Northwest Province, Zambia, where he was a consultant to the Spectral Data Corporation, working through the Regional Remote Sensing Facility in Nairobi, Kenya. Warren Philipson, Program principal investigator, spent one month in the Xinjiang Region of the People's Republic of China, providing remote sensing consultations to a livestock development project. He also spent one month in Syria, coordinating a project on developing remote sensing techniques for agricultural applications. Both of Philipson's projects were conducted for the Food and Agricultural Organization of the United Nations, and both are continuing.

Program staff participated in three technical conferences over the past six months. William Philpot, Program co-investigator, attended the OCEANS '82 Conference in Washington, D.C., serving as co-chairman of the session on Coastal Marine Applications of Remote Sensing. Philipson attended the Fall Technical Meeting of the American Society of Photogrammetry in Hollywood, Florida, where he presented a paper, "An Analysis of Seasat SAR for Detecting Geologic Linears" (Appendix C). Lastly, Katherine Minden, a graduate student, presented the preliminary results of the vineyard study at the International Symposium on Machine Processing of Remotely Sensed Data, held at Purdue University, W. Lafayette, Ind. (Appendices A and C).

In other travel, William Philpot visited NASA Langley Research Center to consult with researchers of the Atmospheric Sciences Division and to borrow a spectral absorption meter. Other equipment, a thermal radiometer and blackbody reference source, was borrowed from the U.S. Army Night Vision Laboratory, through the U.S. Environmental Protection Agency, for use in an EPA-funded study.

Since August 1981, the Program has hosted a Visiting Scholar, Yan Shou-yong, from the Institute of Remote Sensing Application of the Chinese Academy of Sciences, Beijing. Zhu Min-hui, another Cornell Visiting Scholar from the People's Republic of China, was being hosted by the School of Electrical Engineering; however, because Ms. Zhu's major interest is image processing, she recently transferred to the Program. Yan and Zhu will continue to work and study with the Program for approximately six more months.

As in the past, many new and continuing dialogues were also held via the mail and telephone. These were often in response to requests for remote sensing consultations (e.g., Eastman Kodak regularly refers requests to the Program, and Newsletter articles often elicit requests). Philipson, however, has been especially active in developing an itinerary for two Syrians who are scheduled to undertake a Remote Sensing training program in the United States in January.

Newsletters

The Program's "Cornell Remote Sensing Newsletter" continues to be an important link to and beyond the Cornell community (Appendix E). By highlighting remote sensing activities at Cornell while reporting other items of interest, the Newsletter has attracted a readership which greatly exceeds the mailing list of some 500 individuals or groups in 45 states and 27 countries (Appendix D).

Seminars

The Program's weekly Seminar in Remote Sensing was not held during the fall 1982; however, planning for the spring semester has begun. Scheduled guest speakers include those from NASA, NOAA, the U.S. Department of Agriculture, the Canada Centre for Remote Sensing, the Eastman Kodak Co., Exxon Research and Engineering Co., Rochester Institute of Technology, and PAR Technology Corp.

During the fall semester, Philipson and Philpot presented an invited seminar to Cornell's Department of Environmental Engineering on the use of remote sensing in environmental studies. The session was attended by some 50 students and faculty members.

Courses, Special Studies and Graduate Theses

During the fall semester, some 45 students were enrolled in formal courses in remote sensing. Active graduate thesis investigations focused on:

engineering properties of arid region landforms (Ph.D., W. Teng), landform identification through quantitative drainage network analysis (M.S., W. Brooks), shifting cultivation and grazing patterns in Kenya (M.S., G. Wayumba), and soil salinity in Libya (M.S., M. Dribika). In addition, among the approximately 15 graduate students who minor in remote sensing while majoring in other fields (e.g., Geological Science, Natural Resources, Limnology, and City Regional Planning), several have adopted remote sensing topics for their theses.

DATA AND FACILITIES

As described in earlier reports, staff research and instruction have been enhanced through continued acqusition of a wide range of remotely sensed, aircraft and satellite data, and through extension of capabilities for their analysis and interpretation. These data, along with Program facilities and equipment, are made available at no cost to cooperators, students and other interested users.

With assistance from the NASA Office of University Affairs, the Program received Landsat, Skylab, high altitude and low altitude aircraft photographic and scanner coverage of sites in the Northeast. To support Program research, the U.S. Environmental Protection Agency also obtained multispectral coverage over selected test sites; and in the course of various projects, imageries were obtained from the U.S.A.F. Rome Air Development Center, the U.S. Geological Survey, the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration, the St. Lawrence Seaway Development Corporation, the National Archives, the Tri-State Regional Planning Commission, the National Air Photo Library of Canada, Eastman Kodak Company, and several commercial mapping firms. In addition, the Johnson Space Center supplied the Program with copies of selected surplus films.

The Program maintains or has access to spectroradiometers and selected image analysis equipment: zoom and non-zoom stereoscopes, density slicer, color-additive viewer, monoscopic and stereoscopic Zoom Transfer Scopes, densitometer and other photographic and photogrammetric instruments. The Program also has an active file of computer routines for analyzing multispectral digital data ("ORSER"). These routines have received increased usage in Program-sponsored, spin-off and thesis investigations with Landsat and aircraft scanner data. Additionally, the Program's computer routines for analyzing Landsat tapes have been used by researchers at the N.Y.S. College of Environmental Science and Forestry at Syracuse, and the State University of New York at Binghamton, the latter, via a telephone link.

To increase image analysis capabilities, the Program secured funding for a visually interactive digital image analysis facility. A grant for specialized engineering research equipment from the National Science Foundation, combined with additional funding from Cornell's School of Civil and Environmental Engineering and the College of Engineering, was used to purchase a VAX 11/750 computer and an I^2S Model 70 image processing system, which are now being installed.

PROJECTS COMPLETED

Two applied research projects were completed during the six-month period, 1 June - 30 November 1982: "A remote sensing study of concord vineyard canopy reflectance" (Appendix A), and "Relationships between linears and natural gas occurrences in the Southern Tier of New York State" (Appendix B).

In the vineyard study, which was the M.S. thesis investigation of Katherine Minden, field spectroradiometric and airborne multispectral scanner data were related to vineyard yield and other agronomic variables, in an attempt to determine the optimum wavelengths for yield prediction modeling. Relationships between vine canopy reflectance and several management practices were also considered. Spectral analysis of test vines found that, although some correlations with vine yield were significant, they were inadequate for developing a yield prediction model. On the other hand, the findings indicated that the vines examined through field spectroradiometry were not truly representative. A follow-up study is concentrating on the airborne scanner data.

In the gas exploration study, which was conducted for the Southern Tier Central Regional Planning and Development Board, Corning, N.Y., geologic linears identified from aerial photographs, Landsat images and maps were compared to gas well locations in three New York counties. Correlations were found between the dominant trends in regional linears and gas field boundaries and trends. Recommendations for limiting any follow-up exploration to these linear trends are being considered by the planning board.

PROJECTS IN PROGRESS

Program-Sponsored

As of 1 December 1982, the Cornell Remote Sensing Program staff was conducting six applied research projects under the NASA grant.

1. Grapevine yield estimation
2. Vegetable acreage in mucklands
3. Site selection for windmills (phase 2)
4. Spectral effects of sulfur dioxide
5. Screening tomato seedlings for salt tolerance

The objectives, cooperators, users, expected benefits and actions, and status of these projects are described, as follows:

1. *Grapevine Estimation*

-cooperators/users:	Taylor Wine Company; N.Y.S. Agricultural Experiment Station
-users:	Taylor Wine Company and other vineyards; USDA Economics, Statistics, and Cooperatives Service; N.Y.S. Crop Reporting Service

-benefit: Potentially, the capacity to improve and estimate vineyard yield with remotely sensed data

-expected completion date: May 1983

As a follow-up to previous vineyard-related investigations (7th, 9th, 14th, 16th, and 17th Semi-Annual Status Reports, Dec. 1975, Dec. 1976, June 1979, June 1980, and Jan. 1981, respectively, and Appendix A), the Program staff is attempting to develop an algorithm for predicting vineyard yield on the basis of remotely sensed measurements. Efforts are being concentrated on a re-evaluation of the airborne multispectral scanner data.

2. *Vegetable Acreage in Mucklands*

-cooperators/users: N.Y.S. Crop Reporting Service; USDA/SRS

-benefit/action: A more efficient means for collecting statistics on vegetable acreage

-expected completion date: Pilot-study--January 1983

Mucklands are important vegetable-growing areas in New York State. At the request of the New York State Crop Reporting Service, Program staff began a study to test the value of Landsat for inventorying vegetable acreage in mucklands. A crop calendar was compiled and compared to dates of available Landsat data. One July 1981 scene was selected for the pilot study, and the computer-compatible tape was purchased for the Program by the cooperator. Analysis of the single scene, supported by the State's field enumerations, has had some success in separating specific vegetables. Although improvement could almost certainly be had by incorporating a second date of Landsat into the algorithms, no other good scene is available for the 1981 season. At this time, the interpretations and recommendations are being finalized, and follow-up activities with thematic mapper data are being discussed with the cooperators.

3. *Site Selection for Windmills (Phase 2)*

-cooperators: N.Y.S. Energy Office; Niagara, Erie, and Orleans counties, N.Y.

-users: N.Y.S. Energy Office; citizens of New York State

-benefit/action: Selection of best sites for windmills

-expected completion date: 2nd Phase--May 1983

A methodology was developed for identifying and ranking sites of highest wind power potential within any defined region (18th Semi-Annual Status Report, June 81). The methodology was applied to selecting sites in three counties in western New York. State and county officials erected anemometers at 16 sites; but because of the lack of cooperating land owners, few of the recommended sites were used. Site monitoring periods ranged from 2 to 11 months before the program was terminated by state budget cuts. The Program staff is attempting to obtain the collected data in order to relate the wind monitoring results to the criteria relied on for site selection. Although the best sites may not have been monitored, wind differences should still be informative.

5. *Spectral Effects of Sulfur Dioxide*

-cooperator:	Boyce Thompson Plant Research Institute
-users:	U.S. Environmental Protection Agency; other monitoring agencies
-benefit/action:	Development of a procedure for monitoring SO_2 and its effects
-expected completion date:	Feasibility study--May 1983

Researchers at the Boyce Thompson Plant Research Institute, which is located on the Cornell University campus, are investigating the effects of sulfur dioxide on the yield of beans. During the summer of 1980, Program staff collected field spectroradiometric measurements and 70-mm ground photographs of selected rows of beans, exposed to varying concentrations of sulfur dioxide. The spectroradiometric data have been calibrated and film densitometric measurements made. Limited data on bean yield and gas concentration have been provided by the cooperator, and they are being correlated with both types of remotely sensed data.

6. *Screening Tomato Seedlings for Salt Tolerance*

-cooperator/user:	Boyce Thompson Plant Research Institute
-users:	Tomato growers
-benefit/action:	More efficient screening using remote sensing methods
-expected completion date:	May 1983

At the request of researchers at the Boyce Thompson Plant Research Institute, the Program staff undertook a project to determine if remote sensing methods could be applied to reduce the time and costs involved in screening tomato seedlings for salt tolerance. The aim of the initial phase of the work is to use greenhouse photography and densitometry to determine if the leaf spectral response of "salted" tomato seedlings exhibits any correlation with known levels of seedling tolerance. Early results were inconsistent and a more rigorous experiment was planned; however, equipment failures have delayed project implementation.

Spin-Off Projects

During the past six months, the Program staff has been involved in two projects which arose directly from NASA-funded research and teaching activities. The staff is assisting in a characterization of acid lakes in New York's Adirondack Mountains using digital analysis of Landsat data. This project is funded by a Mellon Foundation grant to Cornell's Department of Ecology and Systematics. The staff is also evaluating the feasibility of using remote sensing to characterize the contents of liquid chemical waste storage drums. This project is funded primarily by the Environmental Protection Agency.

In another ongoing investigation, William Philpot was awarded an NSF grant to extend his Ph.D. research through verification of a model for radiative transfer in non-homogeneous waters. This work will continue through at least 1984.

FUTURE PROJECTS

The Program staff is continually soliciting and receiving proposals for new remote sensing, applied research projects. As described, criteria for project acceptance are that the projects must be, in some way, unique; that project acceptance would not compete unduly with private companies or consultants; and that, if completed successfully, the project would produce tangible benefits or actions by defined users.

PROGRAM STAFF

The Program staff is comprised of Warren R. Philipson, principal investigator, Ta Liang and William D. Philpot, co-investigators, and Chain-Chin Yen, computer data analyst. Donald J. Belcher, Arthur J. McNair, and Ernest E. Hardy are general consultants to the Program and, for specific projects, assistance has been provided by many Cornell and non-Cornell personnel. Students who have contributed significantly to the Program staff effort over the past six months include Katherine Minden, William Teng, Anthony Vodacek, and Ellen Weeks.

LIST OF APPENDICES

APPENDIX A

VINEYARD YIELD EXTIMATION

A REMOTE SENSING STUDY OF CONCORD VINEYARD CANOPY REFLECTANCE

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment for the Degree of

Master of Science

by

Katherine Anne Minden

August 1982

ABSTRACT

This study used field spectroradiometric and airborne multispectral scanner data to relate vineyard canopy reflectance to vine yield and other agronomic variables, and to assess the optimum wavelengths for yield prediction modeling. Relationships between vine canopy reflectance and several management practices were also examined.

Field spectroradiometric measurements of 18 vines were collected on three dates, at the Vineyard Laboratory of the New York State Agricultural Experiment Station, in Fredonia, New York. Replicated vines had been subjected to nine agronomic treatments involving levels of nitrogen, weed control, pruning and training.

During field data collection, radiance from a white Lambertian standard and vine radiance were measured simultaneously with portable spectroradiometers (ISCO Model SR), taking readings at intervals of 25 nm from 400 to 1100 nm. The data were transformed into percent hemispherical-conical reflectance.

Correlations were then computed between the spectral reflectance of each vine, on each date, and vine yield. Relationships between vine reflectance and pruning weight, clusters, nitrogen application and weed control were also evaluated.

As an extension of the field program, one date of airborne multispectral scanner data (M2S, 11 channels) was flown by NASA

over the vineyards of the Taylor Wine Company, Inc., in Hammondsport, New York. The spectral radiance values for eight vineyard sections of Concord grapevines were averaged and related statistically to yield.

An analysis of variance indicated that the 18 vines sampled were not representative of the average vine response to available nitrogen. Spectral analysis of these vines found that, although some correlations between vine yield, pruning weight, clusters per vine and reflectance were statistically significant, they were inadequate for developing a yield prediction model. It was apparent, however, that reflectance data collection could be limited to certain wavelengths, depending on the growth stage.

It is also of note that canopy reflectance was strongly influenced by available nitrogen, which was determined by the method of weed control and nitrogen input, as well as growth stage.

BIOGRAPHICAL SKETCH

Katherine Minden was born on [redacted] in [redacted], [redacted] She attended Montclair High School for three years, and spent her senior year in Brazil as a Rotary Exchange Student. In 1974, she entered the Natural Resource Department at Michigan State University where she focused her studies on International Resource Policy and Watershed Management. After graduating with a B.S., she worked at the U.S. Geological Survey EROS Program office in Reston, Virginia, as a physical scientist, specializing in Landsat studies of Antarctica. In January, 1980, she enrolled at Cornell University as a graduate student in Civil and Environmental Engineering, majoring in Aerial Photographic Studies and Remote Sensing. While at Cornell, she was employed as a research assistant for remote sensing studies of snow depth, SO_2 and vineyard yield. She was also a teaching assistant for a graduate course in image analysis of landforms.

She is a member of the American Society of Photogrammetry, American Women in Science and the Association of Women Geoscientists.

In memory of my mother,

Joan Lancy Minden

She set an example of great courage and strength that I will always strive to follow. Her encouragement and support were abundant, and her giving and love were unending.

ACKNOWLEDGEMENTS

Thanks are due to the many people who contributed their knowledge, time and support to the success of this project.

My graduate committee, Professors Warren Philipson, Ta Liang and Ernest Hardy, are to be thanked for their assistance throughout my graduate career. I am particularly indebted to Professor Philipson, whose invitation precipitated my entering the Remote Sensing Program, and whose assistance in this thesis investigation made the completion of my degree possible. I also thank Professor Liang for his patience and guidance which allowed me to clarify the direction of my research when it seemed most overwhelming.

The assistance in the field of Mike Duggin of Syracuse-ESF was indispensable. In addition, thanks are due him for developing the method of radiance data transformation.

The viticultural staff of the Fredonia Experiment Station gave generously of their time, expertise and friendly support. I am especially grateful to Dr. Nelson Shaulis, John Harker, Harriet Hubbard, and Dr. Robert Poole for their invaluable assistance.

The staff of Taylor Winery Co., Inc. also devoted many hours to this study. Special thanks go to Harland Tyler, Jurgen Loenholdt and Glen Salva.

Several Cornell professionals were instrumental in this research. Special thanks are due to Chain-Chin Yen who did excellent work in computer processing. John Yost and Glen Darling designed and built necessary field equipment with unsurpassed ingenuity. Ron Clayton, Don Warholic and Dick Mandl are to be sincerely thanked for the loan of their spectroradiometers.

This study would not have been possible without the help of a terrific team of field technicians. Lisa Balliet, Tom Erb, Bill Hafker, Karen Jahn, Sandy Matulonis, Dave Smith, John Stanturf and William Teng worked with enthusiasm and cooperation through many long and hot days reading instruments.

My officemates and other friends provided an atmosphere of mutual support throughout the ups and downs of graduate school and the difficulties of everyday living. I am especially grateful for the friendships of Elaine Aderhold, Bill Brooks, Zekai Can, Mustafa Dribika, Anna Gibson, Katsutoshi Kozai, Christina Stas, Gordon Wayumba, Ellen Weeks, Yemane Zecharias and Kathy Zvanovec.

Helen Lewis did an excellent job of typing, and I thank her.

Most important are the thanks due to my parents, brothers, sister and brother-in-law whose unfailing confidence in my abilities has been my mainstay throughout.

Lastly, I must thank my husband, Parker Auburn, who still wanted to marry me after seeing me perform as a graduate student. Through taking a great interest in my work, he shared all the joy of learning and the misery of writer's block. Thus, he also shares the excitement of finishing at last.

This study was supported by NASA Grant NGL 33-010-171.

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CHAPTER 1

INTRODUCTION

In New York State, vineyard management decisions focus on assessing crop status and applying appropriate treatments for maximizing crop yield. Remote sensing methods have previously been applied to problems addressed by viticulturalists. Results have included cost-effective methods of assessing drainage; soil depth, compaction, and texture; and crop health and vigor.

The staff of the Remote Sensing Program at Cornell University has been involved in developing remote sensing techniques for vineyard management since 1975. All past studies were applied to the vineyards of the Taylor Wine Company, Inc., of Hammondsport, New York. In 1977, a preliminary assessment of vineyard yield using remotely sensed data was performed. The results were promising enough to merit the more in-depth study described here.

This research was intended to determine the extent to which grapevine characteristics, including yield, could be described through the spectral properties of the vine canopy. In addition, it was hoped that this study would lead to the development of remote sensing procedures that the viticulturalist could apply operationally.

The specific objectives of this research are:

1. To relate vineyard canopy reflectance to vine yield and other agronomic variables through field spectroradiometric measurements;

2. To define the optimum wavelength(s) for yield prediction modeling; and

3. To extend the ground-level results to the design of airborne data collection.

CHAPTER 2

LITERATURE REVIEW

Remote sensing is the science of detecting information about an object, area or phenomenon from a distance, without direct contact with the target. Remote sensors record variations in reflectance and exitance of electromagnetic energy by objects under study. It is a tool that has been used in many fields to assist in the inventory, monitoring and mapping of earth resources (Reeves, 1975). This literature review consists of an examination of remote sensing applications to crop condition and yield assessment. The specific focus is on the potential of remote sensing techniques for vineyard yield estimation.

The main concern of vineyard management in New York State is optimizing yield. Crop yield data affect all stages of production, including processing, storage and disposal (Luney and Dill, 1970). Ordinarily, yield estimates are made by ground checks during the growing season. The vineyard manager observes the crop vigor, the number of clusters and buds, and the pruning weight of cuttings to calculate the yield potential. The expected yield is incorporated into the production plans for each wine. Over large areas, ground checks can be time consuming. Detailed observations can often be made only for a small number of plants. Thus, the accuracy of potential yield estimates is limited.

Remote sensing has been used to obtain more timely, rapid and accurate assessment of crop conditions and yield. Studies have been primarily devoted to measuring stress effects on plant vigor (Colwell, 1970). The losses in crop vigor are evaluated and equated to a percent loss in expected yield. More recent quantitative studies explore the relationship of spectral response to agronomic properties (McDaniel and Haas, 1982). These variables include leaf area index, biomass, disease, percent green percent ground cover, nutritional status and yield. The following sections will discuss the studies and their applicability to vineyard yield estimation.

2.1 Spectral Characteristics of Crops

2.1.1 Leaf Reflectance

Plant canopy reflectance is largely the product of the interaction of radiation with individual leaves and within multiple layers of leaves. Therefore, an understanding of the optical characteristics of leaves is necessary when attempting to analyze canopy characteristics.

Incident energy is reflected, transmitted, and absorbed by a leaf. All three processes contribute to any evaluation of leaf spectral properties. Figure 2.1 shows the percent incident energy that undergoes each process as a function of the wavelength of that energy. The variations in percent energy reflected by a leaf between different wavelengths can be related to plant physiology. Factors that affect reflectance include chlorophyll and other pigments, water content, maturation, senescence, and internal leaf structure (Bauer, 1975).

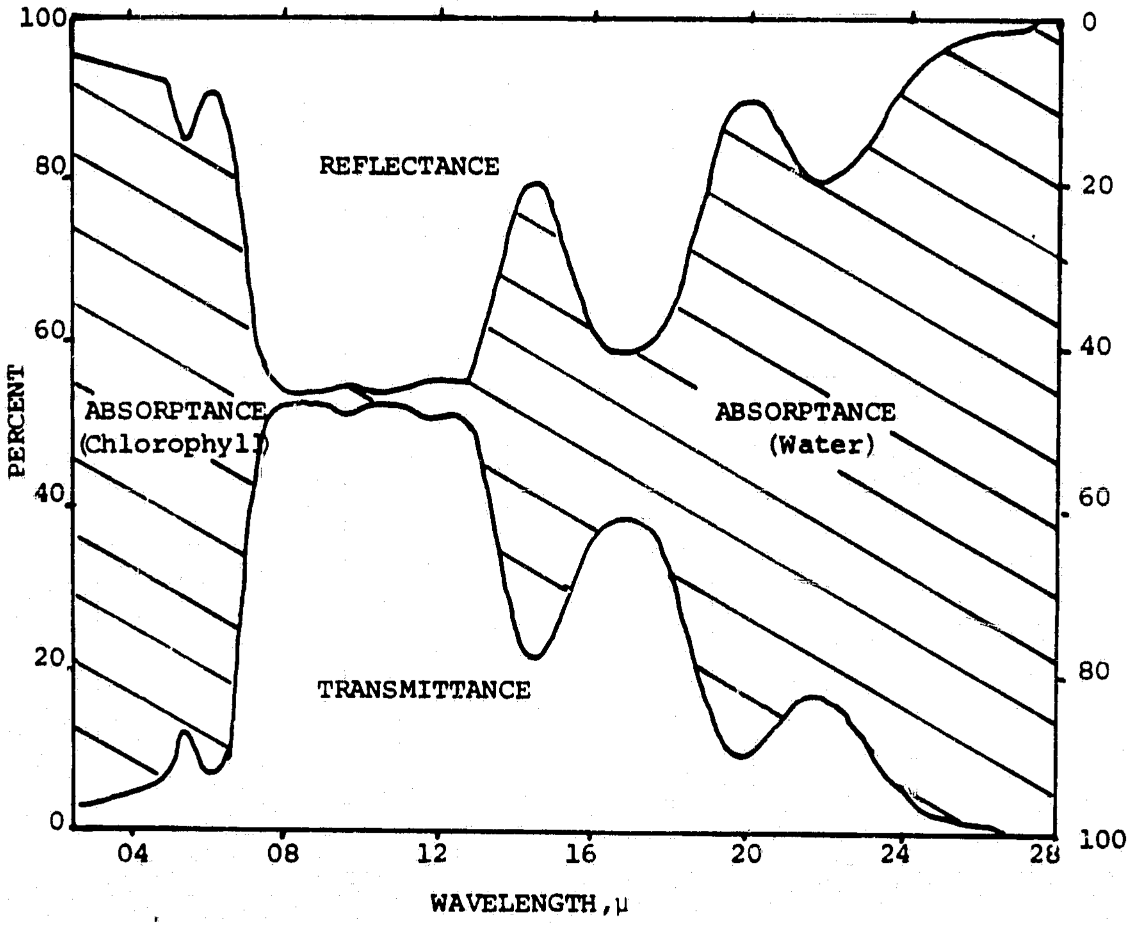

Figure 2.1 Plant leaf reflectance, absorptance, and transmittance spectra (Knipling, 1970).

Plant reflectance in the visible region of the spectrum (400 to 700 nm) is relatively low due to the absorption of visible light by chlorophyll and other pigments (Wiegend et al., 1972). Chlorophyll absorbs slightly less radiation in the green wavelengths than in the blue or red wavelengths. Therefore, a small peak occurs in the reflectance curve of a vigorous plant at approximately 550 nm.

Plant pigments become transparent in the near-infrared (near-IR) region of 750-1350 nm. Therefore, the internal leaf structure becomes dominant (Myers and Allen, 1968, Wiegand et al., 1972; and Bauer, 1975). The result is that a high reflectance curve exists in this region along with a corresponding decrease in absorption.

Leaf structure continues to exert a slight influence in the 1350-2500 nm infrared wavelength interval. However, the dominant plant parameter that affects reflectance at those wavelengths is leaf turgidity. There are two strong water absorption bands at 1450 and 1950 nm (Myers and Allen, 1968, Wiegand et al., 1972; and Bauer, 1975).

As the leaf matures, the structure of the leaf mesophyll expands and the percent chlorophyll present increases. A corresponding increase in reflectance in the near-IR and green wavelength peak, as well as a decrease in the red wavelengths occurs (Myers, 1975).

When the leaf enters senescence, the chlorophyll production drops and becomes less dominant in the leaf spectra (Myers, 1975). The red reflectance increases and the green reflectance decreases. Leaf turgidity also drops during senescence. When the turgidity reaches 70-80% or below, reflectance in the visible and near-IR increases. This effect, which is most significant in the near-IR, is partly due to the increase in air interfaces in the leaf structure that accompanies dehydration (Myers and Allen, 1968).

2.1.2 Canopy Reflectance

There are both quantitative and qualitative differences between optical properties of individual leaves and those of canopies. Colwell (1974) summarized the significant parameters affecting canopy reflectance. They are: leaf area and orientation; leaf hemispherical transmittance and reflectance; the characteristics of other plant canopy components (trunks, petiole, etc.); background surfaces (soil, leaf litter); solar zenith angle, look angle, and azimuth angle.

A decrease in the leaf area index can result in a canopy reflectance increase in the red and a decrease in the near-IR (Suits, 1972). Light-toned soil background reflectance causes an increase in the near-IR and a decrease in the red, depending on the percent cover, look angle, and the solar zenith angle (Colwell, 1974). Variations in the tone of the background, whether soil, rock, or vegetation, will cause variations in the total canopy reflectance. Increasing shadow within the canopy has caused decreases in the near-IR reflectance.

Colwell (1974) also observed that canopy reflectance, when measured from a 20^{o} look angle in a downsun direction, was higher in the green, red, and the near-IR than when measured with a vertical look angle. When the look angle was 20^{o} upsun, the reflectance decreased in the green and red relative to the vertical measurements. The near-IR reflectance increased slightly.

Egbert and Ulaby (1972) found that the variations of percent reflectance of the horizontal and vertical components of a vegetation canopy also change in relation to look angle and solar zenith angle. The greater the percent canopy cover, the less the angular dependence (Colwell, 1974).

The effects of the solar zenith angle, look angle and the azimuth angle on the reflectance of pasture vegetation were studied by Duggin (1980a). Using ground level radiometers, he found that the reflectance in the red and near-IR changed as the elevation of the detector changed. This change was highly dependent on the solar zenith angle and the azimuth angle. These factors affected the red reflectance up to 60% and the near-IR up to almost 40%.

Measurements taken at different times are also varied with the solar zenith angle. The geometric relationships of the sun to the detector and target are illustrated in figure 2.2, where z is the solar zenith angle and ϕ is the azimuth of the detector with respect to the sun.

2.2 Remote Sensing of Yield

Yield estimation with remote sensing is based on the ability to define plant morphological factors that correlate with yield and, at the same time, affect canopy reflectance. Several parameters that are commonly considered are leaf area, maturity, plant vigor, and plant health. Leaf area is characterized by the leaf area index, which represents the cumulative leaf area and layering in a plant or field of plants (Wiegand et al., 1979). Maturity indicates the growth stage. Plant vigor is the rate of growth, while plant health is an indicator of disease, nutrient, and insect effect.

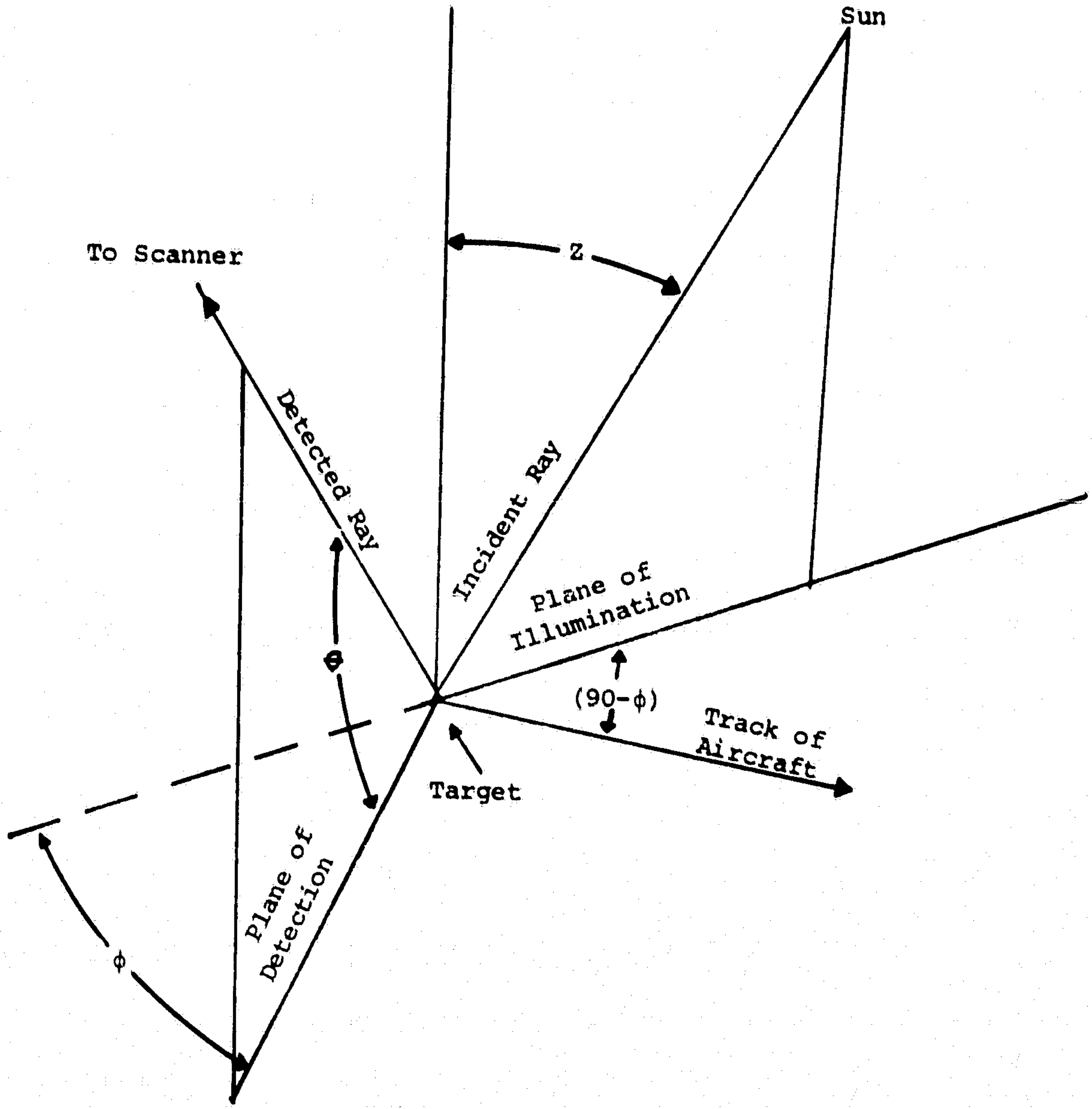

Figure 2.2 Geometric relationships between solar zenith angle, target and detector (Duggin, 1980a).

Some methods of yield prediction combine historical crop yield information with assessment of crop condition on aerial data to determine a yield potential (Colwell, 1979). Other techniques apply crop reflectance data directly to the development of yield prediction equations (Kanemasu, 1974; Idso et al., 1977; Wiegand, et al., 1979). These and other remote sensing research involved with yield prediction are discussed in the following sections.

2.2.1 Aerial Photography

Panachromatic black-and-white, color, and color-infrared (color-IR) aerial photography have been used for yield prediction research. The advantages of aerial photographs over other technology include the low cost of equipment; high spatial resolution; the ease of acquiring and processing data; and the ability to often use unaided human interpretation. Photographic emulsions are spectrally limited to the visible and near-IR wavelengths; however, combinations of film and filter sensitivities and densotometric measurement, can provide wavelength specific information.

Colwell et al. (1966) examined medium and large scale, black-and-white aerial photographs to determine acreage and yield for raisin and wine grape crops in California. To estimate total yield, photo counts of raisin drying trays laid out between rows of vines were multiplied by the average yield per tray of 20-25 lbs. Crop acreage was also measured on the photographs. The use of aerial photographs in this instance allowed the growers to save substantially on field checking, and to stabilize production (Colwell, 1970).

Allen and Von Steen (1969) examined color and color-IR aerial photography in determining fruit tree yields. They found a significant correlation between the actual yield and the fruit per tree counted by eye on oblique color photographs.

Because the optical density of fruit differs from that of foliage, fruit has also been located by densitometric measurements (Myers, 1975). This system of fruit counting on aerial photographs was computerized. The round shape of most fruit along with its tonal variations, generally a darker perimeter than center, are taken into account in computer decision making. Although the computer accounted for less fruit than manual photo interpretation, it was a more consistent method.

Houseman and Huddleston (1966) developed an operational system for fruit tree yield forecasting that entails making plant measurements on aerial photographs. They estimate preharvest sampling through a predictor equation which incorporates the maturing of fruit, the number of fruit at each level of maturity, and the stage of crop development. The probability that a fruit at some maturity level would contribute to harvest was calculated. The sum of the above factors is used to estimate the number of fruit that will actually be harvested. Several years of historical data on the trees are necessary to implement this method.

In another study using large scale color-IR film, Von Steen et al. (1969) found statistically significant correlations between film density and plant yield parameters for five vegetable crops. The film was flown late in the growing season when crop canopies were well developed and soil reflectance was minimized. A densitometer with blue, green, red and neutral filters was used to make density measurements on the color and color-IR films. Crop yield potential was predictable with this technique.

2.2.2 Spectroradiometers

2.2.2.1 System Operation

In order to determine whether spectral information can be used for crop yield study and which wavelength(s) would be optimum, the character of the plant reflectance signature must be examined over a broad spectrum. A spectroradiometer is used to make measurements of radiant flux in narrow spectral bands. Radiometers work on the same principle as spectroradiometers, the only difference being that they have broader bandwidths. There are several types of both instruments available for *in situ* field work.

2.2.2.2 Application of Ground-Based Spectroradiometers and Radiometers to Crop Yield Study

Spectroradiometers and radiometers can be designed as portable field equipment. Therefore, they have been used to collect *in situ*, non-destructive crop reflectance measurements. This provides a means for better understanding the response of aerial data without significant atmospheric interference. Thus, more appropriate mission planning and sensor design is possible.

Vegetation study with these instruments usually involves measurements of spectral radiance and agronomic factors. Statistical analyses are then used to investigate and define the relationship between the two data sets.

In one example, Tucker (1977) studied a grass canopy with a spectroradiometer. The instrument had a spectral range of 350-800 nm. He found a significant correlation of total wet and total dry biomass with reflectance in the blue spectral region (350-450 nm), while leaf water content was closely related to percent reflectance in the blue, green, and red bands (450-800 nm).

In a study of soybean rust severity and yield, Casey and Burgess (1979) measured canopy reflectance with radiometers. The instruments were mounted on a tower seven meters above the canopy. They collected radiant flux across four broad spectral bands: green, 500-600 nm; red, 600-700 nm; near-IR, 700-800 nm and 800-900 nm. The reflectance measurements for each band were correlated with yield and with disease severity. Their results show a highly significant relationship between all four bands and both plant parameters. For yield, the correlation coefficients were positive with the near-IR bands and negative with the visible bands. The relationships were reversed for the disease severity correlations.

In an earlier study of wheat sorghum and soybean canopies, Kanemasu (1974) used a spectroradiometer to monitor red and near-IR radiance over one growing season. To compensate for changes in the solar elevation during the season, he used a simple ratio of the two bands. He found that the correlation of reflectance with the leaf area index was higher with the ratioed data than with single band data. He also found that when soil reflectance dominated the canopy reflectance, as with a mature crop, the ratio value decreased to less than one. He concluded that the ratioed value was a better indicator of crop development than the near-IR reflectance measurements alone.

Tucker et al. (1979a) used a two-channel radiometer to monitor corn and soybean crop development. The instrument measured radiant flux in the red and near-IR regions. The plant parameters measured were percent crop cover, plant height, biomass/unit area, and plant chlorosis (or chlorophyll density/unit area). They found that red reflectance decreased with increasing green leaf biomass and chlorophyll. When senescence began, the red increased with chlorophyll breakdown and leaf loss. The near-IR reflectance increased with the increase in green leaf biomass and dropped with senescence. Linear combinations of the two bands in several combinations were developed to compensate for variability due to sun angle, time of day, and atmospheric effects. The spectral variables used by Tucker et al. (1979a) are the following:

1. IR - red,
2. IR + red,
3. $\frac{\text{Infrared}}{\text{red}}$,
4. $\frac{\text{Infrared} - \text{red}}{\text{Infrared} + \text{red}}$ = Vegetation Index (VI),
5. VI + 0.5 = Transformed Vegetation Index (TVI).

The first two spectral variables were not significantly correlated with the measured plant parameters. However, the three ratios were found to be significantly related to plant height measured early in the season, and to the other parameters throughout the season. The results were consistent with another study (Tucker,

1979) which examined these and other ratios in relation to biomass, leaf water content, and chlorophyll content from a grass canopy. The principal findings of the corn and soybean monitoring were that five stages of crop growth, from emergency to maturity, could be defined by the spectral properties of the canopy, and that correlations were highest with the Vegetation Index ratio.

In another study, Tucker et al. (1979b) collected in situ reflectance data with two-band radiometers of alfalfa fields. The wavelengths examined were red (650-700 nm) and near-IR (775-825 nm). The agronomic parameters studied were: plant height, percent canopy cover, percent drought stress, total wet biomass, total dry biomass, and water forage content. The IR/red ratio and the Vegetation Index ratio were also used in the data analysis. Highly significant correlations were found between all four reflectance variables and all six agronomic variables, when sampled pre-drought. Canopy cover was 85%. When sampled post-drought, the canopy cover was only 50%. The correlation coefficients dropped for all agronomic variables except forage water content and estimated drought stress.

In summary, in situ collection of crop canopy reflectance data has been satisfactorily accomplished with spectroradiometers and radiometers. Several plant parameters can be defined by spectral information. Ratios of the red and near-IR bands can provide more significant relationships between reflectance and plant parameters than single channel data.

2.2.3 Multispectral Scanners--Landsat

Research discussed in the preceding section illustrates that agronomic variables that relate to crop yield affect different regions of the plant reflectance curve. Therefore, when aerial data began to be used for crop study, multispectral scanners became a major data source. Platforms for the scanners include airplanes and satellites.

The Landsat Multispectral Scanner (MSS) has been used extensively in previous crop studies. This satellite-mounted MSS is a wide-band scanner with four channels (USGS, 1979). Two of the channels collect data in the visible, and two in the near-infrared. They are defined respectively as: band 4 (green, 500-600 nm), band 5 (red, 600-700 nm), band 6 (near-infrared, 700-800 nm), and band 7 (near-infrared, 800-1100 nm).

As part of a study of plant characteristics that relate to yield, Wiegand et al. (1974) analyzed Landsat MSS data. They correlated reflectance data from bands 4, 5, and 6, and linear combinations of those data with four measured plant parameters of corn, sorghum and cotton. These were: plant population, canopy cover, plant height, and leaf area index. The spectral variables were: band 5/band 6 and band 6-band 5.

They found that the four plant parameters explained a highly significant percent of the brightness variability in all three bands alone and the combined spectral data. The best correlations for leaf area index were found with band 6-band 5 and with band 6. They concluded that ratioing was a viable method for normalizing soil background reflectance. A further conclusion was that band 6 and possibly band 7 contain certain information that can be related to probable crop yield and to rangeland animal carrying capacity.

In later research, Colwell et al. (1977) based a Landsat study of wheat yield on two propositions. One asserts that early season vegetative development is a good indicator of potential crop yield. The second is that Landsat MSS data can provide a reasonable estimate of wheat vegetative development. To test those theories, they correlated two between-channel ratios of MSS brightness values with green wheat cover and with yield. The ratios were the SQ75 and the TVI as shown in the following equations.

$$\sqrt{\frac{MSS7}{MSS5}} = SQ75$$

$$\sqrt{\frac{MSS7 - MSS5}{MSS7 + MSS5}} + 0.5 = TVI$$

The correlation coefficient of the SQ75 data with the percent wheat cover was extremely high (0.98). The correlation with yield was also very significant (0.80).

Landsat data have also been integrated into previously established crop yield models. Heilman et al. (1977) used Landsat MSS data in an evapotranspiration model to predict winter wheat yield. The major assumption of this model is that soil moisture is the main limitation to winter wheat growth. Therefore, the model combines daily estimates of solar radiation, temperature change, precipitation and other ground-based data. To allow the model to respond to crop growth, leaf area indices derived from Landsat were also integrated into the equation. In general, the yields calculated were well correlated with those estimated by the Statistical Reporting Service.

The Large Area Crop Inventory Experiment (LACIE) also used Landsat data to assist in yield modeling (Houston, et al. 1979, Stuff et al. 1979). The MSS data were used to determine the spectral signatures, and thus the acreages, of different crops. Ground-based climatological information and agricultural statistics were used to formulate the actual yield predicting model. Some spectral variables developed from the MSS data were highly correlated with green leaf area. However, these relationships were found to be unique to the training data used, and were inconsistent when applied to other regions, years and scenes.

2.2.4 Thermal Scanners

Possibly due to the emergence of the Landsat MSS as a prime tool for the study of crops, little has been done in wavelengths other than the visible and near-infrared.

Thermal scanners have been used in an attempt to develop a remote sensing yield prediction model that would not require collection of ground-based data. Isdo et al. (1977 and 1979) developed the stress-degree-day (SDD) concept which relates the crop yield to the plant water stress. The model uses the difference between crop canopy temperature, measured by the scanner, and ambient air temperature to calculate the SDD. When these data were combined with the traditional growing-degree-day concept, reasonable estimates of yield were possible.

2.3 Vineyard Management for Yield Optimization

Effective management practices for vineyard yield optimization maintain a delicate balance between plant health and plant vigor. Health is defined by the levels of disease, insects and nutrients present in and on the vine. Vigor is the rate of vine growth which is usually measured by the annual weight of prunings taken in the dormant period. Generally, an increase in plant health results in an increase in yield, however, the same does not necessarily hold true for vigor (Shaulis, 1980, personal communication).

If the vine has too little leaf area, it will not be able to absorb enough sunlight for chlorophyll and sugar production. The resulting yield will be low. On the other hand, if there is too great a leaf area, the layering effect in the canopy will block the sunlight from reaching the leaves most crucial to fruit production. Again, the grape yield will be depressed. Therefore, to optimize yield, the vineyard manager must control fertilizer and other inputs to obtain a maximum benefit for plant health while maintaining a moderate rate of vine growth or vigor.

2.3.1 Traditional Methods

In New York State, vineyard managers depend on field observations for plant status assessment. The viticulturalist walks each vineyard and, by close observation of the leaves and fruit, locates low vigor vines. If the exact cause of decline cannot be identified in the field, laboratory analyses are run on leaf and soil samples. Once a problem is defined, a proper treatment is developed and applied.

Vineyard management for yield optimization consists of combinations of weed control, fertilization, pruning, and grafting of disease resistant rootstock (Shaulis and Steel 1969). To determine the appropriate treatment for a vineyard, viticulturalists rate plant vigor, leaf area, size and color. This information can then be combined with pruning weight, historic yields, and climatic factors to estimate future yield.

Experiments at Fredonia, N. Y., study the response of Concord grapevines to combinations of the various treatments (Shaulis et al 1955, 1969). Statistical analyses show significant relationships between yield and most treatments. These include grafted rootstocks, varying levels of pruning severity, weed control, increasing amounts of nitrogen, and different training methods. The interactions of these treatments often have a more significant effect on yield than when considered separately.

2.3.2 Remote Sensing Methods

Traditional assessment of vineyard plant, soil and drainage status over large regions can be very time consuming. A more cost and time effective assessment can sometimes be made with remotely sensed data.

For example, using black-and-white aerial photography, Clore (1973) observed a lack of canopy cover in vineyards in Washington State. Field checks found the gaps to be the result of poor soil conditions and crop damage.

Feldner and Allan (1976) also used black-and-white airphotos to monitor vineyards. On three dates during the season, they obtained 1:10,000 scale photos of a 270 km^2 grape growing region in Spain with the intent of monitoring the total acreage in vines and determining when vineyard managers were planting new vineyards.

Local farmers, trained in photo interpretation, delineated four vine categories based on age differences. Plants in the two older categories were accounted for with 100 percent accuracy. The two young vine classes were defined with only 70 percent accuracy. A comparison of the three dates of photography showed that spring and early summer photos were useful for identifying vines at least two years old. However, fall photos were best for identifying all classes of vines.

Philipson et al. (1980) used 1:24,000 scale black-and-white aerial photography to determine soil drainage limitation classes at a new vineyard site. Using stereoscopic analysis, they delineated three classes based on relative photo tone and topography. Existing tile drainage was also located. Based on this study, new tile drains were installed as needed, and existing drains were incorporated into the system.

In a follow-up study, Philipson et al. (1980) used large-scale color-IR aerial photographs to assess vine health and vigor. Using visual airphoto interpretation, they defined six classes of first-year vine status, high vigor, average vigor, low vigor, very low vigor or gap, gap or dead plant, and double plant. Field checking of the six classes found a 100 percent agreement with actual plant condition. To make their survey more useful to the vineyard manager, they grouped the vines into broader classes of low-to-average vigor and average-to-high vigor. Management decisions based on these vineyard status maps resulted in increased input to low vigor areas.

Additional uses of color-IR aerial photography for vineyard management were developed by Wildman (1979) for some California vineyards. Tonal differences of vines were used to determine levels of plant vigor. They were also used to monitor plant response to soil depth, texture, compaction, irrigation drainage problems, disease, and pest infestation. By delineating patterns of tonal changes, the areal extent of stress-affected plants was documented. An operational program that acquires annual photos was established. This cost- and time-effective photo analysis will be used by vineyard managers to determine the optimum time to replace entire vineyard blocks. In addition, soil irrigation practices which were developed from the analysis resulted in greatly increased yields.

Crop yield was the focus of another study by Philipson et al. (1980). They used airborne multispectral scanner digital data, as well as color-IR film, to evaluate 16 vineyard sections of three grape varieties. Average plant yields for each variety were compared statistically to two plant parameters measured on the film and to the average radiance value of each variety measured in each of the 11 scanner channels. The two plant parameters, canopy continuity and width, showed little correlation with yield. However, the relationship of yield with reflectance, as measured by the scanner, was found to be significant. In particular, the Concord variety showed the highest correlations (Table 2.1).

Thermal-IR imagery was used to assist in vineyard site development for cold-sensitive grape varieties developed in the Niagara fruit belt (Stewart et al., 1978). A line scanning radiometer (800-1400 nm) was flown during the spring of three successive years. Ground truth for surface temperatures and meteorological conditions were also recorded. Three classes of temperature zones were

Table 2.1

Correlation Between Yield and Remotely Sensed Spectral and Morphological Factors. (Philipson et al., 1980).

Variety	Delaware		Concord		Catawba	
Correlated Variables	r June	Aug	r June	Aug	r June	Aug
Yield, 1977 versus:						
Chan 1	-.13	-.79	-.02	-.90	-.22	-.47
Chan 2	-.13	-.80	-.02	-.94	-.25	-.45
Chan 3	-.10	-.79	-.00	-.96	-.25	-.45
Chan 4	-.06	-.76	.01	-.96	-.27	-.49
Chan 5	-.10	-.80	.00	-.96	-.26	-.41
Chan 6	-.11	-.82	.01	-.96	-.24	-.33
Chan 7	-.11	-.82	.01	-.96	-.21	-.33
Chan 8	.31	-.71	.07	-.96	-.18	-.71
Chan 9	.79	-.64	.12	-.95	-.13	-.85
Chan 10	.88	-.67	.12	-.94	-.11	-.82
Chan 11	-.39	-.98	-.58	-.65	-.34	-.11
Continuity		.19		-.16		-.16
Width		.19		-.16		-.16
Yield, 1976	.99		-.81		.45	

distinguished: cold, intermediate and warm. Cold areas were found to be sites where plants were most likely to sustain frost damage under radiation frost conditions. Therefore, frost resistant varieties were planted at those sites.

2.4 Summary

Although little research has been carried out specifically on grape yield, the literature shows that yield prediction for some crops is possible with remotely sensed data.

The spatial properties of black-and-white and color-IR aerial photography have been utilized in combination with agronomic data to predict yield. However, the applications of film spectral responses have not been well developed or documented. Fruit has been identified by its density on large-scale color-IR photography, but canopy reflectance was not examined at the same time.

Most studies of crop canopy reflectance and its relationship with plant agronomic variables have been performed with non-photographic systems, in particular with radiometers and the Landsat Multispectral Scanner. The bulk of this research has applied remote sensing methods to grain crops and legumes. The data base that exists for these crops is now quite extensive.

Generally, researchers have found that crop parameters correlate best with reflectance measured in the red and near-IR wavelengths, and with ratios of those wavelength bands.

In the actual study of vineyard reflectance with color-IR film and an airborne multispectral scanner, certain conclusions can be drawn. First, that differences in vine vigor can be defined visually by observing variations in the response of color-IR film. Second, that some relationship appears to exist between yield and reflectance of Delaware and Concord grapes.

The present study was conducted to further define the specific spectral properties of vineyard canopies and to determine the relationship of these properties to crop yield. In particular, several sets of spectral measurements of single vine and whole vineyard canopies were collected and were related statistically to yield, agronomic parameters, and management input.

CHAPTER 3

MATERIALS AND METHODS

3.1 Site Descriptions

Remotely sensed data were collected at two locations in New York State. The first, the Vineyard Laboratory of the New York State Agricultural Experiment Station, at Fredonia, is an experimental site with highly controlled plant treatment and conditions. The ability to acquire detailed information about individual vines made this an excellent site for collection of the ground-based data.

The aerial data would have to be acquired over a larger region where access to a reasonable number of Concord vineyard sections would be possible. The Taylor Wine Company vineyards at Hammondsport, New York, easily met this condition. In addition, historical data were available for Hammondsport as past remote sensing yield studies were based at this site (Philipson et al, 1980).

3.1.1 Fredonia

3.1.1.1 Physical Characteristics

The Vineyard Laboratory at Fredonia is located in western New York approximately three miles southeast of Lake Erie (Figure 3.1). The vineyards are part of the Chautauqua County grape belt, one of the highest grape production regions in New York.

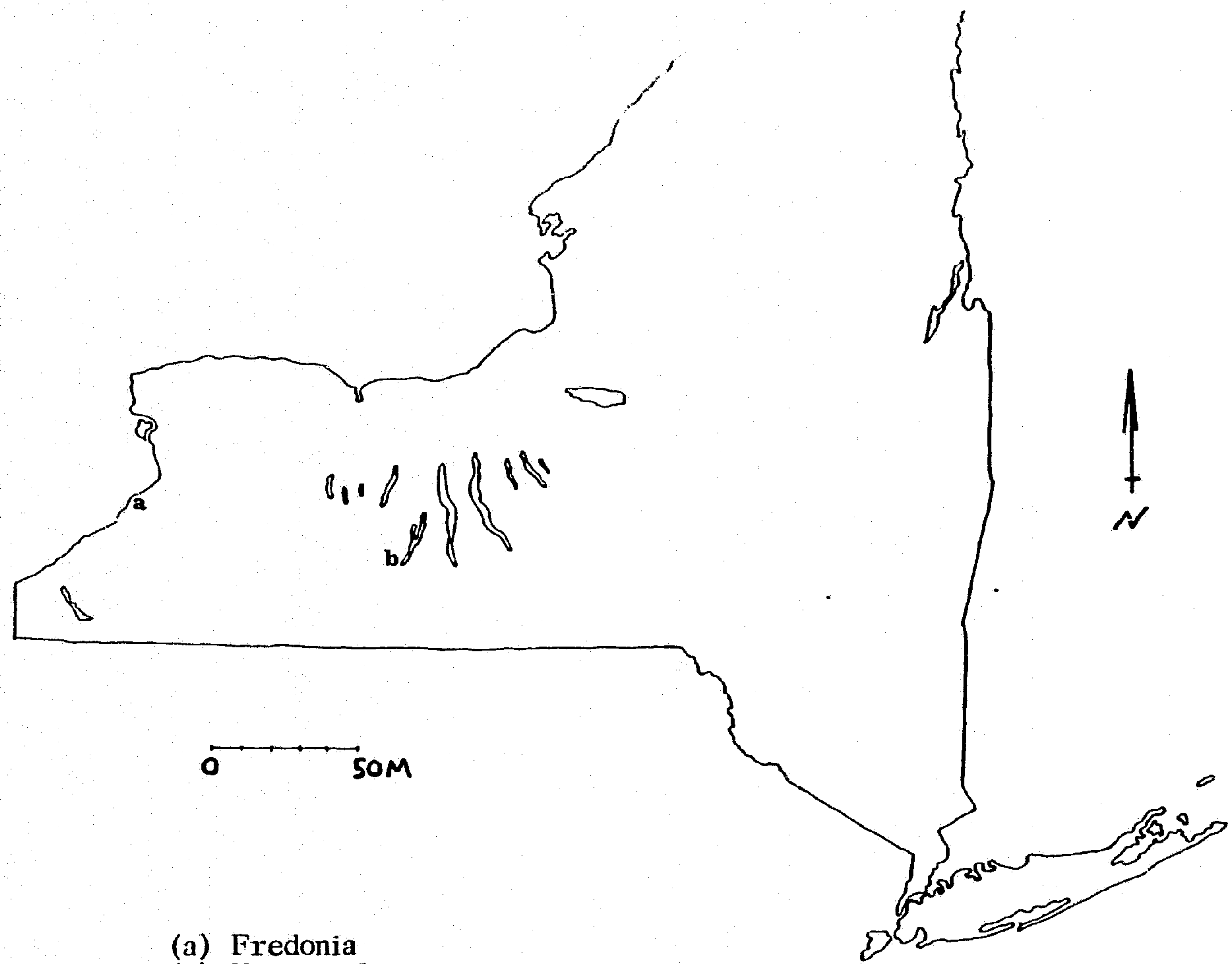

Figure 3.1 Locations of the two vineyard study sites in New York State.

The high yields are largely due to climatological factors. The regional climate is strongly moderated by the presence of Lake Erie, resulting in a lengthened growing season (Pack, 1978). At Fredonia, the average length of frost-free growing season is 175 days (Patrie, 1951).

The terrain, modified by glacial lakes, is smooth and level (Figure 3.2). Local soils are derived from glacial till, lacustrine sediments and old beach deposits that are remnant of glacial lakes (Morrison et al., 1914).

3.1.1.2 Vineyard Management Practices

In 1956, the west tier vineyard at Fredonia was planted with Concord grapevines on deep, well-drained, acid soils (Shaulis and Steel, 1969). It serves as a test site for studying the effects of various management practices on vine health, vigor and yield. These practices include combinations of nitrogen input, weed control, pruning, and training. A broad range of vine sizes and yields result from the interactions of the treatments.

For this study, nine Concord treatment blocks of six vines each were selected on the basis of their expected yields (Table 3.1). Treatment blocks that represented low, medium and high management input were examined. A brief description of each of the treatment inputs follows (Shaulis and Steel, 1969).

Cultivated vs Sod--There are two types of weed control used. The first is sod, where grass between rows is mowed several times during each growing season. No tillage occurs in these rows, but an herbicide is applied. Cultivated blocks receive discing between rows

Figure 3. 2 The gently sloping terrain at Fredonia is evident in the regional topographic contours. (U. S. G. S. Dunkir, New York 15' Quadrangle)

Treatment	Cultivated or Sod	Pruning Severity	Rootstock	Nitrogen N/Ac/Yr	Training	Location Row #	Location Vine #
1	C	30+10	Own	0	HRU[2]	409	7-12
2	C	30+10	Own	50	HRU[2]	414	20-25
3	C	30+10	Own	100	HRU[2]	413	33-38
4	S	30+10	Own	0	HRU[2]	413	1- 6
5	S	30+10	Own	50	HRU[2]	409	33-38
6	S	30+10	Own	100	HRU[2]	408	14-19
7[1]	C	30+10	Grafted	100	HRU[2]	416	33-38
8[1]	S	30+10	Own	0	GDC[3]	428	20-25
9[1]	C	30+10	Grafted	100	GDC[3]	406	20-25

[1] These represent the high and low extremes of treatment.

[2] HRU is the Hudson River Umbrella.

[3] GDC is the Geneval Double Curtain

Table 3.1 Management Treatments Applied to Selected Concord Vines at Fredonia, New York (See Appendix A).

throughout the season to prevent the establishment of grass and weeds.

Pruning Severity--The scale of pruning severity of all plants examined in detail was kept constant. Thirty nodes are retained at pruning time for the first pound of prunings and ten additional nodes are retained for each additional pound of prunings.

Rootstock--The grafted vines have a phylloxera-resistant rootstock.

Nitrogen Fertilization--The nitrogen application varies between 0, 50, and 100 lbs. N/acre/year.

Training--The Hudson River Umbrella, which is very common in New York State, is a single curtain training method where the vine spreads along a single wire. The Geneva Double Curtain in which the vine is positioned along two wires, several feet apart, is becoming more popular as this method allows the vine more space to spread (Figure 3.3). Thus, a greater number of leaves are directly exposed to sunlight, and an increase in chlorophyll production results.

3.1.2 Hammondsport

3.1.2.1 Physical Characteristics

The Taylor Wine vineyards at Hammondsport are located on the western shore of Keuka Lake. The vines are grown on moderate slopes, approximately 350 meters above the lake surface (Figure 3.4). Good air drainage, the proximity of the lake, and the southern exposure moderate the local climate and extend the frost-free growing season two to five weeks longer than in nearby areas of higher

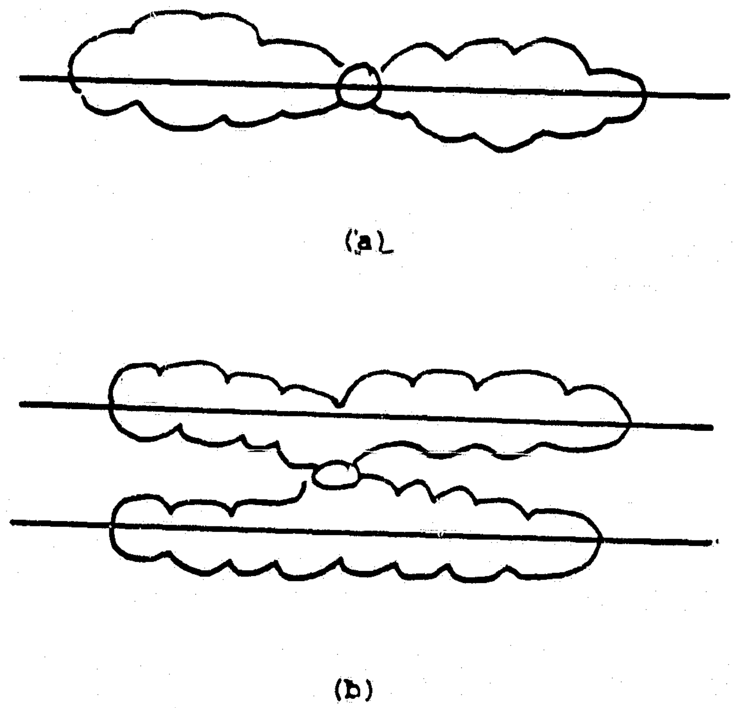

Figure 3.3 Single (a) and double (b) curtain training of vineyard canopy.

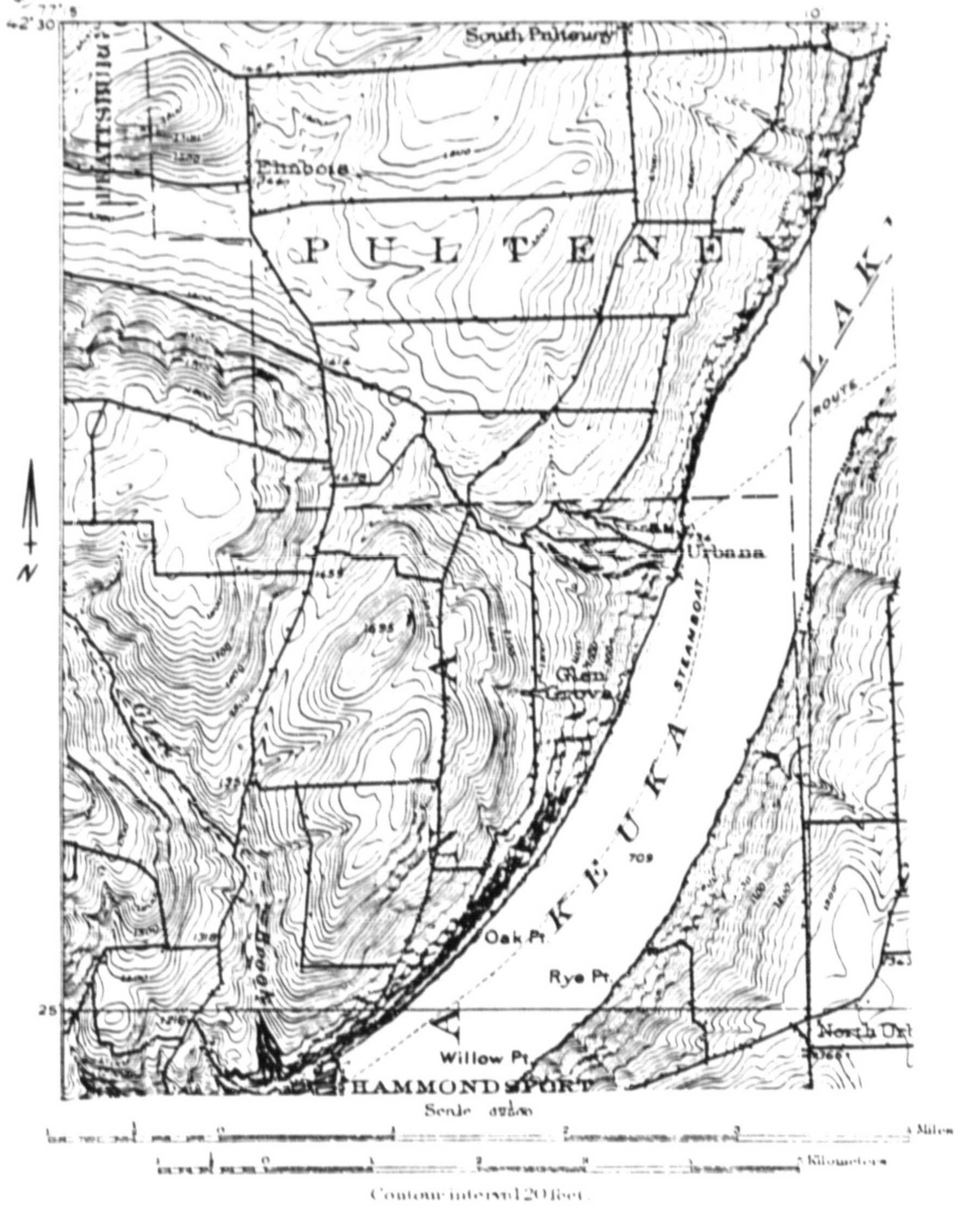

Figure 3.4 The Taylor Vineyards are grown on the moderate slopes that form the western boundary of Keuka Lake. (U.S.G.S. Hammondsport Quadrangle)

elevations (Harding, 1957; Pack, 1978).

Glaciation shaped the sloping terrain and deposited glacial till and moraine from which the local soils are derived. In addition, some soils are developed from lacustrine sediments (USDA, 1978). In general, sites planted with vineyards have deep gravelly soils; however, even the poorer soils are cultivated where slope and climate are the dominant factors in producing high yields.

3.1.2.2 Vineyard Management Practices

The specific vineyard sections examined at Hammondsport were selected on the basis of three factors: the canopy continuity observed on 1977 color-IR airphotos, age, and the necessity that they be planted with only one variety of grape, Concord.

The management treatment of these eight sections is comparable to the Fredonia site. The crop inputs are summarized as follows (Salva, 1981, personal correspondence) (Also, see Appendix A).

Pruning Severity	30 + 10
Rootstock	own
Total N/acre/yr	350 lbs.
Training	Umbrella Kniffen (single curtain)
Cultivation and Herbicide	Alternate row

Alternate rows are disced until late in the growing season. At this time, an oat cover crop is planted in the disced rows. Every other row is sprayed with an herbicide and mowed throughout the season.

3.2 Data Selection

3.2.1 Information Needs

The intent of this research was to develop a detailed characterization of Concord vineyard canopy reflectance and to synthesize this information into a practical format for vineyard managers. Consequently, a controlled setting was required for spectral data collection. The data were compared with additional spectral data that were imaged from an aerial platform during the same season that the ground measurements were made.

Already existing remotely sensed data were not examined in this project, however, these data may be useful for historical information on crop status and for testing theories developed from the current study. A list of available imagery can be obtained from the New York State Department of Transportation.

3.2.2 Field Data

Vineyard agronomic variables often do not have the same relationship to crop yield as with other crops for which substantial data have already been collected. For example, wheat yield is usually positively correlated with wheat leaf area index. However, with vineyards, too much leaf can result in excessive layering and depressed yield. The optimum leaf area is not easily determined. Therefore, detailed information on vineyard reflectance is needed to study yield factors specific to grapevines. This information was collected at Fredonia with field portable spectroradiometers.

The ISCO spectroradiometer was selected largely for three reasons. The first is the wide spectral range over which it can measure spectral radiance (400-1100 nm) (Figure 3.5). The second is the large number of discrete bands available within that range. The instrument is capable of measuring 30 bands, each of 25 nm width. In addition, the instrument was expected to be portable and, as such, convenient for work in the field. Three such instruments were available at Cornell.

The spectroradiometer has three main parts (Figure 3.6). The first consists of a cosine collector with a hemispherical field-of-view (FOV) on the end of a fiber optic probe (Rennilson, 1978; Hudson, 1969). This system collects radiant flux over a 180° FOV and transfers it to the monochromator. The monochromator or wedge interference filter is part of the second system which divides the radiant flux into narrow spectral bands. To reach the filter the light first passes through a chopper which automatically adjusts the dark current to prevent machine drift. The filter allows continuous scanning from 400-1100 nanometers (nm), through the visible and near-infrared ranges.

The third system consists of a photodiode, amplifier and coherent detector. Together these convert the radiant flux into an electrical signal. The signal is measured in units of energy rate intensity per bandwidth. The meter of the spectroradiometer can then be read in microwatts per centimeter squared per nanometer (w $cm^{-2}nm^{-1}$). There are eight ranges of sensitivity on the scale of 0.3, 1.0, 3.0, 10, 30, 100, 300 and 1000 w cm^{-2} nm^{-1}. These measurements can be converted to percent incoming radiance reflected by means of a calibration technique (Section 3.4.1.1).

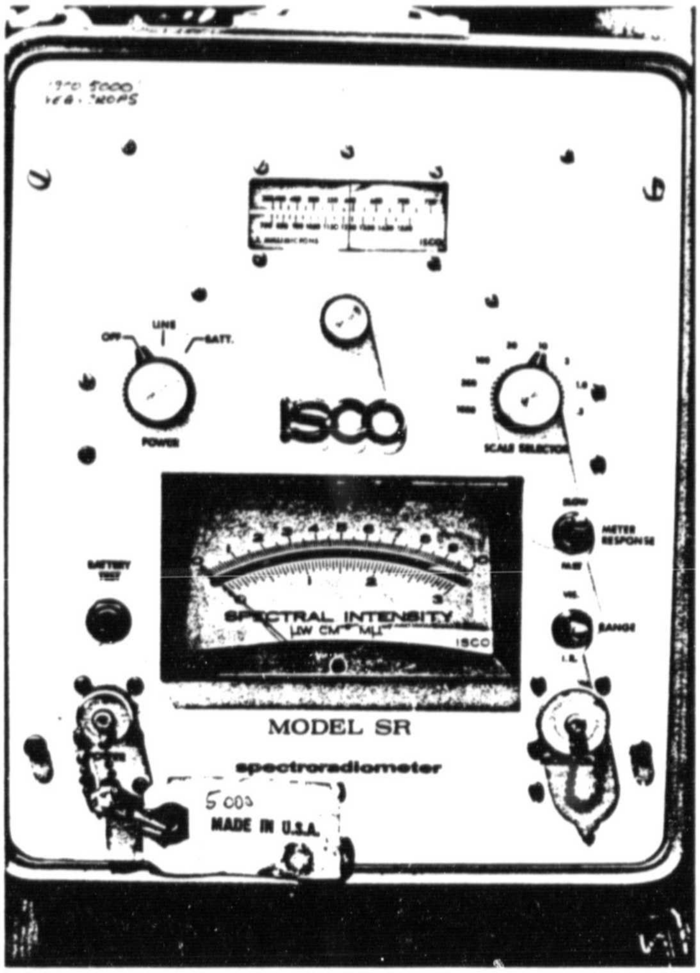

Figure 3. 5 ISCO spectroradiometer showing scale and sensitivity ranges.

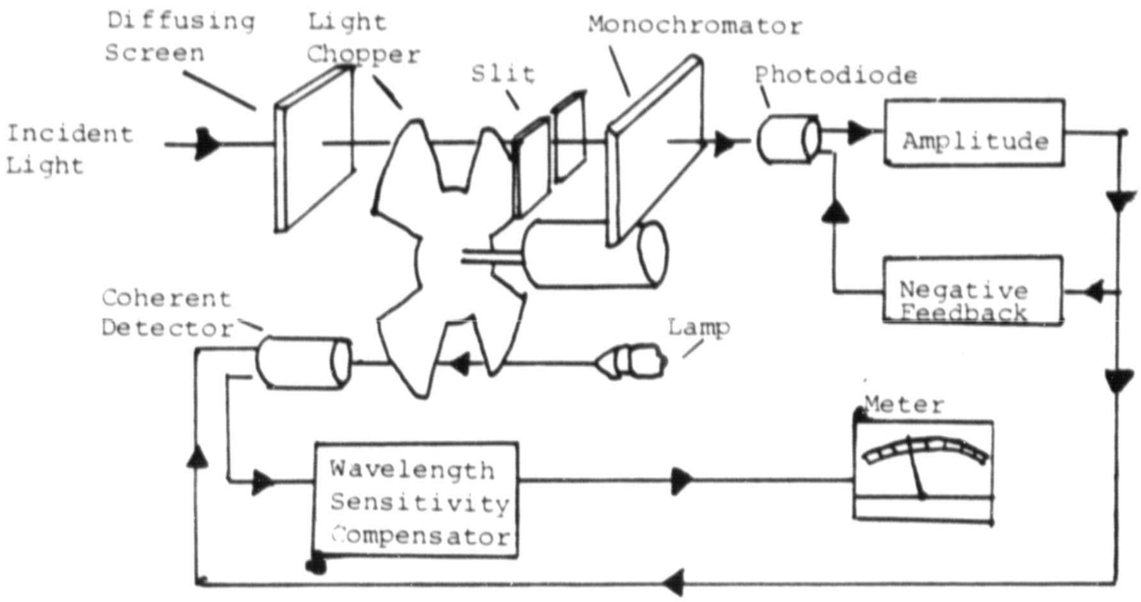

Figure 3.6 Diagram of the significant internal systems of the ISCO spectroradiometer (ISCO manual).

Color-infrared film was also selected for ground-level data collection. The portion of the spectrum that the film responds to has been found to be useful in yield studies. In addition, the technology involved in exposing, developing and analyzing the film is relatively accessible to vineyard managers.

The viticulturalists at Fredonia annually collect detailed agronomic information on each vine, including counts of yield, nodes, clusters and other agronomic variables. Both current and historic data of this nature were made available to this project (Appendix A).

3.2.3 Airborne Data

Selection of airborne sensors for the study of vineyard canopy reflectance was based on agronomic characteristics of the crop and on previously discussed information needs. Sensor spatial resolution was limited by the distance between rows of vines and by the canopy width. Furthermore, adequate spectral resolution was required to discriminate between vineyard canopy, grass boundaries, weeds and soil, as well as to correspond to the ground sensors used.

The Bendix Modular Multiband Scanner (M2S), used in the preliminary vineyard assessment study, was used again for airborne data collection. The M2S is an optical-mechanical line-scanning system that is operated from an aircraft (Bendix, 1972). The system contains an imaging spectrometer that measures energy over a spectral range of blue through the thermal IR (420-1040 nm), split into ten narrow wavelength bands (Table 3.2). There is also a thermal detector that collects data from 800-12.08 nm Spatial resolution limited by the instantaneous field-of-view (IFOV) of 2.5

Table 3.2

M2S Channel Classification

Channel Channel	Range (Nanometers)	Nominal Spectral Band
1	420-460	blue
2	460-500	blue
3	500-540	green
4	550-580	green
5	580-620	green/red
6	620-660	red
7	660-700	red
8	700-750	near-infrared
9	770-860	near-infrared
10	960-1040	near-infrared
11	8000-12080	thermal-infrared

Table 3.3

Flight Data Summary
NASA Mission 430--3 September 1980

Sensor	Altitude, ft.	Pixel Resolution	Nominal Scale
M2S IFOV = 2.5 mrad	1500	At Nadir = 2M x 2M	
		At image edge = 6.2M x 6.2M	
	3000	At nadir = 5M x 5M	
		At image edge = 12 M x 8M	
Zeiss Camera Focal Length = 15 cm.	1500		1 = 3,000
	3000		1 = 6,000

milliradians. The smallest possible ground area that can be resolved, the resolution element, is determined by the IFOV in combination with the plane altitude. The swathwidth is broken into 803 elements which are represented on the final digital format by picture elements or "pixels."

The scanning action of the detector is accomplished by mechanically rotating a mirror that moves the IFOV in a direction perpendicular to the flight line (Bendix, 1972; Lillesand and Kiefer, 1979). The swath width is determined by the total scan angle of 50° on either side of the nadir. The spectral information is electronically converted to a numerical format of 256 brightness levels. It is recorded on high density tape while still on the aircraft. Eventually, the information is recorded on computer compatible tape (CCT) and is then accessible to the user.

The spectral range of the M2S was comparable to that of the spectroradiometers and was split into eleven discrete bands. Therefore, differences between cover types could be defined by examining reflectance in one or more of these channels.

In addition to the M2S, color-infrared film was selected for aerial data collection for the same reasons that it was utilized at ground level, as well as for the advantages of the film's spatial resolution relative to that of the scanner. The film used was Kodak Aerochrome, infrared 2443, (24 cm format). The camera focal length was 15.25 cm.

3.3 Data Collection

3.3.1 Instrument Calibration

In order to provide accurate and viable reflectance data, the instruments were calibrated using a procedure developed by Duggin (1980a) and modified by Duggin and Philipson (1981). Their calibration equations account for the sun-angle dependence of the cosine receptors used and for the wavelength and time dependent variations between instruments.

A white Lambertion reflectance target was used as a standard for the instrument calibration. The field portable target was coated with barium sulfate, and its absolute reflectance values were determined at the Eastman Kodak Research Laboratories, Rochester, N.Y.

The fiber optic probe of each instrument was equipped with a thirty-degree cone receptor to limit the field of view. One instrument had a one-meter probe (Spectroradiometer #1) and the other two had two-meter probes (Spectroradiometer #2 and #3).

To determine the initial between-instrument calibration factor, the three receptors were mounted one meter above the target which was set in a horizontal plane with a level (Figure 3.7). Each probe viewed a circle with a radius of approximately 24 centimeters.

Three operators took simultaneous readings from the spectroradiometers at thirty wavelength intervals, each of 25 nm width (Figure 3.8). The two spectral ranges of the instruments were visible, 400-750 nm, and near-infrared, 750-1150 nm.

Data collected on July 9 and 10 were used to develop the

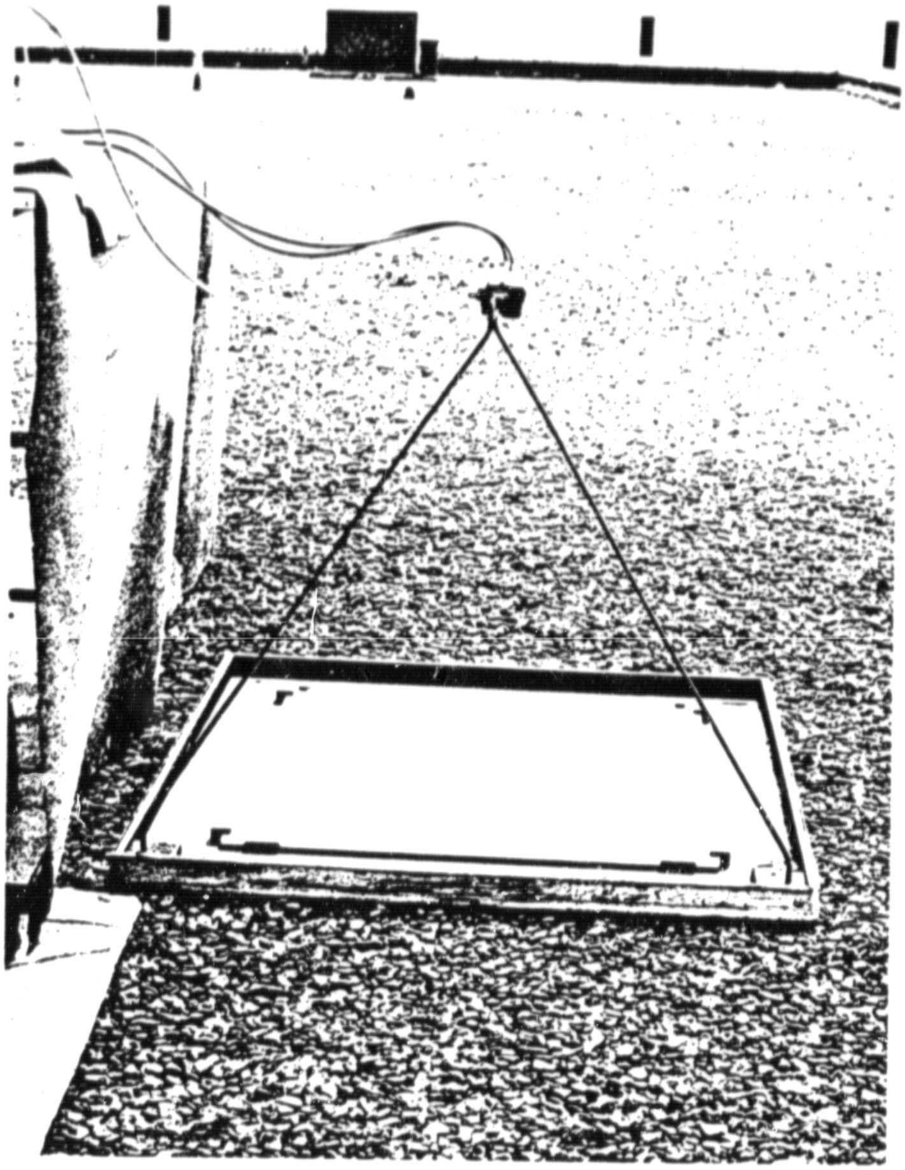

Figure 3.7 Three receptors mounted horizontally above the white Lambertian reflectance target.

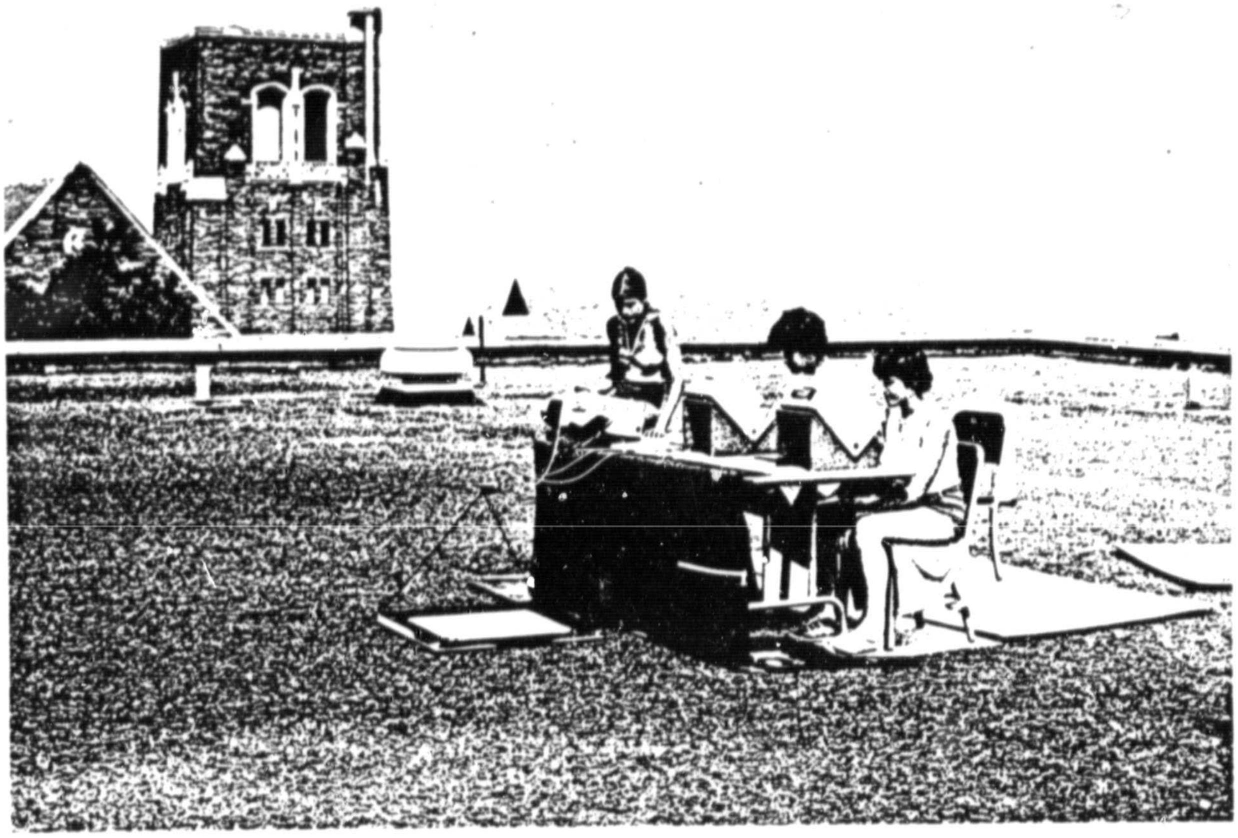

Figure 3.8 Simultaneous manual readings were made by three operators.

calibration equations at each wavelength. The calibration factor ($C(\lambda)$) was calculated for each pair of instruments such that

$$C_1(\lambda) = \frac{V_1(\lambda)}{V_2(\lambda)}$$

and

$$C_2(\lambda) = \frac{V_1(\lambda)}{V_3(\lambda)}$$

where at any wavelength, $C_1(\lambda)$ is the calibration between spectroradiometers #1 and #2, and $C_2(\lambda)$ is the calibration between spectroradiometers #1 and #3. The voltages measured from the respective instruments are $V_1(\lambda)$, $V_2(\lambda)$ and $V_3(\lambda)$ (Duggin and Philipson, 1981).

It was found that the calibration factors varied with the length of time instruments were operated due to different rates of instrument drift (Duggin and Philipson, 1981). Therefore, regression equations based on operation time were developed to predict the final calibration factor at each wavelength.

3.3.2 Field Data Collection

Each of nine management treatments selected for study was applied to a block of six plants (Table 3.1). To facilitate field work, two viticulturally representative plants were picked from each block for detailed study. This evaluation was based on the viticultural history of each vine, its position relative to others in its block, and its apparent health and vigor. Thus, spectroradiometric measurements were collected on 18 vines out of a total of 54 vines. These data were collected at three times during the season, July 17 or 18, August 21 or 22, and September 12, 1980. Weather conditions in

July and September were fairly cloud-free, although the August date was heavily overcast.

In order to collect in situ radiance data over the Concord vineyard canopy, the spectroradiometers were mounted on a grape harvesting tractor that was stripped of the normal harvesting and pruning equipment (Figure 3.9). Thus, the instruments could be moved over the vines without damaging the leaves or fruit. The spectroradiometer receptors from units #2 and #3 were positioned on rods one meter above the canopy target. The two probes were placed 20 centimeters apart so that they viewed the canopy of the same plant (Figure 3.10). The probe of Spectroradiometer #1 was mounted one meter above the standard reflector in order to obtain calibration data for each reading.

Simultaneous measurements were made from the three instruments (Figure 3.11). The spectral reflectance of each vine's canopy could then be calculated by using the following equations (Duggin and Philipson, 1981).

For Spectroradiometer #2:

$$R_1(\lambda) = \frac{V_2(\lambda)}{V_1(\lambda)} \times K( );$$

and for Spectroradiometer #3:

$$R_{(2)}(\lambda) = C2(\lambda) \times \frac{V_3(\lambda)}{V1(\lambda)} \times K( ),$$

where at any wavelength, ,

$R(\lambda)$ = the present reflectance;

$C(\lambda)$ =the calibration factor adjusted for machine drift;

$V(\lambda)$ = the voltage measured from each radiometer; and

Figure 3.9 Spectroradiometers mounted on a grape harvesting tractor for field data collection.

Figure 3.10 Positioning of cone receptors from Spectroradiometers #2 and #3.

FIELD SPECTROMETER DATA

ISCO No.	DETECTOR:	OBNO = T =	R.H. =	FLUX =
OBSERVER:	ASSISTANT:	OBNO = T =	R.H. =	FLUX =

DATE	TARGET	LOCATION	NOBS	LAT	LONG	LONG (S.M.)	EOT	DECLINATION

OBNO	TARGET, ROCK TYPE OR METEGROLOGICAL CONDITIONS	TIME

VIS. λ: 400	425	450	475	500	525	550	575
600	625	650	675	700	725	750	
I.R. λ: 750	775	800	825	850	875	900	925
950	975	1000	1025	1050	1075	1100	

OBNO	TARGET, ROCK TYPE OR METEOROLOGICAL CONDITIONS	TIME

VIS. λ: 400	425	450	475	500	525	550	575
600	625	650	675	700	725	750	
I.R. λ: 750	775	800	825	850	875	900	925
950	975	1000	1025	1050	1075	1100	

Figure 3.11 Data sheet on which spectroradiometer readings were recorded (Duggin, 1980).

$K(\lambda)$ = the actual spectral reflectance of the standard reflector.

Simultaneous readings with the three instruments were made at the beginning and end of each day's data collection with all three receptors mounted over the Lambertian standard reflector. Thus, changes in instrument behavior could be compensated for by adjusting the calibration factors.

The color-IR photos were taken with a Hasselblad camera (70 mm. format) held at a height of approximately one meter above the canopy. One photograph was exposed over each vine immediately following the spectroradiometric readings.

3.3.3 Airborne Data Collection

The aerial mission for data collection over the two vineyard sites was flown by NASA on September 3, 1980. The plane flew west of the Fredonia site which resulted in inadequate data for aerial analysis of the experimental vineyards. In addition, although the Hammondsport site was not adequately flown to cover all the Taylor Winery vineyards, sufficient aerial data were collected to perform analyses using eight Concord vineyard sections.

The mission was flown at two altitudes to provide sufficient detail. Flight data are summarized in Table 3.3.

3.4 Data Analysis

The purpose of the data analysis was to define the relationship of canopy reflectance to yield and other plant variables. Statistical analyses performed on the data included correlations and regressions and analyses of variance.

3.4.1 Spectroradiometer Data

Using the calibration equations described in Section 3.3, the spectroradiometric measurements of radiance were transformed into percent reflectance. The reflectance data were plotted versus wavelength for each plant. In general, these reflectance curves were typical of green vegetation with peaks in the green and near-infrared regions, and troughs in the blue and red regions (Figure 3.12).

Additional data were generated from the reflectance values. First, linear combinations of pairs of spectral bandwidths were developed to produce four new spectral variables. The combinations selected were those found useful in previous crop studies (Chapter 2). Data points found at the peaks and troughs of the reflectance curves were averaged with two points nearest them to develop the new variables. The resulting linear combinations were:

$$\frac{\% R_{900} - \% R_{675}}{\% R_{900} + \% R_{675}} \quad ; \qquad (1)$$

$$(\% R_{900} - 5 \times (\% R_{550})); \qquad (2)$$

$$\frac{\% R_{550}}{\% R_{675}} \quad ; \text{ and} \qquad (3)$$

$$\frac{\% R_{900}}{\% R_{675}} \qquad (4)$$

where, for example, $\% R_{900}$ is the percent reflectance measured at the 900 nm wavelength interval.

The second set of data generated consisted of the thirty wavelengths of spectroradiometer data averaged into spectral bandwidths

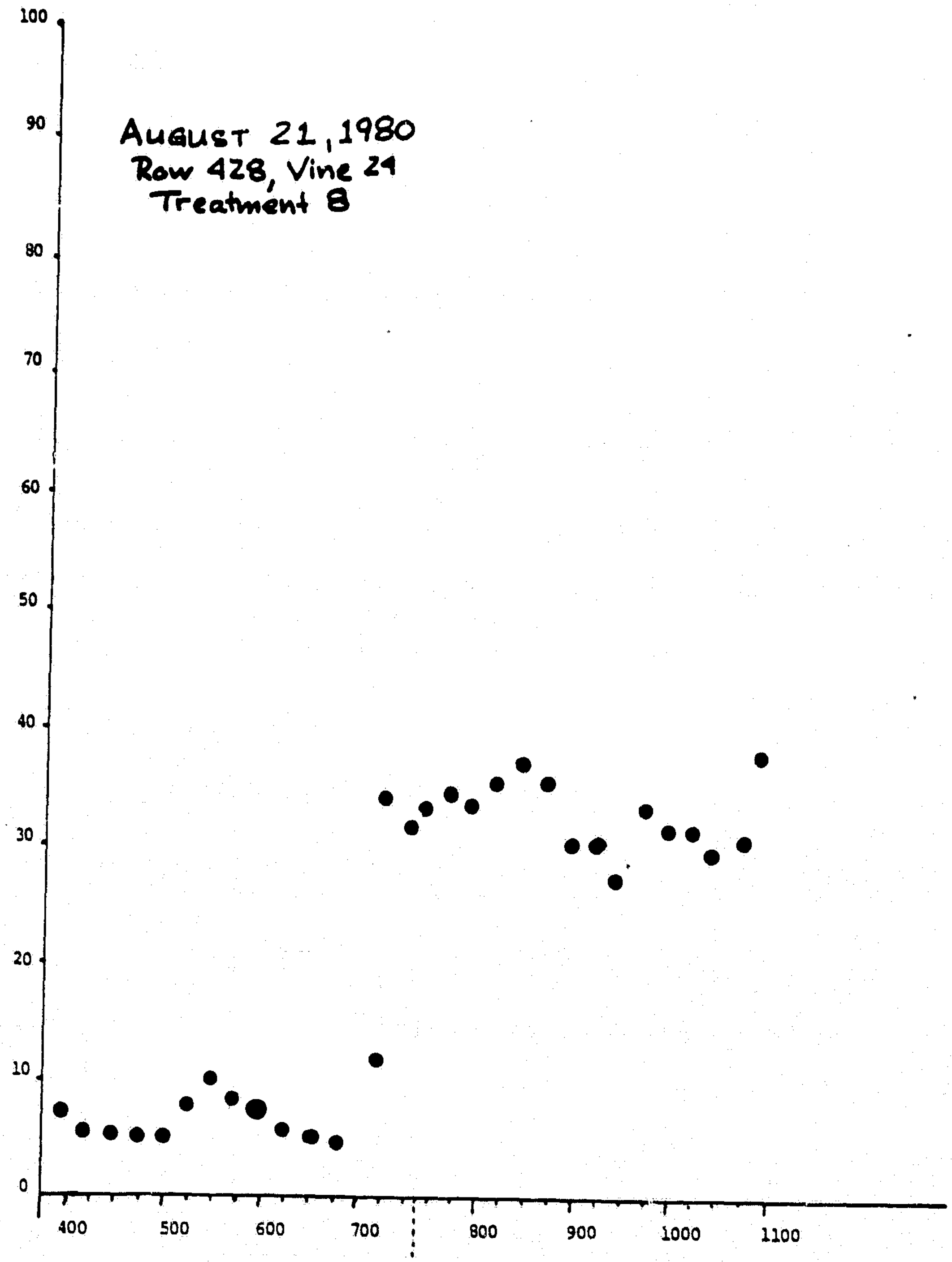

Figure 3.12 Typical spectra of grapevine canopy measured by spectroradiometers

corresponding as closely as possible with the visible and near-infrared channels of the M2S (multispectral) scanner (Table 3.4). This data set of averaged spectral bandwidths will be referred to as the simulated multispectral scanner (SM2S) data.

3.4.1.1 Analysis of Reflectance and Yield

The preliminary analyses of the Concord canopy reflectance data were based on two assumptions. The first was that all plants with similar yields would reflect in a like fashion that would be different from plants with lower or higher yields. The second assumption was that plants with a low nitrogen input would yield less than plants which received a high nitrogen input (i.e., pounds of nitrogen applied was the management treatment which had the strongest effect on yield). Thus, all 18 vines sampled were examined statistically as one group.

In order to define any linear relationships between yield and percent reflectance (%R) in 30 wavelengths, the variables were correlated with each other. To define possible curvilinear relationships, the %R data were also correlated with transformation of yield (Y). They were $1/Y$, Y^2, Y^3, and Y^4. The %R data were plotted against yield and its transformations.

In addition, the yield of a vine for any given year is affected by the plant condition and yields during the three previous years, (Shaulis, 1981, personal communications). For example, a vine that has a low yield one year will have stored, unused sugars that will contribute to a higher yield in the following year. Therefore, yields for all 18 plants from 1977 to 1979 were correlated with data collected in 1980 for yield and reflectance. Trends in yields were

Table 3.4 Spectral Bandwidths of the Simulated M2S Reflectance Data

Simulated M2S (SM2S) Bands	Spectroradiometer Bands		
Band	Band	'nm	
1	1	400	
	2	425	
	3	450	
2	4	475	
3	5	500	
	6	525	
4	7	550	
	8	575	Visible Range
5	9	600	
	10	625	
6	11	650	
7	12	675	
	13	700	
8	14	725	
	15	750	
9	16	750	
	17	775	
	18	800	
	19	825	
	20	850	
	21	875	
	22	900	Near-Infrared Range
	23	925	
10	24	950	
	25	975	
	26	1000	
	27	1025	
	28	1050	
	29	1075	
	30	1100	

evaluated by correlating combinations of 1980 yield and other years with 1980 data.

The SM2S %R data were correlated with yield using data from the 18 plants. Ratios and other linear between-channel combinations were also developed for SM2S %R data, and correlated with yield. They were:

*B9 - B7/B9 + B7	B9/B5
B9 - (5 x B4)	B1/B5
B4/B7	B1/B7
B9/B11	B1/B10
B7/B11	B9/B7
B9/B10	

3.4.1.2 Analysis of the Nitrogen Effect on Yield and Reflectance

Shaulis and Kendall (1969) found that the management treatment which most strongly affects yield is the quantity of nitrogen applied per year. The second most important effect on yield is due to the weed control method used. The combination of these two treatments determines the available nitrogen. Therefore, 12 of the 18 vines sampled were stratified into two groups of six vines based on nitrogen and method of weed control.

The first group was cultivated for weed control (Treatments 1-3) while the second was planted with sod and sprayed with herbicides (Treatments 4-6) (Section 3.1.1.2). In each group, two plants received 0 lbs. nitrogen, two received 50 lbs. nitrogen and two

*B = band

received 100 lbs. nitrogen. The yield data of each group was correlated with %R. A two-way analysis of variance was run using the 12 plants selected to determine the effect of nitrogen input and weed control on yield. In addition, to determine whether the response of the 12 plants to nitrogen input was representative of grapevine behavior, the same analysis of variance was made using all plants in the six treatment blocks from which they were selected. Treatments 7, 8 and 9 included either grafted rootstock or double curtain training. Both of these could cause a significant change in yield or vine vigor, so they were not used in the above analyses. However, to further define the effect of nitrogen on reflectance, all nine management treatments were broken into groups with comparable nitrogen input. Based on this division, plots of %R versus wavelength were made.

3.4.1.3 Analysis of Agronomic Variables and Reflectance

In addition to yield, there are two agronomic variables which are measured on the vines of the experimental vineyards. They are the pruning weight, which corresponds to the number of nodes per vine, and the number of clusters of grapes per vine. To further define the spectral characteristics of vine canopy, the two variables were examined in relation to yield and reflectance. Pruning weight, clusters, yield/pruning weight, yield/cluster and clusters/pruning weight were correlated with yield. Transformations of pruning weight (PW) were also correlated with yield. They were: PW^2, PW^3, $1/PW$ and $\log_{10}PW$. Pruning weight and the number of clusters were correlated with %R.

Also, because nitrogen appeared to strongly affect vines, analyses of variance were made to define the relationship between the number of clusters and the pruning weight to nitrogen input.

3.4.1.4 The Effect of Time on Yield-Reflectance Relationships

In order to check for error due to the time of day or instrument drift with duration of instrument operation, the 18 plants were stratified by time of operation. Based on this factor, each day's readings were split into three groups and correlated with yield.

3.4.1.5 Additional Analyses

Linear and multiple regressions were used to examine relationships that became apparent with the correlations. Because none of these added significant information to the analysis, however, they are not included in this report.

All statistical procedures are summarized in Table 3.5.

Table 3.5

Summary of Spectroradiometer Data Analysis

SPECTRORADIOMETRIC DATA--30 Wavelengths

1. Correlations of %R with yield of 18 plants, and smaller groups stratified by time and by treatment.

2. Correlations of %R with PW/Y for 18 plants and by time and treatment.

3. Correlation matrices and plots of Y, $Y^{1/2}$, Y^2, Y^3, and Y^4 with %R .

ANALYSES OF VARIANCE

1. Tests relationship of yield to nitrogen input for 12 plants.

2. Tests relationship of yield to nitrogen input for 36 plants.

3. Tests relationship of pruning weight to nitrogen input for 12 plants.

4. Tests relationship of pruning weight to N input for 36 plants.

5. Tests relationship of clusters to nitrogen input for 12 plants.

6. Tests relationship of clusters to N input for 36 plants.

Table 3. 5 (Continued)

PLANT PARAMETERS

1. Correlation matrix of yields 80-77, brush weight.
2. Correlation matrices BW vs %R , 18 plants, 3 dates.
3. Correlation Y 79-77 with %R for all 18 plants.
4. Correlation of all measured plant parameters with each other.
5. Correlation of Y 79-77 with %R by time and by treatment.
6. Correlation of Y 79-77 with %R SM2S by time and treatment.
7. Plots of % R vs for comparable treatments based on nitrogen input.

SIMULATED M2S (SM2S) - 11 BANDS

1. Correlations of %R with yield of 18 plants, and stratified by time and by treatment.

3.4.2 Multispectral Scanner Data Analysis

The airborne multispectral scanner (M2S) data were used to generate relative reflectance values for selected Concord vineyard sections at Hammondsport. Average reflectance values from each channel were found for the individual sections, and average reflectances were correlated with yields. Some ratios of channel pairs were also correlated with yield. The procedure followed for obtaining average reflectance values is discussed in the following section.

3.4.2.1 Site Location and Boundary Definition

Field maps representing the vineyards were used to locate each section on a frame of the color-IR film (Figures 3.13, 3.14). The multispectral scanner (M2S) flight line that corresponded to each frame was then determined using the flight log. Each line was examined on a visicorder strip of Channel 7 which had sufficient contrast for visual location of each vineyard. When the position of a vineyard on the visicorder strip was determined, its pixel location on the M2S computer compatible tapes (CCTs) was calculated.

The ORSER Program (Borden, et al., 1977) was used on the Cornell University IBM 370/168 computer to subset the vineyard data from the tapes. A digital brightness map (NMAP) of each section was produced where each pixel was represented by a symbol, designating up to ten groups of brightness levels (Figure 3.15). Due to an error in recording the CCTs, the NMAPs were mirror images of the actual vineyard sections as well as of the color-IR film transparencies. In selecting and locating the sections, this problem was compensated for by reversing the film transparency on a light table.

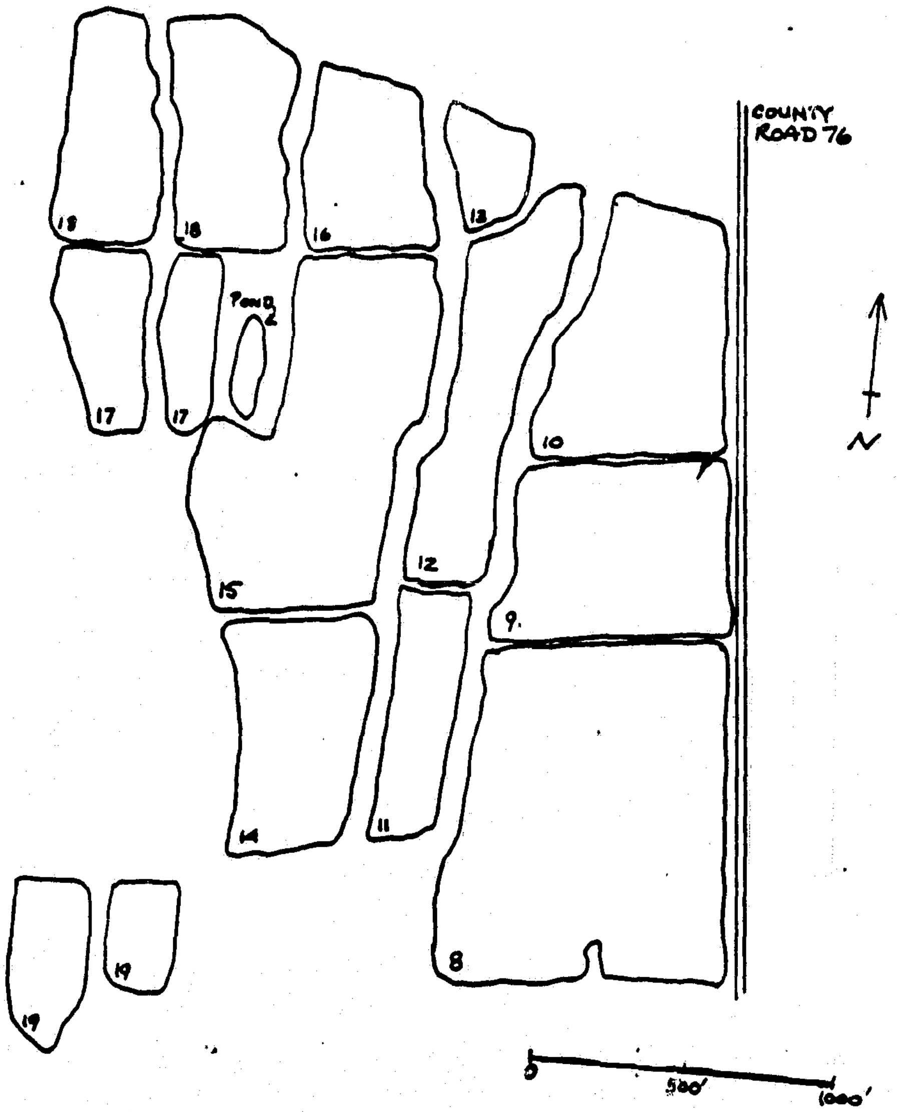

Figure 3.13 Field map of Taylor vineyard Area II.

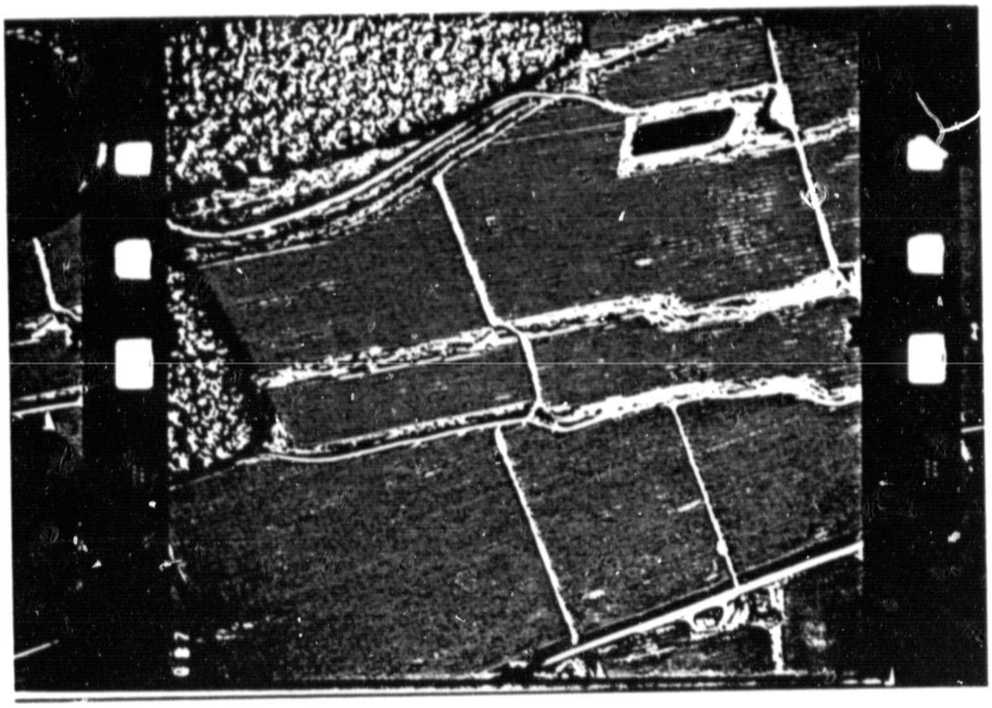

Figure 3.14 Black-and-white copy of color-infrared aerial photograph of Taylor vineyard sections 8-15 and 17 in Area II (Figure 3.13).

Figure 3.15 Geometrically corrected NMAP of vineyard section II-14. Note that NMAP is a mirror image of the aerial photograph (Figure 3.14) of the same section.

The next step in processing the M2S data was to precisely define the actual field boundaries using the NMAPs and the corresponding frames of the color-infrared film on a Zoom Transfer Scope. Some difficulty in transferring the boundary data was caused by two factors, the spectral signature of the grassed waterways that bounded each vineyard section and the scanner data geometry.

The problem of separating the spectral signature of the Concord vineyard canopy from that of the grasses became significant when the vineyard section imaged was in direct sunlight. Although ratios of channels 7 and 9 and channels 4 and 9 were used to assist definition, the final field boundaries were set several pixels within the apparent boundaries to insure exclusion of grass pixels.

When vineyard sections were imaged entirely in cloud shadow, the resulting canopy signature differed sufficiently from the field boundary. In addition, the row pattern present in the vineyard was visible in these NMAPs, and boundaries were clearly defined.

Three types of systematic, geometric distortion are inherent in the scanner system (Lillesand and Kiefer, 1979). The first distortion, one-dimensional relief displacement, results from the side-looking view of the scanner and causes vertical objects to be displaced at right angles from the nadir. In vineyards, relief displacement can cause the reflectance values to vary depending on the distance from the nadir and the angle of the rows in relation to the view angle. Vineyard sections selected for this study were viewed from approximately the same angle so the effect of the displacement was minimized.

The second type of systematic distortion is pixel size variation along the scanline. The greater the view angle from the nadir, the greater the ground area included in a pixel. To a much smaller degree, the ground area covered in a pixel increases along the flight direction with increased scanning angle.

Tangential scale distortion which is caused by the constant rate of the scan mirror oscillation occurs perpendicular to the flight direction. The ground area scanned per unit of time increases with increasing distance from the nadir. The result is an increasing compression of the image scale (Figure 3.16).

The effects of both cell size variation and tangential scale distortion could be corrected on a pixel-by-pixel basis, however, such resampling alters the radiometric values of the pixels.

The ORSER Display Program was used to partially correct the scanner data geometry and the resulting NMAPs were reduced by 50%. This produced NMAPs which could be used effectively on the Zoom Transfer Scope. After locating the section boundaries on the corrected NMAPs, the corresponding pixels were found on the original NMAPs and a new subset of each section was produced. Average radiance values for each section were then calculated.

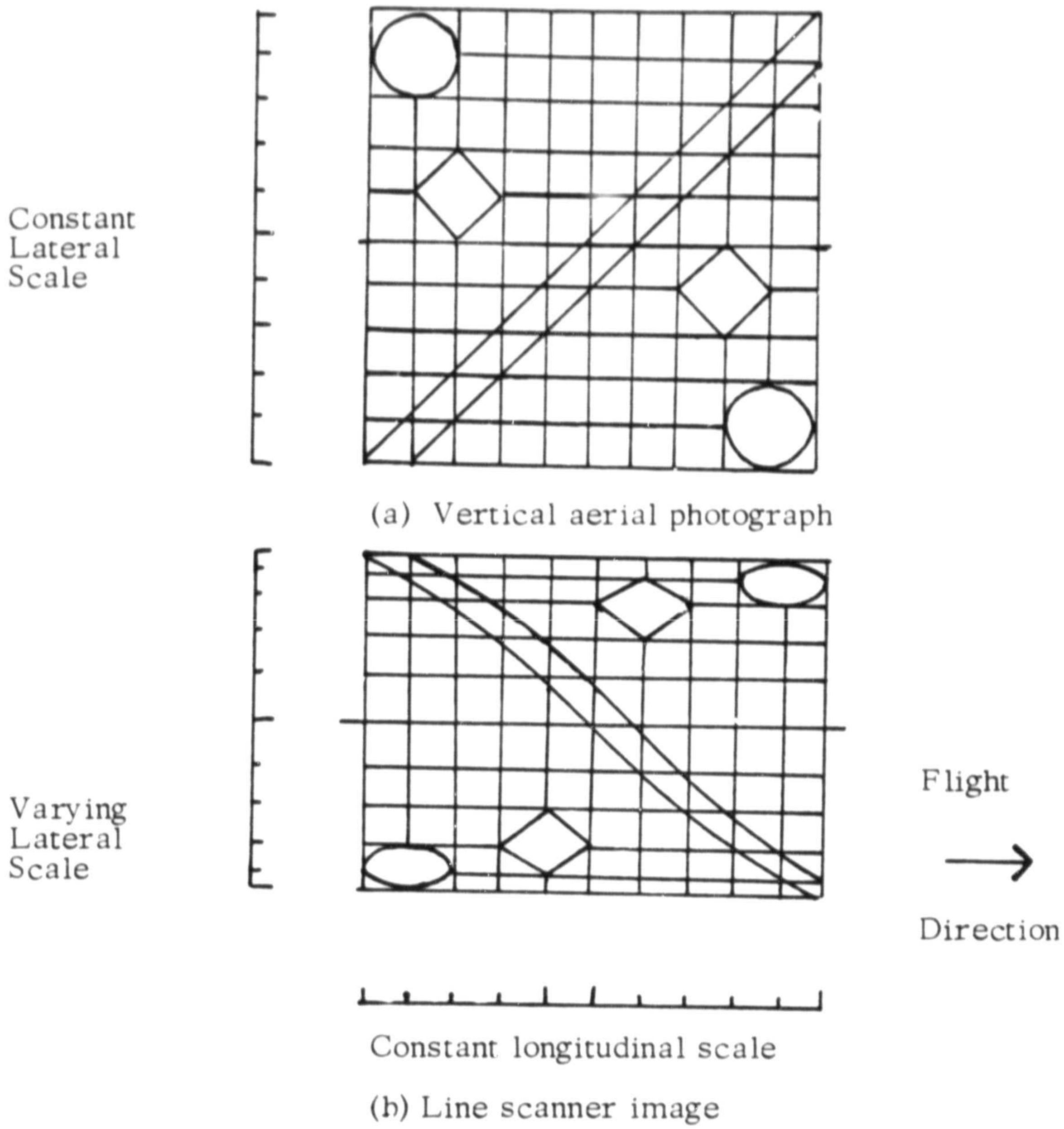

Figure 3.16 Tangential scale distortion in unrectified line scanner imagery (Lillesand and Kiefer 1979).

CHAPTER 4

RESULTS

4.1 Introduction

The results of the statistical procedures applied to the vineyard canopy spectral data are presented in this chapter. Unless otherwise stated, the evaluation of the correlations was limited to a 10% level of significance (Fisher, 1954). Complete lists of correlations are available in Appendix B. The interpretation of the numerical results in relation to agronomic variables and instrumentation is included in Chapter 5.

4.2 Canopy Reflectance and Yield

Yield data from 1980 and percent reflectance from 30 wavelengths, collected on three dates, were correlated using a sample of 18 vines. The resulting correlations are summarized in Table 4.1.

Correlations between yield and reflectance for 18 vines sampled were generally poor, with most values being below the 10% significance level. There were no significant correlations between July reflectance data and 1980 yield. For August data, reflectance was positively correlated with yield, with significant correlations occuring in the visible range from 400 to 525 nm and from 675 to 725 nm. Yield and reflectance were negatively correlated for September data with significant relationships in the near-infrared range from 775 to 850 nm. Correlations between yield, reflectance and

Table 4.1

Summary of correlations between yield of 18 vines and their reflectance at 30 wavelengths

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July	-.299 to .327	0
August	-.286 to .549	9
September	-.539 to .117	8

combinations of yields from 1977 to 1980 did not provide significant information.

Four ratios of reflectance data were also correlated with 1980 yield using all 18 vines sampled (Table 4.2). The results were generally poor; however, the ratio of ($\%R_{550nm}/ \%R_{675\ nm}$) was significantly correlated with yield for August, while the linear reflectance variable of ($\%R_{900\ nm} - 5 \times (\%R_{550\ nm})$) was significantly correlated with yield for September data.

Curvilinear relationships between 1980 yield (Y) and reflectance were examined by first plotting and then correlating $1/Y$, Y^2, Y^3, Y^4 and log Y for 1980 with reflectance for all 18 vines. The resulting correlations were at approximately the same levels of significance as the linear relationship between 1980 yield and reflectance. The results are summarized in Table 4.3.

Ratios of each month's reflectance measurements at 30 wavelengths with every other month's measurements were not significantly correlated with yield (Table 4.4).

The relationships between the simulated multispectral scanner (SM2S) data and 1980 yield for all 18 vines were similar to those of the 30 wavelengths of data (Table 4.5). The main differences were that the correlation coefficients were generally less significant and that often a relationship that was positive with the uncombined data, was negative with the averaged SM2S data.

Ratios of the SM2S data were correlated with yield and are summarized in Table 4.6. For all 18 plants, on all three dates, only one reflectance variable, band 9 -(5 x band 4), was significantly correlated with yield at the 10% significance level.

Table 4.2

Correlations between yield and reflectance ratios for 18 vines

Ratios	July	August	September
(1) $\frac{\%R_{900} - \%R_{675}}{\%R_{900} + \%R_{675}}$	-.025	-.126	-.304
(2) $\%R_{900} - 5 \times (\%R_{550}))$	.162	.137	-.474
(3) $\frac{\%R_{550}}{\%R_{675}}$	-.349	-.526	.050
(4) $\frac{\%R_{900}}{\%R_{675}}$	-.001	-.113	-.314

Table 4.3

Summary of correlations between linear transformations of 1980 yield (Y) of 18 vines and reflectance at 30 wavelengths

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
	$1/Y$	
July	-.300 to .820	1
August	.049 to .547	9
September	-.543 to .152	9
	Y^2	
July	-.299 to .420	2
August	.035 to .545	9
September	-.541 to .161	9
	Y^3	
July	-.298 to .442	2
August	.021 to .540	9
September	-.541 to .169	9
	Y^4	
July	-.209 to .225	0
August	-.543 to .013	8
September	-.001 to .515	8
	log Y	
July	-.276 to .269	0
August	.029 to .547	8
September	-.527 to .022	8

Table 4.4

Summary of correlations between yield and reflectance ratioed by month, for 18 vines

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
August / July	-.263 to .248	0
September / July	-.312 to .238	0
September / August	-.318 to .287	0

Table 4.5

Summary of correlations between yield and simulated scanner (SM2S) averaged reflectance values for 18 vines

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July	-.299 to .342	0
August	.180 to .805	6
September	-.172 to .350	0

C-2

Table 4.6

Summary of correlations between yield and ratioed SM2S reflectance data for 18 vines

Month	Range of correlations	No. of wavelengths with correlations significant at at 10% level
July	-.229 to .295	0
August	-.376 to .264	1
September	-.477 to .190	1

4.3 The Effect of Weed Control and Nitrogen Application

When data from all 36 vines which received treatments 1 - 6 were analyzed in a two-way analysis of variance (ANOVA), the interaction of the method of weed control and the level of nitrogen application was found to significantly affect vine yield at a 5% level (Table 4.7). However, when the same ANOVA was computed using data from only the 12 vines which were spectroradiometrically sampled, the relationship between weed control, nitrogen and yield was not significant (Table 4.7). Therefore, it was apparent that the vines sampled for this study were not representative of vine response to available nitrogen.

The nitrogen-weed control effect was considered strong enough to merit separating the 12 comparable vines from Treatments 1 - 6 by method of weed control and then correlating 1980 yield with reflectance (Table 4.8). In general, the correlations improved over those for 18 plants sampled, especially with Group 2 (sod with herbicides), where a high number of correlations were above the 10% significance level. It was also noted that, in most cases, the correlation coefficients for Group 1 (cultivated) had the opposite sign from those for all 18 plants sampled, while Group 2 (sod) had the same sign.

Most management treatments affect nitrogen uptake and/or chlorophyll production, and as such, affect reflectance. Therefore, plots of reflectance versus wavelength were graphed for each date, for each pair or triplet of vines which were comparable by management treatment. For example, vines from Treatments 2 and 9 differ only in the method of weed control used. The plots helped illustrate the contrast between stratified treatment groups such as those used

Table 4.7

The response of yield to the method of weed control and nitrogen application for 36 vines, (a) and for 12 sampled vines (b)

Two-Way Analysis of Variance

Due to:	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio
Nitrogen	2	59.6	29.8	.9085
Weed Control	1	63.0	63.0	1.9207
Interaction	2	575.6	287.8	8.7744*
Error	30	984.3	32.8	
Total	35	1682.5		

(a)

Nitrogen	2	13.3	6.7	0.140
Weed Control	1	5.6	5.6	0.120
Interaction	2	224.7	112.3	2.34
Error	6	288.1	48.0	
Total	11	531.7		

(b)

*Significant at a 1% level

Table 4.8

Summary of correlations between yield and reflectance for vine groups stratified by method of weed control

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July		
Group 1*	-.601 to .637	0
Group 2**	-.507 to .751	8
August		
Group 1	-.390 to .734	1
Group 2	.147 to .840	18
September		
Group 1	-.714 to .291	2
Group 2	-.845 to .459	10

*Groul 1: Treatments 1, 2 and 3 with cultivation.
**Group 2: Treatments 4, 5 and 6 with sod and herbicide

to look at the effect of methods of weed control and nitrogen application, and the changes that occur in the reflectance patterns throughout the season. They are included in Appendix C for this reason.

4.4 Agronomic Variables and Reflectance

Pruning weight and the number of clusters per vine were correlated with yield from 1977 to 1980, with linear transformations of yield, and with some ratios of yield, pruning weight and clusters (Table 4.9). The number of clusters was highly correlated with yield, and its transformations, and with pruning weight at a 1% significance level. Pruning weight was significantly correlated with yield at a 5% level. Therefore, if either variable was significantly correlated with reflectance, it might be incorporated into a yield prediction model.

The results of a two-way analysis of variance (ANOVA) on all 36 vines which received Treatments 1 - 6 showed that the interaction of nitrogen and weed control has a strong effect on clusters at a 1% significance level (Table 4.10). For the 12 vines which were spectrally sampled, the effect was not significant at a 1% or a 5% level (Table 4.10).

ANOVAS of pruning weight showed that this variable was significantly affected by nitrogen and weed control, both separately and interactively, for 36 vines, but not for the 12 sampled vines (Table 4.11).

Thus, it was again apparent that the spectrally sampled vines were not representative of vine response, but that nitrogen input and

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Table 4.9

Correlations between several agronomic variables for 18 vines

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.483								
C3	0.290	0.441							
C4	0.247	0.426	0.685						
C5	0.998	0.493	0.300	0.250					
C6	0.993	0.461	0.261	0.234	0.983				
C7	0.971	0.437	0.225	0.211	0.955	0.993			
C8	0.939	0.412	0.186	0.182	0.917	0.974	0.994		
C9	0.993	0.501	0.309	0.251	0.998	0.971	0.936	0.893	
C10	0.422	0.256	-0.308	-0.308	0.428	0.408	0.391	0.373	0.433
C11	0.840	0.387	-0.088	-0.148	0.838	0.835	0.820	0.793	0.834
C12	0.119	0.047	0.566	0.520	0.123	0.107	0.091	0.075	0.126
C13	-0.043	-0.100	0.342	0.333	-0.043	-0.043	-0.046	-0.048	-0.044
C14	0.370	0.246	0.722	0.688	0.375	0.352	0.328	0.290	0.378
C15	0.457	0.282	-0.294	-0.302	0.463	0.445	0.429	0.411	0.457
C16	0.341	0.193	-0.317	-0.315	0.349	0.324	0.305	0.286	0.356

	C10	C11	C12	C13	C14	C15
C11	0.713					
C12	-0.754	-0.326				
C13	-0.826	-0.343	0.924			
C14	-0.419	-0.181	0.786	0.499		
C15	0.994	0.747	-0.771	-0.842	-0.422	
C16	0.932	0.625	-0.710	-0.736	-0.401	0.955

C1 = Yield 1980
C2 = Yield 1979
C3 = Yield 1978
C4 = Yield 1977
C5 = Yield 1980
C6 = $Yield^2$ 1980
C7 = $Yield^3$ 1980
C8 = $Yield^4$ 1980
C 9 = log Yield 1980
C10 = Pruning Weight
C11 = Clusters per vine
C12 = Yield 1980/Pruning Weight
C13 = Clusters/Pruning Weight
C14 = Yield/Clusters
C15 = Pruning Weight
C16 = Pruning $Weight^2$

Table 4.10

The response of clusters per vine to the method of weed control and nitrogen application for 36 vines (a) and for 12 sampled vines (b)

Two-Way Analysis of Variance

Due to:	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio
Nitrogen	2	2110	1055	0.956
Weed Control	1	1272	1272	1.153
Interaction	2	15268	7634	6.921*
Error	30	33091	1103	
Total	35	51742		

(a)

Nitrogen	2	168	84	0.075
Weed Control	1	37	37	0.033
Interaction	2	6105	3053	2.719
Error	6	6740	1123	
Total	11	13057		

(b)

*Significant at a 1% level

Table 4.11

The response of pruning weight to method of weed control and nitrogen application for 36 vines (a) and for 12 sampled vines (b)

Two-Way Analysis of Variance

Due to:	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio
Nitrogen	2	5.792	2.896	5.275**
Weed Control	1	2.571	2.571	4.683**
Interaction	2	8.874	4.437	8.082*
Error	30	16.482	0.549	
Total	35	33.719		

(a)

Nitrogen	2	.995	0.498	0.739
Weed Control	1	.001	0.001	0.001
Interaction	2	1.902	0.951	1,411*
Error	6	4.045	0.674	
Total	11	6.942		

(b)

*Significant at a 1% level
**Significant at a 5% level

method of weed control do affect the two agronomic variables considered.

Pruning weight and the number of clusters per vine were correlated with reflectance using data from all 18 vines, and from the weed control-nitrogen groups of 6 vines each.

When all 18 vines were considered as a group, correlations between pruning weight and reflectance were highly significant in many wavelengths (Table 4.12). For July, 12 significant correlations occurred in the visible range and 2 in the near-infrared range at 1000-1025 nm. The highest number of significant correlations were found for August data where all correlations for the 15 near-infrared wavelengths were significant as well as 2 visible wavelengths (675-700 nm). For September data, 5 significant correlations were present in the visible range.

When pruning weight was correlated with reflectance for the vine groups stratified by method of weed control, there were no significant correlations in July and August, while for September there were 12 in the near-infrared range, most of which were for Group 2 (sod) data (Table 4.13).

In contrast, when the number of clusters per vine was correlated with reflectance, almost the opposite occurred. When all 18 vines sampled were used, there were 2 significant correlations for July and none for September. On the other hand, for August data, there were 17 significant correlations which were mostly in the near-infrared range, with the best correlations in the visible range (Table 4.14). When yields from the smaller groups were correlated with reflectance, there were no significant correlations for Group 1

Table 4.12

Summary of correlations between pruning weight of 18 vines and reflectance at 30 wavelengths

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July	-.047 to .759	14
August	.104 to .785	17
September	-.103 to .548	5

Table 4.13

Summary of correlations between pruning weight and reflectance for vines stratified by method of weed control

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July		
Group 1*	-.459 to .642	0
Group 2**	-.169 to .834	1
August		
Group 1	-.706 to .599	1
Group 2	-.034 to .655	0
September		
Group 1	-.643 to .702	2
Group 2	-.798 to .569	10

*Group 1: Treatments 1, 2 and 3 with cultivation
**Group 2: Treatments 4, 5 and 6 with sod and herbicide

Table 4.14

Summary of correlations between clusters per vine and reflectance at 30 wavelengths

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July	-.318 to .494	2
August	.034 to .529	17
September	-.338 to .187	0

(cultivated), but for Group 2, there were 15 in July, 17 in August, and 13 in September (Table 4.15).

4.5 The Effect of Time on Yield-Reflectance Relationships

Each day's measurements of percent reflectance were stratified into three groups by time of day and correlated with yield, clusters per vine and pruning weight (Tables 4.16, 4.17, 4.18, and 4.19). The resulting correlations were generally better than those for all 18 vines, and sometimes better than those for plants stratified by method of weed control. In most correlations with 1980 yield, the significant relationships were in the visible range.

4.6 Multispectral Scanner Reflectance Data and Yield

Correlations between yield and reflectance, and some combinations of reflectance variables, were computed for the M2S data (Table 4.20). There were 3 correlations that were significant at a 10% level. They were: band 6, green; band 7, red; and band 7 + band 5, red plus green.

Table 4.15

Summary of correlations between clusters per vine and reflectance for vines stratified by method of weed control

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July		
Group 1*	-.665 to .130	0
Group 2**	-.416 to .827	15
August		
Group 1	-.400 to .712	1
Group 2	.037 to .830	17
September		
Group 1	-.728 to .405	1
Group 2	-.910 to .678	13

*Group 1: Treatments 1, 2 and 3 with cultivation
**Group 2: Treatments 4, 5 and 6 with sod and herbicide

Table 4.16

Nine groups of vines stratified by time of day

	July* Treatment	August Treatment	September Treatment
Group 1 A. M.	8	8	7
	8	8	7
	6	9	2
	6	9	2
		4	4
		4	4
Group 2 Midday	5	1	3
	5	1	3
	1	5	5
	1	5	5
	4	6	1
	4	6	1
Group 3 P. M.	3	2	6
	3	2	6
	2	3	9
	2	3	9
	7	7	8
	7	7	8

*July Treatment #9 was observed on the day preceding other July measurements in the late afternoon

Table 4.17

Summary of correlations between yield and reflectance for vines stratified by time of day

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July		
Group 1*	-.290 to .954	7
Group 2*	-.559 to .133	0
Group 3*	-.708 to 469	3
August		
Group 1	.135 to .769	9
Group 2	-.268 to .795	6
Group 3	-.100 to .781	2
September		
Group 1	-.851 to .585	5
Group 2	-.811 to .585	3
Group 3	-.906 to .477	2

*Groups 1, 2 and 3 are defined in Table 4.16

Table 4.18

Summary of correlations between yield and simulated M2S reflectance for vines stratified by time of day

Month	Range of correlations	No. of wavelengths with correlations significant at a 10% level
July		
Group 1*	-.173 to .900	8
Group 2*	-.148 to .117	0
Group 3	-.682 to .394	1
August		
Group 1	-.006 to .823	3
Group 2	-.448 to .818	2
Group 3	-.025 to .679	1
September		
Group 1	-.726 to .003	3
Group 2	-.738 to .606	2
Group 3	-.555 to .269	0

*Groups 1, 2 and 3 are defined in Table 4.16

Table 4.19

Summary of correlations for clusters and pruning weight

with reflectance for vines stratified by time of day

Clusters			Pruning Weight		
Month	Range of Correlations	No. of wavelengths with correlations significant at a 10% level	Month	Range of Correlations	No. of wavelengths with correlations significant at a 10% level
July			July		
Group 1	-.094 to .959	13	Group 1	-.088 to .856	9
Group 2	-.435 to .376	0	Group 2	-.124 to .655	0
Group 3	-.841 to .655	10	Group 3	-.842 to .989	26
August			August		
Group 1	-.147 to .790	7	Group 1	-.130 to .942	15
Group 2	-.085 to .811	9	Group 2	-.039 to .873	11
Group 3	-.099 to .805	5	Group 3	-.321 to .902	8
September			September		
Group 1	-.856 to .169	4	Group 1	-.921 to .714	2
Group 2	-.718 to .750	3	Group 2	-.835 to .907	3
Group 3	-.808 to .970	7	Group 3	-.655 to .957	7

Table 4.20

Band	Spectral Range (Nanometers)	Correlation
1	420- 460	-.399
2	460- 500	-.390
3	500- 540	-.421
4	550- 580	-.387
5	580- 620	-.367
6	620- 660	-.633*
7	660- 700	-.620*
8	700- 750	.250
9	770- 860	.451
10	960- 1040	.411
11	8000-12080	-.263
Combined Variable		
**B7/B9	-.540	
B6/B4	-.084	
B7/B5	-.456	
B7+B5	-.586*	
B7-B5	-.541	
***VI	-.454	
****TVI	-.455	

*Significant at a 10% level
**Band
***Vegetation Index
****Transformed Vegetation Index

CHAPTER 5
DISCUSSION

5.1 Vineyard Canopy Spectral Characteristics

5.1.1 Canopy Reflectance and Yield

Most correlations between spectral reflectance and yield were below the 10% significance level when all 18 vines sampled were included. August reflectance data showed better correlation with yield than did July or September, for possibly two reasons. The first is that leaf turgidity, chlorophyll and leaf area were higher in August than in July or September. This occurrence is partially supported by the dominance of significant correlations in the blue and green wavelengths (400 to 525 nm). The second possible explanation is that the August data collection occurred under overcast skies. This would have limited inter-leaf shadowing and modified the effects of solar zenith angle.

Positive correlations in July and August, and negative correlations in September indicate the change from chlorophyll production in the leaf to sugar production in the fruit and a drop in leaf turgidity due to senescence. This would also explain the higher correlations in the near-infrared range (775 to 975 nm) for September measurements which were made immediately prior to harvest. At this time, senescence causes an increase in air interfaces in the leaf structure as well as the drop in leaf turgidity, which together result in an increase in the near-infrared reflectance.

Yields from 1979 were correlated with yields from 1980 at a 10% level of significance, but yields from 1977 and 1978 and combinations of yields were not significantly correlated with 1980 yield.

Ratios and other combinations of spectral reflectance were poorly correlated with yield. The green/red ratio which was significant for August data probably relates to the dominance of green chlorophyll pigments over red pigments at this crop stage, while the near-infrared/green ratio which was significant in September relates to the processes of senescence.

In most cases, when transformations of yield were correlated with reflectance, no new information was gained. Also, correlations were very low when ratios of the spectral reflectance of different months were correlated with yield.

The relationships between simulated multispectral scanner (SM2S) data and yield also added little new information, though it was expected to indicate the wavelengths and ratios on which to focus studies of the aerial multispectral scanner (M2S) data. Generally, the correlations were poor for 18 vines sampled.

5.1.2 The Effect of Weed Control and Nitrogen Application

An analysis of variance (ANOVA) found that weed control and nitrogen input affect grapevine yield through their interactive effect on available nitrogen. Since available nitrogen also determines the leaf chlorophyll content, the two treatments became a dominant factor in assessing yield-reflectance relationships for vineyard canopy. Although another ANOVA showed that the vines that were spectrally sampled were not, as a group, representative of the vine response to available nitrogen, correlations between yield and reflectance consistently improved when vines were stratified by method of weed control (i.e., sod with herbicides versus cultivated). The best correlations occurred for those vines which were maintained with sod and herbicides. In addition, the correlations for the 6 vines in the sod group had the same positive and negative relationships as all 18 vines sampled. It may be that simply by chance, these 6 vines were more representative of average vine response to available nitrogen than some other vines sampled and therefore, the correlations improved over those for all 18 vines or for vines which were cultivated.

5.1.3 Agronomic Variables and Reflectance

Pruning weight and the number of clusters per vine were both found to be strongly affected by the method of weed control and the quantity of nitrogen applied. In addition, both variables were found to be significantly correlated with yield.

Correlations between pruning weight and reflectance were highly significant when all 18 plants sampled were included. The most significant correlations were in the visible range for July and September, and in the infrared range for August data. Correlations between pruning weight and September reflectance were also high in the infrared range for the vine treatment group which had mowed sod and herbicides for weed control.

The number of clusters per vine was significantly correlated with August reflectance data in the infrared range for all 18 vines sampled. In addition, clusters per vine was highly correlated with reflectance for all three months when only vines from Treatment

Group 2 (sod) were included. Several correlations with Treatment Group 2 (cultivated) were just below the 10% significance level cutoff point.

From these analyses, it was apparent that the number of clusters per vine and pruning weight for the spectroradiometrically sampled vines were not representative of the average vine response. Therefore, the number of clusters and the pruning weight were not well correlated with available nitrogen. Clusters and pruning weight both correlate significantly with yield and with reflectance under different conditions, but for either variable, spectral data collected in August resulted in the highest number of significant correlations.

5.1.4 The Effect of Time on Yield-Reflectance Relationships

Correlations between reflectance and yield, clusters and pruning weight for vine groups stratified by time were usually more significant than for all 18 vines sampled and often better than for groups stratified by method of weed control. Time in this instance may represent either the time of day or the duration of spectroradiometer operation.

In the first case, the time effect could be due to inter-leaf shadowing changing with solar zenith angle, or it could be a response to varying angles of leaf orientation. The second possibility is that a systematic instrument error existed which changed with the duration of instrument use due to heat accumulation or other instrument factors. This seems a less likely explanation because the effect is not consistent across both spectral ranges, and it was not apparent in the calibration procedures previous to *in situ* data collection. A third possible explanation is that by chance random selection, some of these vine groups provided higher correlations.

5.1.5 Multispectral Scanner Reflectance Data and Yield

The lack of correlation between scanner data and yield was probably due to several factors. First, the data were collected very late in the growing season (September 3) while ground data analyses indicated that mid-season data collection might have been optimal.

The second factor was the atmospheric conditions at the time of data collection which included heavy haze and at least 50% cloud cover. Because of these conditions the vineyard sections were limited to those in sunlight or those in cloud shadow. The majority of Concord vineyard sections were in cloud shadow. These fields lacked between-row vine shadow, simplifying boundary definition; however, the cloud shadow resulted in depressed values of reflectance.

A third factor which may have affected spectral data was that an average value of reflectance was found for each vineyard section and used in ratios and other reflectance combinations. It is possible that a pixel-by-pixel approach would result in different reflectance values.

5.2 Limitations of Current Study

5.2.1 ISCO Spectroradiometer

The three ISCO spectroradiometers which were used in this study for field data collection had inherent problems, most of which were compensated for in the calibration procedure.

The instruments had dry solder joints which broke during operation. Most of these were repaired before field use. One instrument had a bent chopper shaft which limited data collection to the slow response scale. There were differences in detector sensitivity, scale, and wavelength range between the three spectroradiometers.

The fiber optic probes of the instruments were manually aligned with the monochromator slit, but lack of precision reduced instrument sensitivity. In addition, several optical fibers in the probe of one spectroradiometer broke during field operation. The probe had to be replaced and the calibration repeated.

Lastly, the instruments were manually read by different observers, which probably resulted in slightly different meter readings. Also, reading errors occurred, such as incorrect decimal point positions. Some reading errors could be corrected after data collection while others became anomalies which probably had a minor effect on data analysis.

5.2.2 Multispectral Scanner

There are four factors which affected the value of the airborne Multispectral Scanner (M2S) data. Initially, the mission was improperly flown, and the entire Fredonia site was not covered. Ground data from sampled vines could not be compared with aerial data from the same vines. Secondly, the mission was flown later in the season than requested and the vine senescence was already occurring. Thirdly, the mission was flown during periods of excessive haze. Lastly, scales of scanner data collected during this mission were 1:3000 and 1:6000, with the corresponding ground resolution limited to about 2 meters. Although it is probably unnecessary, a slightly lower altitude might provide useful information for detailed vine study.

CHAPTER 6

CONCLUSIONS

Analyses of variance indicate that the 18 spectrally sampled vines were not representative of vine reponse to available nitrogen. In addition, it was found that available nitrogen, which was determined by the method of weed control and nitrogen input, as well as by growth stage, significantly influenced Concord canopy reflectance.

Some correlations between vine yield, clusters, pruning weight and spectral reflectance are statistically significant, although they are inadequate for developing a reliable yield prediction model. It is apparent, however, that reflectance data collection could be limited to certain wavelengths depending on growth stage and the agronomic variable of interest.

In July, the highest correlations with yield occurred in several different visible and near-infrared wavelengths. In August, data collection for yield would depend on the weed control method: the visible range for cultivated rows, and the infrared range for sod and herbicide application.

Also, in July and August data collection in the infrared range is optimum for studies of clusters per vine and pruning weight. In September, for all three agronomic variables, data collection could generally be limited to the near-infrared range. At any time during the season, the main wavelength intervals of interest, in relation to plant status, are:

400 nm – 450 nm	blue: strong absorption by chlorophyll and carotenoids
675 nm	red: strong chlorophyll absorption
750-775 nm – 850-900 nm	infrared: mesophyll structure, turgidity, and inter-leaf scattering

Because optimum wavelengths have been defined here, the efficiency of data collection will be increased. Greater efficiency and accuracy would also result if a field portable spectroradiometer were designed with automatic scanning capabilities.

Time of day had an effect on correlation of reflectance and yield, and this might relate to leaf-layer shadowing, leaf orientation, leaf moisture stress due to diurnal temperature changes, or a systematic instrument error. It should be evaluated in future sampling.

The lack of correlation between the airborne multispectral scanner data and yield was probably due to the combination of poor weather conditions and the late growth stage of the imaged vineyards.

In conclusion, selection of vines for sampling for yield prediction modeling should be random rather than by viticultural standards of average vines. On the other hand, because Concord canopy reflectance was strongly influenced by available nitrogen, vines should be stratified for modeling, based on weed control and nitrogen input. Lastly, selection of spectral ranges for sampling should be based on vine growth stage.

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APPENDICES

APPENDIX A

A. 1

Table of vines by row and management practice
for Fredonia site.

Row	Vine	Pruning Weight	Nodes/ Vine	Clusters/ Vine	Yield lb/vine	Treatment
409	07	2.0	40	132	24.3	1
	08	1.7	37	98	19.0	1
	09	2.0	40	80	22.0	1
	10	1.5	35	50	13.4*	1
	11	3.0	50	170	30.8	1
	12	3.1	51	157	29.1	1
414	20	3.1	51	183	26.8	2
	21	3.9	59	150	25.2	2
	22	*	*	*	*	2
	23	3.4	54	150	28.4	2
	24	4.3	63	159	33.6	2
	25	2.3	43	98	15.8	2
413	33	3.1	51	178	27.4	3
	34	0.7	21	36	7.8	3
	35	2.0	40	86	15.5	3
	36	2.8	48	71	16.3	3
	37	1.9	39	123	23.3	3
	38	1.6	36	73	14.0	3
413	01	1.2	32	72	10.4	4
	02	2.0	40	99	14.9	4
	03	1.1	31	44	8.2*	4
	04	1.0	30	80	14.8	4
	05	1.3	33	118	24.0	4
	06	0.7	21	52	9.2	4
409	33	1.4	34	89	15.0	5
	34	3.7	57	155	29.2	5
	35	1.5	35	66	14.7	5
	36	2.4	44	127	27.0	5
	37	1.7	37	098	14.0	5
	38	1.8	38	092	20.3	5
408	14	3.5	55	184	33.2	6
	15	3.3	53	146	24.7	6
	16	3.5	55	134	28.4	6
	17	3.4	54	157	28.6	6
	18	2.3	43	129	22.2	6
	19	1.3	33	93	19.4	6

*Vines that were severely affected by disease or pests, and were not used in analyses.

Row	Vine	Pruning Weight	Nodes/ Vine	Clusters/ Vine	Yield lb/Vine	Treatment
416	33	2.6	46	59	11.2	7
	34	5.2	72	174	26.5	7
	35	5.2	72	176	26.7	7
	36	4.2	62	92	15.9	7
	37	5.1	71	126	20.1	7
	38	3.8	58	80	17.0	7
428	20	2.0	40	103	20.8	8
	21	1.4	34	81	19.2	8
	22	1.4	34	112	21.4	8
	23	1.5	35	111	24.8	8
	24	1.6	36	104	26.4	8
	25	1.2	32	73	14.8	8
406	20	2.3	43	165	29.7	9
	21	3.1	51	131	21.3	9
	22	4.1	61	197	38.9	9
	23	3.9	59	159	20.5	9
	24	5.5	75	164	20.0	9
	25	2.4	44	134	25.5	9

*Vines that were severely affected by disease or pests, and were not used in analyses.

A. 2

Table of vineyard sections and yields
for Hammondsport site.

Area II Section	Area, Acres	Yield, tons/acre
11	3.04	4.388
12	5.74	4.388
13	1.44	4.388
14	5.14	5.895
15	11.05	4 230
16	3.85	4.230
17	4.04	5.100
18	8.93	4.886

APPENDIX B

Correlations between reflectance and agronomic variables in the matrices in this section are represented as follows:

	Columns
Spectroradiometric Data	1-30
Agronomic Variables	31-36
Simulated Multispectral Scanner Data	1- 9
Agronomic Variables	10-15

B. 1

Percent Reflectance Data

at 30 Wavelengths

July 17, 18, 1980

JULY 17 AND JULY 18, 1980

30 WAVE LENGTH SPECTRORADIOMETER SR DATA

WL= 400	WL= 425	WL= 450	WL= 475	WL= 500	WL= 525	WL= 550	WL= 575
2.9030	2.4250	2.6635	2.4905	2.5310	4.2150	6.5165	5.3435
3.0135	2.6960	3.1700	3.0840	3.2590	4.9870	7.4965	6.5145
3.0975	1.9925	2.2570	2.5585	2.5175	4.6125	7.2345	5.5485
3.3960	2.3100	2.6345	2.6325	2.6360	4.5340	7.0880	5.0595
4.7945	2.2905	3.4725	3.6550	3.7465	6.3035	10.1915	9.5585
2.8405	2.6390	2.7590	2.9460	2.9400	4.6705	7.6195	7.4245
3.2015	3.1535	3.1295	3.2655	3.8230	6.6020	11.0230	10.9194
3.3425	2.8000	2.9060	3.1300	3.7485	6.5325	10.4385	10.7290
17.1460	2.4510	2.8600	2.9055	3.1525	5.2375	8.9015	8.8600
1.0935	2.2135	2.0495	2.1100	2.3825	4.3210	5.7970	6.7255
17.7900	2.9040	2.9310	3.1545	3.4210	5.7760	9.1340	8.1760
2.5295	2.4690	2.3635	2.4575	2.9140	4.9940	8.1800	7.2995
3.0390	2.9460	2.9385	3.2435	3.4235	6.0885	10.1345	8.5280
2.5020	2.8500	3.0435	2.9970	3.2240	5.8460	9.6985	7.9415
3.3395	2.8790	3.0850	3.2505	3.4010	6.4190	10.2990	8.1800
4.0005	3.5980	3.5360	3.7635	4.0030	7.0560	10.8290	8.4745
4.7390	4.3995	4.9260	5.4145	5.8830	9.7320	15.1305	11.9670
4.0050	3.8080	4.1070	4.3135	4.5470	7.8690	12.4815	8.8845

WL= 600	WL= 625	WL= 650	WL= 675	WL= 700	WL= 725	WL= 750	WL=
4.3150	3.8990	3.4160	3.0795	7.7505	25.0950	43.8605	
5.1015	4.6090	4.2585	4.0555	8.8340	29.4590	50.8395	
4.7315	3.7750	3.4100	2.8695	8.4220	26.3435	45.6385	
4.8285	4.2150	3.5870	3.1135	7.9250	25.4500	41.2415	
5.8480	5.1520	4.3550	4.0345	10.7160	39.2775	74.2105	
4.6280	4.0160	19.2965	3.2965	8.4415	31.8435	63.8770	
5.6545	5.6310	4.4695	3.8005	12.1030	45.6405	71.5450	
6.7915	5.6360	4.6440	4.0405	11.7295	41.6995	64.5855	
5.4395	4.4525	4.0825	3.2575	8.6855	34.4025	52.6580	
4.5425	3.7630	3.1015	2.4130	7.4290	26.7675	39.9735	
5.7230	4.6950	3.9260	3.2445	9.2195	33.3470	56.1640	
4.7865	3.9185	3.1115	2.6585	8.8125	33.2650	52.6885	
60.2720	4.8915	4.3940	3.7405	10.3420	39.3620	64.0550	
5.9025	5.0015	3.8805	3.3490	9.6270	35.4140	62.5150	
6.3030	5.0650	4.0260	3.3520	10.7580	40.5190	66.7770	
6.8300	5.5935	4.6225	4.2285	11.2710	41.4755	69.6200	
10.6675	9.2185	7.6745	6.6430	14.7590	46.2200	76.5520	
7.4285	6.4090	11.5350	4.7660	12.4970	45.6505	75.6795	

WL= 750	WL= 775	WL= 800	WL= 825	WL= 850	WL= 875	WL= 900	WL= 925
56.9760	68.6905	68.0785	66.5140	66.3685	67.1390	68.1980	66.0690
46.9870	56.2580	55.6855	57.8635	59.0905	59.7370	59.2700	62.7130
40.6450	52.2515	47.6795	50.8190	51.3110	50.8130	49.5420	45.2700
34.5070	39.0695	40.1405	41.8880	38.5365	42.5260	39.7950	41.8420
86.1520	87.0965	38.3255	91.4570	91.0455	90.8720	94.4730	97.3225
52.2665	58.9850	62.3865	62.1025	61.6020	62.3750	66.0315	68.0830
55.3280	66.1295	65.4200	66.0200	66.3595	66.5810	66.5165	69.1870
48.8765	56.5045	57.8360	60.3560	59.8495	60.4850	61.7865	64.6415
50.9040	56.6110	59.3200	60.8360	60.3865	61.8235	62.3950	60.6185
38.7685	45.4425	47.7570	48.7985	48.2835	50.6510	49.9440	49.8600
44.8305	54.3155	56.5875	57.4240	55.7525	58.8360	62.8515	55.1650
42.8350	51.3405	52.3900	53.3655	52.6650	53.8530	52.6115	53.5780
56.6895	65.5485	66.8250	68.6530	68.3725	69.1355	65.7910	65.8420
48.7560	57.3520	58.0160	59.0690	57.6140	58.0085	57.1650	63.4280
45.9265	55.9210	54.8040	56.5265	54.5075	54.7715	50.2050	49.1145
45.2810	49.0685	49.9210	49.4175	47.5330	46.6760	43.8240	41.9280
40.1255	48.2750	47.0845	48.3760	48.1370	48.4325	44.4465	39.9005
39.6835	46.9045	47.7535	48.4570	47.8390	46.6090	45.4715	42.1800

WL= 950	WL= 975	WL=1000	WL=1025	WL=1050	WL=1075	WL=1100	WL=
100.0000	100.0000	41.1455	44.1720	57.8840	53.5420	51.0055	
100.0000	100.0000	46.0145	48.3720	50.6880	45.8610	43.5350	
100.0000	100.0000	28.9275	32.4480	43.0485	39.3970	35.6340	
100.0000	96.7520	31.3830	32.3950	35.3190	32.1120	30.2625	
100.0000	100.0000	93.9770	88.1990	81.7630	73.2115	68.4100	
93.2525	90.2075	62.4095	60.3580	50.4850	49.7445	45.0125	
46.6775	47.3815	63.6405	60.9940	62.2735	52.1835	48.9955	
35.7525	35.7735	53.3175	52.0530	53.0965	47.4080	39.4255	
34.4720	34.7835	48.9635	47.6620	53.5400	45.1745	38.7520	
27.0945	28.5595	35.1670	34.8835	42.6170	37.0685	31.1980	
32.1245	37.2610	45.1985	40.7500	50.3140	56.0405	46.7940	
35.6795	36.6675	33.2745	33.1715	44.7565	30.0075	33.1505	
54.5225	54.9495	40.9535	44.6215	61.2440	68.1410	63.0845	
64.1435	62.0145	46.5365	50.8840	60.4340	52.7915	43.6620	
66.8415	69.9170	46.0055	47.6280	53.5435	45.1805	37.7900	
64.2135	62.0535	31.0385	33.3885	45.4620	32.6345	32.1820	
79.9180	71.5095	55.6940	59.2285	49.7340	40.3170	35.7235	
72.0870	74.4590	70.4610	71.1705	49.2650	38.1255	35.2755	

STATEMENTS EXECUTED= 10

R;

B. 2

Percent Reflectance Data

at 30 Wavelengths

August 20, 21, 1980

ORIGINAL PAGE IS
OF POOR QUALITY

AUGUST 20 AND AUGUST 21, 1980

30 WAVE LENGTH SPECTRORADIOMETER NR DATA

WL= 400	WL= 425	WL= 450	WL= 475	WL= 500	WL= 525	WL= 550	WL= 575
2.4000	2.6850	2.8600	2.9900	2.9750	4.7550	7.4550	5.8800
2.5550	2.6550	2.6500	2.8600	2.6900	4.7500	8.5750	5.6550
2.2200	2.7100	2.6500	2.5900	3.3950	5.5150	6.2000	2.6100
2.0300	2.0150	2.2600	2.1500	2.1100	3.4550	5.5600	4.0700
1.6550	2.4100	2.5650	2.7100	2.7750	4.4050	7.1750	5.3650
2.4250	2.3500	2.7550	2.8650	2.9650	5.3650	7.5450	5.3250
3.1500	2.7900	2.8000	2.7400	2.8100	4.1600	6.2250	4.0450
2.1100	2.5500	2.7500	2.8350	2.3400	4.7650	7.6150	6.0100
3.6250	2.8700	3.2550	3.1750	3.3400	5.3100	8.3150	6.7400
2.9000	2.5600	2.9200	2.8300	2.8300	5.0600	7.7600	5.1550
2.2400	2.6400	2.6450	2.6500	2.6000	4.3950	7.1400	5.7650
2.3950	2.1400	2.5150	2.3100	2.3050	3.7100	5.6700	4.2200
1.7450	2.2050	2.3900	2.2200	2.2900	3.9700	6.0550	5.0400
2.9450	2.4200	2.6850	2.5750	2.6800	4.6700	6.4150	5.4000
2.2050	2.3700	2.7750	2.6000	2.6550	4.5350	6.7950	5.2550
2.3200	2.4650	2.6600	2.4000	2.5000	4.4250	7.0850	5.4850
2.2950	2.3150	2.4850	2.4000	2.4300	3.9600	5.8750	4.4950
2.8600	2.9400	3.2200	3.1700	3.1750	4.8900	7.2350	5.7250

WL= 600	WL= 625	WL= 650	WL= 675	WL= 700	WL= 725	WL= 750	WL=
4.7600	3.8900	3.2500	2.8850	8.5900	32.2550	51.3950	
4.6200	3.7600	3.0000	2.5500	7.9100	29.2050	44.9700	
4.5550	2.1500	3.1850	2.7850	7.7950	29.9750	47.0900	
3.2400	2.6300	2.1800	1.8950	6.5550	26.1450	42.4050	
4.3950	3.6150	2.9100	2.6050	7.5350	28.8250	46.2300	
4.5000	3.6050	3.0950	2.7350	7.3300	27.6400	45.2400	
4.0550	3.3350	2.7400	2.5150	7.5350	26.0000	43.9800	
4.7700	3.9000	3.0500	2.6950	8.3550	30.5400	51.0600	
6.0950	4.5450	3.8450	3.2200	8.7750	34.3500	28.1500	
4.8100	4.0250	3.2050	2.7350	8.8800	33.0450	53.6800	
4.6100	3.6350	2.9100	2.4600	8.1000	31.4550	49.6350	
3.4600	2.8600	2.4100	2.2050	6.6000	27.6150	45.1350	
3.9400	3.2550	2.6450	2.1500	6.7650	25.5700	40.5450	
4.0000	3.1850	2.6050	2.4900	8.3550	33.5450	46.9200	
4.2950	3.6150	3.0250	2.6500	7.7900	31.2950	50.5050	
4.2650	3.5300	2.9150	2.4500	7.5200	25.8750	42.9950	
3.5900	3.2200	2.5650	2.3100	6.4350	26.4500	46.2500	
4.2750	3.4550	2.9100	2.8050	8.8800	30.2950	53.1700	

WL= 750	WL= 775	WL= 800	WL= 825	WL= 850	WL= 875	WL= 900	WL= 925
47.6980	52.2470	55.6945	56.1860	58.8070	59.0455	60.2765	50.2890
49.6580	54.8955	57.2010	57.8200	56.1255	58.3445	62.7165	55.3975
38.0420	39.4210	42.3795	43.5010	43.0845	43.9810	44.8465	37.2645
27.2775	30.3985	32.7090	32.9595	33.5695	34.5590	35.3760	32.2880
37.6330	42.7330	44.7715	45.6875	46.4565	46.2685	49.0625	40.0545
38.4635	40.8125	42.4170	43.2805	45.1515	43.8025	43.7685	35.5360
23.9855	26.3305	25.9975	26.8300	28.0740	27.7235	25.3650	24.6530
25.0325	27.1220	27.8245	28.3700	29.0295	29.1305	28.7425	28.6565
31.2655	35.4530	37.5355	38.1810	39.1890	39.9430	41.3140	31.8230
32.2555	37.6120	39.4755	40.1270	40.7730	41.4845	42.8870	36.9145
28.0575	32.8480	33.6370	34.2730	35.3835	35.4385	34.3240	28.4035
26.3580	29.3090	30.4485	31.3845	32.7720	32.6550	31.8635	29.5205
23.4030	27.7495	29.1285	29.3840	30.0950	29.9645	30.8805	28.4510
28.3000	32.5380	33.7580	34.7015	35.7580	35.6335	35.8465	30.9570
29.3635	34.8160	35.2920	35.9195	36.9830	36.3715	37.0375	31.5890
30.6365	35.2715	35.1610	36.2190	36.3555	37.5765	38.1670	39.1185
29.7045	35.1880	36.4055	37.9930	38.7600	39.0780	35.3635	37.9665
39.9300	46.0500	47.7190	49.5045	50.2945	50.3305	50.8310	50.2300

WL= 950	WL= 975	WL=1000	WL=1025	WL=1050	WL=1075	WL=1100	WL=
51.7750	50.9635	50.2135	51.2880	51.8565	45.0220	64.7050	
66.9205	62.7845	51.4535	30.0355	48.6305	52.8890	58.3855	
40.4450	35.2705	37.0760	36.8545	33.1440	34.2770	28.0860	
31.0600	25.5965	29.9245	30.6175	26.4845	26.6380	23.3170	
43.3850	36.1625	41.0175	41.6575	40.6645	36.9720	27.7380	
51.7145	44.9860	40.2455	41.2790	35.9645	30.9945	30.7130	
18.8750	24.9060	22.1525	21.9410	18.9425	18.5690	20.1785	
21.0995	23.1830	24.4205	23.5265	22.5890	20.0545	23.5895	
31.7420	30.2070	33.6955	32.9675	30.9635	27.6020	29.1965	
31.5825	33.7940	35.2490	35.1490	31.8420	31.1835	28.7255	
28.2605	31.3115	28.1155	27.7310	26.7350	23.6770	24.3560	
27.0105	27.6010	27.2900	25.5580	24.5960	22.9390	20.9125	
24.8470	26.0290	24.5955	23.8163	23.3260	19.8830	15.6090	
29.6875	27.0225	29.9820	28.1945	27.7615	25.7220	17.9980	
31.5690	32.6305	30.9305	29.7070	26.9240	26.1765	19.0100	
32.9795	28.4230	32.2405	31.2745	28.9350	28.1855	19.6450	
33.4800	31.9395	33.0880	33.1700	29.2725	29.0320	20.0100	
45.2505	44.7365	46.4335	44.7210	38.7735	39.1825	29.3480	

STATEMENTS EXECUTED= 10

R;

B. 3

Percent Reflectance Data at

30 Wavelengths

September 12, 1980

SEPTEMBER 12, 1980

30 WAVE LENGTH SPECTRORADIOMETER SR DATA

WL= 400	WL= 425	WL= 450	WL= 475	WL= 500	WL= 525	WL= 550	WL= 575
2.7400	2.9660	2.8045	2.6835	2.6980	4.6305	3.6655	6.5595
1.4275	1.8590	1.9475	1.9165	1.9665	3.1980	5.5025	4.5420
1.1075	1.8305	1.9385	2.0815	2.0420	4.0260	7.1705	5.8540
0.8820	1.8640	1.3645	1.5205	1.5355	2.9470	4.4525	3.5475
0.7565	1.9395	1.6845	1.7315	1.7985	3.1055	4.6870	3.9195
1.0285	2.0150	1.8905	1.7045	1.7915	3.8670	5.3445	5.2015
1.0705	1.8040	1.7115	1.8265	1.8400	3.0465	4.6145	3.0690
0.9150	1.9345	1.6015	1.9705	1.7795	3.2890	5.2150	5.0955
1.2565	2.3975	1.9525	1.9460	2.0640	3.8805	5.8090	4.7510
0.7620	1.7255	1.5205	1.6955	1.7375	3.6100	5.5430	4.7815
0.8255	1.8670	1.7325	1.8130	1.8695	3.3750	6.0905	5.1370
1.1265	1.7635	1.7515	1.8210	1.9310	4.0520	5.3225	5.4460
0.3935	2.2360	2.0730	2.1555	2.2600	3.6395	6.1155	5.1420
1.0965	1.6230	1.8210	1.9680	2.0730	4.3625	5.5195	5.5060
1.2270	2.1235	1.9375	2.1230	2.1295	4.5435	7.0195	6.0890
0.9350	1.3670	1.8040	2.0635	2.0745	3.5735	5.4255	4.5680
1.1055	1.5380	1.5095	1.7730	1.9350	3.7380	6.0665	4.9870
9.3245	1.3875	1.5045	1.6845	1.7520	3.3815	5.3400	4.6980

WL= 600	WL= 625	WL= 650	WL= 675	WL= 700	WL= 725	WL= 750	WL=
4.2030	3.2615	2.8225	2.3945	6.9870	34.6435	53.1380	
3.5290	3.0265	2.5320	2.1170	6.6135	23.7030	41.3700	
4.4510	3.7225	3.1320	2.7460	8.0415	31.9550	47.1145	
2.7515	2.2395	2.0225	1.6820	5.1560	19.4490	37.4840	
2.9915	2.5060	2.1835	1.8770	5.4515	24.1035	36.5385	
3.4760	2.9410	2.4270	1.0850	6.0585	25.5080	38.4330	
3.0075	2.6270	2.3660	2.1420	5.3665	22.4270	34.5890	
3.7235	2.8325	2.3645	2.0040	5.9865	24.6045	36.6050	
3.7765	3.1465	2.7495	2.4725	6.7465	28.4560	42.1935	
3.0030	2.5810	2.2735	1.9155	5.7490	24.6415	41.5490	
3.9685	2.8585	2.4120	2.0060	6.1740	25.8055	39.7060	
3.7705	3.2020	2.7020	2.1220	6.3825	25.4090	37.6705	
3.5160	3.0475	2.6955	2.4330	6.4680	28.1150	42.9880	
4.1225	3.0615	2.5710	2.1660	6.4650	25.8130	40.8465	
5.4070	3.6975	2.7215	2.3810	7.0695	30.9330	44.7485	
3.6265	3.0900	2.5890	2.2435	6.5355	26.3575	40.2275	
3.6945	3.0370	2.5980	2.0640	6.2775	28.3100	44.2135	
3.6810	3.2500	2.6585	2.0295	6.3155	19.9035	34.3110	

WL= 750	WL= 775	WL= 800	WL= 825	WL= 850	WL= 875	WL= 900	WL= 925
68.0750	77.8305	78.8285	78.3530	78.8170	80.8035	79.5700	65.5460
49.6545	54.3215	59.7330	76.1375	72.6025	75.4385	72.5220	61.5040
64.4450	72.9235	77.0440	75.0565	77.4265	78.9065	79.4500	64.7855
51.6580	56.3170	59.5670	60.1885	61.2235	64.0265	65.1365	61.6295
49.4770	69.9905	72.7555	72.8905	75.5180	77.5035	78.7545	61.3580
60.8270	72.2280	72.4670	74.2585	76.9200	79.6135	79.1090	72.5370
45.4655	49.9555	54.0230	52.4990	56.1820	56.6350	59.2760	46.7330
50.6230	55.2530	56.9195	58.2170	60.4445	52.2165	61.2225	51.5310
53.2595	58.4100	56.3950	60.6940	62.6150	64.8815	63.2415	64.5535
49.9520	54.2735	55.3130	56.2910	57.1280	59.1945	58.1040	55.3495
51.2915	54.9715	57.2495	58.2070	60.8235	61.6380	60.1615	57.9085
43.0880	46.4940	46.9445	49.2395	50.6510	53.7555	52.2890	52.4600
45.6340	49.7325	50.3070	52.8500	53.5435	55.4970	52.6380	53.1450
45.2435	47.8350	49.3930	50.7440	51.7855	53.3755	52.5190	50.9450
42.4100	50.0005	50.0745	52.3860	52.6700	74.1955	51.8250	46.2080
42.6570	47.48[illegible]	49.1520	51.5665	52.5540	53.4890	53.8535	50.8010
40.4115	55.9630	58.0245	60.9535	59.0680	61.4695	60.8150	53.3175
33.7015	39.0370	40.4190	41.9120	41.7400	43.3765	42.8345	39.6205

WL= 950	WL= 975	WL=1000	WL=1025	WL=1050	WL=1075	WL=1100	WL=
61.6950	67.8875	67.9130	68.4810	68.1335	71.2915	76.8345	
51.6805	55.9905	59.8560	60.7595	62.5015	63.5605	66.6730	
65.2860	62.9030	60.9395	59.7390	65.9860	67.6925	77.9740	
62.5460	62.1275	57.0080	58.6410	66.6525	65.5985	67.6590	
67.4265	63.9950	61.6115	63.3530	67.4165	70.2425	73.8660	
67.4675	66.7920	63.0385	62.2345	66.5170	69.3530	67.1735	
44.3715	45.9375	43.6595	45.0205	47.6795	49.4605	48.4430	
50.9090	49.6300	45.9930	48.1815	51.4720	56.1790	57.8380	
50.5655	53.8180	49.1940	47.7955	54.0710	55.3200	59.0660	
49.8115	50.1055	55.3675	55.9070	49.6400	54.4865	56.7775	
54.1540	54.5295	52.2835	51.4580	54.7105	62.8450	62.0060	
49.7550	46.4085	43.0080	45.3035	46.5905	51.6475	50.3105	
35.3445	38.5155	45.3870	44.7005	48.9065	53.4485	55.1535	
48.3135	48.4390	42.8435	43.8295	47.6695	51.1510	50.7355	
51.3585	51.3560	53.5490	52.1635	46.9960	55.5400	53.9970	
53.9400	50.4530	46.7065	46.8790	51.3670	54.7100	55.2095	
61.7525	54.1465	50.7040	52.8890	57.2475	62.2420	65.4235	
53.1680	43.6950	42.0095	42.9980	46.2600	52.5075	49.1200	

STATEMENTS EXECUTED= 10
R:

B. 4

Correlations of Percent Reflectance Data at

30 Wavelengths

July 17, 18, 1980

ORIGINAL PAGE IS
OF POOR QUALITY

CORRELATION COEFFICIENTS MATRIX (SPECTRORADIOMETER SR)

JULY 17 AND JULY 18, 1980

--CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21

-- ,C22,C23,C24,C25,C26,C27,C28,C29,C30

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.013								
C3	0.036	0.888							
C4	0.050	0.890	0.983						
C5	0.055	0.915	0.956	0.976					
C6	0.014	0.912	0.921	0.952	0.980				
C7	0.041	0.880	0.892	0.927	0.964	0.990			
C8	0.144	0.678	0.686	0.731	0.829	0.832	0.873		
C9	-0.096	0.150	0.064	0.127	0.114	0.150	0.194	0.143	
C10	-0.012	0.898	0.933	0.951	0.977	0.966	0.944	0.804	0.095
C11	-0.114	0.312	0.289	0.312	0.242	0.173	0.177	0.140	-0.048
C12	-0.041	0.863	0.960	0.964	0.956	0.907	0.870	0.713	0.127
C13	-0.079	0.867	0.868	0.904	0.952	0.974	0.974	0.875	0.158
C14	-0.018	0.768	0.747	0.775	0.841	0.888	0.928	0.891	0.217
C15	-0.057	0.740	0.788	0.815	0.827	0.845	0.875	0.815	0.179
C16	0.019	-0.214	0.075	0.055	0.025	-0.009	0.043	0.233	0.165
C17	0.001	-0.226	0.025	0.007	-0.014	-0.044	0.012	0.192	0.197
C18	0.055	-0.229	0.007	-0.015	-0.029	-0.066	-0.004	0.210	0.206
C19	0.057	-0.257	-0.001	-0.014	-0.027	-0.061	0.002	0.223	0.217
C20	0.044	-0.250	0.005	-0.007	-0.017	-0.058	0.003	0.225	0.219
C21	0.086	-0.304	-0.049	-0.062	-0.069	-0.115	-0.053	0.195	0.219
C22	0.151	-0.338	-0.091	-0.105	-0.110	-0.169	-0.110	0.163	0.128
C23	0.007	-0.373	-0.133	-0.162	-0.157	-0.212	-0.147	0.148	0.112
C24	-0.378	-0.090	0.197	0.149	-0.021	-0.082	-0.144	-0.355	-0.122
C25	-0.359	-0.133	0.156	0.106	-0.067	-0.123	-0.184	-0.397	-0.127
C26	0.042	0.237	0.499	0.484	0.465	0.413	0.453	0.564	-0.078
C27	-0.037	0.299	0.565	0.543	0.514	0.465	0.502	0.562	-0.028
C28	0.023	-0.008	0.239	0.214	0.209	0.199	0.265	0.410	0.226
C29	0.072	-0.085	0.029	0.053	0.028	0.027	0.091	0.198	0.712
C30	0.052	-0.144	0.067	0.063	0.023	-0.012	0.043	0.173	0.480

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.181								
C12	0.957	0.273							
C13	0.935	0.172	0.879						
C14	0.786	0.187	0.701	0.926					
C15	0.744	0.387	0.723	0.879	0.938				
C16	-0.057	-0.008	0.029	0.070	0.184	0.355			
C17	-0.084	-0.043	-0.007	0.056	0.160	0.315	0.970		
C18	-0.111	0.013	-0.036	0.022	0.159	0.314	0.978	0.986	
C19	-0.108	-0.023	-0.033	0.031	0.162	0.312	0.981	0.985	0.994
C20	-0.097	-0.012	-0.014	0.039	0.158	0.306	0.973	0.986	0.989
C21	-0.144	-0.041	-0.066	-0.024	0.097	0.240	0.964	0.974	0.986
C22	-0.193	0.019	-0.110	-0.081	0.041	0.198	0.941	0.947	0.971
C23	-0.225	0.018	-0.144	-0.106	0.040	0.184	0.926	0.922	0.950
C24	0.007	0.259	0.201	-0.077	-0.269	-0.022	0.203	0.197	0.120
C25	-0.048	0.239	0.148	-0.115	-0.292	-0.043	0.221	0.223	0.145
C26	0.384	0.417	0.432	0.469	0.527	0.680	0.690	0.631	0.656
C27	0.446	0.429	0.503	0.518	0.558	0.710	0.666	0.619	0.630
C28	0.147	-0.041	0.179	0.276	0.405	0.514	0.931	0.939	0.935
C29	-0.036	-0.046	0.025	0.075	0.201	0.296	0.745	0.780	0.795
C30	-0.046	0.000	0.047	0.057	0.150	0.302	0.882	0.914	0.917

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.996								
C21	0.994	0.994							
C22	0.974	0.975	0.987						
C23	0.957	0.955	0.967	0.972					
C24	0.121	0.129	0.104	0.085	0.105				
C25	0.147	0.154	0.129	0.114	0.127	0.995			
C26	0.664	0.665	0.638	0.651	0.636	0.175	0.181		
C27	0.638	0.643	0.606	0.604	0.599	0.246	0.247	0.987	
C28	0.940	0.936	0.915	0.875	0.867	0.090	0.108	0.745	0.750
C29	0.801	0.795	0.802	0.752	0.716	0.006	0.027	0.389	0.395
C30	0.919	0.917	0.921	0.890	0.853	0.190	0.215	0.569	0.566

	C28	C29
C29	0.776	
C30	0.880	0.941

B. 5

Correlations of Percent Reflectance Data at

30 Wavelengths

August 20, 21, 1980

ORIGINAL PAGE IS
OF POOR QUALITY

AUGUST 20 AND AUGUST 21, 1980

-- CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21

-- ,C22,C23,C24,C25,C26,C27,C28,C29,C30

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.608								
C3	0.748	0.826							
C4	0.584	0.838	0.900						
C5	0.489	0.821	0.739	0.825					
C6	0.404	0.660	0.691	0.744	0.896				
C7	0.357	0.596	0.643	0.797	0.544	0.676			
C8	0.389	0.359	0.593	0.631	0.200	0.308	0.773		
C9	0.475	0.696	0.742	0.785	0.758	0.789	0.835	0.619	
C10	0.404	0.421	0.619	0.665	0.279	0.350	0.814	0.953	0.726
C11	0.452	0.702	0.763	0.781	0.815	0.840	0.785	0.523	0.970
C12	0.545	0.792	0.877	0.897	0.920	0.875	0.729	0.496	0.891
C13	0.549	0.787	0.833	0.831	0.719	0.716	0.719	0.607	0.749
C14	0.490	0.505	0.645	0.636	0.578	0.612	0.549	0.480	0.678
C15	-0.284	0.056	-0.002	0.092	0.001	0.061	-0.018	-0.046	-0.255
C16	0.041	0.404	0.299	0.545	0.471	0.503	0.565	0.147	0.336
C17	0.047	0.396	0.318	0.541	0.416	0.453	0.578	0.213	0.322
C18	0.035	0.381	0.302	0.531	0.427	0.460	0.560	0.187	0.328
C19	0.043	0.392	0.313	0.535	0.437	0.463	0.550	0.177	0.319
C20	0.053	0.388	0.335	0.555	0.445	0.461	0.539	0.204	0.323
C21	0.060	0.393	0.321	0.537	0.431	0.450	0.548	0.191	0.326
C22	0.038	0.370	0.306	0.524	0.419	0.458	0.585	0.211	0.355
C23	0.002	0.342	0.249	0.429	0.280	0.302	0.484	0.156	0.164
C24	-0.042	0.227	0.157	0.416	0.317	0.412	0.516	0.123	0.220
C25	0.065	0.360	0.270	0.522	0.347	0.419	0.585	0.222	0.281
C26	0.051	0.366	0.331	0.545	0.428	0.453	0.547	0.201	0.296
C27	-0.009	0.294	0.374	0.500	0.497	0.449	0.317	0.149	0.266
C28	-0.019	0.325	0.260	0.512	0.382	0.409	0.555	0.234	0.324
C29	0.015	0.342	0.223	0.456	0.347	0.375	0.523	0.121	0.245
C30	0.096	0.302	0.251	0.524	0.336	0.342	0.583	0.264	0.376

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.658								
C12	0.595	0.937							
C13	0.590	0.719	0.802						
C14	0.492	0.640	0.702	0.838					
C15	-0.122	-0.187	-0.028	0.247	0.141				
C16	0.178	0.406	0.462	0.366	0.254	0.215			
C17	0.238	0.389	0.442	0.381	0.277	0.235	0.987		
C18	0.215	0.394	0.441	0.378	0.295	0.217	0.988	0.996	
C19	0.204	0.389	0.445	0.377	0.289	0.226	0.987	0.997	0.999
C20	0.227	0.396	0.465	0.387	0.308	0.239	0.981	0.991	0.994
C21	0.220	0.394	0.449	0.387	0.303	0.216	0.984	0.994	0.998
C22	0.237	0.411	0.443	0.404	0.320	0.177	0.978	0.988	0.993
C23	0.162	0.231	0.291	0.301	0.125	0.265	0.918	0.946	0.937
C24	0.123	0.276	0.306	0.187	0.110	0.133	0.958	0.950	0.947
C25	0.237	0.334	0.370	0.295	0.184	0.218	0.951	0.953	0.943
C26	0.211	0.366	0.436	0.366	0.260	0.218	0.980	0.990	0.991
C27	0.148	0.375	0.486	0.350	0.275	0.267	0.765	0.767	0.785
C28	0.257	0.378	0.422	0.357	0.286	0.197	0.972	0.979	0.985
C29	0.153	0.301	0.345	0.318	0.222	0.210	0.972	0.982	0.982
C30	0.319	0.398	0.399	0.380	0.297	0.156	0.879	0.856	0.866

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.995								
C21	0.998	0.996							
C22	0.990	0.982	0.990						
C23	0.942	0.923	0.940	0.931					
C24	0.946	0.932	0.933	0.934	0.890				
C25	0.941	0.932	0.931	0.923	0.888	0.960			
C26	0.993	0.991	0.991	0.983	0.947	0.950	0.932		
C27	0.792	0.832	0.805	0.768	0.689	0.678	0.624	0.819	
C28	0.982	0.986	0.986	0.984	0.913	0.925	0.911	0.976	0.807
C29	0.982	0.963	0.978	0.981	0.962	0.943	0.931	0.973	0.698
C30	0.851	0.857	0.868	0.864	0.785	0.796	0.862	0.827	0.587

	C28	C29
C29	0.960	
C30	0.886	0.851

B. 6

Correlations of Percent Reflectance Data at

30 Wavelengths

September 12, 1980

SEPTEMBER 12, 1980

-- CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,C16,C17,C18,C19,C20,C21

-- ,C22,C23,C24,C25,C26,C27,C28,C29,C30

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.231								
C3	0.021	0.823							
C4	-0.049	0.745	0.902						
C5	-0.029	0.720	0.921	0.955					
C6	-0.022	0.428	0.636	0.655	0.719				
C7	-0.003	0.558	0.765	0.798	0.781	0.868			
C8	0.037	0.427	0.675	0.728	0.722	0.898	0.973		
C9	0.023	0.207	0.348	0.473	0.448	0.736	0.644	0.748	
C10	0.243	0.165	0.507	0.575	0.588	0.732	0.706	0.785	0.784
C11	0.208	0.250	0.591	0.640	0.678	0.685	0.704	0.736	0.565
C12	-0.026	0.407	0.619	0.719	0.722	0.586	0.595	0.606	0.537
C13	0.092	0.275	0.579	0.644	0.643	0.693	0.741	0.770	0.671
C14	-0.262	0.647	0.749	0.822	0.837	0.794	0.859	0.821	0.625
C15	-0.184	0.639	0.735	0.781	0.811	0.715	0.810	0.732	0.510
C16	-0.342	0.656	0.563	0.419	0.343	0.264	0.507	0.352	-0.005
C17	-0.310	0.575	0.480	0.325	0.287	0.214	0.422	0.267	-0.035
C18	-0.308	0.474	0.443	0.279	0.231	0.069	0.323	0.163	-0.100
C19	-0.319	0.480	0.449	0.270	0.241	0.066	0.311	0.155	-0.093
C20	-0.356	0.498	0.437	0.255	0.212	0.053	0.296	0.139	-0.115
C21	-0.363	0.548	0.468	0.319	0.269	0.238	0.299	0.289	0.236
C22	-0.351	0.450	0.373	0.187	0.143	0.001	0.227	0.065	-0.184
C23	-0.441	0.517	0.359	0.114	0.136	0.116	0.252	0.111	-0.165
C24	-0.008	0.017	0.019	-0.139	-0.154	-0.046	0.074	-0.031	-0.097
C25	-0.214	0.391	0.286	0.105	0.074	0.121	0.259	0.110	-0.031
C26	-0.221	0.505	0.419	0.231	0.207	0.138	0.322	0.189	0.050
C27	-0.212	0.450	0.360	0.182	0.152	0.078	0.273	0.130	-0.030
C28	-0.203	0.363	0.263	0.074	0.055	-0.088	0.128	-0.046	-0.258
C29	-0.153	0.346	0.303	0.117	0.101	-0.031	0.223	0.078	-0.106
C30	-0.226	0.416	0.339	0.226	0.195	0.046	0.297	0.139	-0.083

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.930								
C12	0.806	0.907							
C13	0.932	0.941	0.872						
C14	0.603	0.728	0.767	0.766					
C15	0.546	0.620	0.642	0.702	0.900				
C16	0.059	0.183	0.254	0.297	0.506	0.549			
C17	0.021	0.113	0.150	0.212	0.509	0.513	0.896		
C18	-0.015	0.071	0.109	0.202	0.399	0.469	0.857	0.946	
C19	0.001	0.076	0.103	0.221	0.392	0.477	0.818	0.908	0.984
C20	-0.031	0.051	0.102	0.186	0.387	0.428	0.863	0.944	0.991
C21	0.160	0.118	0.176	0.295	0.502	0.512	0.765	0.871	0.901
C22	-0.093	-0.003	0.046	0.119	0.321	0.366	0.847	0.943	0.987
C23	-0.091	0.009	0.039	0.143	0.331	0.395	0.853	0.852	0.838
C24	-0.040	-0.088	-0.234	0.066	0.063	0.164	0.474	0.681	0.736
C25	-0.065	-0.069	-0.101	0.095	0.283	0.372	0.762	0.891	0.874
C26	-0.016	-0.016	-0.006	0.164	0.377	0.522	0.774	0.873	0.907
C27	-0.098	-0.094	-0.103	0.076	0.304	0.465	0.737	0.860	0.909
C28	-0.172	-0.098	-0.102	0.041	0.186	0.332	0.738	0.863	0.912
C29	-0.066	-0.052	-0.102	0.117	0.245	0.382	0.684	0.831	0.901
C30	0.003	0.088	0.096	0.240	0.400	0.519	0.767	0.898	0.927

	C19	C20	C21	C22	C23.	C24	C25	C26	C27
C20	0.987								
C21	0.909	0.909							
C22	0.974	0.993	0.886						
C23	0.862	0.881	0.783	0.872					
C24	0.737	0.718	0.682	0.750	0.623				
C25	0.855	0.868	0.842	0.885	0.818	0.894			
C26	0.905	0.890	0.907	0.878	0.805	0.761	0.899		
C27	0.904	0.885	0.880	0.884	0.772	0.799	0.906	0.986	
C28	0.907	0.902	0.796	0.921	0.837	0.850	0.923	0.806	0.902
C29	0.912	0.889	0.835	0.885	0.788	0.865	0.902	0.919	0.928
C30	0.915	0.906	0.827	0.905	0.801	0.799	0.882	0.895	0.896

	C28	C29
C29	0.959	
C30	0.949	0.944

B. 7

Percent Reflectance for

SM2S Data

July 17, 18, 1980

JULY 17 AND JULY 18, 1980

11 CHANNELS SH2S DATA

CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7
2.6928	2.4905	3.3730	5.9300	4.3150	3.6575	5.4150
2.9598	3.0840	4.1230	7.0055	5.1015	4.4338	6.4447
2.7157	2.5585	3.5650	6.3915	4.7315	3.5925	5.6458
2.7802	2.6325	3.6100	6.5737	4.8285	3.9010	5.5192
3.5192	3.6550	5.0250	9.8750	5.8480	4.7535	7.3752
2.7462	2.9460	3.8052	7.5220	4.6280	11.6562	5.8690
3.1882	3.2655	5.2125	10.9712	6.6545	5.0502	7.9517
3.0428	3.1300	5.1405	10.5837	6.7915	5.1400	7.8850
7.4857	2.9055	4.1950	8.8807	5.4395	4.2675	5.9715
2.0522	2.1100	3.3517	6.7612	4.5435	3.4322	4.9210
7.8777	3.1545	4.5985	8.6550	5.7230	4.3105	6.2320
2.4540	2.4575	3.9540	7.7393	4.7865	3.5150	5.7355
2.9912	3.2435	4.7560	9.3312	60.2720	4.6427	7.0413
2.8318	2.9970	4.5350	8.8200	5.9025	4.4410	6.4880
3.1178	3.2505	4.9100	9.2395	6.3030	4.5455	7.0550
3.7282	3.7635	5.5295	9.6517	6.8300	5.1080	7.7498
4.7048	5.4145	7.8075	13.5487	10.6675	8.4465	10.7010
4.0000	4.3135	6.2080	10.6830	7.4285	8.9720	8.6315

CH 8	CH 9	CH10	CH11	CH
41.9772	67.3560	71.3293	54.1438	
42.4285	57.7269	73.5966	46.6947	
37.5423	50.5748	65.3439	39.3598	
33.7328	40.4321	65.1324	32.5645	
66.5467	89.7592	95.5439	74.4615	
49.3290	61.4902	76.5568	48.4140	
57.5045	66.1019	54.6734	54.4842	
51.7205	59.0062	44.2254	46.9100	
45.9882	59.7953	41.4702	45.8222	
35.1698	48.1865	31.4261	36.9612	
44.7805	56.5931	38.8335	51.0495	
42.9295	52.0228	34.6982	38.6382	
53.3688	67.7069	48.7793	70.8232	
49.8950	58.0119	56.0946	52.2958	
51.0742	55.3061	57.5980	45.5047	
52.1255	48.5232	47.8997	38.7595	
54.2992	48.0610	66.5875	41.9248	
53.6728	47.5126	72.0469	40.8890	

STATEMENTS EXECUTED= 6

R;

B. 8

Percent Reflectance for

SM2S Data

August 20, 21, 1980

AUGUST 20 AND AUGUST 21, 1980

11 CHANNELS SH2S DATA

CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7
2.6483	2.9900	3.8650	6.6675	4.7600	3.5700	5.7375
2.6200	2.8600	3.7200	7.1150	4.6200	3.3800	5.2300
2.5267	2.5900	4.4550	4.4050	4.5550	2.6675	5.2900
2.1017	2.1500	2.7925	4.8150	3.2400	2.4050	4.2250
2.2100	2.7100	3.5950	6.2700	4.3950	3.2625	5.0700
2.5100	2.8650	4.1650	6.6850	4.5800	3.3500	5.0325
2.9133	2.7400	3.4850	5.5350	4.0550	3.0375	5.0250
2.4700	2.8350	3.8025	6.8125	4.7700	3.4750	5.5250
3.2500	3.1750	4.3250	7.5275	6.0950	4.1950	5.9975
2.7933	2.8300	3.9450	6.9575	4.8100	3.6150	5.8075
2.5083	2.6500	3.4975	6.4525	4.6100	3.2725	5.2800
2.3500	2.3100	3.0075	4.9450	3.4600	2.6350	4.4025
2.1133	2.2200	3.1300	5.5475	3.9400	2.9500	4.4575
2.6833	2.5750	3.6750	5.9075	4.0000	2.8950	5.4225
2.4767	2.6000	3.5950	6.0250	4.2950	3.3200	5.2200
2.4817	2.4000	3.4625	6.2850	4.2650	3.2225	4.9850
2.3650	2.4000	3.1950	5.1850	3.5900	2.8925	4.3725
3.0067	3.1700	4.0325	6.4800	4.2750	3.1825	5.8425

CH 8	CH 9	CH10	CH11	CH
43.7827	56.3960	51.0600	53.8612	
41.2777	56.8773	52.7985	53.3027	
38.3557	42.4734	37.4115	31.8357	
31.9425	32.8391	29.2996	25.4798	
37.5627	45.1834	40.5556	35.1248	
37.1145	43.0928	44.5562	32.5573	
31.3218	26.9911	21.9686	19.2300	
35.5442	28.2953	23.0574	22.0777	
31.2552	38.0603	32.3030	29.2540	
39.6602	39.8944	33.9436	30.5837	
36.3825	34.3160	28.8546	24.9227	
33.0360	31.4138	26.8649	22.8158	
29.8393	29.2643	24.8219	19.6060	
36.2550	34.4778	28.7216	23.8272	
37.0562	35.8764	31.2092	24.0368	
33.1688	36.1167	31.2294	25.5885	
34.1348	37.4849	32.9194	26.1048	
41.1483	48.7797	45.4479	35.7680	

STATEMENTS EXECUTED= 6
R;

B.10

Correlations of Percent Reflectance

for SM2S Data

July 17, 18, 1980

August 20, 21, 1980

September 12, 1980

SEPTEMBER 12, 1980

11 CHANNELS SM2S DATA

CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 7
2.8368	2.6885	3.6642	7.6125	4.2030	3.0420	4.6908
1.7447	1.9165	2.5822	5.0222	3.5290	2.7792	4.3652
1.6282	2.0815	3.0340	6.5122	4.4510	3.4272	5.3938
1.3702	1.5205	2.2412	4.0000	2.7515	2.1310	3.4190
1.4602	1.7315	2.4520	4.3033	2.9915	2.3447	3.6642
1.6473	1.7045	2.8292	5.7730	3.4760	2.6840	3.9718
1.5287	1.8265	2.4432	4.2417	3.0075	2.4965	3.7542
1.4837	1.9705	2.5342	5.6552	3.7235	2.5985	3.9952
1.8688	1.9460	2.9722	5.2800	3.7765	2.9480	4.6095
1.3560	1.6955	2.6737	5.1622	3.6080	2.4272	3.8322
1.4950	1.8130	2.6222	5.6137	3.9685	2.6352	4.0900
1.5472	1.8210	2.9915	5.8842	3.7705	2.9520	4.2522
1.7342	2.1585	2.9497	5.6287	3.5160	2.8715	4.4505
1.5135	1.9680	3.2177	6.0127	4.1225	2.8162	4.3155
1.7627	2.1230	3.3365	6.5542	6.4870	3.2095	4.7252
1.5353	2.0635	2.8240	4.9967	3.6265	2.8395	4.3895
1.3843	1.7730	2.8365	5.5267	3.6945	2.8175	4.1707
4.1055	1.6845	2.5667	5.0190	3.6810	2.9542	4.1725

CH 8	CH 9	CH10	CH11	CH
51.9522	78.9265	66.4941	72.0865	
38.2425	69.6466	59.5736	65.9117	
47.8382	76.2714	62.2169	70.5508	
36.1970	60.2645	60.1006	66.6400	
36.7063	73.7315	64.0965	70.5083	
41.5893	75.0973	64.8831	67.6828	
34.1605	53.8589	44.7472	48.5277	
37.2775	58.6100	48.6796	55.1630	
41.3030	60.5991	50.3432	56.4523	
38.7142	56.4400	52.7979	53.6347	
38.9350	58.5779	53.1062	59.8538	
35.3892	49.4169	46.1187	49.5162	
38.9123	52.3860	41.1119	52.5028	
37.3010	50.6266	45.8564	49.8520	
39.3638	55.8653	52.2342	52.1777	
36.4140	50.8498	49.4946	53.7622	
37.6450	59.0956	54.8730	61.6377	
29.3053	41.3969	45.4676	49.2958	

STATEMENTS EXECUTED= 6

R;

B. 9

Percent Reflectance for

SM2S Data

September 12, 1980

CORRELATION COEFFICIENTS MATRIX (SM2S)

JULY 17 AND JULY 18, 1980

-- CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.300								
C3	0.277	0.966							
C4	0.308	0.866	0.947						
C5	-0.064	0.127	0.137	0.177					
C6	0.042	0.561	0.467	0.417	-0.015				
C7	0.177	0.949	0.983	0.941	0.152	0.475			
C8	0.129	0.646	0.665	0.760	0.225	0.381	0.695		
C9	0.014	-0.018	-0.055	0.094	0.213	-0.051	0.006	0.634	
C10	-0.221	0.339	0.149	0.034	-0.124	0.408	0.225	0.373	0.415
C11	0.056	0.108	0.075	0.199	0.521	-0.024	0.120	0.662	0.919

	C10
C11	0.349

AUGUST 20 AND AUGUST 21, 1980

-- CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.805								
C3	0.661	0.794							
C4	0.541	0.755	0.479						
C5	0.662	0.785	0.797	0.768					
C6	0.624	0.779	0.593	0.918	0.902				
C7	0.789	0.885	0.817	0.715	0.821	0.761			
C8	0.219	0.560	0.501	0.360	0.260	0.261	0.562		
C9	0.225	0.541	0.460	0.392	0.324	0.318	0.418	0.836	
C10	0.180	0.521	0.452	0.374	0.279	0.279	0.350	0.805	0.984
C11	0.197	0.520	0.387	0.418	0.335	0.338	0.394	0.802	0.966

	C10
C11	0.939

SEPTEMBER 12, 1980

-- CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.220								
C3	0.193	0.807							
C4	0.215	0.773	0.903						
C5	0.113	0.478	0.684	0.694					
C6	0.350	0.612	0.743	0.749	0.706				
C7	0.209	0.682	0.729	0.735	0.651	0.952			
C8	-0.073	0.703	0.657	0.723	0.321	0.436	0.596		
C9	-0.172	0.297	0.184	0.296	-0.021	0.054	0.208	0.769	
C10	-0.063	0.095	0.078	0.182	-0.029	-0.064	0.044	0.608	0.904
C11	-0.083	0.146	0.029	0.154	-0.150	-0.053	0.096	0.638	0.921

	C10
C11	0.946

B. 11

Correlations between Yield 1977-1980,
Pruning Weight, Clusters and Reflectance
at 30 Wavelengths
July 17, 18, 1980

t gel/ out

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.013								
C3	0.036	0.888							
C4	0.050	0.890	0.983						
C5	0.055	0.915	0.956	0.976					
C6	0.014	0.912	0.921	0.952	0.980				
C7	0.041	0.888	0.892	0.927	0.964	0.990			
C8	0.144	0.678	0.686	0.731	0.829	0.832	0.873		
C9	-0.096	0.150	0.064	0.127	0.114	0.150	0.194	0.143	
C10	-0.012	0.898	0.933	0.951	0.977	0.966	0.944	0.804	0.095
C11	-0.114	0.312	0.289	0.312	0.242	0.173	0.177	0.140	-0.048
C12	-0.041	0.863	0.960	0.964	0.956	0.907	0.870	0.713	0.127
C13	-0.079	0.867	0.868	0.904	0.952	0.974	0.974	0.875	0.158
C14	-0.018	0.788	0.747	0.775	0.841	0.888	0.928	0.891	0.217
C15	-0.057	0.740	0.788	0.815	0.827	0.845	0.875	0.815	0.179
C16	0.019	-0.214	0.075	0.055	0.025	-0.009	0.043	0.233	0.165
C17	0.001	-0.226	0.025	0.007	-0.014	-0.044	0.012	0.192	0.197
C18	0.055	-0.229	0.007	-0.015	-0.029	-0.066	-0.004	0.210	0.206
C19	0.057	-0.257	-0.001	-0.014	-0.027	-0.061	0.002	0.223	0.217
C20	0.044	-0.250	0.005	-0.007	-0.017	-0.058	0.003	0.225	0.219
C21	0.086	-0.304	-0.049	-0.062	-0.069	-0.115	-0.053	0.195	0.219
C22	0.151	-0.338	-0.091	-0.105	-0.110	-0.169	-0.110	0.163	0.128
C23	0.007	-0.373	-0.133	-0.162	-0.157	-0.212	-0.147	0.148	0.112
C24	-0.378	-0.090	0.197	0.149	-0.021	-0.082	-0.144	-0.355	-0.122
C25	-0.359	-0.133	0.156	0.106	-0.067	-0.123	-0.184	-0.397	-0.127
C26	0.042	0.237	0.499	0.484	0.465	0.413	0.453	0.564	-0.078
C27	-0.037	0.299	0.565	0.543	0.514	0.465	0.502	0.562	-0.028
C28	0.083	-0.008	0.239	0.214	0.209	0.199	0.265	0.410	0.226
C29	0.072	-0.085	0.029	0.053	0.028	0.027	0.091	0.198	0.712
C30	0.052	-0.144	0.067	0.063	0.023	-0.012	0.043	0.173	0.480
C31	0.062	-0.156	0.105	0.075	0.025	-0.009	-0.031	0.020	-0.299
C32	0.014	-0.243	0.018	-0.022	-0.076	-0.204	-0.274	-0.214	-0.209
C33	-0.120	-0.325	-0.218	-0.215	-0.284	-0.290	-0.322	-0.416	-0.060
C34	0.172	-0.227	-0.230	-0.177	-0.165	-0.226	-0.240	-0.144	-0.036
C35	0.040	0.636	0.759	0.728	0.699	0.658	0.618	0.469	-0.063
C36	0.109	0.122	0.339	0.263	0.217	0.167	0.141	0.190	-0.318

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.181								
C12	0.957	0.273							
C13	0.935	0.172	0.879						
C14	0.786	0.187	0.701	0.926					
C15	0.744	0.387	0.723	0.879	0.938				
C16	-0.057	-0.008	0.029	0.070	0.184	0.355			
C17	-0.084	-0.043	-0.007	0.056	0.160	0.315	0.970		
C18	-0.111	0.013	-0.036	0.022	0.159	0.314	0.978	0.986	
C19	-0.108	-0.023	-0.033	0.031	0.162	0.312	0.981	0.985	0.994
C20	-0.097	-0.012	-0.014	0.039	0.158	0.306	0.973	0.986	0.989
C21	-0.144	-0.041	-0.066	-0.024	0.097	0.240	0.964	0.974	0.986
C22	-0.193	0.019	-0.110	-0.081	0.041	0.198	0.941	0.947	0.971
C23	-0.225	0.018	-0.144	-0.106	0.040	0.184	0.926	0.922	0.950
C24	0.007	0.259	0.201	-0.077	-0.269	-0.022	0.203	0.197	0.120
C25	-0.048	0.239	0.148	-0.115	-0.292	-0.043	0.221	0.223	0.145
C26	0.384	0.417	0.432	0.469	0.527	0.680	0.690	0.631	0.656
C27	0.446	0.429	0.503	0.518	0.558	0.710	0.666	0.619	0.630
C28	0.147	-0.041	0.179	0.276	0.405	0.514	0.931	0.939	0.935
C29	-0.036	-0.046	0.025	0.075	0.201	0.296	0.745	0.780	0.795
C30	-0.046	0.000	0.047	0.057	0.150	0.302	0.882	0.914	0.917
C31	0.003	0.070	0.125	-0.025	-0.046	0.030	0.276	0.138	0.152
C32	-0.044	-0.081	0.162	-0.180	-0.421	-0.302	0.215	0.223	0.171
C33	-0.261	-0.232	-0.140	-0.263	-0.358	-0.347	-0.185	-0.157	-0.256
C34	-0.190	-0.001	-0.081	-0.202	-0.264	-0.272	-0.264	-0.270	-0.290
C35	0.693	0.311	0.753	0.618	0.478	0.520	0.134	0.093	0.089
C36	0.178	0.188	0.290	0.141	0.132	0.215	0.359	0.235	0.272

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.996								
C21	0.994	0.994							
C22	0.974	0.975	0.987						
C23	0.957	0.955	0.967	0.972					
C24	0.121	0.129	0.104	0.085	0.105				
C25	0.147	0.154	0.129	0.114	0.127	0.995			
C26	0.664	0.665	0.638	0.651	0.636	0.175	0.181		
C27	0.638	0.643	0.606	0.604	0.599	0.246	0.247	0.987	
C28	0.940	0.936	0.915	0.875	0.867	0.090	0.108	0.745	0.750
C29	0.801	0.795	0.802	0.752	0.716	0.006	0.027	0.389	0.395
C30	0.919	0.917	0.921	0.890	0.853	0.190	0.215	0.569	0.566
C31	0.183	0.195	0.165	0.198	0.221	0.243	0.236	0.324	0.327
C32	0.187	0.224	0.229	0.255	0.230	0.566	0.552	0.031	0.048
C33	-0.209	-0.175	-0.202	-0.234	-0.191	0.439	0.442	-0.383	-0.339
C34	-0.242	-0.213	-0.213	-0.184	-0.158	0.042	0.021	-0.376	-0.390
C35	0.068	0.085	0.032	0.029	-0.047	0.187	0.164	0.500	0.558
C36	0.254	0.258	0.223	0.260	0.244	0.212	0.208	0.489	0.494

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.776							
C30	0.880	0.941						
C31	0.171	-0.112	-0.008					
C32	0.059	-0.016	0.153	0.483				
C33	-0.273	-0.229	-0.209	0.290	0.441			
C34	-0.391	-0.229	-0.283	0.247	0.426	0.685		
C35	0.227	-0.026	0.052	0.422	0.256	-0.308	-0.308	
C36	0.295	-0.060	0.088	0.840	0.387	-0.088	-0.148	0.713

B.12

Correlations between Yield 1977-1980,

Pruning Weight, Clusters and Reflectance

at 30 Wavelengths

August 20, 21, 1980

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.608								
C3	0.748	0.826							
C4	0.384	0.838	0.900						
C5	0.489	0.821	0.789	0.825					
C6	0.404	0.660	0.691	0.744	0.896				
C7	0.357	0.596	0.643	0 797	0.544	0.676			
C8	0.389	0.359	0.593	0.631	0.200	0.308	0.773		
C9	0.475	0.696	0.742	0.785	0.758	0.789	0.835	0.619	
C10	0.404	0.421	0.619	0.665	0.279	0.350	0.814	0.953	0.726
C11	0.452	0.702	0.763	0.781	0.815	0.840	0.785	0.523	0.970
C12	0.545	0.792	0.877	0.897	0.920	0.875	0.729	0.496	0.891
C13	0.549	0.787	0.833	0.831	0.719	0.716	0.719	0.607	0.749
C14	0.490	0.505	0.645	0.636	0.578	0.612	0.549	0.480	0.678
C15	-0.284	0.056	-0.002	0.092	0.001	0.061	-0.018	-0.046	-0.255
C16	0.041	0.404	0.299	0.545	0.471	0.503	0.565	0.147	0.336
C17	0.047	0.396	0.318	0.541	0.416	0.453	0.578	0.213	0.322
C18	0.035	0.381	0.302	0.531	0.427	0.460	0.560	0.187	0.328
C19	0.043	0.392	0.313	0.535	0.437	0.463	0.550	0.177	0.319
C20	0.053	0.388	0.335	0.555	0.445	0.461	0.539	0.204	0.323
C21	0.060	0.393	0.321	0.537	0.431	0.450	0.548	0.191	0.326
C22	0.038	0.370	0.306	0.524	0.419	0.458	0.585	0.211	0.355
C23	0.002	0.342	0.249	0.429	0.280	0.302	0.484	0.156	0.164
C24	-0.042	0.227	0.157	0.416	0.317	0.412	0.516	0.123	0.220
C25	0.085	0.360	0.270	0.522	0.347	0.419	0.585	0.222	0.281
C26	0.051	0.366	0.331	0.545	0.428	0.453	0.547	0.201	0.296
C27	-0.009	0.294	0.374	0.500	0.497	0.449	0.317	0.149	0.266
C28	-0.019	0.325	0.260	0.512	0.382	0.409	0.555	0.234	0.324
C29	0.015	0.342	0.223	0.456	0.347	0.375	0.523	0.121	0.245
C30	0.096	0.382	0.251	0.524	0.336	0.342	0.583	0.264	0.376
C31	0.450	0.469	0.548	0.463	0.547	0.447	0.069	0.067	0.206
C32	0.764	0.573	0.690	0.546	0.463	0.393	0.408	0.355	0.491
C33	0.950	0.461	0.337	0.294	0.425	0.233	0.072	0.055	0.340
C34	0.406	0.276	0.160	0.103	0.221	0.080	-0.063	-0.062	0.191
C35	0.203	0.271	0.286	0.373	0.274	0.320	0.369	0.104	0.187
C36	0.360	0.378	0.505	0.418	0.506	0.514	0.151	0.055	0.215

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.658								
C12	0.595	0.937							
C13	0.590	0.719	0.802						
C14	0.492	0.640	0.702	0.838					
C15	-0.122	-0.187	-0.028	0.247	0.141				
C16	0.178	0.406	0.462	0.366	0.254	0.215			
C17	0.238	0.389	0.442	0.381	0.277	0.235	0.987		
C18	0.215	0.394	0.441	0.378	0.295	0.217	0.988	0.996	
C19	0.204	0.389	0.445	0.377	0.289	0.226	0.987	0.997	0.999
C20	0.227	0.396	0.465	0.387	0.308	0.239	0.981	0.991	0.994
C21	0.220	0.394	0.449	0.387	0.303	0.216	0.984	0.994	0.998
C22	0.237	0.411	0.443	0.404	0.320	0.177	0.978	0.988	0.993
C23	0.162	0.231	0.291	0.301	0.125	0.265	0.918	0.946	0.937
C24	0.123	0.276	0.306	0.187	0.110	0.133	0.958	0.950	0.947
C25	0.237	0.334	0.370	0.295	0.184	0.218	0.951	0.953	0.943
C26	0.211	0.366	0.436	0.366	0.260	0.218	0.980	0.990	0.991
C27	0.148	0.375	0.486	0.350	0.275	0.267	0.765	0.767	0.785
C28	0.257	0.378	0.422	0.357	0.286	0.197	0.972	0.979	0.985
C29	0.193	0.301	0.345	0.318	0.222	0.210	0.972	0.982	0.982
C30	0.319	0.398	0.399	0.380	0.297	0.156	0.879	0.856	0.866
C31	0.043	0.286	0.474	0.448	0.391	0.131	0.165	0.163	0.168
C32	0.452	0.484	0.537	0.547	0.493	-0.132	-0.044	-0.007	-0.021
C33	0.120	0.290	0.335	0.219	0.081	-0.456	-0.272	-0.338	-0.337
C34	0.037	0.152	0.212	0.038	0.188	-0.346	-0.343	-0.363	-0.381
C35	0.149	0.217	0.328	0.411	0.415	0.295	0.743	0.767	0.777
C36	0.034	0.328	0.472	0.529	0.518	0.306	0.395	0.409	0.428

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.995								
C21	0.998	0.996							
C22	0.990	0.982	0.990						
C23	0.942	0.923	0.940	0.931					
C24	0.946	0.932	0.933	0.934	0.890				
C25	0.941	0.932	0.931	0.923	0.888	0.960			
C26	0.993	0.991	0.991	0.983	0.947	0.950	0.932		
C27	0.792	0.832	0.805	0.768	0.689	0.678	0.624	0.819	
C28	0.982	0.986	0.986	0.984	0.913	0.925	0.911	0.976	0.807
C29	0.982	0.963	0.978	0.981	0.962	0.943	0.931	0.973	0.898
C30	0.851	0.857	0.868	0.864	0.785	0.796	0.862	0.827	0.587
C31	0.179	0.200	0.170	0.140	0.127	0.089	0.169	0.182	0.233
C32	-0.013	-0.035	-0.021	-0.009	-0.008	-0.122	0.012	-0.023	-0.182
C33	-0.335	-0.338	-0.333	-0.332	-0.394	-0.349	-0.333	-0.339	-0.275
C34	-0.372	-0.380	-0.384	-0.405	-0.467	-0.362	-0.323	-0.414	-0.461
C35	0.769	0.762	0.775	0.784	0.751	0.666	0.735	0.746	0.508
C36	0.436	0.451	0.437	0.416	0.405	0.290	0.348	0.433	0.466

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.960							
C30	0.886	0.851						
C31	0.109	0.105	0.075					
C32	-0.104	-0.003	-0.040	0.483				
C33	-0.345	-0.332	-0.196	0.290	0.441			
C34	-0.412	-0.371	-0.321	0.247	0.426	0.685		
C35	0.739	0.785	0.746	0.422	0.256	-0.308	-0.308	
C36	0.372	0.372	0.295	0.840	0.387	-0.088	-0.148	0.713

B.13

Correlations between Yield 1977-1980,
Pruning Weight, Clusters and Reflectance
at 30 Wavelengths
September 12, 1980

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.231								
C3	0.081	0.823							
C4	-0.049	0.745	0.902						
C5	-0.089	0.720	0.921	0.955					
C6	-0.082	0.428	0.636	0.655	0.719				
C7	-0.003	0.558	0.765	0.798	0.781	0.868			
C8	0.037	0.427	0.675	0.728	0.722	0.898	0.973		
C9	0.083	0.207	0.348	0.478	0.448	0.736	0.644	0.748	
C10	0.243	0.165	0.507	0.575	0.588	0.732	0.706	0.765	0.784
C11	0.208	0.250	0.591	0.640	0.678	0.685	0.704	0.736	0.565
C12	-0.086	0.407	0.619	0.719	0.722	0.586	0.595	0.606	0.537
C13	0.092	0.275	0.579	0.644	0.643	0.693	0.741	0.770	0.671
C14	-0.262	0.647	0.749	0.822	0.837	0.794	0.859	0.821	0.625
C15	-0.184	0.639	0.735	0.781	0.811	0.715	0.810	0.732	0.510
C16	-0.342	0.656	0.563	0.419	0.343	0.264	0.507	0.352	-0.005
C17	-0.310	0.575	0.480	0.325	0.287	0.214	0.422	0.267	-0.035
C18	-0.308	0.474	0.443	0.279	0.231	0.069	0.323	0.163	-0.100
C19	-0.319	0.480	0.449	0.270	0.241	0.066	0.311	0.155	-0.093
C20	-0.356	0.498	0.437	0.295	0.212	0.053	0.296	0.139	-0.115
C21	-0.363	0.548	0.468	0.319	0.269	0.238	0.399	0.289	0.236
C22	-0.351	0.450	0.373	0.187	0.143	0.001	0.227	0.065	-0.184
C23	-0.441	0.517	0.359	0.114	0.136	0.116	0.252	0.111	-0.165
C24	-0.008	0.017	0.019	-0.139	-0.154	-0.046	0.074	-0.031	-0.097
C25	-0.214	0.391	0.286	0.105	0.074	0.121	0.259	0.110	-0.031
C26	-0.221	0.505	0.419	0.231	0.207	0.138	0.322	0.189	0.050
C27	-0.212	0.450	0.360	0.182	0.152	0.078	0.273	0.130	-0.030
C28	-0.203	0.363	0.263	0.074	0.055	-0.088	0.128	-0.046	-0.258
C29	-0.193	0.346	0.303	0.117	0.101	-0.031	0.223	0.078	-0.106
C30	-0.226	0.416	0.339	0.226	0.195	0.046	0.297	0.139	-0.083
C31	0.117	-0.200	-0.182	-0.071	-0.066	-0.213	-0.112	-0.048	-0.076
C32	0.278	0.045	0.097	0.242	0.291	0.242	0.101	0.172	0.341
C33	0.651	-0.427	-0.310	-0.214	-0.225	-0.254	-0.242	-0.210	-0.117
C34	0.414	-0.388	-0.341	-0.371	-0.336	-0.262	-0.305	-0.299	-0.357
C35	-0.103	0.486	0.511	0.517	0.483	0.182	0.321	0.270	0.273
C36	-0.203	0.085	0.014	0.112	0.111	-0.048	0.016	0.056	0.176

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.930								
C12	0.806	0.907							
C13	0.932	0.941	0.872						
C14	0.683	0.728	0.767	0.766					
C15	0.546	0.620	0.642	0.702	0.900				
C16	0.059	0.183	0.254	0.297	0.506	0.549			
C17	0.021	0.113	0.150	0.212	0.509	0.513	0.896		
C18	-0.015	0.071	0.109	0.202	0.399	0.469	0.857	0.946	
C19	0.001	0.076	0.103	0.221	0.392	0.477	0.818	0.908	0.984
C20	-0.031	0.051	0.102	0.186	0.387	0.428	0.863	0.944	0.991
C21	0.160	0.118	0.176	0.295	0.502	0.512	0.765	0.871	0.901
C22	-0.093	-0.003	0.046	0.119	0.321	0.366	0.847	0.943	0.987
C23	-0.091	0.009	0.039	0.143	0.331	0.395	0.853	0.852	0.838
C24	-0.040	-0.088	-0.234	0.066	0.063	0.164	0.474	0.681	0.736
C25	-0.065	-0.069	-0.101	0.095	0.283	0.372	0.762	0.881	0.874
C26	-0.016	-0.016	-0.006	0.164	0.377	0.522	0.774	0.873	0.907
C27	-0.098	-0.094	-0.103	0.076	0.304	0.465	0.737	0.860	0.909
C28	-0.172	-0.098	-0.102	0.041	0.186	0.332	0.738	0.863	0.912
C29	-0.066	-0.052	-0.102	0.117	0.245	0.382	0.684	0.831	0.901
C30	0.003	0.088	0.096	0.240	0.400	0.519	0.767	0.898	0.927
C31	-0.173	-0.184	-0.222	-0.143	-0.261	-0.064	-0.371	-0.539	-0.459
C32	0.156	0.044	0.033	0.044	0.129	0.188	-0.433	-0.396	-0.484
C33	0.077	0.061	-0.091	-0.006	-0.340	-0.276	-0.450	-0.470	-0.480
C34	-0.364	-0.366	-0.498	-0.392	-0.443	-0.343	-0.242	-0.225	-0.284
C35	0.090	0.076	0.183	0.218	0.298	0.548	0.260	0.110	0.253
C36	-0.080	-0.143	-0.063	-0.002	-0.019	0.187	-0.168	-0.338	-0.226

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.987								
C21	0.909	0.909							
C22	0.974	0.993	0.886						
C23	0.862	0.881	0.783	0.872					
C24	0.737	0.718	0.682	0.750	0.623				
C25	0.855	0.868	0.842	0.885	0.818	0.894			
C26	0.905	0.890	0.907	0.878	0.805	0.761	0.899		
C27	0.904	0.885	0.880	0.884	0.772	0.795	0.906	0.986	
C28	0.907	0.902	0.796	0.921	0.837	0.850	0.923	0.884	0.902
C29	0.912	0.889	0.835	0.885	0.788	0.865	0.902	0.919	0.928
C30	0.915	0.906	0.827	0.905	0.801	0.799	0.882	0.895	0.896
C31	-0.421	-0.483	-0.508	-0.524	-0.368	-0.437	-0.505	-0.293	-0.292
C32	-0.487	-0.524	-0.370	-0.551	-0.490	-0.314	-0.324	-0.199	-0.233
C33	-0.492	-0.512	-0.584	-0.488	-0.477	-0.046	-0.281	-0.414	-0.417
C34	-0.325	-0.307	-0.475	-0.270	-0.224	0.082	-0.039	-0.180	-0.159
C35	0.292	0.215	0.323	0.152	0.126	-0.049	0.116	0.421	0.402
C36	-0.162	-0.235	-0.127	-0.295	-0.129	-0.335	-0.282	-0.024	-0.046

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.959							
C30	0.949	0.944						
C31	-0.358	-0.256	-0.324					
C32	-0.396	-0.308	-0.336	0.483				
C33	-0.262	-0.265	-0.294	0.290	0.441			
C34	-0.101	-0.117	-0.197	0.247	0.426	0.685		
C35	0.165	0.263	0.231	0.422	0.256	-0.308	-0.308	
C36	-0.174	-0.059	-0.120	0.840	0.387	-0.088	-0.148	0.713

B. 14

Correlations between Yield 1977-1980,
Pruning Weight, Clusters and
SM2S Reflectance Data
July 17, 18, 1980
August 20, 21, 1980
September 12, 1980

— CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10 C11 C12 C13 C14 C15

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.300								
C3	0.277	0.966							
C4	0.308	0.866	0.947						
C5	-0.064	0.127	0.137	0.177					
C6	0.042	0.561	0.467	0.417	-0.015				
C7	0.177	0.949	0.983	0.941	0.152	0.475			
C8	0.129	0.646	0.665	0.760	0.225	0.381	0.695		
C9	0.014	-0.018	-0.055	0.094	0.213	-0.051	0.006	0.634	
C10	-0.221	0.339	0.149	0.034	-0.124	0.408	0.225	0.373	0.415
C11	0.056	0.108	0.275	0.199	0.521	-0.024	0.120	0.662	0.919
C12	0.054	0.075	0.004	-0.008	-0.299	0.064	0.025	0.127	0.166
C13	-0.015	-0.022	-0.157	-0.255	-0.209	-0.087	-0.070	-0.171	0.208
C14	-0.188	-0.215	-0.289	-0.376	-0.060	-0.286	-0.229	-0.357	-0.201
C15	0.104	-0.177	-0.204	-0.203	-0.035	-0.057	-0.167	-0.330	-0.246

	C10	C11	C12	C13	C14
C11	0.349				
C12	0.342	0.004			
C13	0.463	0.061	0.483		
C14	0.183	-0.247	0.290	0.441	
C15	-0.152	-0.307	0.247	0.426	0.685

t sush out

— CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10 C11 C12 C13 C14 C15

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.805								
C3	0.661	0.794							
C4	0.941	0.755	0.479						
C5	0.862	0.785	0.797	0.768					
C6	0.624	0.779	0.593	0.918	0.902				
C7	0.789	0.885	0.817	0.715	0.821	0.761			
C8	0.219	0.560	0.501	0.360	0.260	0.261	0.562		
C9	0.225	0.341	0.460	0.392	0.324	0.318	0.418	0.836	
C10	0.180	0.521	0.452	0.374	0.279	0.279	0.350	0.805	0.984
C11	0.197	0.520	0.387	0.418	0.335	0.338	0.394	0.802	0.966
C12	0.531	0.463	0.497	0.070	0.206	0.154	0.474	0.269	0.176
C13	0.771	0.546	0.430	0.404	0.491	0.509	0.567	0.025	-0.020
C14	0.524	0.294	0.314	0.067	0.344	0.207	0.261	-0.387	-0.337
C15	0.344	0.103	0.137	-0.066	0.191	0.092	0.089	-0.352	-0.377

	C10	C11	C12	C13	C14
C11	0.939				
C12	0.170	0.097			
C13	-0.082	-0.049	0.483		
C14	-0.349	-0.288	0.290	0.441	
C15	-0.408	-0.375	0.247	0.426	0.685

t sepsh out

— CORR C1,C2,C3,C4,C5,C6,C7,C8,C9,C10 C11 C12 C13 C14 C15

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.220								
C3	0.193	0.807							
C4	0.215	0.773	0.903						
C5	0.113	0.478	0.684	0.694					
C6	0.350	0.612	0.743	0.749	0.706				
C7	0.209	0.682	0.729	0.735	0.651	0.952			
C8	-0.073	0.703	0.657	0.723	0.321	0.436	0.596		
C9	-0.172	0.297	0.184	0.296	-0.021	0.054	0.208	0.769	
C10	-0.063	0.095	0.078	0.182	-0.029	-0.064	0.044	0.608	0.904
C11	-0.083	0.146	0.029	0.154	-0.150	-0.053	0.096	0.638	0.921
C12	0.053	-0.071	-0.175	-0.085	-0.076	-0.180	-0.169	-0.303	-0.495
C13	0.297	0.242	0.276	0.132	0.341	0.113	0.042	-0.157	-0.465
C14	0.521	-0.214	-0.261	-0.230	-0.117	0.072	-0.030	-0.435	-0.532
C15	0.289	-0.371	-0.306	-0.304	-0.357	-0.371	-0.432	-0.363	-0.333

	C10	C11	C12	C13	C14
C11	0.946				
C12	-0.404	-0.320			
C13	-0.283	-0.353	0.483		
C14	-0.299	-0.279	0.290	0.441	
C15	-0.074	-0.144	0.247	0.426	0.685

B. 15-20

Correlations between Yield 1977-1980,
Pruning Weight, Clusters and Reflectance
Stratified by Method of
Weed Control

B. 15

July 17, 18, 1980

Group 1

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.274								
C3	0.048	0.913							
C4	-0.006	0.934	0.976						
C5	0.014	0.943	0.980	0.997					
C6	-0.188	0.951	0.953	0.977	0.967				
C7	-0.072	0.880	0.952	0.972	0.955	0.970			
C8	0.573	0.503	0.747	0.759	0.755	0.625	0.748		
C9	-0.194	0.159	0.045	0.212	0.182	0.169	0.267	0.289	
C10	-0.155	0.950	0.978	0.959	0.965	0.934	0.968	0.635	0.111
C11	0.172	0.841	0.909	0.954	0.955	0.876	0.913	0.874	0.382
C12	0.004	0.936	0.942	0.974	0.981	0.926	0.924	0.759	0.318
C13	-0.230	0.918	0.915	0.959	0.940	0.991	0.974	0.618	0.259
C14	-0.109	0.957	0.936	0.949	0.928	0.960	0.996	0.719	0.259
C15	-0.185	0.887	0.934	0.950	0.930	0.974	0.992	0.662	0.245
C16	0.298	0.239	0.398	0.458	0.435	0.346	0.540	0.758	0.740
C17	0.137	0.122	0.280	0.345	0.302	0.284	0.489	0.620	0.744
C18	0.240	0.024	0.184	0.248	0.214	0.156	0.371	0.609	0.763
C19	0.242	-0.047	0.120	0.185	0.148	0.100	0.319	0.568	0.750
C20	0.264	-0.108	0.051	0.121	0.085	0.027	0.246	0.532	0.753
C21	0.286	-0.237	-0.032	-0.011	-0.046	-0.107	0.114	0.444	0.742
C22	0.405	-0.363	-0.182	-0.144	-0.166	-0.262	-0.036	0.392	0.628
C23	0.237	-0.348	-0.181	-0.186	-0.207	-0.268	-0.043	0.259	0.541
C24	-0.414	0.806	0.820	0.805	0.779	0.893	0.891	0.404	0.108
C25	-0.426	0.760	0.779	0.774	0.741	0.872	0.872	0.381	0.111
C26	0.510	-0.370	0.003	-0.076	-0.111	-0.123	0.086	0.395	-0.048
C27	0.290	-0.206	0.118	0.047	0.006	0.028	0.241	0.398	0.099
C28	0.056	0.085	0.272	0.270	0.231	0.240	0.451	0.501	0.551
C29	-0.147	0.119	0.088	0.213	0.178	0.172	0.321	0.354	0.957
C30	-0.093	0.093	0.103	0.211	0.174	0.165	0.332	0.392	0.922
C31	0.637	-0.143	-0.023	-0.154	-0.088	-0.280	-0.310	0.077	-0.590
C32	0.778	-0.065	0.040	0.012	0.068	-0.179	-0.166	0.377	-0.125
C33	0.666	0.529	0.754	0.703	0.730	0.563	0.602	0.863	-0.133
C34	0.800	0.218	0.401	0.378	0.419	0.177	0.248	0.741	0.065
C35	0.642	0.390	0.520	0.491	0.531	0.367	0.314	0.583	-0.336
C36	0.613	0.026	0.130	0.014	0.079	-0.103	-0.167	0.157	-0.619

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.868								
C12	0.929	0.975							
C13	0.961	0.863	0.901						
C14	0.962	0.878	0.892	0.969					
C15	0.973	0.860	0.893	0.981	0.996				
C16	0.362	0.645	0.523	0.397	0.536	0.478			
C17	0.289	0.486	0.366	0.365	0.510	0.456	0.949		
C18	0.170	0.436	0.303	0.230	0.383	0.323	0.965	0.981	
C19	0.108	0.372	0.230	0.181	0.336	0.274	0.941	0.978	0.996
C20	0.034	0.324	0.178	0.108	0.260	0.197	0.927	0.957	0.990
C21	-0.102	0.204	0.050	-0.023	0.128	0.064	0.873	0.913	0.963
C22	-0.232	0.095	-0.061	-0.199	-0.026	-0.096	0.810	0.821	0.905
C23	-0.198	0.002	-0.105	-0.273	-0.014	-0.073	0.742	0.792	0.858
C24	0.908	0.639	0.719	0.905	0.919	0.940	0.286	0.346	0.183
C25	0.874	0.600	0.669	0.894	0.904	0.924	0.271	0.358	0.186
C26	-0.068	-0.020	-0.165	-0.085	0.130	0.057	0.468	0.582	0.568
C27	0.094	0.078	-0.031	0.076	0.296	0.234	0.571	0.710	0.669
C28	0.295	0.356	0.277	0.304	0.492	0.444	0.848	0.936	0.904
C29	0.150	0.375	0.302	0.264	0.330	0.304	0.845	0.883	0.891
C30	0.155	0.373	0.292	0.255	0.346	0.313	0.877	0.922	0.929
C31	-0.189	-0.082	-0.081	-0.400	-0.356	-0.375	-0.274	-0.503	-0.380
C32	-0.145	0.207	0.130	-0.262	-0.236	-0.276	0.109	-0.176	-0.024
C33	0.599	0.770	0.707	0.491	0.555	0.514	0.390	0.160	0.172
C34	0.220	0.575	0.477	0.110	0.186	0.132	0.467	0.187	0.294
C35	0.358	0.533	0.488	0.281	0.248	0.227	-0.009	-0.258	-0.226
C36	-0.036	0.055	0.064	-0.228	-0.220	-0.233	-0.311	-0.557	-0.460

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.996								
C21	0.977	0.991							
C22	0.919	0.946	0.973						
C23	0.870	0.888	0.910	0.949					
C24	0.146	0.062	-0.061	-0.221	-0.107				
C25	0.157	0.072	-0.046	-0.218	-0.114	0.994			
C26	0.607	0.587	0.596	0.623	0.645	0.063	0.101		
C27	0.697	0.664	0.650	0.641	0.722	0.276	0.306	0.954	
C28	0.901	0.871	0.827	0.766	0.842	0.428	0.431	0.685	0.845
C29	0.881	0.883	0.858	0.755	0.724	0.204	0.207	0.194	0.364
C30	0.921	0.920	0.894	0.800	0.780	0.218	0.221	0.292	0.459
C31	-0.407	-0.374	-0.347	-0.147	-0.169	-0.474	-0.540	-0.063	-0.242
C32	-0.058	-0.013	0.007	0.155	-0.007	-0.534	-0.594	-0.093	-0.276
C33	0.118	0.088	0.008	0.027	-0.089	0.270	0.220	0.171	0.103
C34	0.245	0.260	0.229	0.317	0.160	-0.167	-0.230	0.110	0.001
C35	-0.268	-0.277	-0.323	-0.282	-0.459	-0.013	-0.051	-0.133	-0.293
C36	-0.494	-0.473	-0.465	-0.298	-0.351	-0.356	-0.419	-0.160	-0.341

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.765							
C30	0.827	0.994						
C31	-0.441	-0.601	-0.578					
C32	-0.294	-0.205	-0.204	0.837				
C33	0.089	-0.111	-0.078	0.498	0.630			
C34	0.065	0.051	0.072	0.649	0.894	0.858		
C35	-0.389	-0.429	-0.430	0.638	0.742	0.874	0.777	
C36	-0.532	-0.665	-0.652	0.972	0.832	0.605	0.673	0.782

B. 16

July 17, 18, 1980

Group 2

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.235								
C3	0.126	0.010							
C4	0.185	0.035	0.993						
C5	0.076	0.385	0.805	0.803					
C6	0.056	0.414	0.703	0.697	0.986				
C7	-0.034	0.437	0.692	0.672	0.974	0.990			
C8	-0.194	0.497	0.628	0.619	0.936	0.945	0.961		
C9	0.045	0.589	0.565	0.575	0.939	0.965	0.953	0.960	
C10	-0.024	0.503	0.689	0.692	0.975	0.977	0.972	0.984	0.983
C11	-0.247	-0.093	-0.156	-0.124	-0.508	-0.617	-0.594	-0.410	-0.532
C12	-0.144	0.105	0.842	0.859	0.881	0.815	0.799	0.858	0.785
C13	-0.239	0.469	0.591	0.571	0.920	0.943	0.968	0.993	0.947
C14	-0.314	0.477	0.569	0.533	0.875	0.896	0.945	0.968	0.893
C15	-0.351	0.029	0.868	0.836	0.710	0.614	0.657	0.697	0.519
C16	-0.193	-0.508	0.830	0.792	0.476	0.377	0.385	0.318	0.167
C17	-0.181	-0.404	0.872	0.827	0.546	0.448	0.467	0.393	0.242
C18	-0.195	-0.449	0.862	0.825	0.493	0.385	0.396	0.329	0.180
C19	-0.158	-0.469	0.859	0.823	0.518	0.418	0.423	0.352	0.211
C20	-0.189	-0.445	0.863	0.826	0.532	0.432	0.442	0.379	0.229
C21	-0.123	-0.447	0.875	0.841	0.531	0.429	0.432	0.357	0.222
C22	-0.032	-0.442	0.886	0.865	0.502	0.385	0.375	0.304	0.185
C23	-0.280	-0.455	0.834	0.802	0.494	0.388	0.400	0.375	0.204
C24	-0.327	-0.581	0.482	0.464	-0.058	-0.200	-0.176	-0.132	-0.333
C25	-0.270	-0.588	0.512	0.494	-0.042	-0.186	-0.167	-0.130	-0.329
C26	-0.202	-0.314	0.888	0.865	0.531	0.406	0.419	0.410	0.246
C27	-0.274	-0.319	0.863	0.838	0.518	0.396	0.414	0.420	0.242
C28	-0.130	-0.307	0.917	0.878	0.668	0.582	0.593	0.513	0.386
C29	0.260	-0.288	0.923	0.921	0.560	0.441	0.409	0.299	0.253
C30	0.115	-0.314	0.921	0.899	0.534	0.413	0.408	0.306	0.214
C31	-0.290	-0.507	0.545	0.573	0.372	0.304	0.248	0.318	0.220
C32	-0.132	-0.401	0.537	0.587	0.387	0.314	-0.236	0.313	0.261
C33	-0.908	-0.046	0.102	0.016	0.146	0.154	0.275	0.375	0.127
C34	-0.247	0.050	-0.790	-0.734	-0.539	-0.466	-0.498	-0.316	-0.267
C35	-0.079	-0.169	0.636	0.690	0.579	0.511	0.436	0.518	0.483
C36	-0.206	-0.416	0.692	0.720	0.476	0.385	0.334	0.391	0.291

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	-0.455								
C12	0.875	-0.110							
C13	0.966	-0.474	0.812						
C14	0.921	-0.436	0.757	0.985					
C15	0.667	0.072	0.860	0.674	0.702				
C16	0.330	-0.048	0.619	0.314	0.320	0.802			
C17	0.403	-0.086	0.651	0.392	0.410	0.849	0.991		
C18	0.346	-0.014	0.633	0.319	0.331	0.828	0.996	0.995	
C19	0.371	-0.072	0.648	0.346	0.349	0.815	0.998	0.994	0.997
C20	0.391	-0.062	0.665	0.373	0.380	0.838	0.997	0.995	0.997
C21	0.381	-0.075	0.653	0.348	0.350	0.817	0.996	0.994	0.997
C22	0.346	-0.003	0.649	0.281	0.271	0.790	0.981	0.972	0.988
C23	0.374	0.049	0.689	0.363	0.369	0.863	0.987	0.979	0.985
C24	-0.155	0.589	0.300	-0.164	-0.126	0.602	0.753	0.721	0.773
C25	-0.151	0.566	0.300	-0.171	-0.136	0.599	0.782	0.741	0.794
C26	0.410	0.144	0.737	0.380	0.388	0.909	0.953	0.959	0.970
C27	0.416	0.168	0.741	0.393	0.406	0.920	0.947	0.951	0.960
C28	0.533	-0.200	0.730	0.510	0.515	0.865	0.968	0.987	0.972
C29	0.387	-0.082	0.630	0.261	0.231	0.700	0.885	0.889	0.907
C30	0.365	-0.037	0.616	0.280	0.281	0.774	0.935	0.948	0.958
C31	0.330	0.096	0.683	0.280	0.191	0.563	0.702	0.630	0.664
C32	0.353	0.118	0.694	0.256	0.143	0.492	0.604	0.530	0.574
C33	0.212	0.105	0.246	0.430	0.544	0.546	0.311	0.351	0.299
C34	-0.369	0.313	-0.381	-0.327	-0.379	-0.611	-0.712	-0.780	-0.751
C35	0.563	0.036	0.834	0.455	0.339	0.584	0.568	0.523	0.550
C36	0.417	0.117	0.775	0.342	0.261	0.681	0.777	0.723	0.756

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.999								
C21	0.999	0.998							
C22	0.986	0.981	0.990						
C23	0.985	0.990	0.981	0.968					
C24	0.739	0.741	0.732	0.761	0.798				
C25	0.761	0.760	0.755	0.787	0.809	0.998			
C26	0.958	0.965	0.960	0.963	0.979	0.809	0.822		
C27	0.949	0.958	0.948	0.946	0.981	0.820	0.827	0.997	
C28	0.979	0.982	0.981	0.956	0.956	0.614	0.637	0.939	0.928
C29	0.903	0.892	0.919	0.954	0.853	0.620	0.661	0.881	0.844
C30	0.947	0.942	0.959	0.977	0.909	0.696	0.731	0.932	0.904
C31	0.697	0.693	0.683	0.697	0.751	0.586	0.580	0.698	0.712
C32	0.606	0.600	0.598	0.636	0.657	0.505	0.503	0.629	0.635
C33	0.289	0.325	0.264	0.157	0.379	0.314	0.270	0.335	0.394
C34	-0.732	-0.731	-0.752	-0.736	-0.642	-0.358	-0.403	-0.673	-0.634
C35	0.582	0.582	0.580	0.614	0.632	0.389	0.388	0.635	0.638
C36	0.779	0.778	0.772	0.795	0.827	0.642	0.643	0.806	0.812

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.896							
C30	0.939	0.931						
C31	0.632	0.574	0.546					
C32	0.547	0.565	0.502	0.977				
C33	0.317	-0.093	0.081	0.123	-0.052			
C34	-0.793	-0.800	-0.844	-0.062	-0.002	-0.108		
C35	0.572	0.579	0.509	0.923	0.967	-0.040	-0.062	
C36	0.731	0.703	0.677	0.979	0.965	0.109	-0.215	0.942

B. 17

August 20, 21, 1980

Group 1

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.270								
C3	0.581	0.754							
C4	0.324	0.639	0.918						
C5	0.272	0.943	0.811	0.763					
C6	0.435	0.861	0.911	0.816	0.949				
C7	0.090	0.356	0.752	0.916	0.499	0.593			
C8	0.115	-0.362	0.225	0.324	-0.327	-0.131	0.600		
C9	0.086	0.818	0.847	0.864	0.877	0.892	0.773	0.066	
C10	-0.086	-0.252	0.254	0.418	-0.210	-0.062	0.714	0.962	0.228
C11	0.045	0.838	0.792	0.800	0.913	0.910	0.682	-0.088	0.984
C12	0.294	0.885	0.926	0.915	0.943	0.945	0.735	-0.000	0.958
C13	0.670	0.765	0.797	0.630	0.650	0.648	0.365	0.043	0.544
C14	0.745	0.623	0.653	0.466	0.487	0.478	0.183	0.010	0.314
C15	0.515	0.793	0.789	0.767	0.795	0.723	0.478	-0.107	0.617
C16	0.031	0.658	0.677	0.848	0.833	0.758	0.708	-0.106	0.788
C17	-0.031	0.621	0.667	0.873	0.768	0.683	0.779	0.030	0.787
C18	-0.080	0.632	0.626	0.833	0.780	0.675	0.720	-0.059	0.764
C19	-0.033	0.655	0.647	0.843	0.797	0.693	0.720	-0.063	0.775
C20	-0.002	0.609	0.676	0.880	0.766	0.690	0.783	0.036	0.778
C21	-0.027	0.630	0.624	0.828	0.777	0.668	0.701	-0.072	0.740
C22	-0.131	0.601	0.550	0.781	0.727	0.589	0.676	-0.071	0.708
C23	-0.227	0.539	0.417	0.672	0.658	0.482	0.570	-0.157	0.608
C24	0.040	0.415	0.643	0.853	0.665	0.677	0.815	0.136	0.715
C25	0.050	0.455	0.710	0.873	0.693	0.750	0.863	0.197	0.808
C26	-0.026	0.516	0.611	0.846	0.702	0.627	0.765	0.047	0.706
C27	-0.094	0.433	0.535	0.797	0.642	0.567	0.744	0.045	0.654
C28	-0.143	0.494	0.562	0.824	0.629	0.529	0.791	0.141	0.700
C29	-0.112	0.586	0.465	0.689	0.699	0.525	0.540	-0.199	0.599
C30	-0.069	0.387	0.448	0.682	0.641	0.573	0.591	-0.142	0.567
C31	0.734	0.521	0.566	0.194	0.395	0.541	-0.017	-0.059	0.316
C32	0.591	0.657	0.542	0.246	0.426	0.438	0.007	-0.070	0.334
C33	0.726	0.635	0.537	0.371	0.596	0.533	-0.012	-0.390	0.227
C34	0.672	0.731	0.672	0.478	0.581	0.546	0.177	-0.090	0.402
C35	0.599	0.581	0.267	-0.013	0.432	0.348	-0.396	-0.611	0.038
C36	0.712	0.572	0.486	0.105	0.439	0.531	-0.170	-0.285	0.256

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.080								
C12	0.120	0.939							
C13	0.019	0.471	0.712						
C14	-0.067	0.241	0.526	0.966					
C15	-0.070	0.580	0.808	0.879	0.829				
C16	0.054	0.802	0.842	0.392	0.235	0.731			
C17	0.204	0.771	0.829	0.417	0.258	0.734	0.979		
C18	0.120	0.763	0.811	0.390	0.237	0.729	0.986	0.996	
C19	0.113	0.773	0.827	0.421	0.268	0.751	0.986	0.996	0.999
C20	0.203	0.763	0.827	0.415	0.260	0.737	0.983	0.999	0.994
C21	0.098	0.738	0.802	0.410	0.268	0.753	0.984	0.993	0.998
C22	0.118	0.702	0.757	0.372	0.232	0.718	0.956	0.984	0.991
C23	0.040	0.615	0.657	0.285	0.165	0.661	0.916	0.944	0.962
C24	0.265	0.715	0.735	0.208	0.050	0.550	0.935	0.915	0.904
C25	0.330	0.805	0.784	0.212	0.019	0.481	0.888	0.863	0.843
C26	0.206	0.695	0.759	0.332	0.191	0.690	0.975	0.988	0.985
C27	0.207	0.651	0.693	0.223	0.086	0.610	0.959	0.967	0.964
C28	0.326	0.663	0.727	0.343	0.196	0.662	0.920	0.978	0.967
C29	-0.026	0.607	0.683	0.370	0.267	0.741	0.925	0.941	0.961
C30	-0.004	0.610	0.614	0.090	-0.029	0.522	0.933	0.885	0.904
C31	-0.177	0.304	0.384	0.652	0.627	0.322	-0.115	-0.181	-0.204
C32	-0.128	0.280	0.443	0.866	0.859	0.558	-0.030	-0.014	-0.035
C33	-0.469	0.236	0.485	0.797	0.858	0.841	0.381	0.317	0.337
C34	-0.134	0.344	0.595	0.979	0.986	0.849	0.287	0.304	0.289
C35	-0.706	0.083	0.244	0.658	0.741	0.559	0.026	-0.058	-0.021
C36	-0.400	0.276	0.354	0.638	0.635	0.357	-0.095	-0.188	-0.190

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.994								
C21	0.998	0.992							
C22	0.989	0.978	0.991						
C23	0.958	0.936	0.965	0.987					
C24	0.899	0.929	0.898	0.854	0.797				
C25	0.839	0.875	0.827	0.775	0.693	0.972			
C26	0.982	0.992	0.986	0.971	0.939	0.947	0.877		
C27	0.961	0.973	0.968	0.955	0.933	0.956	0.879	0.993	
C28	0.963	0.973	0.964	0.976	0.950	0.874	0.805	0.972	0.959
C29	0.960	0.936	0.970	0.982	0.991	0.788	0.674	0.936	0.921
C30	0.895	0.898	0.906	0.874	0.864	0.943	0.863	0.933	0.956
C31	-0.173	-0.176	-0.202	-0.281	-0.390	-0.199	-0.062	-0.267	-0.355
C32	-0.001	-0.027	-0.025	-0.048	-0.122	-0.244	-0.177	-0.134	-0.247
C33	0.363	0.329	0.378	0.320	0.293	0.175	0.087	0.294	0.217
C34	0.322	0.300	0.316	0.286	0.221	0.064	0.046	0.219	0.110
C35	0.007	-0.057	0.013	-0.027	-0.029	-0.240	-0.281	-0.115	-0.194
C36	-0.158	-0.184	-0.181	-0.258	-0.340	-0.235	-0.129	-0.270	-0.356

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.932							
C30	0.840	0.862						
C31	-0.330	-0.313	-0.345					
C32	-0.097	-0.046	-0.355	0.837				
C33	0.203	0.415	0.238	0.498	0.630			
C34	0.229	0.318	-0.001	0.649	0.894	0.858		
C35	-0.187	0.086	-0.135	0.638	0.742	0.874	0.777	
C36	-0.353	-0.250	-0.306	0.972	0.832	0.605	0.673	0.782

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August 20, 21, 1980

Group 2

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.675								
C3	0.858	0.856							
C4	0.807	0.922	0.951						
C5	0.814	0.915	0.978	0.986					
C6	0.528	0.873	0.875	0.842	0.893				
C7	0.284	0.818	0.675	0.660	0.696	0.915			
C8	0.266	0.844	0.654	0.678	0.697	0.898	0.992		
C9	0.038	0.694	0.496	0.534	0.542	0.808	0.949	0.963	
C10	-0.075	0.600	0.417	0.447	0.490	0.800	0.883	0.888	0.932
C11	0.087	0.626	0.575	0.538	0.598	0.886	0.918	0.897	0.922
C12	0.610	0.813	0.924	0.885	0.931	0.965	0.789	0.769	0.681
C13	0.580	0.912	0.884	0.891	0.893	0.938	0.903	0.906	0.828
C14	0.161	0.480	0.496	0.612	0.540	0.543	0.498	0.544	0.636
C15	0.953	0.697	0.766	0.876	0.828	0.682	0.474	0.516	0.480
C16	0.898	0.840	0.918	0.883	0.926	0.773	0.544	0.528	0.304
C17	0.854	0.843	0.908	0.888	0.933	0.796	0.557	0.545	0.333
C18	0.865	0.839	0.898	0.897	0.932	0.764	0.514	0.510	0.297
C19	0.869	0.820	0.878	0.878	0.913	0.733	0.478	0.474	0.254
C20	0.882	0.817	0.885	0.894	0.921	0.721	0.457	0.457	0.241
C21	0.874	0.823	0.867	0.868	0.901	0.718	0.474	0.471	0.244
C22	0.891	0.847	0.948	0.897	0.945	0.818	0.597	0.574	0.362
C23	0.828	0.667	0.740	0.671	0.742	0.589	0.362	0.331	0.077
C24	0.877	0.773	0.869	0.831	0.833	0.716	0.456	0.437	0.208
C25	0.868	0.836	0.916	0.957	0.957	0.741	0.475	0.489	0.309
C26	0.904	0.777	0.876	0.845	0.888	0.697	0.435	0.419	0.187
C27	0.864	0.784	0.843	0.832	0.875	0.692	0.436	0.428	0.197
C28	0.884	0.833	0.867	0.859	0.894	0.717	0.492	0.486	0.252
C29	0.872	0.752	0.836	0.801	0.853	0.676	0.417	0.399	0.162
C30	0.816	0.867	0.783	0.885	0.821	0.580	0.486	0.531	0.362
C31	0.641	0.493	0.760	0.742	0.778	0.620	0.259	0.245	0.147
C32	0.503	0.310	0.654	0.614	0.650	0.468	0.084	0.061	-0.014
C33	-0.006	0.954	0.295	0.294	0.379	0.652	0.728	0.720	0.656
C34	-0.747	-0.445	-0.528	-0.383	-0.427	-0.293	-0.258	-0.206	0.025
C35	0.534	0.205	0.620	0.505	0.573	0.455	0.085	0.033	-0.034
C36	0.716	0.455	0.764	0.701	0.756	0.579	0.202	0.170	0.037

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.960								
C12	0.688	0.810							
C13	0.700	0.793	0.901						
C14	0.520	0.562	0.612	0.685					
C15	0.427	0.491	0.796	0.752	0.857				
C16	0.297	0.404	0.801	0.714	0.188	0.603			
C17	0.357	0.448	0.828	0.715	0.221	0.638	0.994		
C18	0.317	0.401	0.807	0.695	0.238	0.666	0.989	0.997	
C19	0.280	0.360	0.777	0.660	0.196	0.639	0.987	0.994	0.999
C20	0.257	0.340	0.777	0.663	0.236	0.676	0.982	0.988	0.997
C21	0.263	0.339	0.754	0.650	0.163	0.610	0.988	0.991	0.996
C22	0.345	0.470	0.847	0.762	0.240	0.625	0.995	0.987	0.977
C23	0.132	0.218	0.600	0.464	-0.157	0.320	0.938	0.927	0.918
C24	0.244	0.344	0.760	0.621	0.108	0.562	0.990	0.990	0.988
C25	0.288	0.377	0.823	0.735	0.447	0.827	0.935	0.945	0.963
C26	0.204	0.307	0.746	0.623	0.124	0.578	0.991	0.987	0.989
C27	0.236	0.313	0.732	0.603	0.106	0.570	0.983	0.987	0.991
C28	0.255	0.334	0.739	0.657	0.131	0.573	0.991	0.988	0.990
C29	0.204	0.295	0.716	0.577	0.050	0.519	0.982	0.981	0.981
C30	0.164	0.214	0.583	0.744	0.457	0.701	0.765	0.737	0.762
C31	0.258	0.381	0.791	0.509	0.458	0.791	0.730	0.771	0.784
C32	0.104	0.247	0.676	0.360	0.408	0.717	0.610	0.646	0.663
C33	0.806	0.719	0.485	0.450	-0.034	0.065	0.412	0.461	0.417
C34	0.181	0.037	-0.239	-0.338	0.330	0.065	-0.634	-0.550	-0.526
C35	0.097	0.280	0.655	0.313	0.301	0.576	0.559	0.586	0.586
C36	0.150	0.298	0.748	0.448	0.293	0.678	0.778	0.805	0.812

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.998								
C21	0.999	0.995							
C22	0.971	0.966	0.969						
C23	0.931	0.912	0.942	0.913					
C24	0.992	0.985	0.992	0.976	0.963				
C25	0.956	0.971	0.946	0.929	0.791	0.921			
C26	0.993	0.989	0.993	0.976	0.956	0.998	0.934		
C27	0.996	0.990	0.997	0.961	0.958	0.996	0.928	0.995	
C28	0.993	0.987	0.997	0.973	0.952	0.989	0.930	0.992	0.994
C29	0.987	0.979	0.990	0.962	0.975	0.998	0.904	0.996	0.997
C30	0.755	0.777	0.764	0.754	0.587	0.696	0.833	0.733	0.719
C31	0.774	0.793	0.742	0.741	0.604	0.761	0.840	0.757	0.747
C32	0.655	0.680	0.620	0.622	0.501	0.653	0.735	0.652	0.632
C33	0.406	0.356	0.412	0.416	0.444	0.408	0.247	0.358	0.415
C34	-0.539	-0.520	-0.569	-0.630	-0.710	-0.599	-0.401	-0.616	-0.572
C35	0.577	0.593	0.541	0.587	0.484	0.604	0.622	0.595	0.552
C36	0.809	0.822	0.782	0.784	0.705	0.819	0.830	0.814	0.797

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.989							
C30	0.776	0.685						
C31	0.697	0.734	0.431					
C32	0.570	0.627	0.305	0.977				
C33	0.422	0.406	0.100	0.123	-0.052			
C34	-0.623	-0.615	-0.530	-0.062	-0.002	-0.108		
C35	0.499	0.576	0.155	0.923	0.967	-0.040	-0.062	
C36	0.745	0.799	0.411	0.979	0.966	0.109	-0.215	0.942

B.19

September 12, 1980

<u>Group 1</u>

ORIGINAL PAGE IS
OF POOR QUALITY

0— CCRR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*
— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.775								
C3	0.700	-0.370							
C4	0.479	0.100	0.832						
C5	0.717	-0.384	0.591	0.839					
C6	0.693	-0.441	0.762	0.609	0.813				
C7	0.360	0.048	0.754	0.812	0.793	0.857			
C8	0.405	-0.042	0.781	0.794	0.829	0.835	0.990		
C9	0.327	0.043	0.920	0.821	0.837	0.807	0.975	0.970	
C10	0.669	-0.253	0.905	0.835	0.920	0.918	0.914	0.912	0.910
C11	0.743	-0.345	0.919	0.807	0.921	0.896	0.845	0.842	0.850
C12	0.712	-0.257	0.914	0.844	0.883	0.719	0.724	0.701	0.761
C13	0.517	-0.107	0.828	0.783	0.820	0.845	0.905	0.871	0.914
C14	0.504	-0.079	0.901	0.865	0.893	0.813	0.921	0.900	0.953
C15	0.274	0.007	0.618	0.532	0.573	0.647	0.730	0.665	0.769
C16	-0.005	0.354	0.364	0.458	0.289	0.278	0.506	0.395	0.553
C17	0.064	0.310	0.393	0.485	0.317	0.299	0.504	0.394	0.546
C18	0.064	0.291	0.371	0.448	0.284	0.223	0.418	0.306	0.473
C19	0.009	0.341	0.341	0.438	0.264	0.262	0.475	0.361	0.516
C20	0.031	0.337	0.309	0.484	0.306	0.241	0.468	0.357	0.524
C21	0.038	0.324	0.351	0.449	0.276	0.282	0.483	0.370	0.519
C22	0.071	0.276	0.310	0.393	0.221	0.182	0.350	0.234	0.395
C23	-0.169	0.181	0.062	-0.019	0.010	0.272	0.341	0.255	0.353
C24	-0.164	0.237	-0.019	-0.026	-0.073	0.210	0.280	0.178	0.278
C25	-0.280	0.300	-0.094	-0.109	-0.171	0.022	0.130	0.022	0.162
C26	-0.210	0.267	0.044	0.002	-0.040	0.086	0.209	0.104	0.263
C27	-0.243	0.292	-0.083	-0.095	-0.159	0.037	0.138	0.027	0.163
C28	-0.281	0.313	-0.168	-0.151	-0.247	-0.051	0.044	-0.071	0.064
C29	-0.377	0.401	-0.033	-0.030	-0.099	0.071	0.260	0.159	0.306
C30	-0.164	0.351	0.136	0.181	0.067	0.208	0.384	0.273	0.414
C31	-0.714	0.291	-0.486	-0.531	-0.441	-0.198	-0.093	-0.064	-0.092
C32	-0.626	0.037	-0.434	-0.678	-0.440	-0.422	-0.412	-0.359	-0.320
C33	-0.822	0.546	-0.452	-0.453	-0.536	-0.621	-0.360	-0.421	-0.242
C34	-0.770	0.301	-0.461	-0.589	-0.515	-0.675	-0.514	-0.505	-0.380
C35	-0.643	0.200	-0.426	-0.626	-0.487	-0.355	-0.299	-0.333	-0.208
C36	-0.728	0.276	-0.537	-0.618	-0.513	-0.222	-0.147	-0.138	-0.140

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.989								
C12	0.917	0.952							
C13	0.964	0.952	0.904						
C14	0.968	0.948	0.918	0.978					
C15	0.779	0.730	0.765	0.913	0.847				
C16	0.519	0.526	0.618	0.719	0.656	0.891			
C17	0.545	0.560	0.660	0.735	0.670	0.890	0.996		
C18	0.489	0.518	0.648	0.682	0.620	0.853	0.986	0.993	
C19	0.502	0.514	0.613	0.703	0.632	0.879	0.998	0.998	0.991
C20	0.511	0.528	0.649	0.704	0.651	0.866	0.994	0.996	0.996
C21	0.518	0.532	0.628	0.715	0.641	0.883	0.996	0.999	0.991
C22	0.440	0.477	0.615	0.635	0.559	0.819	0.971	0.982	0.995
C23	0.302	0.299	0.263	0.525	0.392	0.810	0.808	0.780	0.752
C24	0.254	0.258	0.247	0.484	0.334	0.771	0.828	0.809	0.786
C25	0.113	0.129	0.171	0.364	0.231	0.702	0.827	0.803	0.802
C26	0.215	0.235	0.291	0.460	0.346	0.778	0.882	0.861	0.862
C27	0.133	0.153	0.200	0.382	0.245	0.711	0.839	0.820	0.820
C28	0.045	0.069	0.132	0.296	0.154	0.639	0.803	0.785	0.792
C29	0.167	0.152	0.167	0.418	0.314	0.736	0.835	0.797	0.779
C30	0.354	0.354	0.395	0.588	0.481	0.847	0.945	0.927	0.909
C31	-0.410	-0.508	-0.684	-0.354	-0.357	-0.213	-0.270	-0.346	-0.397
C32	-0.572	-0.606	-0.681	-0.532	-0.497	-0.340	-0.380	-0.446	-0.437
C33	-0.506	-0.517	-0.411	-0.292	-0.297	0.069	0.323	0.263	0.299
C34	-0.656	-0.672	-0.614	-0.553	-0.496	-0.294	-0.151	-0.215	-0.174
C35	-0.403	-0.406	-0.417	-0.206	-0.273	0.174	0.246	0.185	0.200
C36	-0.428	-0.507	-0.665	-0.324	-0.366	-0.101	-0.133	-0.208	-0.250

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.995								
C21	0.999	0.993							
C22	0.982	0.984	0.984						
C23	0.807	0.754	0.801	0.748					
C24	0.836	0.780	0.834	0.798	0.981				
C25	0.835	0.792	0.828	0.816	0.956	0.975			
C26	0.886	0.855	0.878	0.866	0.955	0.959	0.988		
C27	0.850	0.807	0.845	0.837	0.950	0.978	0.998	0.986	
C28	0.818	0.775	0.813	0.819	0.916	0.959	0.991	0.968	0.994
C29	0.830	0.789	0.817	0.769	0.963	0.949	0.970	0.969	0.958
C30	0.946	0.913	0.941	0.905	0.947	0.961	0.956	0.974	0.960
C31	-0.301	-0.353	-0.323	-0.430	0.176	0.078	0.085	0.018	0.035
C32	-0.406	-0.420	-0.434	-0.465	0.030	-0.094	0.006	-0.026	-0.050
C33	0.312	0.309	0.281	0.291	0.468	0.434	0.598	0.579	0.560
C34	-0.173	-0.160	-0.206	-0.195	0.069	-0.018	0.155	0.140	0.104
C35	0.236	0.199	0.211	0.197	0.636	0.565	0.669	0.633	0.627
C36	-0.156	-0.218	-0.179	-0.270	0.359	0.273	0.291	0.216	0.243

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.934							
C30	0.932	0.958						
C31	0.025	0.232	-0.030					
C32	-0.046	0.106	-0.175	0.837				
C33	0.584	0.650	0.463	0.493	0.630			
C34	0.126	0.237	-0.013	0.649	0.894	0.858		
C35	0.634	0.702	0.486	0.638	0.742	0.874	0.777	
C36	0.238	0.405	0.143	0.972	0.932	0.605	0.673	0.782

B. 20

September 12, 1980

Group 2

0— CCAR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36 V

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.378								
C3	0.586	0.659							
C4	0.368	0.392	0.752						
C5	0.445	0.419	0.801	0.996					
C6	0.726	-0.228	0.315	0.342	0.383				
C7	0.597	-0.066	0.534	0.436	0.466	0.892			
C8	0.490	-0.100	0.431	0.435	0.452	0.888	0.985		
C9	0.660	-0.214	0.199	0.411	0.435	0.946	0.777	0.806	
C10	0.868	0.428	0.834	0.712	0.764	0.748	0.793	0.715	0.686
C11	0.776	0.569	0.833	0.830	0.865	0.596	0.645	0.584	0.617
C12	0.599	0.641	0.739	0.890	0.905	0.347	0.359	0.321	0.459
C13	0.848	0.457	0.754	0.755	0.800	0.719	0.709	0.653	0.737
C14	0.663	0.760	0.834	0.802	0.835	0.359	0.455	0.387	0.410
C15	0.347	0.318	0.377	0.689	0.669	0.457	0.499	0.546	0.641
C16	0.252	0.276	0.041	-0.587	-0.534	-0.031	0.081	-0.036	-0.231
C17	-0.144	0.159	-0.144	-0.696	-0.659	-0.507	-0.431	-0.537	-0.707
C18	-0.255	0.046	-0.217	-0.721	-0.692	-0.551	-0.479	-0.568	-0.750
C19	-0.154	0.161	-0.128	-0.675	-0.639	-0.521	-0.441	-0.548	-0.723
C20	-0.133	0.164	-0.120	-0.669	-0.631	-0.508	-0.436	-0.545	-0.712
C21	-0.125	0.175	-0.112	-0.669	-0.630	-0.502	-0.425	-0.535	-0.706
C22	-0.152	0.112	-0.169	-0.699	-0.661	-0.508	-0.458	-0.561	-0.708
C23	0.259	0.407	0.132	-0.523	-0.463	-0.177	-0.076	-0.218	-0.384
C24	-0.123	-0.189	-0.381	-0.825	-0.785	-0.328	-0.397	-0.478	-0.519
C25	-0.015	-0.031	-0.301	-0.800	-0.752	-0.254	-0.344	-0.438	-0.480
C26	-0.432	-0.020	-0.412	-0.844	-0.837	-0.617	-0.515	-0.566	-0.761
C27	-0.497	-0.135	-0.503	-0.875	-0.873	-0.631	-0.569	-0.604	-0.764
C28	-0.175	0.119	-0.097	-0.620	-0.595	-0.529	-0.453	-0.557	-0.742
C29	-0.295	0.052	-0.150	-0.646	-0.621	-0.575	-0.466	-0.554	-0.787
C30	-0.317	0.190	-0.191	-0.608	-0.583	-0.727	-0.673	-0.760	-0.866
C31	-0.433	-0.156	0.004	0.459	0.382	0.032	0.214	0.348	0.192
C32	-0.563	-0.269	-0.168	0.355	0.270	-0.080	0.045	0.197	0.106
C33	0.759	0.407	0.521	0.434	0.469	0.713	0.748	0.705	0.736
C34	-0.196	-0.805	-0.709	-0.708	-0.713	0.281	0.153	0.223	0.228
C35	-0.544	-0.172	-0.249	0.379	0.234	-0.168	-0.107	0.042	0.079
C36	-0.385	-0.068	0.061	0.571	0.495	-0.004	0.138	0.267	0.189

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.953								
C12	0.785	0.932							
C13	0.969	0.983	0.890						
C14	0.848	0.959	0.956	0.901					
C15	0.594	0.746	0.775	0.735	0.747				
C16	0.018	-0.139	-0.360	-0.111	-0.098	-0.381			
C17	-0.405	-0.524	-0.594	-0.545	-0.430	-0.822	0.777		
C18	-0.499	-0.621	-0.676	-0.643	-0.537	-0.889	0.696	0.989	
C19	-0.406	-0.523	-0.587	-0.548	-0.429	-0.835	0.753	0.999	0.991
C20	-0.392	-0.511	-0.577	-0.535	-0.420	-0.836	0.753	0.998	0.989
C21	-0.382	-0.501	-0.571	-0.525	-0.409	-0.825	0.767	0.999	0.987
C22	-0.427	-0.551	-0.612	-0.567	-0.467	-0.864	0.733	0.996	0.993
C23	0.006	-0.127	-0.292	-0.127	-0.052	-0.489	0.959	0.872	0.794
C24	-0.479	-0.656	-0.753	-0.612	-0.653	-0.920	0.671	0.915	0.932
C25	-0.385	-0.562	-0.678	-0.518	-0.551	-0.863	0.756	0.933	0.929
C26	-0.553	-0.740	-0.779	-0.759	-0.626	-0.780	0.710	0.926	0.939
C27	-0.731	-0.821	-0.842	-0.831	-0.723	-0.836	0.625	0.901	0.933
C28	-0.407	-0.529	-0.582	-0.560	-0.448	-0.883	0.670	0.982	0.989
C29	-0.485	-0.604	-0.653	-0.642	-0.519	-0.896	0.637	0.970	0.991
C30	-0.548	-0.591	-0.543	-0.647	-0.451	-0.844	0.542	0.943	0.956
C31	-0.014	0.137	0.233	0.079	0.157	0.637	-0.620	-0.729	-0.683
C32	-0.191	-0.028	0.117	-0.080	-0.002	0.524	-0.697	-0.699	-0.631
C33	0.826	0.818	0.649	0.863	0.761	0.771	0.198	-0.426	-0.547
C34	-0.384	-0.569	-0.748	-0.426	-0.721	-0.299	0.263	0.117	0.163
C35	-0.243	-0.030	0.176	-0.082	0.035	0.569	-0.709	-0.700	-0.646
C36	0.027	0.215	0.365	0.146	0.250	0.678	-0.732	-0.787	-0.744

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	1.000								
C21	1.000	1.000							
C22	0.997	0.998	0.997						
C23	0.859	0.862	0.872	0.840					
C24	0.912	0.916	0.911	0.936	0.733				
C25	0.927	0.932	0.930	0.946	0.816	0.990			
C26	0.919	0.910	0.911	0.914	0.737	0.859	0.852		
C27	0.896	0.887	0.886	0.900	0.656	0.880	0.855	0.990	
C28	0.989	0.990	0.987	0.991	0.799	0.909	0.911	0.882	0.872
C29	0.973	0.975	0.972	0.977	0.750	0.895	0.884	0.912	0.908
C30	0.952	0.950	0.945	0.953	0.701	0.841	0.833	0.881	0.879
C31	-0.727	-0.744	-0.741	-0.754	-0.745	-0.798	-0.845	-0.486	-0.478
C32	-0.695	-0.712	-0.713	-0.710	-0.806	-0.721	-0.792	-0.426	-0.392
C33	-0.450	-0.444	-0.426	-0.479	0.071	-0.507	-0.392	-0.515	-0.614
C34	0.092	0.087	0.087	0.125	0.055	0.403	0.359	0.317	0.372
C35	-0.699	-0.715	-0.717	-0.712	-0.798	-0.729	-0.789	-0.423	-0.390
C36	-0.780	-0.794	-0.794	-0.803	-0.812	-0.864	-0.910	-0.583	-0.570

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.990							
C30	0.960	0.955						
C31	-0.725	-0.631	-0.646					
C32	-0.683	-0.582	-0.571	0.977				
C33	-0.529	-0.590	-0.631	0.123	-0.052			
C34	0.051	0.098	-0.063	-0.062	-0.002	-0.108		
C35	-0.704	-0.620	-0.539	0.923	0.967	-0.040	-0.062	
C36	-0.766	-0.687	-0.654	0.979	0.966	0.109	-0.215	0.942

B. 21-29

Correlations Between Yield 1977-1980,
Pruning Weight, Clusters and Reflectance
Stratified by Time of Day

B. 21

July 17, 18, 1980

Group 1

ORIGINAL PAGE IS
OF POOR QUALITY

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*
— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.635								
C3	0.367	0.470							
C4	0.587	0.240	0.910						
C5	0.529	0.311	0.948	0.991					
C6	0.804	-0.058	0.816	0.952	0.928				
C7	0.807	-0.083	0.766	0.940	0.897	0.986			
C8	0.619	0.149	0.809	0.953	0.910	0.922	0.957		
C9	0.789	-0.071	0.797	0.915	0.903	0.976	0.933	0.849	
C10	0.592	0.211	0.946	0.926	0.947	0.917	0.857	0.832	0.936
C11	-0.401	0.499	-0.015	0.119	0.065	-0.096	0.023	0.265	-0.205
C12	0.291	0.508	0.954	0.877	0.932	0.765	0.687	0.709	0.785
C13	0.795	-0.061	0.792	0.948	0.923	0.989	0.981	0.913	0.946
C14	0.622	0.147	0.808	0.964	0.926	0.927	0.958	0.985	0.842
C15	0.501	0.208	0.718	0.894	0.845	0.822	0.883	0.952	0.703
C16	0.611	0.052	0.751	0.790	0.769	0.795	0.826	0.816	0.659
C17	0.532	0.046	0.666	0.685	0.674	0.686	0.714	0.689	0.535
C18	0.479	0.148	0.717	0.724	0.711	0.695	0.731	0.747	0.539
C19	0.561	0.094	0.743	0.776	0.761	0.765	0.794	0.789	0.622
C20	0.539	0.107	0.734	0.768	0.757	0.750	0.775	0.764	0.607
C21	0.538	0.127	0.762	0.781	0.771	0.761	0.785	0.783	0.621
C22	0.500	0.160	0.746	0.775	0.760	0.739	0.774	0.790	0.590
C23	0.471	0.258	0.828	0.839	0.831	0.779	0.805	0.844	0.645
C24	0.426	-0.470	0.077	-0.058	-0.002	0.150	0.027	-0.213	0.261
C25	0.451	-0.423	0.151	0.040	0.100	0.222	0.105	-0.144	0.289
C26	0.537	0.225	0.823	0.914	0.881	0.858	0.901	0.960	0.740
C27	0.527	0.238	0.833	0.913	0.885	0.853	0.892	0.946	0.733
C28	0.595	0.065	0.763	0.780	0.771	0.784	0.800	0.774	0.655
C29	0.533	0.118	0.741	0.765	0.751	0.746	0.777	0.778	0.600
C30	0.519	0.136	0.760	0.756	0.750	0.737	0.758	0.757	0.597
C31	0.879	-0.290	0.623	0.824	0.797	0.930	0.908	0.763	0.913
C32	-0.053	0.125	0.219	0.008	0.115	0.004	-0.126	-0.260	0.051
C33	0.044	-0.379	-0.400	-0.279	-0.254	-0.177	-0.262	-0.442	-0.028
C34	-0.189	-0.068	-0.371	-0.192	-0.187	-0.212	-0.252	-0.301	-0.089
C35	0.138	0.244	0.520	0.344	0.375	0.296	0.305	0.327	0.149
C36	0.411	0.216	0.775	0.663	0.678	0.637	0.640	0.653	0.515

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	-0.187								
C12	0.909	-0.042							
C13	0.874	-0.056	0.756						
C14	0.814	0.258	0.734	0.942					
C15	0.678	0.446	0.633	0.854	0.975				
C16	0.703	0.022	0.598	0.826	0.852	0.830			
C17	0.585	-0.008	0.533	0.742	0.757	0.751	0.976		
C18	0.617	0.094	0.565	0.740	0.797	0.802	0.985	0.988	
C19	0.673	0.049	0.605	0.808	0.840	0.827	0.995	0.938	0.994
C20	0.655	0.048	0.616	0.803	0.828	0.819	0.984	0.992	0.989
C21	0.683	0.045	0.630	0.804	0.836	0.821	0.992	0.988	0.994
C22	0.653	0.122	0.611	0.786	0.843	0.845	0.987	0.983	0.996
C23	0.732	0.158	0.699	0.812	0.883	0.877	0.976	0.948	0.978
C24	0.247	-0.998	0.107	0.110	-0.205	-0.399	0.018	0.042	-0.058
C25	0.270	-0.937	0.203	0.227	-0.082	-0.251	0.185	0.258	0.138
C26	0.776	0.285	0.695	0.872	0.969	0.964	0.924	0.842	0.895
C27	0.775	0.267	0.711	0.873	0.964	0.959	0.936	0.866	0.914
C28	0.708	-0.042	0.631	0.822	0.825	0.792	0.993	0.986	0.984
C29	0.659	0.066	0.602	0.790	0.830	0.823	0.992	0.989	0.997
C30	0.676	0.017	0.619	0.776	0.807	0.790	0.990	0.989	0.995
C31	0.766	-0.234	0.634	0.954	0.813	0.704	0.707	0.650	0.605
C32	0.155	-0.601	0.363	0.055	-0.145	-0.241	0.085	0.226	0.130
C33	-0.232	-0.392	-0.139	-0.151	-0.379	-0.458	-0.574	-0.522	-0.625
C34	-0.275	0.110	-0.100	-0.181	-0.255	-0.256	-0.636	-0.621	-0.661
C35	0.340	-0.088	0.364	0.341	0.384	0.398	0.780	0.856	0.853
C36	0.671	-0.094	0.605	0.650	0.677	0.642	0.935	0.930	0.948

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.996								
C21	0.999	0.997							
C22	0.996	0.995	0.997						
C23	0.981	0.976	0.985	0.989					
C24	-0.010	-0.008	-0.004	-0.082	-0.112				
C25	0.183	0.206	0.192	0.119	0.067	0.944			
C26	0.913	0.895	0.910	0.921	0.955	-0.237	-0.109		
C27	0.930	0.917	0.929	0.939	0.969	-0.218	-0.075	0.998	
C28	0.995	0.992	0.996	0.986	0.971	0.083	0.268	0.893	0.912
C29	0.999	0.997	0.999	0.998	0.983	-0.027	0.170	0.909	0.928
C30	0.996	0.993	0.998	0.993	0.980	0.023	0.213	0.893	0.914
C31	0.691	0.697	0.683	0.654	0.653	0.280	0.405	0.700	0.705
C32	0.139	0.197	0.169	0.123	0.093	0.616	0.778	-0.147	-0.091
C33	-0.556	-0.508	-0.553	-0.582	-0.604	0.384	0.386	-0.582	-0.572
C34	-0.608	-0.562	-0.604	-0.596	-0.579	-0.113	-0.111	-0.466	-0.469
C35	0.805	0.809	0.816	0.810	0.771	0.106	0.290	0.564	0.599
C36	0.934	0.920	0.941	0.928	0.926	0.131	0.270	0.807	0.828

	C28	C29	C30	C31	C32	C33.	C34	C35
C29	0.993							
C30	0.995	0.997						
C31	0.718	0.668	0.652					
C32	0.198	0.143	0.188	0.162				
C33	-0.517	-0.572	-0.578	0.107	0.371			
C34	-0.612	-0.617	-0.646	-0.019	0.056	0.860		
C35	0.809	0.820	0.846	0.217	0.389	-0.654	-0.802	
C36	0.945	0.938	0.959	0.499	0.241	-0.677	-0.792	0.912

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Group 2

ORIGINAL PAGE IS
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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.069								
C3	0.420	0.871							
C4	0.394	0.907	0.990						
C5	0.139	0.940	0.941	0.962					
C6	0.012	0.946	0.891	0.921	0.988				
C7	0.039	0.922	0.920	0.925	0.986	0.984			
C8	-0.056	0.816	0.848	0.842	0.922	0.940	0.961		
C9	0.006	0.889	0.869	0.895	0.959	0.980	0.963	0.971	
C10	-0.036	0.893	0.856	0.879	0.950	0.978	0.962	0.974	0.998
C11	0.197	0.788	0.901	0.904	0.915	0.912	0.917	0.955	0.962
C12	0.086	0.835	0.886	0.903	0.954	0.960	0.954	0.971	0.988
C13	-0.229	0.889	0.779	0.801	0.929	0.966	0.960	0.950	0.952
C14	-0.162	0.866	0.822	0.816	0.925	0.941	0.973	0.957	0.921
C15	-0.062	0.934	0.871	0.878	0.964	0.967	0.985	0.922	0.921
C16	0.173	0.724	0.886	0.825	0.831	0.796	0.888	0.889	0.801
C17	0.104	0.848	0.900	0.859	0.880	0.856	0.927	0.879	0.824
C18	0.236	0.822	0.939	0.893	0.881	0.862	0.916	0.872	0.822
C19	0.219	0.814	0.945	0.903	0.904	0.867	0.938	0.907	0.855
C20	0.159	0.790	0.916	0.868	0.880	0.852	0.928	0.917	0.850
C21	0.278	0.808	0.952	0.907	0.884	0.845	0.914	0.888	0.842
C22	0.448	0.845	0.991	0.971	0.904	0.856	0.891	0.837	0.851
C23	-0.043	0.783	0.848	0.816	0.886	0.890	0.946	0.978	0.909
C24	-0.189	0.761	0.705	0.662	0.757	0.754	0.834	0.772	0.688
C25	-0.035	0.856	0.763	0.738	0.786	0.771	0.828	0.705	0.676
C26	0.089	0.825	0.883	0.856	0.871	0.876	0.915	0.944	0.910
C27	0.002	0.771	0.835	0.800	0.839	0.852	0.901	0.955	0.890
C28	0.132	0.828	0.910	0.869	0.877	0.863	0.925	0.921	0.870
C29	0.533	0.858	0.880	0.909	0.802	0.761	0.731	0.609	0.726
C30	0.391	0.912	0.902	0.907	0.831	0.798	0.801	0.681	0.749
C31	0.133	-0.403	-0.078	-0.108	-0.128	-0.127	-0.110	0.117	0.042
C32	0.281	0.040	0.325	0.340	0.328	0.312	0.290	0.427	0.433
C33	0.083	-0.180	0.178	0.046	0.038	-0.016	0.149	0.269	0.045
C34	0.310	-0.057	0.272	0.251	0.257	0.175	0.226	0.233	0.178
C35	0.234	0.106	0.358	0.370	0.353	0.360	0.332	0.503	0.509
C36	0.252	-0.264	0.088	0.049	-0.005	-0.013	0.012	0.233	0.162

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.952								
C12	0.978	0.983							
C13	0.961	0.852	0.919						
C14	0.931	0.850	0.903	0.978					
C15	0.927	0.837	0.896	0.968	0.982				
C16	0.806	0.847	0.824	0.785	0.884	0.855			
C17	0.836	0.810	0.814	0.845	0.925	0.927	0.967		
C18	0.827	0.845	0.828	0.801	0.887	0.894	0.980	0.989	
C19	0.855	0.882	0.872	0.829	0.909	0.908	0.986	0.979	0.994
C20	0.856	0.877	0.864	0.834	0.915	0.898	0.995	0.981	0.990
C21	0.844	0.884	0.856	0.793	0.873	0.875	0.981	0.972	0.995
C22	0.841	0.901	0.865	0.742	0.791	0.832	0.895	0.899	0.944
C23	0.919	0.906	0.914	0.915	0.964	0.920	0.956	0.940	0.930
C24	0.712	0.604	0.655	0.821	0.904	0.891	0.859	0.930	0.871
C25	0.697	0.578	0.626	0.782	0.850	0.890	0.803	0.922	0.870
C26	0.922	0.924	0.896	0.859	0.895	0.871	0.929	0.929	0.934
C27	0.911	0.911	0.888	0.865	0.906	0.859	0.935	0.917	0.916
C28	0.881	0.884	0.863	0.845	0.910	0.896	0.973	0.979	0.982
C29	0.713	0.728	0.701	0.589	0.575	0.686	0.603	0.686	0.729
C30	0.752	0.728	0.709	0.676	0.697	0.785	0.731	0.830	0.846
C31	0.018	0.237	0.151	-0.128	-0.128	-0.250	0.032	-0.207	-0.119
C32	0.391	0.580	0.541	0.239	0.202	0.147	0.253	0.071	0.164
C33	0.050	0.210	0.138	0.058	0.232	0.107	0.544	0.360	0.395
C34	0.128	0.295	0.316	0.124	0.162	0.162	0.268	0.115	0.184
C35	0.478	0.655	0.593	0.298	0.250	0.181	0.308	0.134	0.221
C36	0.140	0.376	0.266	-0.042	-0.030	-0.142	0.181	-0.094	0.045

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.996								
C21	0.993	0.990							
C22	0.942	0.919	0.962						
C23	0.952	0.969	0.934	0.844					
C24	0.857	0.870	0.822	0.683	0.860				
C25	0.837	0.831	0.818	0.742	0.780	0.957			
C26	0.936	0.950	0.950	0.908	0.955	0.783	0.760		
C27	0.924	0.949	0.931	0.859	0.974	0.797	0.736	0.991	
C28	0.978	0.987	0.985	0.926	0.962	0.858	0.838	0.983	0.973
C29	0.706	0.661	0.746	0.886	0.567	0.452	0.630	0.713	0.615
C30	0.808	0.779	0.843	0.914	0.685	0.659	0.808	0.810	0.729
C31	-0.043	-0.015	-0.034	-0.044	0.064	-0.378	-0.559	0.028	0.092
C32	0.257	0.248	0.247	0.313	0.320	-0.162	-0.270	0.272	0.297
C33	0.413	0.456	0.402	0.212	0.414	0.354	0.148	0.301	0.381
C34	0.271	0.236	0.207	0.200	0.225	0.040	-0.075	0.031	0.066
C35	0.302	0.307	0.313	0.374	0.392	-0.124	-0.229	0.400	0.422
C36	0.109	0.136	0.136	0.140	0.188	-0.281	-0.435	0.198	0.246

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.708							
C30	0.828	0.958						
C31	-0.057	-0.278	-0.391					
C32	0.195	0.143	-0.023	0.841				
C33	0.373	-0.230	-0.091	0.467	0.243			
C34	0.091	-0.046	-0.136	0.509	0.696	0.448		
C35	0.292	0.212	0.068	0.848	0.964	0.229	0.500	
C36	0.111	-0.094	-0.198	0.974	0.846	0.497	0.448	0.888

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<u>Group 3</u>

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.942								
C3	0.917	0.980							
C4	0.936	0.974	0.990						
C5	0.925	0.970	0.990	0.999					
C6	0.941	0.965	0.990	0.997	0.996				
C7	0.902	0.945	0.982	0.993	0.994	0.993			
C8	0.818	0.844	0.898	0.933	0.945	0.934	0.950		
C9	-0.286	-0.301	-0.356	-0.243	-0.245	-0.292	-0.234	-0.076	
C10	0.864	0.916	0.967	0.975	0.983	0.978	0.985	0.975	-0.261
C11	0.593	0.720	0.701	0.671	0.645	0.649	0.666	0.427	-0.226
C12	0.898	0.954	0.972	0.989	0.994	0.982	0.985	0.964	-0.162
C13	0.945	0.952	0.977	0.993	0.989	0.996	0.992	0.931	-0.245
C14	0.908	0.941	0.941	0.935	0.919	0.933	0.925	0.765	-0.326
C15	0.932	0.948	0.935	0.926	0.908	0.925	0.905	0.737	-0.370
C16	-0.740	-0.768	-0.801	-0.732	-0.720	-0.758	-0.721	-0.518	0.793
C17	-0.764	-0.796	-0.777	-0.704	-0.693	-0.721	-0.662	-0.453	0.770
C18	-0.788	-0.796	-0.798	-0.731	-0.721	-0.755	-0.699	-0.509	0.793
C19	-0.772	-0.783	-0.771	-0.701	-0.691	-0.723	-0.660	-0.467	0.794
C20	-0.727	-0.723	-0.710	-0.635	-0.626	-0.662	-0.592	-0.399	0.835
C21	-0.716	-0.715	-0.693	-0.617	-0.605	-0.641	-0.570	-0.365	0.824
C22	-0.779	-0.728	-0.712	-0.653	-0.641	-0.683	-0.609	-0.428	0.791
C23	-0.891	-0.807	-0.778	-0.752	-0.733	-0.775	-0.708	-0.535	0.619
C24	0.771	0.811	0.894	0.850	0.850	0.877	0.869	0.759	-0.658
C25	0.579	0.583	0.661	0.603	0.585	0.637	0.629	0.420	-0.712
C26	0.333	0.482	0.549	0.510	0.491	0.503	0.557	0.357	-0.255
C27	0.297	0.465	0.544	0.507	0.493	0.498	0.561	0.386	-0.217
C28	-0.813	-0.720	-0.644	-0.614	-0.594	-0.630	-0.542	-0.367	0.582
C29	-0.565	-0.555	-0.576	-0.484	-0.477	-0.524	-0.457	-0.268	0.944
C30	-0.577	-0.542	-0.549	-0.463	-0.456	-0.504	-0.428	-0.248	0.929
C31	0.257	0.425	0.335	0.229	0.225	0.212	0.157	-0.051	-0.572
C32	0.732	0.756	0.746	0.777	0.800	0.769	0.751	0.860	-0.020
C33	-0.318	-0.459	-0.555	-0.553	-0.543	-0.542	-0.621	-0.521	0.013
C34	0.176	0.145	0.044	0.087	0.111	0.066	0.018	0.196	0.294
C35	0.865	0.940	0.933	0.913	0.897	0.904	0.898	0.719	-0.351
C36	0.464	0.582	0.489	0.399	0.384	0.387	0.328	0.076	-0.587

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.952								
C12	0.984	0.598							
C13	0.967	0.661	0.973						
C14	0.855	0.860	0.878	0.941					
C15	0.835	0.835	0.863	0.931	0.994				
C16	-0.686	-0.698	-0.643	-0.739	-0.833	-0.854			
C17	-0.627	-0.657	-0.622	-0.691	-0.795	-0.839	0.957		
C18	-0.673	-0.620	-0.649	-0.729	-0.805	-0.846	0.976	0.991	
C19	-0.635	-0.598	-0.620	-0.693	-0.775	-0.822	0.957	0.996	0.996
C20	-0.571	-0.537	-0.550	-0.630	-0.715	-0.769	0.942	0.986	0.988
C21	-0.542	-0.558	-0.528	-0.610	-0.712	-0.768	0.935	0.989	0.983
C22	-0.582	-0.503	-0.564	-0.661	-0.728	-0.786	0.925	0.967	0.979
C23	-0.657	-0.580	-0.664	-0.771	-0.828	-0.880	0.891	0.925	0.941
C24	0.870	0.617	0.801	0.860	0.846	0.838	-0.923	-0.820	-0.873
C25	0.572	0.707	0.498	0.642	0.765	0.758	-0.920	-0.780	-0.823
C26	0.469	0.882	0.444	0.519	0.693	0.632	-0.614	-0.452	-0.453
C27	0.486	0.848	0.455	0.511	0.662	0.592	-0.570	-0.397	-0.402
C28	-0.491	-0.471	-0.529	-0.619	-0.694	-0.769	0.781	0.891	0.881
C29	-0.451	-0.424	-0.391	-0.489	-0.578	-0.629	0.921	0.927	0.943
C30	-0.424	-0.366	-0.371	-0.469	-0.548	-0.609	0.891	0.919	0.934
C31	0.135	0.469	0.184	0.155	0.338	0.390	-0.547	-0.713	-0.620
C32	0.816	0.133	0.845	0.741	0.524	0.534	-0.317	-0.388	-0.411
C33	-0.560	-0.756	-0.528	-0.567	-0.641	-0.555	0.434	0.233	0.259
C34	0.100	-0.439	0.183	0.033	-0.171	-0.120	0.314	0.097	0.126
C35	0.827	0.902	0.857	0.904	0.989	0.983	-0.842	-0.819	-0.813
C36	0.268	0.655	0.325	0.348	0.558	0.610	-0.703	-0.841	-0.760

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.995								
C21	0.993	0.998							
C22	0.983	0.989	0.985						
C23	0.937	0.928	0.925	0.966					
C24	-0.831	-0.798	-0.772	-0.789	-0.782				
C25	-0.778	-0.764	-0.756	-0.756	-0.744	0.873			
C26	-0.402	-0.346	-0.353	-0.296	-0.335	0.622	0.769		
C27	-0.348	-0.288	-0.292	-0.233	-0.267	0.614	0.729	0.994	
C28	0.901	0.905	0.913	0.941	0.959	-0.601	-0.569	-0.139	-0.060
C29	0.944	0.966	0.960	0.946	0.840	-0.775	-0.797	-0.333	-0.279
C30	0.941	0.968	0.962	0.958	0.855	-0.733	-0.745	-0.242	-0.183
C31	-0.675	-0.679	-0.708	-0.589	-0.463	0.295	0.290	0.216	0.175
C32	-0.410	-0.361	-0.331	-0.385	-0.451	0.510	0.053	-0.080	-0.050
C33	0.192	0.120	0.113	0.088	0.172	-0.576	-0.621	-0.932	-0.956
C34	0.073	0.074	0.082	0.045	0.023	-0.254	-0.634	-0.737	-0.717
C35	-0.789	-0.728	-0.730	-0.721	-0.801	0.831	0.754	0.727	0.697
C36	-0.801	-0.796	-0.826	-0.734	-0.664	0.440	0.483	0.369	0.309

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.802							
C30	0.840	0.994						
C31	-0.578	-0.624	-0.620					
C32	-0.413	-0.199	-0.221	0.115				
C33	-0.087	0.091	-0.002	0.072	-0.067			
C34	-0.142	0.212	0.134	0.082	0.653	0.628		
C35	-0.681	-0.591	-0.555	0.448	0.497	-0.648	-0.178	
C36	-0.743	-0.714	-0.709	0.953	0.141	-0.072	-0.032	0.643

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Group 1

ORIGINAL PAGE IS
OF POOR QUALITY

0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.443								
C3	0.535	0.779							
C4	0.482	0.730	0.945						
C5	0.240	0.793	0.749	0.581					
C6	0.464	0.722	0.780	0.652	0.929				
C7	0.512	0.540	0.652	0.848	0.212	0.392			
C8	0.239	0.022	0.438	0.647	-0.210	-0.054	0.753		
C9	0.431	0.877	0.941	0.937	0.808	0.830	0.728	0.353	
C10	0.232	0.194	0.531	0.743	-0.090	0.024	0.822	0.980	0.483
C11	0.418	0.885	0.949	0.879	0.895	0.883	0.584	0.215	0.980
C12	0.330	0.838	0.947	0.869	0.896	0.860	0.531	0.229	0.962
C13	0.416	0.911	0.860	0.833	0.645	0.547	0.588	0.305	0.858
C14	0.297	0.873	0.784	0.709	0.650	0.478	0.393	0.158	0.762
C15	0.210	0.729	0.807	0.702	0.632	0.451	0.294	0.230	0.713
C16	0.606	0.835	0.796	0.883	0.443	0.496	0.870	0.519	0.842
C17	0.526	0.773	0.730	0.858	0.332	0.375	0.889	0.589	0.785
C18	0.527	0.794	0.734	0.847	0.347	0.372	0.856	0.555	0.781
C19	0.521	0.809	0.746	0.856	0.375	0.398	0.858	0.544	0.800
C20	0.507	0.780	0.807	0.898	0.387	0.398	0.837	0.610	0.814
C21	0.522	0.790	0.745	0.844	0.345	0.352	0.824	0.556	0.771
C22	0.472	0.767	0.671	0.801	0.285	0.294	0.838	0.549	0.731
C23	0.515	0.683	0.522	0.674	0.129	0.164	0.809	0.507	0.592
C24	0.674	0.608	0.646	0.805	0.242	0.439	0.971	0.633	0.716
C25	0.721	0.654	0.681	0.816	0.246	0.413	0.941	0.622	0.718
C26	0.533	0.740	0.754	0.882	0.315	0.368	0.900	0.648	0.786
C27	-0.019	0.359	0.710	0.615	0.473	0.327	0.168	0.394	0.544
C28	0.404	0.704	0.732	0.856	0.275	0.266	0.824	0.665	0.741
C29	0.476	0.728	0.529	0.684	0.193	0.221	0.820	0.463	0.634
C30	0.638	0.635	0.632	0.704	0.140	0.164	0.705	0.556	0.570
C31	0.635	0.712	0.768	0.534	0.798	0.776	0.153	-0.136	0.656
C32	0.399	0.622	0.209	0.330	0.287	0.387	0.591	-0.040	0.462
C33	-0.363	-0.134	-0.327	-0.514	0.344	0.269	-0.657	-0.847	-0.224
C34	-0.150	0.430	0.049	0.044	0.563	0.542	0.079	-0.486	0.342
C35	0.633	0.682	0.480	0.511	0.151	0.130	0.534	0.263	0.460
C36	0.627	0.739	0.690	0.472	0.670	0.592	0.125	-0.147	0.572

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.343								
C12	0.352	0.991							
C13	0.460	0.855	0.839						
C14	0.317	0.794	0.793	0.974					
C15	0.357	0.769	0.802	0.908	0.954				
C16	0.646	0.760	0.703	0.885	0.762	0.632			
C17	0.716	0.683	0.630	0.854	0.729	0.599	0.988		
C18	0.687	0.689	0.636	0.879	0.767	0.636	0.989	0.998	
C19	0.679	0.709	0.657	0.885	0.773	0.641	0.991	0.997	0.999
C20	0.735	0.736	0.701	0.912	0.811	0.726	0.976	0.982	0.986
C21	0.687	0.687	0.641	0.900	0.800	0.683	0.981	0.990	0.997
C22	0.684	0.631	0.578	0.857	0.750	0.609	0.971	0.992	0.995
C23	0.628	0.477	0.405	0.752	0.639	0.460	0.927	0.957	0.960
C24	0.703	0.587	0.510	0.609	0.416	0.276	0.904	0.900	0.875
C25	0.700	0.603	0.526	0.689	0.516	0.379	0.943	0.938	0.923
C26	0.764	0.683	0.637	0.849	0.721	0.613	0.983	0.996	0.992
C27	0.448	0.603	0.686	0.631	0.681	0.864	0.338	0.323	0.344
C28	0.788	0.648	0.622	0.874	0.779	0.702	0.940	0.970	0.973
C29	0.597	0.518	0.445	0.759	0.643	0.451	0.933	0.960	0.960
C30	0.647	0.499	0.448	0.807	0.727	0.628	0.894	0.906	0.921
C31	-0.067	0.769	0.749	0.678	0.696	0.700	0.488	0.362	0.395
C32	0.074	0.368	0.258	0.357	0.229	-0.049	0.613	0.594	0.580
C33	-0.859	-0.097	-0.079	-0.436	-0.337	-0.325	-0.617	-0.698	-0.691
C34	-0.383	0.346	0.306	0.060	0.030	-0.132	0.082	0.029	0.016
C35	0.372	0.415	0.341	0.763	0.719	0.555	0.821	0.819	0.847
C36	-0.059	0.677	0.649	0.788	0.790	0.758	0.542	0.438	0.484

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.986								
C21	0.995	0.992							
C22	0.993	0.974	0.992						
C23	0.953	0.910	0.951	0.975					
C24	0.876	0.836	0.842	0.853	0.853				
C25	0.921	0.891	0.901	0.902	0.903	0.986			
C26	0.991	0.988	0.988	0.983	0.941	0.902	0.940		
C27	0.349	0.489	0.397	0.307	0.119	0.062	0.130	0.372	
C28	0.970	0.987	0.981	0.973	0.916	0.799	0.855	0.979	0.491
C29	0.957	0.904	0.946	0.976	0.993	0.859	0.898	0.937	0.096
C30	0.909	0.920	0.940	0.920	0.922	0.761	0.855	0.913	0.348
C31	0.406	0.449	0.421	0.323	0.224	0.269	0.348	0.362	0.498
C32	0.590	0.451	0.523	0.589	0.654	0.690	0.650	0.534	-0.449
C33	-0.669	-0.709	-0.709	-0.711	-0.739	-0.620	-0.680	-0.734	-0.283
C34	0.045	-0.066	-0.040	0.010	-0.021	0.105	0.013	-0.034	-0.329
C35	0.835	0.809	0.863	0.856	0.899	0.649	0.757	0.800	0.154
C36	0.488	0.522	0.521	0.434	0.369	0.261	0.376	0.430	0.471

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.905							
C30	0.915	0.880						
C31	0.323	0.221	0.420					
C32	0.401	0.718	0.376	0.115				
C33	-0.775	-0.670	-0.817	0.072	-0.067			
C34	-0.130	0.093	-0.316	0.082	0.653	0.628		
C35	0.791	0.866	0.942	0.448	0.497	-0.648	-0.178	
C36	0.421	0.351	0.571	0.953	0.141	-0.072	-0.032	0.643

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Group 2

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.638								
C3	0.833	0.753							
C4	0.640	0.845	0.939						
C5	0.729	0.838	0.965	0.987					
C6	0.471	0.634	0.865	0.920	0.870				
C7	0.330	0.604	0.787	0.885	0.818	0.979			
C8	0.339	0.647	0.786	0.891	0.822	0.970	0.996		
C9	0.543	0.718	0.900	0.941	0.919	0.932	0.940	0.949	
C10	0.492	0.699	0.886	0.950	0.908	0.986	0.982	0.982	0.978
C11	0.622	0.706	0.943	0.950	0.938	0.947	0.929	0.931	0.991
C12	0.676	0.730	0.969	0.973	0.976	0.928	0.890	0.886	0.966
C13	0.334	0.656	0.747	0.859	0.775	0.963	0.960	0.961	0.857
C14	0.262	0.355	0.669	0.681	0.618	0.873	0.910	0.906	0.856
C15	-0.745	-0.450	-0.658	-0.502	-0.616	-0.278	-0.236	-0.251	-0.544
C16	0.437	0.198	0.610	0.474	0.442	0.700	0.665	0.658	0.633
C17	0.374	0.154	0.518	0.383	0.344	0.622	0.597	0.597	0.558
C18	0.379	0.156	0.549	0.417	0.380	0.657	0.635	0.631	0.596
C19	0.385	0.144	0.542	0.403	0.368	0.642	0.616	0.612	0.581
C20	0.397	0.133	0.531	0.378	0.349	0.610	0.584	0.581	0.562
C21	0.405	0.147	0.553	0.405	0.376	0.636	0.610	0.606	0.586
C22	0.404	0.141	0.588	0.447	0.418	0.685	0.656	0.645	0.623
C23	0.193	-0.110	0.401	0.283	0.235	0.603	0.555	0.516	0.408
C24	0.295	-0.020	0.415	0.245	0.228	0.483	0.484	0.481	0.489
C25	0.305	0.101	0.337	0.191	0.151	0.414	0.397	0.413	0.369
C26	0.414	0.103	0.577	0.421	0.397	0.662	0.623	0.608	0.590
C27	0.441	0.183	0.608	0.468	0.437	0.700	0.657	0.647	0.615
C28	0.321	0.096	0.539	0.416	0.379	0.669	0.661	0.650	0.619
C29	0.369	0.054	0.506	0.350	0.317	0.616	0.567	0.551	0.500
C30	0.440	0.405	0.767	0.726	0.678	0.908	0.892	0.863	0.846
C31	0.754	0.752	0.740	0.738	0.795	0.494	0.370	0.367	0.492
C32	0.866	0.600	0.890	0.777	0.823	0.706	0.555	0.534	0.620
C33	0.638	0.806	0.563	0.612	0.673	0.268	0.192	0.216	0.375
C34	0.407	0.610	0.266	0.309	0.387	-0.075	-0.069	-0.020	0.204
C35	0.453	-0.039	0.449	0.258	0.257	0.475	0.338	0.294	0.241
C36	0.536	0.207	0.673	0.558	0.552	0.716	0.585	0.538	0.495

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.978								
C12	0.957	0.985							
C13	0.938	0.857	0.819						
C14	0.871	0.848	0.756	0.839					
C15	-0.385	-0.560	-0.599	-0.066	-0.233				
C16	0.655	0.678	0.582	0.656	0.864	-0.206			
C17	0.578	0.597	0.484	0.604	0.828	-0.139	0.990		
C18	0.615	0.634	0.526	0.626	0.857	-0.167	0.996	0.997	
C19	0.599	0.622	0.514	0.608	0.845	-0.172	0.996	0.998	1.000
C20	0.571	0.603	0.494	0.572	0.825	-0.196	0.991	0.997	0.997
C21	0.597	0.628	0.521	0.595	0.841	-0.204	0.995	0.996	0.999
C22	0.641	0.667	0.570	0.628	0.870	-0.215	0.997	0.984	0.994
C23	0.499	0.472	0.399	0.569	0.741	0.102	0.894	0.874	0.887
C24	0.463	0.517	0.396	0.419	0.789	-0.248	0.940	0.953	0.957
C25	0.377	0.400	0.270	0.443	0.671	-0.047	0.907	0.955	0.931
C26	0.611	0.641	0.550	0.598	0.842	-0.210	0.993	0.978	0.988
C27	0.647	0.667	0.576	0.657	0.849	-0.182	0.998	0.986	0.992
C28	0.632	0.651	0.543	0.617	0.891	-0.190	0.985	0.977	0.989
C29	0.545	0.559	0.466	0.579	0.789	-0.085	0.983	0.979	0.981
C30	0.880	0.872	0.799	0.862	0.965	-0.257	0.929	0.885	0.909
C31	0.507	0.545	0.669	0.409	0.048	-0.497	-0.009	-0.110	-0.088
C32	0.669	0.720	0.794	0.589	0.396	-0.486	0.484	0.385	0.408
C33	0.337	0.386	0.502	0.218	-0.144	-0.538	-0.265	-0.337	-0.327
C34	0.065	0.162	0.233	-0.133	-0.274	-0.653	-0.440	-0.468	-0.465
C35	0.348	0.354	0.347	0.418	0.440	0.038	0.742	0.707	0.710
C36	0.607	0.596	0.620	0.638	0.555	-0.085	0.696	0.619	0.642

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.999								
C21	0.999	0.999							
C22	0.994	0.990	0.994						
C23	0.886	0.870	0.877	0.905					
C24	0.961	0.970	0.966	0.955	0.814				
C25	0.936	0.945	0.933	0.891	0.754	0.911			
C26	0.989	0.986	0.990	0.998	0.920	0.951	0.883		
C27	0.992	0.986	0.991	0.994	0.912	0.928	0.899	0.994	
C28	0.988	0.983	0.987	0.994	0.897	0.967	0.883	0.988	0.979
C29	0.983	0.978	0.980	0.982	0.947	0.926	0.905	0.989	0.989
C30	0.900	0.881	0.897	0.925	0.820	0.803	0.727	0.909	0.926
C31	-0.094	-0.108	-0.085	-0.048	-0.113	-0.268	-0.247	-0.044	0.007
C32	0.407	0.393	0.414	0.455	0.415	0.233	0.215	0.471	0.506
C33	-0.333	-0.336	-0.321	-0.309	-0.471	-0.456	-0.397	-0.322	-0.267
C34	-0.466	-0.448	-0.445	-0.463	-0.756	-0.439	-0.440	-0.490	-0.468
C35	0.716	0.704	0.711	0.734	0.873	0.592	0.609	0.771	0.778
C36	0.640	0.615	0.635	0.686	0.811	0.471	0.436	0.713	0.731

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.968							
C30	0.919	0.873						
C31	-0.126	-0.080	0.195					
C32	0.373	0.449	0.587	0.843				
C33	-0.372	-0.373	-0.059	0.911	0.582			
C34	-0.484	-0.578	-0.302	0.535	0.125	0.817		
C35	0.678	0.825	0.631	0.187	0.653	-0.199	-0.623	
C36	0.629	0.736	0.730	0.455	0.828	0.060	-0.448	0.923

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Group 3

0— C088 C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.697								
C3	0.707	0.956							
C4	0.742	0.948	0.978						
C5	0.783	0.948	0.984	0.995					
C6	0.823	0.803	0.893	0.841	0.890				
C7	0.464	0.765	0.815	0.677	0.715	0.820			
C8	0.520	0.705	0.747	0.635	0.696	0.872	0.886		
C9	0.248	0.522	0.650	0.490	0.537	0.738	0.914	0.883	
C10	-0.030	0.340	0.485	0.325	0.331	0.424	0.774	0.491	0.818
C11	0.089	0.456	0.606	0.453	0.465	0.560	0.848	0.620	0.894
C12	0.723	0.834	0.950	0.909	0.924	0.911	0.813	0.694	0.689
C13	0.810	0.802	0.878	0.841	0.890	0.987	0.770	0.887	0.706
C14	0.762	0.342	0.521	0.552	0.599	0.749	0.283	0.449	0.329
C15	0.687	0.736	0.860	0.897	0.881	0.761	0.521	0.391	0.383
C16	0.674	0.963	0.924	0.924	0.910	0.717	0.713	0.541	0.422
C17	0.640	0.946	0.914	0.920	0.899	0.685	0.687	0.494	0.399
C18	0.649	0.949,	0.910	0.935	0.910	0.669	0.632	0.469	0.345
C19	0.652	0.941	0.894	0.922	0.897	0.650	0.610	0.441	0.310
C20	0.666	0.936	0.899	0.934	0.908	0.660	0.595	0.434	0.302
C21	0.659	0.939	0.882	0.909	0.885	0.643	0.611	0.437	0.299
C22	0.658	0.990	0.961	0.952	0.944	0.771	0.762	0.643	0.513
C23	0.501	0.895	0.774	0.777	0.750	0.497	0.607	0.402	0.267
C24	0.621	0.945	0.892	0.906	0.882	0.645	0.650	0.464	0.349
C25	0.483	0.886	0.880	0.916	0.873	0.580	0.562	0.392	0.337
C26	0.645	0.955	0.900	0.922	0.893	0.660	0.636	0.477	0.337
C27	0.601	0.927	0.860	0.887	0.857	0.592	0.591	0.403	0.277
C28	0.681	0.962	0.887	0.913	0.895	0.666	0.624	0.491	0.312
C29	0.668	0.993	0.871	0.891	0.870	0.642	0.624	0.438	0.301
C30	0.598	0.960	0.904	0.925	0.899	0.649	0.641	0.494	0.359
C31	0.522	0.434	0.565	0.668	0.661	0.559	0.109	0.302	0.159
C32	0.614	0.543	0.706	0.781	0.763	0.634	0.286	0.294	0.239
C33	0.674	0.066	0.051	0.049	0.134	0.425	0.083	0.324	0.027
C34	0.324	-0.348	-0.178	-0.125	-0.101	0.057	-0.311	-0.318	-0.295
C35	0.951	0.489	0.696	0.736	0.731	0.684	0.367	0.366	0.401
C36	0.646	0.557	0.663	0.761	0.780	0.657	0.208	0.390	0.201

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.984								
C12	0.599	0.698							
C13	0.326	0.479	0.860						
C14	0.038	0.161	0.645	0.753					
C15	0.387	0.477	0.914	0.701	0.671				
C16	0.390	0.470	0.843	0.683	0.281	0.795			
C17	0.404	0.478	0.840	0.647	0.265	0.814	0.997		
C18	0.328	0.411	0.817	0.645	0.280	0.820	0.990	0.994	
C19	0.302	0.381	0.800	0.624	0.267	0.810	0.989	0.993	0.999
C20	0.289	0.372	0.811	0.636	0.303	0.834	0.984	0.990	0.998
C21	0.293	0.369	0.788	0.614	0.248	0.790	0.991	0.993	0.996
C22	0.410	0.510	0.859	0.754	0.314	0.785	0.986	0.978	0.977
C23	0.295	0.384	0.634	0.468	-0.023	0.584	0.946	0.944	0.938
C24	0.351	0.424	0.796	0.614	0.216	0.780	0.994	0.997	0.996
C25	0.370	0.450	0.783	0.567	0.236	0.838	0.929	0.948	0.964
C26	0.309	0.391	0.795	0.637	0.246	0.785	0.993	0.993	0.998
C27	0.295	0.364	0.753	0.565	0.179	0.762	0.983	0.988	0.993
C28	0.246	0.333	0.769	0.650	0.249	0.750	0.987	0.982	0.989
C29	0.303	0.373	0.784	0.606	0.233	0.772	0.991	0.991	0.989
C30	0.319	0.406	0.782	0.636	0.218	0.770	0.984	0.986	0.994
C31	-0.100	0.044	0.548	0.625	0.781	0.715	0.353	0.362	0.426
C32	0.202	0.301	0.777	0.623	0.775	0.944	0.578	0.603	0.632
C33	-0.353	-0.286	0.111	0.434	0.571	-0.013	-0.024	-0.084	-0.091
C34	-0.163	-0.187	0.082	-0.004	0.608	0.243	-0.242	-0.230	-0.238
C35	0.321	0.427	0.793	0.674	0.821	0.902	0.492	0.512	0.531
C36	-0.088	0.065	0.631	0.718	0.805	0.767	0.475	0.476	0.536

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.999								
C21	0.999	0.996							
C22	0.969	0.965	0.966						
C23	0.945	0.928	0.955	0.918					
C24	0.997	0.992	0.997	0.974	0.962				
C25	0.956	0.961	0.942	0.931	0.870	0.950			
C26	0.998	0.995	0.998	0.978	0.956	0.998	0.951		
C27	0.996	0.991	0.997	0.958	0.968	0.997	0.950	0.996	
C28	0.991	0.986	0.994	0.973	0.959	0.990	0.923	0.995	0.989
C29	0.994	0.989	0.998	0.960	0.962	0.995	0.922	0.994	0.994
C30	0.991	0.988	0.988	0.982	0.952	0.993	0.965	0.996	0.990
C31	0.406	0.448	0.370	0.419	0.118	0.345	0.510	0.386	0.338
C32	0.619	0.656	0.589	0.583	0.330	0.568	0.692	0.585	0.556
C33	-0.078	-0.072	-0.056	-0.029	-1.177	-0.100	-0.308	-0.072	-0.123
C34	-0.225	-0.193	-0.228	-0.319	[illegible]	-0.275	-0.283	-0.273	-0.282
C35	0.509	0.547	0.475	0.523	0.209	0.466	0.606	0.480	0.438
C36	0.519	0.557	0.488	0.535	0.246	0.461	0.583	0.502	0.452

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.991							
C30	0.989	0.980						
C31	0.373	0.322	0.404					
C32	0.548	0.558	0.576	0.871				
C33	-0.001	-0.029	-0.127	0.102	0.009			
C34	-0.282	-0.219	-0.339	0.247	0.396	0.457		
C35	0.438	0.443	0.480	0.872	0.972	0.017	0.389	
C36	0.498	0.446	0.514	0.986	0.881	0.186	0.215	0.866

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Group 1

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36 CC

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.923								
C3	0.936	0.883							
C4	0.927	0.848	0.961						
C5	0.938	0.872	0.981	0.995					
C6	0.760	0.760	0.880	0.853	0.850				
C7	0.819	0.763	0.915	0.909	0.901	0.986			
C8	0.752	0.683	0.886	0.874	0.865	0.980	0.991		
C9	0.587	0.428	0.737	0.793	0.759	0.849	0.892	0.929	
C10	0.440	0.249	0.625	0.670	0.637	0.751	0.796	0.857	0.978
C11	0.493	0.310	0.651	0.726	0.685	0.773	0.823	0.871	0.991
C12	0.455	0.274	0.595	0.718	0.666	0.695	0.756	0.799	0.957
C13	0.435	0.215	0.581	0.667	0.622	0.693	0.757	0.811	0.969
C14	0.717	0.679	0.865	0.907	0.890	0.936	0.951	0.957	0.924
C15	0.871	0.751	0.881	0.959	0.929	0.869	0.930	0.900	0.869
C16	0.633	0.650	0.737	0.738	0.716	0.965	0.936	0.932	0.826
C17	0.405	0.593	0.626	0.594	0.606	0.814	0.730	0.741	0.600
C18	0.533	0.527	0.786	0.768	0.780	0.808	0.803	0.845	0.822
C19	0.544	0.442	0.777	0.699	0.735	0.659	0.690	0.740	0.725
C20	0.416	0.429	0.708	0.632	0.663	0.725	0.702	0.760	0.718
C21	0.421	0.430	0.711	0.617	0.655	0.715	0.692	0.751	0.696
C22	0.293	0.378	0.604	0.536	0.565	0.686	0.634	0.693	0.642
C23	0.114	0.218	0.291	0.097	0.134	0.565	0.460	0.501	0.312
C24	-0.611	-0.372	-0.335	-0.426	-0.397	-0.086	-0.220	-0.139	-0.148
C25	0.320	0.618	0.423	0.353	0.372	0.643	0.519	0.486	0.221
C26	0.791	0.883	0.920	0.830	0.871	0.862	0.836	0.811	0.587
C27	0.795	0.920	0.854	0.776	0.826	0.676	0.661	0.606	0.354
C28	0.197	0.532	0.224	0.292	0.241	0.400	0.288	0.230	0.012
C29	0.570	0.677	0.751	0.633	0.699	0.566	0.542	0.539	0.353
C30	0.388	0.443	0.516	0.672	0.627	0.614	0.615	0.615	0.673
C31	0.153	-0.063	-0.165	-0.106	-0.125	-0.412	-0.296	-0.365	-0.321
C32	0.655	0.834	0.490	0.486	0.508	0.328	0.314	0.193	-0.086
C33	-0.113	-0.182	-0.319	-0.216	-0.288	-0.059	-0.047	-0.081	-0.030
C34	-0.137	0.172	-0.206	-0.335	-0.300	-0.040	-0.171	-0.227	-0.517
C35	0.714	0.477	0.516	0.581	0.576	0.153	0.296	0.227	0.231
C36	0.169	-0.065	-0.131	-0.052	-0.071	-0.433	-0.302	-0.365	-0.290

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.990								
C12	0.951	0.980							
C13	0.986	0.992	0.978						
C14	0.842	0.879	0.859	0.815					
C15	0.755	0.818	0.811	0.774	0.913				
C16	0.731	0.761	0.687	0.686	0.882	0.817			
C17	0.518	0.537	0.499	0.432	0.803	0.547	0.795		
C18	0.795	0.791	0.760	0.728	0.907	0.694	0.696	0.825	
C19	0.740	0.698	0.637	0.664	0.741	0.582	0.480	0.560	0.906
C20	0.723	0.687	0.628	0.626	0.792	0.527	0.597	0.791	0.969
C21	0.704	0.661	0.591	0.601	0.765	0.505	0.579	0.766	0.953
C22	0.643	0.613	0.565	0.541	0.751	0.434	0.589	0.866	0.941
C23	0.323	0.249	0.072	0.106	0.313	0.116	0.601	0.551	0.358
C24	-0.058	-0.123	-0.153	-0.160	-0.088	-0.480	-0.040	0.420	0.202
C25	0.095	0.126	0.067	0.004	0.493	0.311	0.677	0.853	0.436
C26	0.470	0.485	0.416	0.383	0.809	0.702	0.726	0.815	0.816
C27	0.211	0.245	0.211	0.143	0.645	0.593	0.506	0.671	0.660
C28	-0.138	-0.065	-0.043	-0.177	0.332	0.202	0.458	0.709	0.237
C29	0.288	0.275	0.231	0.189	0.590	0.410	0.361	0.672	0.777
C30	0.588	0.669	0.757	0.613	0.809	0.685	0.614	0.737	0.729
C31	-0.347	-0.313	-0.281	-0.240	-0.443	-0.046	-0.419	-0.817	-0.654
C32	-0.288	-0.198	-0.179	-0.286	0.235	0.378	0.261	0.297	0.056
C33	-0.060	-0.015	-0.019	0.019	-0.185	0.037	0.167	-0.305	-0.537
C34	-0.598	-0.597	-0.670	-0.670	-0.316	-0.360	0.048	0.162	-0.369
C35	0.148	0.202	0.238	0.228	0.222	0.543	0.014	-0.291	0.053
C36	-0.310	-0.273	-0.218	-0.196	-0.404	-0.020	-0.472	-0.813	-0.577

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.933								
C21	0.943	0.997							
C22	0.835	0.976	0.966						
C23	0.317	0.470	0.498	0.497					
C24	0.068	0.349	0.343	0.509	0.442				
C25	0.148	0.418	0.406	0.534	0.616	0.383			
C26	0.742	0.788	0.792	0.754	0.462	-0.001	0.686		
C27	0.614	0.625	0.631	0.592	0.226	-0.105	0.615	0.942	
C28	-0.116	0.167	0.135	0.319	0.247	0.314	0.905	0.483	0.516
C29	0.801	0.818	0.830	0.789	0.280	0.179	0.481	0.884	0.903
C30	0.424	0.569	0.510	0.618	-0.087	0.078	0.445	0.523	0.451
C31	-0.438	-0.722	-0.703	-0.851	-0.542	-0.851	-0.639	-0.450	-0.290
C32	-0.059	-0.046	-0.048	-0.038	-0.079	-0.386	0.548	0.549	0.734
C33	-0.668	-0.643	-0.658	-0.626	0.031	-0.355	-0.050	-0.460	-0.542
C34	-0.499	-0.300	-0.282	-0.175	0.462	0.305	0.638	0.069	0.121
C35	0.238	-0.069	-0.059	-0.248	-0.484	-0.921	-0.387	0.208	0.338
C36	-0.347	-0.652	-0.636	-0.789	-0.658	-0.856	-0.710	-0.429	-0.247

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.325							
C30	0.525	0.399						
C31	-0.509	-0.503	-0.509					
C32	0.657	0.409	0.231	0.158				
C33	0.010	-0.818	-0.172	0.441	-0.039			
C34	0.628	-0.044	-0.319	-0.145	0.455	0.249		
C35	-0.341	0.152	0.041	0.702	0.406	-0.031	-0.474	
C36	-0.552	-0.423	-0.429	0.982	0.141	0.306	-0.283	0.767

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Group 2

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21°

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	0.606								
C3	0.894	0.746							
C4	0.553	0.648	0.507						
C5	0.897	0.738	0.982	0.465					
C6	0.411	0.298	0.406	-0.029	0.569				
C7	-0.038	0.114	0.070	0.289	0.178	0.574			
C8	-0.115	-0.045	-0.020	0.094	0.105	0.624	0.977		
C9	-0.101	0.267	0.171	0.163	0.258	0.553	0.913	0.889	
C10	0.726	0.477	0.733	0.491	0.819	0.770	0.641	0.596	0.555
C11	0.872	0.578	0.954	0.429	0.929	0.768	0.382	0.342	0.343
C12	0.924	0.841	0.930	0.958	0.922	0.388	-0.085	-0.193	-0.018
C13	0.537	0.677	0.696	0.445	0.785	0.785	0.707	0.640	0.766
C14	0.438	0.796	0.674	0.369	0.745	0.696	0.564	0.484	0.732
C15	-0.052	0.519	0.233	-0.181	0.319	0.581	0.328	0.331	0.613
C16	-0.152	0.681	0.168	0.324	0.132	-0.075	0.183	0.049	0.453
C17	-0.097	0.724	0.189	0.368	0.149	-0.098	0.110	-0.034	0.368
C18	-0.347	0.415	-0.073	0.245	-0.180	-0.545	-0.145	-0.275	0.102
C19	-0.106	0.707	0.195	0.408	0.147	-0.129	0.158	0.008	0.409
C20	-0.050	0.690	0.243	0.472	0.157	-0.398	0.030	-0.135	0.276
C21	0.012	0.776	0.292	0.519	0.243	-0.098	0.181	0.015	0.407
C22	0.044	0.698	0.255	0.511	0.147	-0.415	-0.194	-0.369	0.020
C23	0.259	0.776	0.573	0.196	0.622	0.558	0.406	0.338	0.677
C24	-0.276	0.206	0.064	0.111	0.111	0.320	0.817	0.785	0.961
C25	-0.085	0.603	0.337	0.189	0.315	0.120	0.363	0.274	0.683
C26	-0.608	0.102	-0.278	-0.474	-0.258	0.032	0.072	0.105	0.398
C27	-0.779	-0.122	-0.530	-0.567	-0.491	-0.007	0.104	0.165	0.348
C28	-0.047	0.640	0.347	0.374	0.290	-0.063	0.307	0.177	0.589
C29	-0.388	0.180	0.023	0.082	-0.007	-0.058	0.533	0.480	0.762
C30	-0.259	0.506	0.127	0.222	0.120	0.076	0.488	0.393	0.747
C31	-0.811	-0.589	-0.623	-0.561	-0.570	0.029	0.471	0.582	0.530
C32	-0.741	-0.406	-0.497	-0.847	-0.466	0.001	-0.019	0.117	0.228
C33	-0.114	0.194	0.222	0.280	0.080	-0.526	0.027	-0.072	0.234
C34	-0.755	-0.319	-0.443	-0.642	-0.501	-0.408	-0.207	-0.136	0.089
C35	-0.832	-0.464	-0.629	-0.835	-0.599	-0.086	-0.045	0.086	0.167
C36	-0.718	-0.414	-0.454	-0.517	-0.397	0.144	0.537	0.634	0.663

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.947								
C12	0.626	0.805							
C13	0.894	0.838	0.604						
C14	0.719	0.711	0.623	0.947					
C15	0.228	0.262	0.236	0.601	0.785				
C16	-0.058	-0.079	0.202	0.355	0.588	0.651			
C17	-0.074	-0.070	0.261	0.327	0.567	0.618	0.993		
C18	-0.447	-0.456	-0.031	-0.098	0.149	0.286	0.876	0.881	
C19	-0.052	-0.073	0.238	0.339	0.563	0.578	0.994	0.995	0.893
C20	-0.107	-0.111	0.270	0.237	0.453	0.414	0.950	0.958	0.934
C21	0.045	0.027	0.337	0.404	0.605	0.536	0.975	0.982	0.858
C22	-0.200	-0.143	0.349	0.088	0.312	0.263	0.861	0.898	0.916
C23	0.485	0.510	0.529	0.810	0.952	0.900	0.732	0.707	0.348
C24	0.348	0.125	-0.151	0.611	0.625	0.579	0.566	0.472	0.311
C25	0.169	0.115	0.215	0.550	0.731	0.741	0.891	0.841	0.689
C26	-0.376	-0.384	-0.296	0.046	0.299	0.777	0.669	0.619	0.577
C27	-0.487	-0.536	-0.523	-0.106	0.110	0.652	0.523	0.471	0.474
C28	0.125	0.060	0.240	0.474	0.644	0.567	0.917	0.881	0.792
C29	0.057	-0.130	-0.209	0.396	0.444	0.462	0.680	0.591	0.592
C30	0.099	-0.022	0.030	0.494	0.656	0.693	0.911	0.857	0.725
C31	-0.239	-0.459	-0.818	-0.097	-0.105	0.225	0.035	-0.069	0.029
C32	-0.482	-0.504	-0.596	-0.226	-0.068	0.497	0.175	0.102	0.183
C33	-0.108	-0.190	0.001	0.030	0.111	-0.029	0.507	0.461	0.664
C34	-0.662	-0.681	-0.567	-0.389	-0.185	0.308	0.333	0.290	0.523
C35	-0.584	-0.620	-0.690	-0.331	-0.170	0.426	0.171	0.105	0.221
C36	-0.117	-0.322	-0.672	0.085	0.104	0.406	0.178	0.067	0.093

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.973								
C21	0.991	0.975							
C22	0.902	0.963	0.914						
C23	0.693	0.585	0.702	0.443					
C24	0.523	0.420	0.501	0.161	0.634				
C25	0.863	0.914	0.844	0.646	0.855	0.780			
C26	0.593	0.478	0.488	0.338	0.547	0.526	0.688		
C27	0.444	0.311	0.325	0.174	0.342	0.470	0.499	0.957	
C28	0.916	0.911	0.913	0.777	0.752	0.712	0.966	0.556	0.365
C29	0.652	0.622	0.614	0.402	0.542	0.908	0.859	0.607	0.515
C30	0.885	0.813	0.857	0.627	0.766	0.851	0.959	0.707	0.583
C31	-0.036	-0.135	-0.133	-0.346	-0.018	0.624	0.221	0.553	0.684
C32	0.082	-0.014	-0.045	-0.150	0.163	0.349	0.312	0.837	0.879
C33	0.535	0.664	0.536	0.589	0.212	0.442	0.627	0.209	0.056
C34	0.296	0.292	0.179	0.195	0.092	0.314	0.437	0.801	0.791
C35	0.084	-0.013	-0.048	-0.133	0.064	0.299	0.242	0.827	0.907
C36	0.100	-0.013	0.007	-0.252	0.202	0.750	0.409	0.650	0.724

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.847							
C30	0.941	0.899						
C31	0.104	0.585	0.353					
C32	0.136	0.417	0.322	0.770				
C33	0.744	0.743	0.575	0.130	0.058			
C34	0.365	0.565	0.432	0.644	0.879	0.462		
C35	0.087	0.375	0.292	0.785	0.985	0.016	0.876	
C36	0.271	0.702	0.506	0.974	0.798	0.206	0.664	0.779

B. 29

September 12, 1980

<u>Group 3</u>

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0— CORR C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21*

— C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32 C33 C34 C35 C36

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C2	-0.600								
C3	-0.450	0.903							
C4	-0.708	0.941	0.921						
C5	-0.809	0.908	0.880	0.952					
C6	-0.489	0.312	0.356	0.434	0.417				
C7	-0.543	0.469	0.442	0.487	0.533	0.933			
C8	-0.382	0.452	0.460	0.458	0.451	0.932	0.976		
C9	-0.189	0.395	0.312	0.374	0.234	0.803	0.779	0.864	
C10	0.125	0.308	0.228	0.221	0.023	0.551	0.532	0.674	0.931
C11	0.161	0.600	0.516	0.354	0.269	0.136	0.345	0.459	0.549
C12	-0.572	0.992	0.946	0.955	0.915	0.362	0.498	0.494	0.415
C13	-0.335	0.651	0.575	0.658	0.484	0.722	0.693	0.772	0.927
C14	-0.866	0.715	0.465	0.693	0.748	0.608	0.742	0.637	0.547
C15	-0.874	0.615	0.361	0.583	0.697	0.565	0.728	0.593	0.434
C16	-0.902	0.682	0.703	0.821	0.923	0.501	0.549	0.422	0.117
C17	-0.825	0.326	0.035	0.300	0.478	0.339	0.497	0.313	0.138
C18	-0.796	0.217	-0.069	0.208	0.396	0.272	0.411	0.217	0.043
C19	-0.788	0.244	-0.061	0.219	0.401	0.234	0.384	0.193	0.038
C20	-0.881	0.352	0.078	0.363	0.534	0.297	0.428	0.235	0.060
C21	-0.610	0.958	0.297	0.497	0.482	0.716	0.813	0.776	0.812
C22	-0.615	0.179	-0.097	0.210	0.384	0.205	0.301	0.100	-0.049
C23	-0.938	0.472	0.314	0.539	0.721	0.246	0.364	0.165	-0.107
C24	0.159	-0.663	-0.864	-0.635	-0.677	-0.040	-0.181	-0.200	0.070
C25	-0.329	-0.271	-0.498	-0.171	-0.208	0.412	0.269	0.208	0.392
C26	-0.522	0.455	0.087	0.338	0.318	0.445	0.567	0.518	0.661
C27	-0.463	0.184	-0.202	0.083	0.103	0.364	0.460	0.384	0.521
C28	-0.420	-0.189	-0.504	-0.229	-0.064	-0.256	-0.161	-0.340	-0.362
C29	-0.295	-0.108	-0.505	-0.251	-0.139	-0.09[illegible]	0.056	-0.067	0.017
C30	-0.498	0.021	-0.349	-0.086	0.082	-0.103	0.069	-0.101	-0.135
C31	0.127	0.380	0.477	0.268	0.317	-0.608	-0.435	-0.430	-0.555
C32	0.070	0.412	0.286	0.381	0.120	-0.197	-0.272	-0.169	0.256
C33	0.733	-0.617	-0.615	-0.648	-0.776	-0.769	-0.899	-0.813	-0.472
C34	0.573	-0.784	-0.643	-0.660	-0.728	-0.599	-0.827	-0.789	-0.612
C35	-0.446	0.932	0.918	0.894	0.811	0.524	0.625	0.667	0.630
C36	-0.549	0.970	0.945	0.907	0.921	0.291	0.475	0.454	0.293

	C10	C11	C12	C13	C14	C15	C16	C17	C18
C11	0.690								
C12	0.323	0.598							
C13	0.861	0.580	0.670						
C14	0.301	0.267	0.673	0.619					
C15	0.165	0.176	0.568	0.464	0.978				
C16	-0.184	-0.082	0.699	0.314	0.706	0.701			
C17	-0.132	-0.119	0.256	0.116	0.834	0.918	0.574		
C18	-0.226	-0.236	0.144	0.008	0.761	0.860	0.529	0.991	
C19	-0.216	-0.201	0.165	0.014	0.768	0.862	0.513	0.991	0.998
C20	-0.221	-0.207	0.284	0.086	0.820	0.897	0.646	0.987	0.985
C21	0.634	0.419	0.522	0.777	0.906	0.858	0.403	0.673	0.590
C22	-0.318	-0.363	0.105	-0.048	0.709	0.802	0.543	0.961	0.984
C23	-0.404	-0.261	0.429	0.019	0.746	0.814	0.842	0.871	0.867
C24	0.086	-0.450	-0.718	-0.147	-0.104	-0.066	-0.522	0.165	0.242
C25	0.244	-0.394	-0.316	0.244	0.378	0.383	-0.033	0.491	0.527
C26	0.953	0.379	0.382	0.626	0.837	0.800	0.209	0.704	0.642
C27	0.401	0.149	0.100	0.410	0.728	0.738	0.082	0.757	0.732
C28	-0.480	-0.466	-0.291	-0.416	0.318	0.441	0.080	0.745	0.814
C29	-0.047	-0.093	-0.217	-0.118	0.442	0.532	-0.106	0.741	0.769
C30	-0.266	-0.191	-0.085	-0.202	0.531	0.641	0.149	0.862	0.893
C31	-0.415	0.293	0.383	-0.320	-0.235	-0.237	0.128	-0.276	-0.299
C32	0.442	0.367	0.385	0.491	0.057	-0.124	-0.139	-0.295	-0.339
C33	-0.179	-0.243	-0.643	-0.486	-0.785	-0.805	-0.811	-0.615	-0.536
C34	-0.450	-0.650	-0.774	-0.640	-0.838	-0.818	-0.578	-0.572	-0.460
C35	0.556	0.702	0.957	0.821	0.637	0.510	0.583	0.142	0.016
C36	0.198	0.598	0.979	0.534	0.630	0.958	0.713	0.274	0.166

	C19	C20	C21	C22	C23	C24	C25	C26	C27
C20	0.985								
C21	0.597	0.610							
C22	0.982	0.980	0.506						
C23	0.862	0.927	0.421	0.888					
C24	0.237	0.130	0.110	0.279	-0.172				
C25	0.513	0.472	0.526	0.555	0.204	0.842			
C26	0.666	0.641	0.935	0.576	0.389	0.302	0.599		
C27	0.748	0.689	0.839	0.679	0.386	0.540	0.754	0.951	
C28	0.826	0.756	0.169	0.851	0.599	0.536	0.520	0.396	0.595
C29	0.791	0.686	0.462	0.743	0.400	0.624	0.616	0.694	0.850
C30	0.911	0.839	0.418	0.862	0.644	0.436	0.501	0.618	0.759
C31	-0.267	-0.222	-0.486	-0.286	0.040	-0.764	-0.906	-0.452	-0.593
C32	-0.291	-0.245	0.125	-0.279	-0.2[illegible]	-0.011	0.007	0.247	0.080
C33	-0.513	-0.589	-0.667	-0.450	-0.648	0.449	-0.030	-0.419	-0.296
C34	-0.468	-0.508	-0.808	-0.337	-0.477	0.441	0.043	-0.663	-0.480
C35	0.031	0.140	0.600	-0.048	0.239	-0.655	-0.251	0.416	0.124
C36	0.186	0.296	0.440	0.115	0.468	-0.808	-0.443	0.296	0.025

	C28	C29	C30	C31	C32	C33	C34	C35
C29	0.881							
C30	0.948	0.950						
C31	-0.204	-0.372	-0.209					
C32	-0.230	-0.114	-0.205	0.162				
C33	0.043	-0.011	-0.158	0.107	0.371			
C34	0.057	-0.177	-0.239	-0.019	0.056	0.860		
C35	-0.466	-0.292	-0.230	0.217	0.389	-0.654	-0.802	
C36	-0.263	-0.219	-0.056	0.499	0.241	-0.677	-0.792	0.912

APPENDIX C

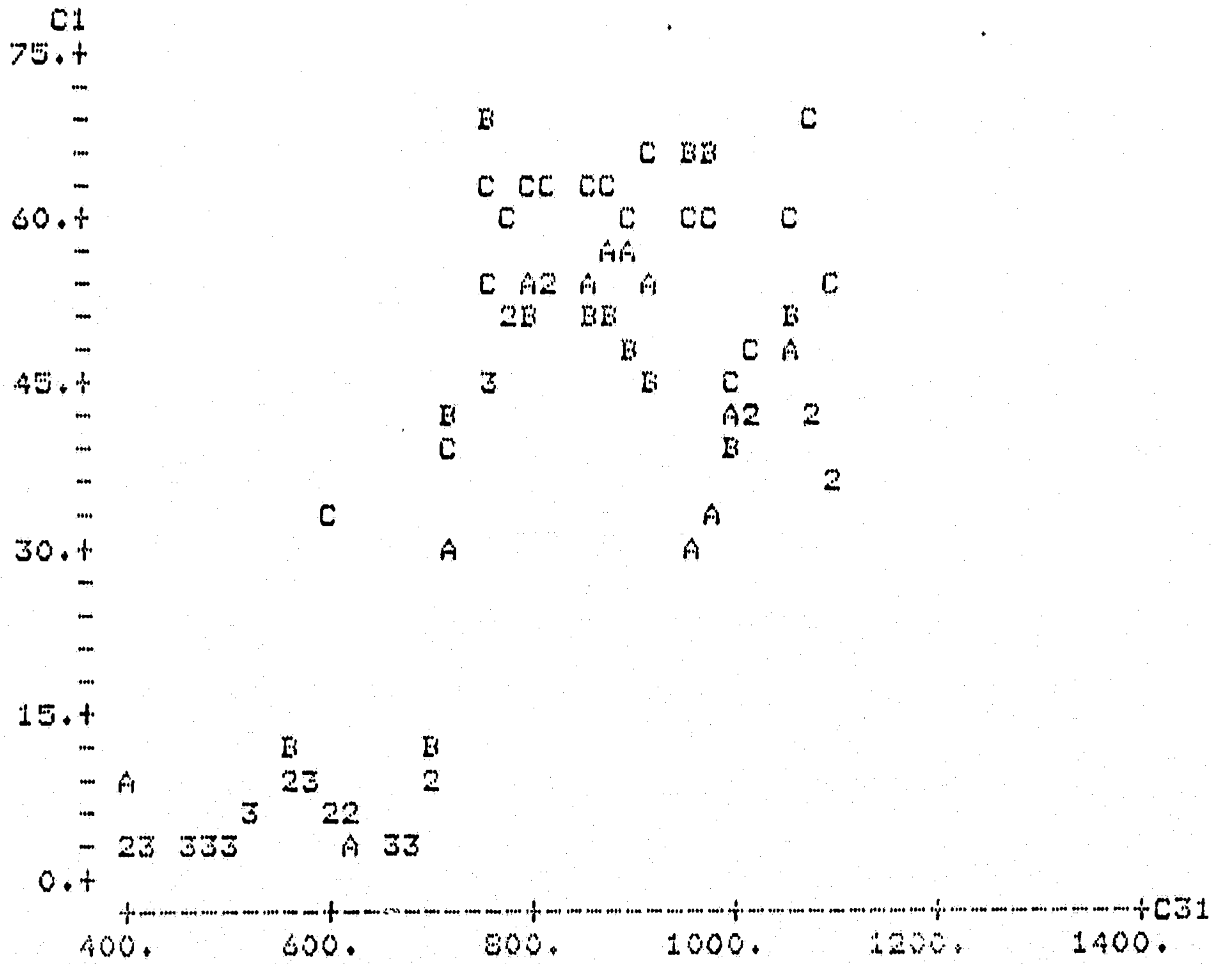
C. 1

Percent reflectance versus wavelength for

Treatments 1. 2 and 3(a) and

Treatments 4, 5 and 6(b) at Fredonia, N. Y

July 1980



(a)

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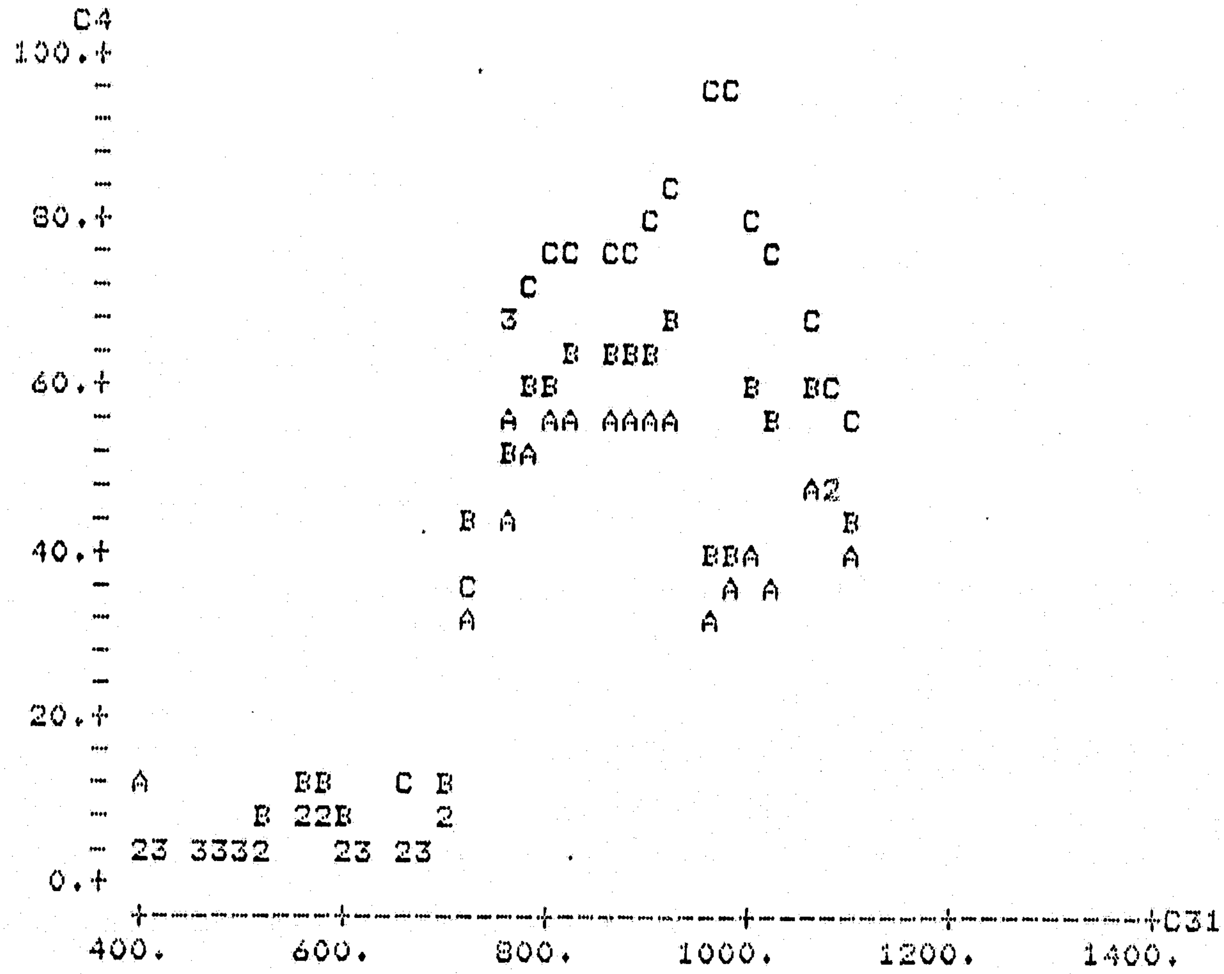


(b)

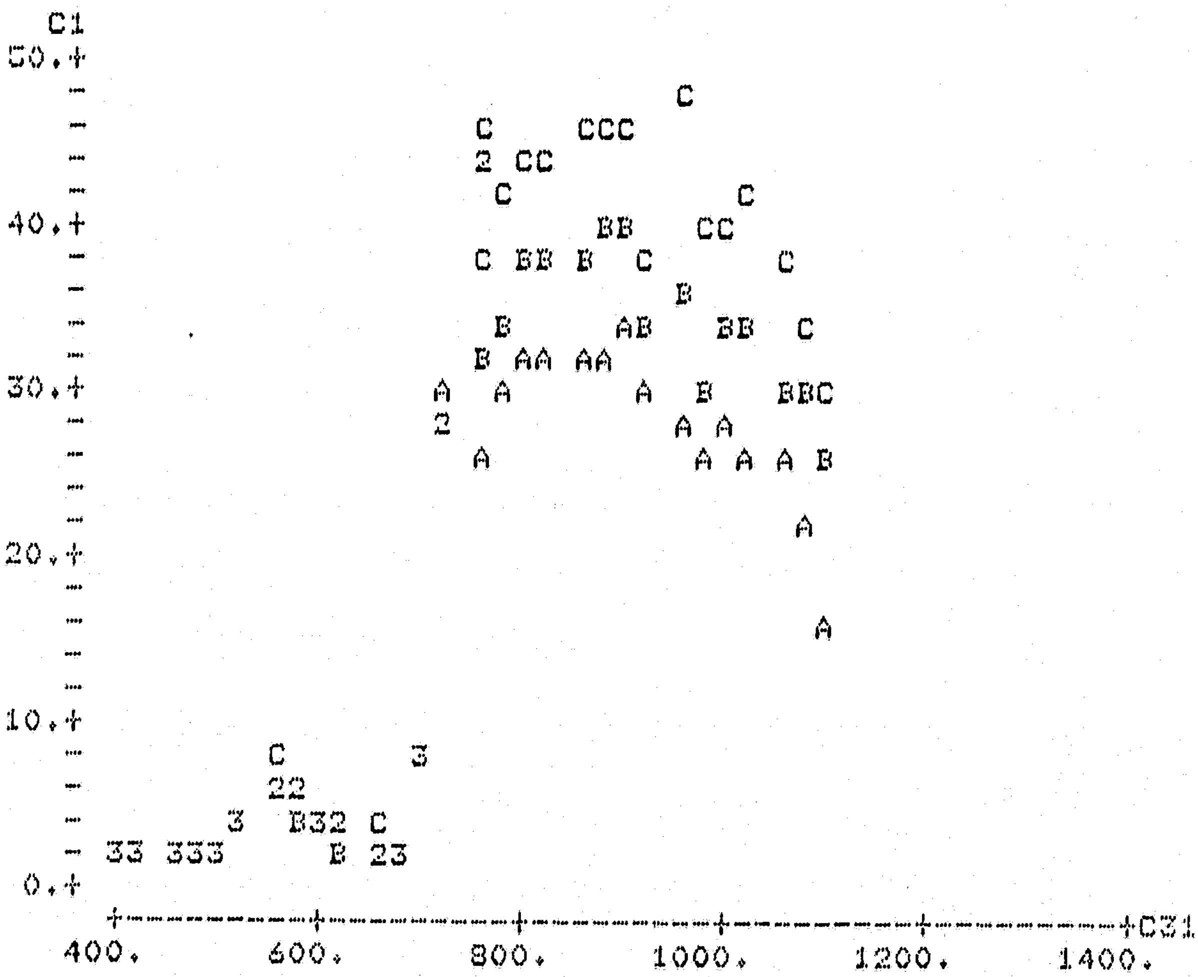
C. 2

Percent reflectance versus wavelength for

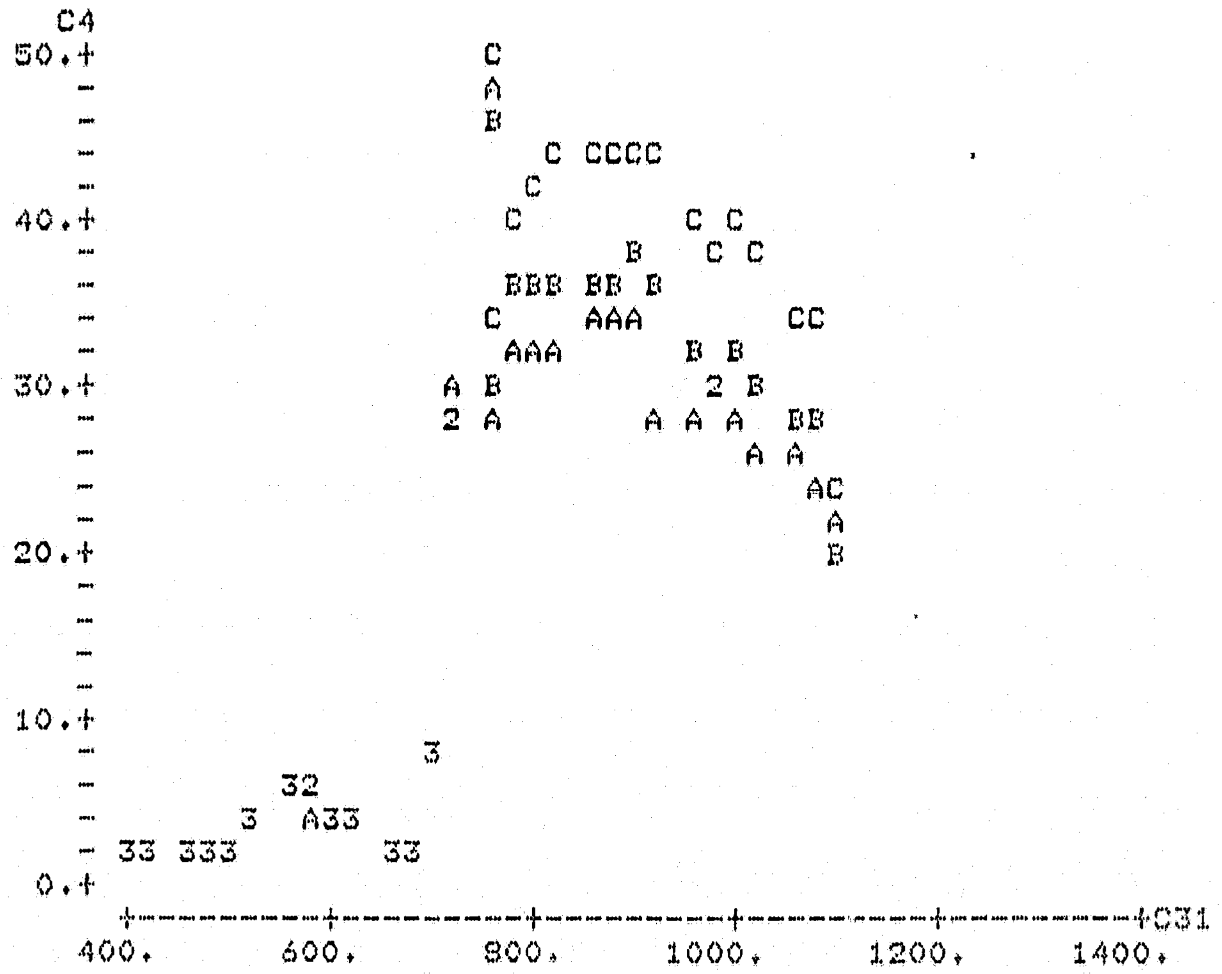
Treatments 1, 2 and 3(a) and

Treatments 4, 5 and 6(b) at Fredonia, N. Y.

August 1980



(a)



(b)

C. 3

Percent reflectance versus wavelength for

Treatments 1, 2 and 3(a) and

Treatments 4, 5 and 6(b) at Fredonia, N. Y.

September 1980

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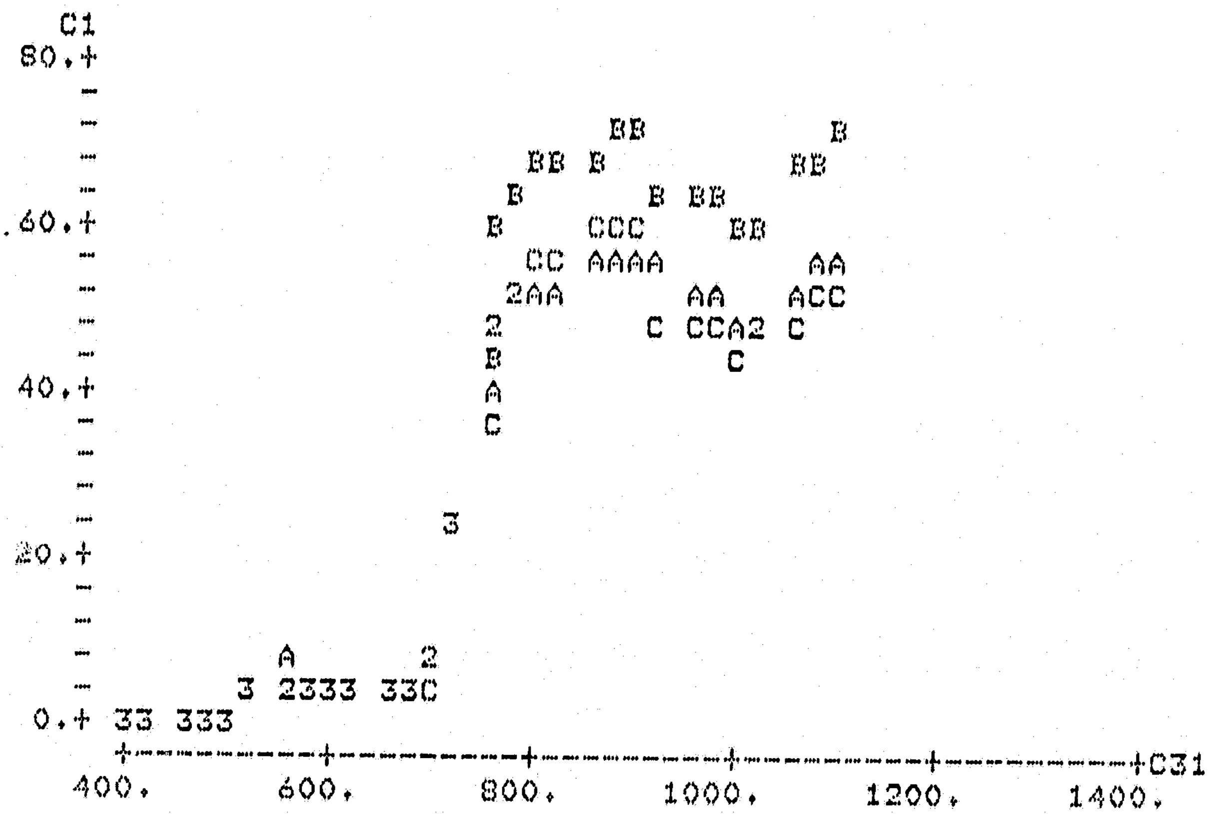

(a)

APPENDIX B

NATURAL GAS EXPLORATION

RELATIONSHIPS BETWEEN LINEARS AND NATURAL GAS OCCURRENCES IN THE SOUTHERN TIER OF NEW YORK STATE

Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853

October 1982

PREFACE

This study was conducted by Ellen J. Weeks, at the request of the Southern Tier Central Regional Planning and Development Board, Corning, New York. David A. Wilcox performed the lineament mapping. The work was supported in part by NASA Grant NGL 33-010-171.

Warren R. Philipson
Principal Investigator
Remote Sensing Program

ABSTRACT

This study relates linears identified from aerial photographs, Landsat images and geologic maps with gas well locations in Chemung, Schuyler and Steuben counties, New York. Correlations between dominant regional linear trends and gas field boundaries and trends were found. This study recommends exploration along these linear trends.

INTRODUCTION

Geological linears are generally surface expressions of subsurface fault and fracture zones. These zones of rock weaknesses can augment oil and gas reservoir permeability by increasing the interconnections between pore spaces trapping hydrocarbons. Conversely, they can seal reservoir rocks, forming structural traps. Recent studies have indicated that linear analysis can be used in hydrocarbon exploration (Howard, 1979; Wescott and Smith, 1979; Fussell, 1980; Blodget, 1981). This study is a preliminary analysis of the relationship between linears identified from aerial photographs and satellite images and natural gas occurrences in Chemung, Schuyler and Steuben counties, New York (Fig. 1).

GEOLOGY OF STUDY AREA

The Southern Tier counties of New York are located within the Appalacian basin, the primary natural gas producing region of the Eastern United States. This area of the Appalachian basin, the Allegheny Plateau Province, is composed primarily of sandstones, siltstones, shales and carbonates--sedimentary rocks deposited in tectonically controlled periods of marine and nonmarine transgression and regression. Structural geology in the Allegheny Plateau Province is characterized by gentle anticlines, synclines and brittle fractures (faults and joints). In this region both stratigraphic and structural components of the regional geology create traps for hydrocarbons migrating through permeable rock units.

Natural gas production in New York State dates from 1821; gas production in the Southern Tier counties dates from 1890 (Kreidler, 1959). Table 1 lists the major oil and gas producing horizons in New York State. Current and historical gas production in the Southern Tier is derived principally from the Lower Devonian Oriskany sandstone. Structural traps in the Oriskany are associated with faulted anticlines. Stratigraphic traps in this formation are commonly associated with sand pinchouts. Examples of both types of traps are present in Steuben County gas fields (Harding, 1966; Harris, 1978).

Natural gas production in the Southern Tier is also associated with the Middle Devonian Onondaga limestone and with various Devonian black shales. Figure 2 shows the detailed relationships between these rock units. Pinnacle reefs form the principal stratigraphic traps in the Onondaga limestone. The Wycoff gas field in Steuben County is an example of this kind of trap. Additional reef field discoveries in western New York and Pennsylvania suggest a reef trend through this region (Mesolella and Weaver, 1975).

FIGURE 1. Study area in New York State.

TABLE 1. Main oil and gas producing horizons in New York State (from Weaver, 1965a).

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SYSTEM		NEW YORK	OIL	GAS
Mississippian	M			
	L	Absent		
Devonian	U	Venango sds. Bradford 1st sd. Chipmunk sd. Bradford 3rd sd. (Richburg sd.)	X X X X	X X X X
	M	Hamilton sh. Onondaga Is. (Dundee Is. of Ontario)		X X
	L	Oriskany sd.		X
Silurian	U	Salina group		
	M	Lockport dol. Herkimer sd. Oneida sd.		X X X
	L	Medina sd.		X
Ordovician	U	Queenston sds.		X
	M	Trenton dol. Black River Is.		X X
	L	Beekmantown dol.		X
Cambrian	U	Trempealeau-Little Falls dol. Theresa-Gatesburg sd. Potsdam sd.		X X X

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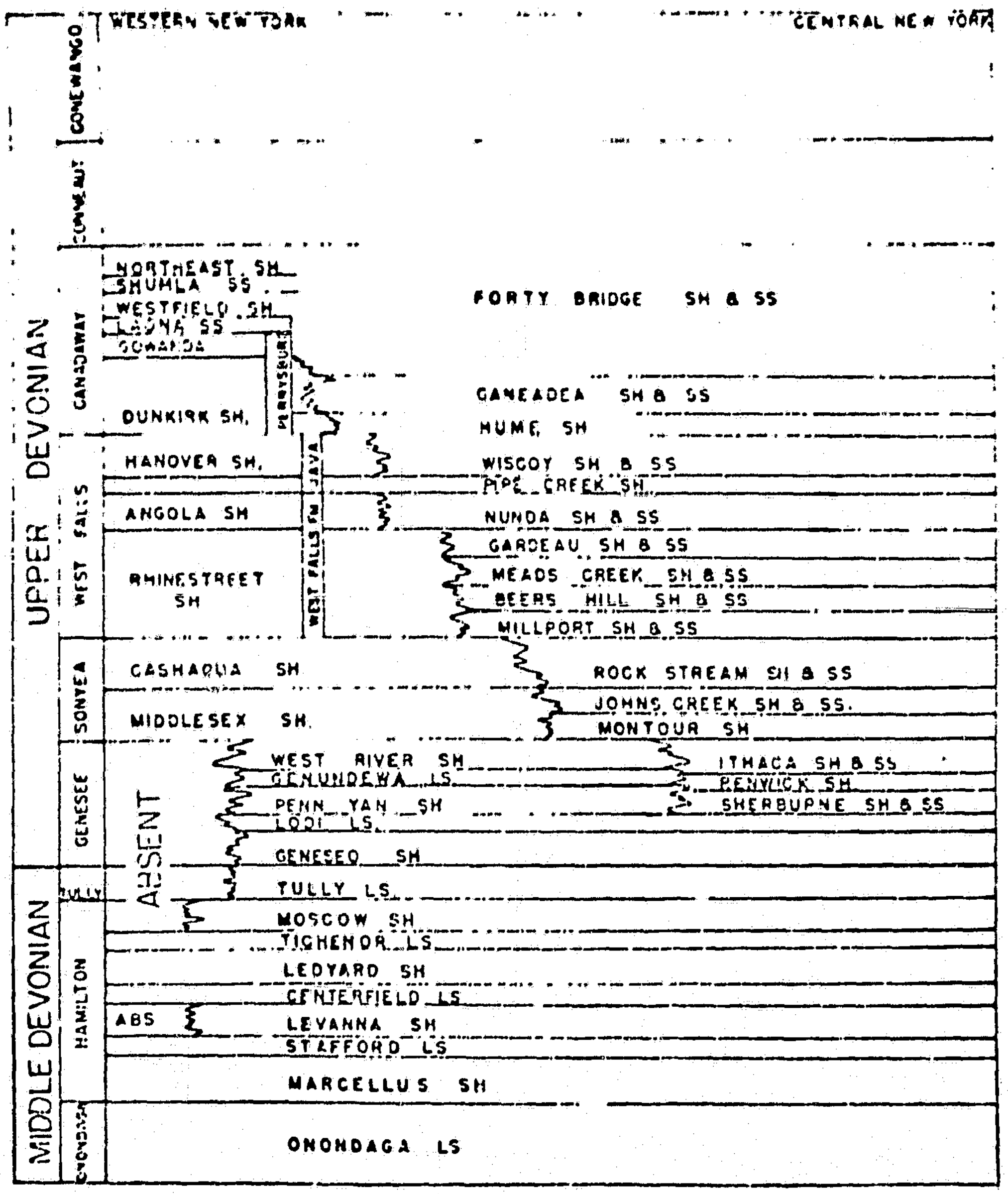


FIGURE 2. Stratigraphic chart of middle and upper Devonian rocks of New York (Van Tyne and Peterson, 1978).

Devonian black shales in the Appalachian basin are currently the focus of private and federal gas exploration programs. Black shales differ from other reservoir rocks in that the hydrocarbons they contain have remained trapped between grains since the time of sediment deposition. Thus, although black shales may contain large quantities of natural gas, it can only be obtained in commercial quantities when the shales are naturally fractured or are artificially fractured during the drilling process. These fractures increase permeability in the shales sufficiently to allow gas to flow. Many gas shows in Devonian black shales in the Southern Tier and western New York counties have been correlated with faulted anticlines trending in a NE/SW direction (Van Tyne and Peterson, 1978). Shales with the greatest potential for development in the Southern Tier are the Rhinestreet, the Geneseo and the Marcellus (Tetra Tech, Inc., 1981). In Steuben County, gas production in the Rathbone Field is derived from the Rhinestreet shale.

Other formations showing potential for natural gas development in the Southern Tier counties are Silurian, Cambrian and Ordovician sands and sandy dolomites. In particular, the Cambro-Ordovician formations are upturned into the Post-Knox unconformity. The combination of this feature and rapid facies changes within these formations creates favorable environments for gas entrapment (Weaver, 1965b).

METHODS AND MATERIALS

The base map used for this study is the 1:250,000 scale, U.S. Geological Survey topographic map, "Elmira, New York." All maps produced were adjusted to this scale.

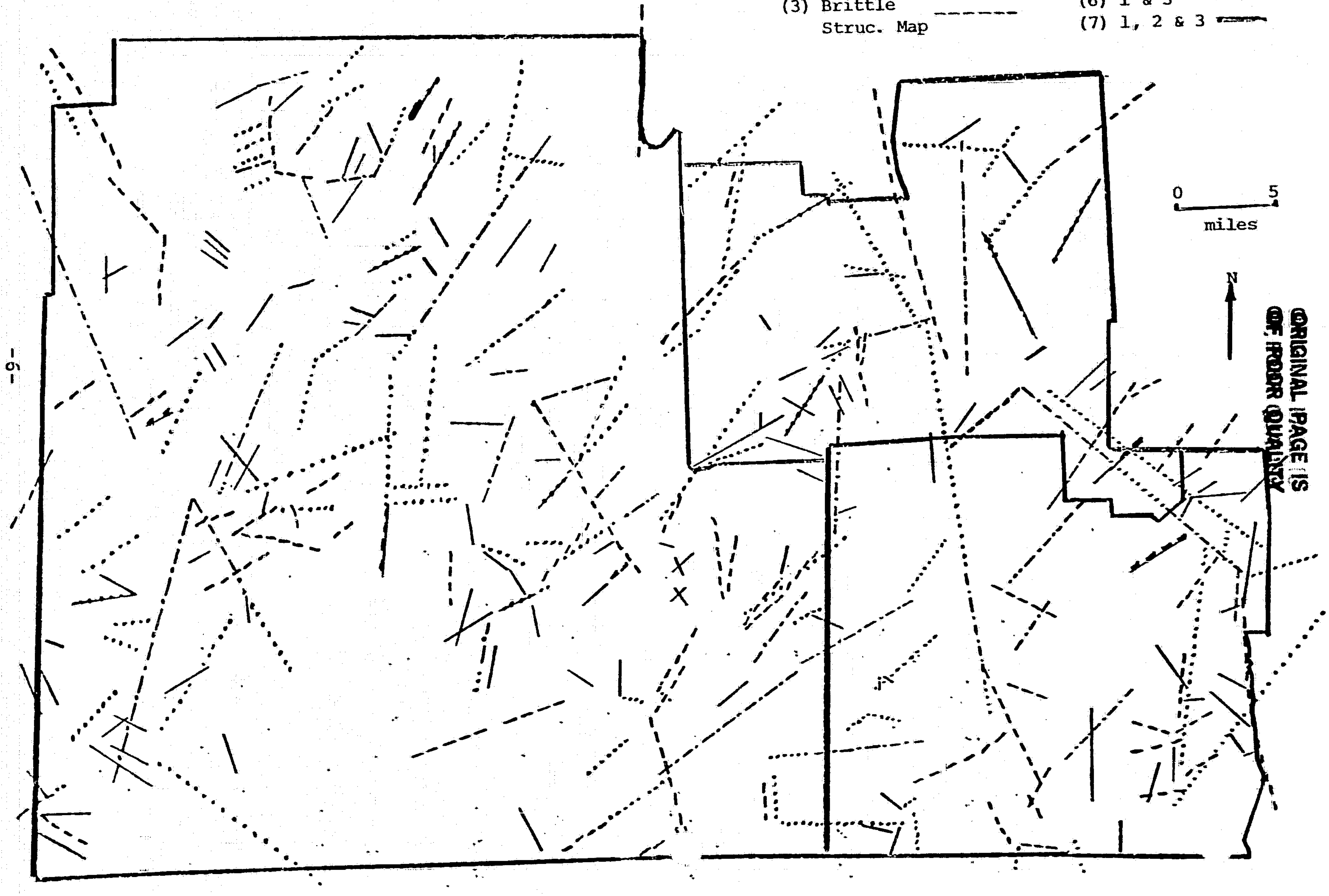
Linears

Linears in the three counties were identified using three sources of information: seasonal Landsat images at a scale of 1:1,000,000, spirng 1968 panchromatic aerial photographs at a scale of 1:24,000, and the "Brittle Structures Map of the Niagara-Finger Lakes Region" produced by the New York State Museum and Science Service at a scale of 1:250,000. Maps of linears identified from individual sources and a composite map (Fig. 3) were produced.

Linears were identified through visual analysis of the aerial photographs and satellite images. Topographic features used to identify linears were long, steep linear hillsides and steep, narrow linear river valleys. Interpretation required a comparative examination of identified linears and the topographic map. In most cases, if a linear feature could not be identified on more than one image source, it was not designated as a linear for the purposes of this study.

Images from Landsat bands 4, 5 and 7 were examined. Band 7 proved the most useful for linear identification because streams and rivers were clearly visible. Also, the November coverage proved most useful, apparently because of the relatively low sun angle and the lack of snow or foliage which obscured features in coverage from other dates. An acetate overlay of linears was made from the Landsat images. This overlay was placed on an overhead projector and projected onto the 1:250,000 base map. Most linears derived from the Landsat images are between 3 and 6 kilometers in length (Fig. 3).

FIGURE 3. Composite map of linears derived from Landsat, aerial photographs and the Brittle Structures Map of New York.



Aerial photographs of the three counties were examined stereoscopically. Linear features were transferred directly to an acetate overlay of the base map. Because linears from the Brittle Structures Map had already been transferred to this overlay, only extensions to these linears were delineated. Most linears identified from these photos are between 1 and 3 kilometers in length (Fig. 3).

The Brittle Structures Map shows linear surface and subsurface features. Surface linear features shown on the map were identified using topographic maps, Landsat and Skylab satellite imagery and high altitude aerial photographs. Subsurface features were derived from geologic maps.

The trend of all linears was measured and is recorded in 10 degree intervals in Table 2.

Natural Gas Occurrences

Two maps were produced to depict the locations of natural gas occurrences in the three counties. One map depicts producing wells and field locations (Fig. 4). The other map adds shows of oil, gas and salt water to this information (Fig. 5). This second map was compiled because shows of gas, oil or salt water in wells are indications of good reservoir rocks and possible nearby gas or oil traps. An additional map of dry wells was also produced to show the extent of drilling coverage in the counties (Fig. 6). The information in these maps was derived from U.S. Department of Energy and New York State Museum and Science Service maps. Data not available at a scale of 1:250,000 were adjusted to this scale by means of a take-off grid.

Well data were available for this study through January 1978 for wells testing Middle and Upper Devonian black shales, and through December 1956 for deep wells testing the Lower Devonian Oriskany sandstone and older formations. Post-1956 deep well data were not included due to the small scale of available maps (AAPG Bulletin, 1956-1981). This omission does not substantially detract from this analysis since relatively few deep wells were drilled in the Southern Tier during this time period.

Comparative Analysis

The positions of identified linears and wells were examined visually for locational relationships. The composite linear map overlay was used. The focus in this analysis was on: (1) the trend of linears and the trend of gas fields, (2) the proximity of gas wells to linears, (3) the relative concentration of linears in gas fields, and (4) linear intersections and gas fields and wells.

RESULTS AND DISCUSSION

This section outlines results obtained from the comparative analysis of linear and gas well locations.

1) There are identifiable relationships between gas field orientation and linear orientation. Linears in the three counties have two dominant

TABLE 2. Linear orientations: Chemung, Schuyler and Steuben counties, N.Y.

DEGREE RANGE (0^{o}=NORTH)	NO. LINEARS	% OF TOTAL
0-9/180-189	11	4.9
10-19/190-199	10	4.5
20-29/200-209	9	4.0
30-39/210-219	18	8.1
40-49/220-229	16	7.2
50-59/230-239	23	10.3
60-69/240-249	30	13.5
70-79/250-259	14	6.3
80-89/260-269	13	5.8
90-99/270-279	14	6.3
100-109/280-289	4	1.8
110-119/290-299	3	1.3
120-129/300-309	12	5.4
130-139/310-319	2	0.9
140-149/320-329	10	4.5
150-159/330-339	14	6.3
160-169/340-349	8	3.6
170-179/350-359	11	4.9
	222	

Dominant Linear Trends:

55-80/235-260 degree range contained 25.6% of observed linears.
55-90/235-270 degree range contained 31.5% of observed linears.
145-165/325-345 degree range contained 11.2% of observed linears.

FIGURE 4. Producing gas wells and field locations in study area.

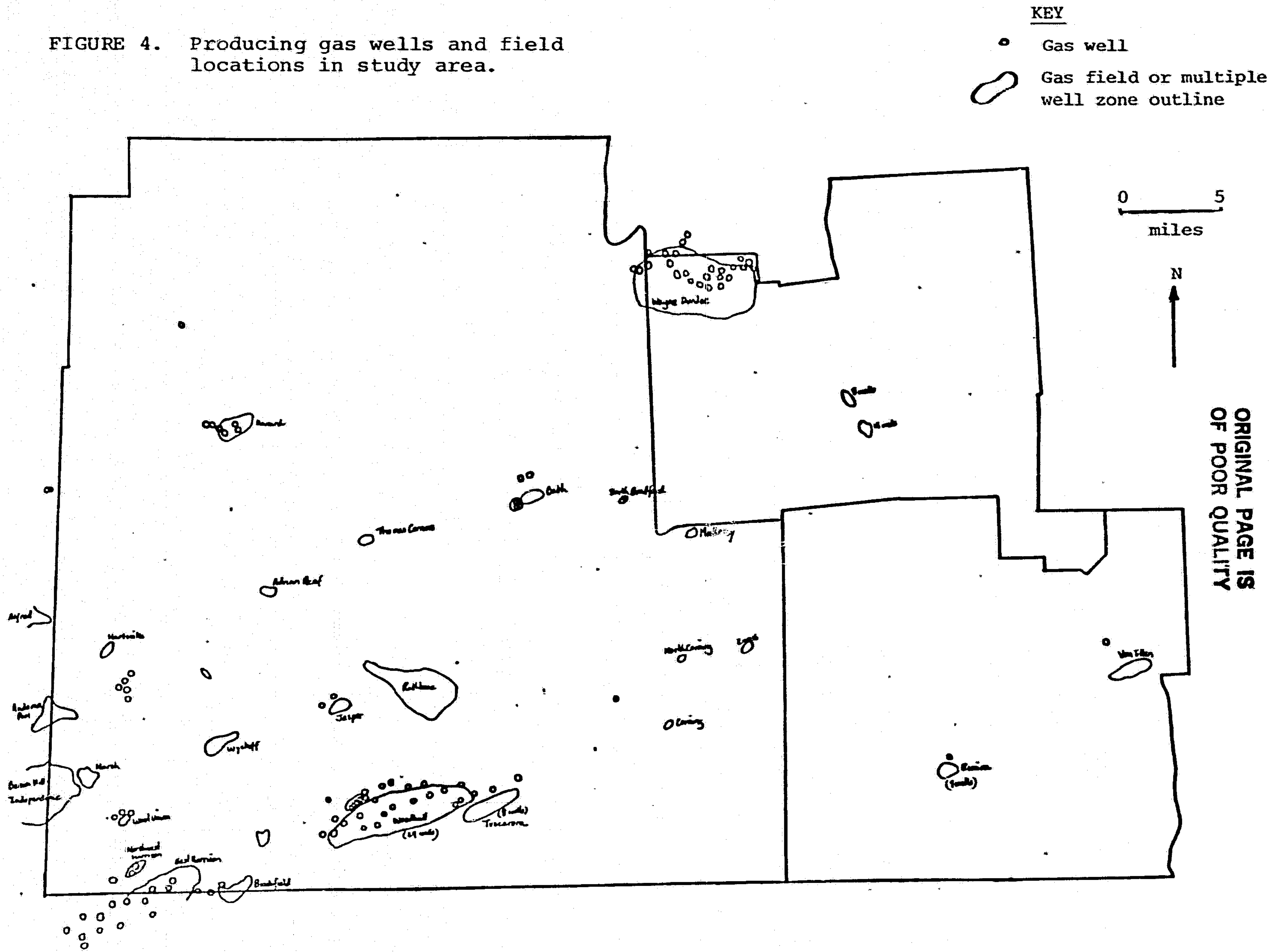


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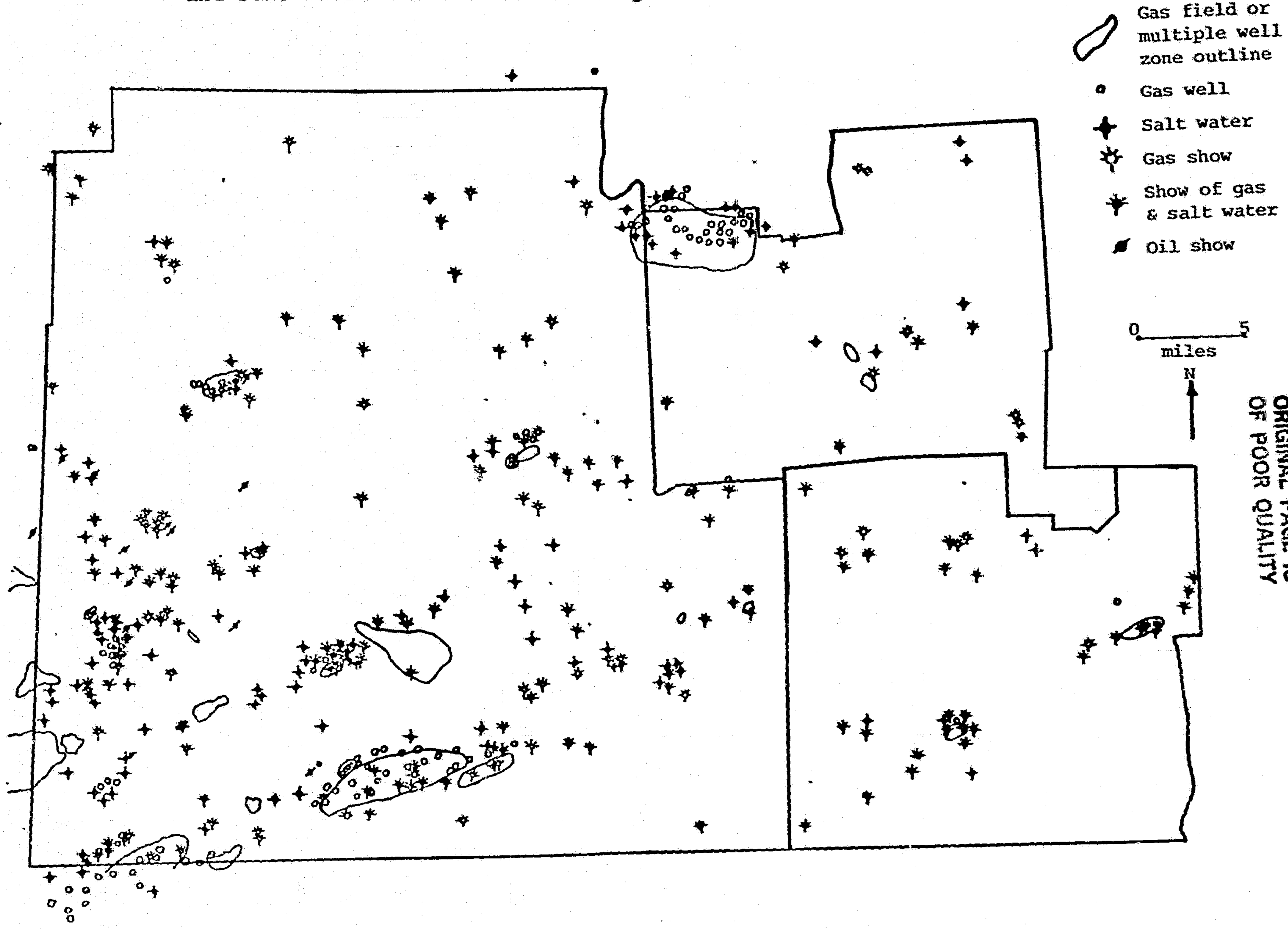
FIGURE 5. Gas wells, gas fields, gas and oil shows, and salt water occurrences in study area.



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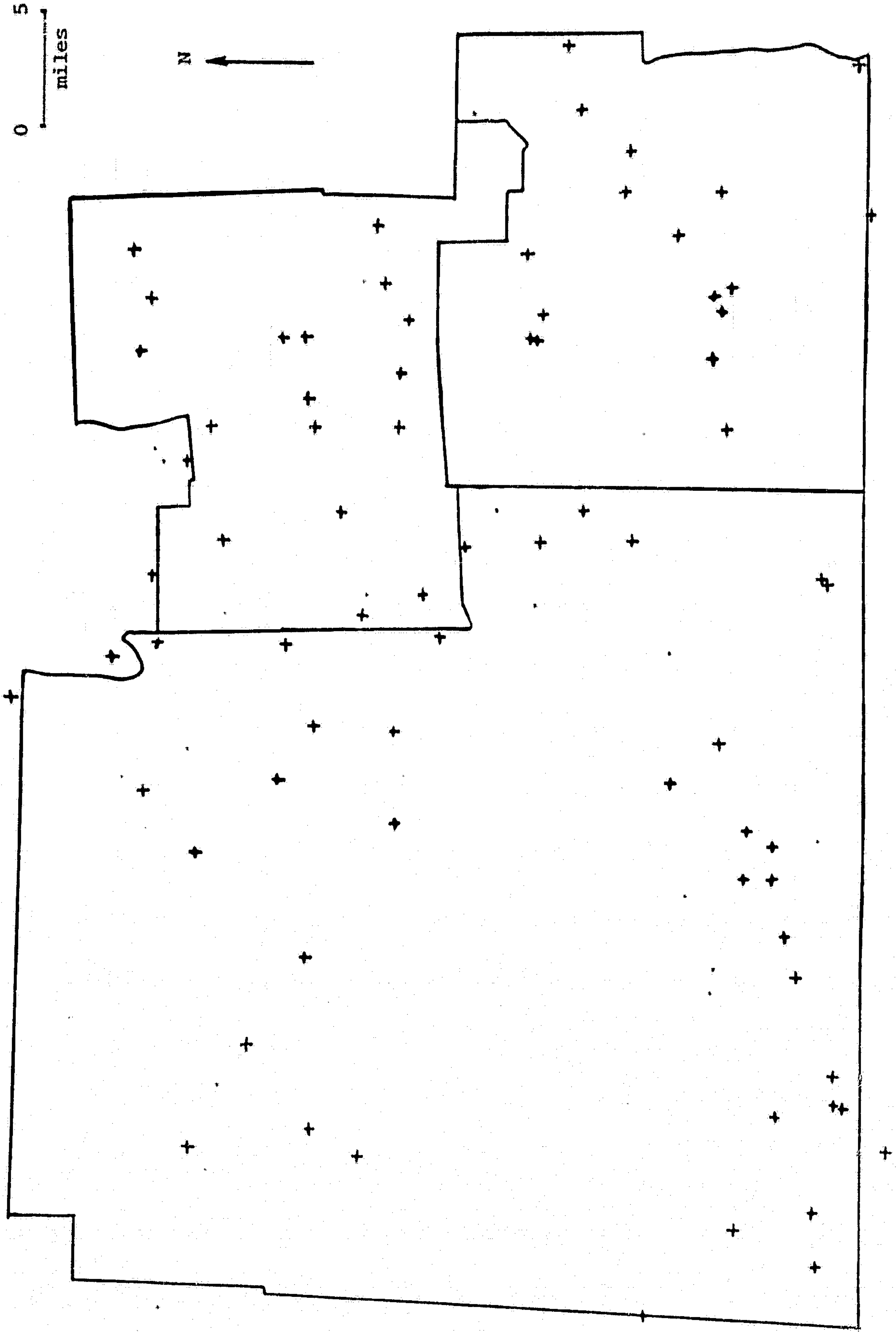

FIGURE 6. Dry holes in study area.

orientations which are nearly orthogonal to each other, NW-SE or ENE-WSW (Table 1). These directions are parallel to major faults and joint sets in the region (Engelder and Geiser, 1980). Most gas fields in the region trend ENE-WSW. These relationships indicate that the regional fracture system is clearly linked to the structural control of gas reservoirs in the Southern Tier.

2) There are observable relationships between gas field location and linear location. Many fields are bounded on at least one side by linears (Mason, Bath, Harysville, Howard, Adrian Reef, Van Etten, Rathbone, and Wayne-Dundee). Of twelve such linears, four trend in a NW-SE direction and five trend in an ENE-WSW direction, paralleling the dominant linear trends in the region. There are also definite locational associations between the subsurface faults identified on the Brittle Structures Map and six major gas fields (Andover Pool, Beech Hill-Independence, West Union, East Harrison, Woodhull, and Jasper). These faults trend ENE-WSW.

Because of problems with map accuracy due to the use of different information sources at different scales, it is more difficult to determine if similar relationships exist between individual non-field wells and wells with gas or salt water shows.

3) There is no increase in the relative concentration of linears in producing, gas show or salt water areas relative to those in areas containing only dry holes or for which drilling data were unavailable.

4) There is no significant relationship between the location of gas fields, individual gas wells, or wells showing gas or salt water with linear intersections. Only two gas fields (Van Etten and Rathbone) of 23 in the region are located at linear intersections. Individual gas wells and wells with gas or salt water shows are located no nearer to linear intersections than they are to single linears or to areas with no linears. This suggests that linear intersection is not a controlling factor in gas reservoir location in the region.

RECOMMENDATIONS

From the results of this analysis it is recommended that future gas exploration efforts in Chemung, Schuyler and Steuben counties should give considerable attention to undrilled areas in close proximity to linears trending NW-SE and ENE-WSW. Analyses of the type performed here should be integrated with detailed geological studies. Suggestions for additional research are:

1) Compiling more accurate and up-to-date maps. In particular, this would involve obtaining detailed locational information for wells from drilling records assembled by the Oil and Gas Section of the New York Geological Survey,

2) Correlating the proximity of gas wells to linears with well production data. A study of a Kentucky gas field demonstrated that cumulative production was higher in wells closely associated with linears (Howard et al., 1979); and,

3) Correlating geologic analyses of subsurface structural and stratigraphic relationships with linear and well location relationships. Such analyses could include the use of:

a) Electric well logs (gamma ray and temperature) to indicate the relative carbon content of black shales and to provide subsurface stratigraphic information;

b) Seismic reflection data to provide information on subsurface stratigraphy and structural geology;

c) Facies analysis to provide insight into the location and characteristics of reservoir rocks and possible stratigraphic traps;

d) Analysis of fracture (fault and joint) density and orientation in black shales and other reservoir rocks, its effect on rock porosity and permeability, and the extent of its surface expression as linears; and,

e) Petrologic studies of the thermal maturity of regional black shales.

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APPENDIX C

RECENT PUBLICATIONS

Eighth International Symposium

Machine Processing of Remotely Sensed Data

with special emphasis on

Crop Inventory and Monitoring

July 7-9, 1982

Purdue University

Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907 USA

Edited by D.C. McDonald and D.B. Morrison
Cover design and layout by S.L. Ferringer

GRAPEVINE CANOPY REFLECTANCE AND YIELD

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K.A. MINDEN, W.R. PHILIPSON

Cornell University
Ithaca, New York

ABSTRACT

Field spectroradiometric and airborne multispectral scanner data were applied in a study of Concord grapevines. Spectroradiometric measurements of 18 experimental vines were collected on three dates during one growing season. Spectral reflectance, determined at 30 intervals from 0.4 to 1.1 μm, was correlated with vine yield, pruning weight, clusters/vine, and nitrogen input. One date of airborne multispectral scanner data (11 channels) was collected over commercial vineyards, and the average radiance values for eight vineyard sections were correlated with the corresponding average yields. Although some correlations were significant, they were inadequate for developing a reliable yield prediction model.

I. INTRODUCTION

Remote sensing has become a major tool for assessing crop condition and yield. Ten years ago, remote sensing research was primarily devoted to evaluating losses in crop vigor due to stress (Colwell, 1970). More recent studies have also explored the relationship of the spectral characteristics of vegetation to agronomic variables (Idso et al., 1977). These variables include biomass, leaf area index, disease, percent green, percent ground cover, nutritional status and yield.

Remote sensing of vineyards has been applied to several management problems, including drainage; soil depth, compaction and texture; and crop health and vigor (Wildman, 1979; Philipson et al., 1980). Ultimately, these factors all affect crop yield, the focus of vineyard management decisions. In large vineyards, detailed observations of crop status are time consuming and, consequently, limited to a small number of plants. A cost-effective method of predicting yield, at the earliest possible stage of crop growth, would be very valuable to viticulturalists.

The intent of this research was to examine relationships between agronomic variables and spectral properties of the vine canopy. The main objective was to define the optimum wavelength(s) for yield prediction modeling.

II. PREVIOUS STUDIES

Factors which affect leaf and canopy reflectance have been defined in several studies (Myers and Allen, 1968; Wiegand et al., 1972; Bauer, 1975). Radiometer have been the main tool for in situ crc canopy spectral reflectance measurements (Kanemasu, 1974; Casey and Burgess, 1979), while the Landsat Multispectral Scanner has provided most of the aerial data for spectral studies of crops (Heilman et al., 1977; Colwell, 1979). For both, statistically significant relationships have been found between reflectance and some agronomic variables for grass, wheat, sorghum, soybean and other crops. Generally, researchers found that crop parameters correlate best with reflectance in the red and near-infrared wavelengths, and with ratios of reflectance in these wavelengths. Linear combinations of two wavelengths are often used to compensate for sun angle and atmospheric effects (Tucker et al., 1979).

Studies of vineyard reflectance and crop condition using color-infrared aerial photography and airborne multispectral scanner data were performed by Philipson et al. (1980). They concluded that differences in vine vigor could be assessed visually with the color-infrared photographs, and that yield-reflectance relationships appear to exist for at least two grape varieties, Delaware and Concord.

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III. METHODS AND MATERIALS

Field spectroradiometric measurements of 18 Concord vines were collected on three dates, at the Vineyard Laboratory of the New York State Agricultural Station, in Fredonia, N.Y. The experimental vineyards are part of the Chataugua County grapebelt, located eight kilometers southeast of Lake Erie. Replicated vines had been subjected to nine agronomic treatments involving levels of nitrogen, weed control, pruning and training.

One major problem in past crop reflectance studies is developing relationships which are applicable to more than just the training data (Stuff and Barnett, 1979; Duggin, 1980). This is caused, at least in part, by not accounting for the effects of solar zenith angle, azimuth angle and look angle. In order to provide accurate reflectance data and account for these effects, three portable spectroradiometers (ISCO model SR) were calibrated using a procedure developed by Duggin (1980) and modified by Duggin and Philipson (1981).

The fiber optic probe of each instrument was equipped with a 30° cone receptor to limit the field-of-view. The instruments were mounted on a grape harvesting tractor, with the probes of two spectroradiometers viewing the vineyard canopy and the probe of the third spectroradiometer viewing a white, Lambertian standard reflector. Radiance from the vines and standard was measured simultaneously, taking readings at intervals of 0.25 μm from 0.40 to 1.1 μm. The data were transformed into percent hemispherical-conical reflectance (Duggin and Philipson, 1981). This procedure was repeated on three dates during the 1980 growing season, July 9 or 10, August 21 or 22, and September 12.

For general analysis and screening, the reflectance data were plotted versus wavelength for each plant, for each date. Correlations were computed between yield and spectral reflectance of each vine on each date. Relationships between vine reflectance and pruning weight, clusters, nitrogen input, and weed control were also evaluated.

As an extension of the field program, airborne multispectral scanner data (M2S, 11 channels) were flown by NASA on September 3, 1980, over the vineyards of the Taylor Wine Company, Inc., in Hammondsport, N.Y. The mission was flown in mid-afternoon with high haze and approximately 60% cloud cover. Sufficient aerial data were collected to analyze eight Concord vineyard sections. The spectral radiance values for each section were correlated with average section yield. Several ratios of average reflectance were also correlated with average yield.

IV. RESULTS

Correlations between yield and reflectance of 18 plants sampled during the 1980 growing season were generally poor, with most values being below the 5% probability level. Yields from 1980 (and 1979) were not significantly correlated with July reflectance data. For August data, reflectance in the visible range was positively and significantly related to yield, while for September data, yield and reflectance were negatively correlated, with the most significant correlations occurring in the near-infrared range.

The level of nitrogen and method of weed control, which together determine the available nitrogen, were found to significantly affect yield, clusters and pruning weight. Because available nitrogen affects chlorophyll levels, 12 of the sampled vines were stratified into two groups of six vines: Group 1 used between-row cultivation for weed control, while Group 2 used mowed sod with herbicides. An analysis of variance showed that the effect of nitrogen on the 12 plants sampled was not as significant as the effect on all plants which received the same treatments at the experimental site. However, correlations between yield and reflectance improved for each group relative to correlations based on all 18 plants.

Pruning weight and the number of clusters per vine were also related to reflectance. Pruning weight was significantly correlated with reflectance when all 18 plants were used, but there was no significant correlation with the plant groups stratified by method of weed control. In contrast, when the number of clusters per vine was correlated with reflectance, the opposite occurred. There were no significant correlations when all 18 plants were used, but when yields from the smaller groups were correlated with reflectance, the resulting coefficients were highly significant. As expected, the number of clusters was highly correlated with yield.

Plants were also stratified into groups based on the time of day in which reflectance measurements were made. Correlations between yield and reflectance for these groups was better than for all 18 vines sampled.

Correlations between the airborne multispectral scanner data and averaged yield were not significant.

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V. DISCUSSION AND CONCLUSIONS

Most correlations between spectral reflectance and yield were generally not significant at the 5% probability level. August reflectance data showed better correlation with yield than did July or September reflectance data.

Clusters per vine were highly correlated with yield, and more highly correlated with reflectance than yield. A yield prediction model based on spectral reflectance might attempt to incorporate some measure of clusters. It is also apparent that a successful model might have to stratify the vines by available nitrogen.

The effect of time of day on reflectance correlations with yield might relate to leaf-layer shadowing, leaf orientation or a systematic instrument error.

Future sampling should be performed on a larger sample. In addition, data collection could be limited to certain wavelengths depending on growth stage. In July, the highest correlations occurred in different visible and near-infrared wavelengths. August data collection, however, could be limited to certain wavelengths depending on the weed control method: the visible range for cultivated rows, and the infrared for those with sod and herbicide application. In September, the data collection could generally be limited to the infrared range. At any time, the main visible wavelengths to be considered are 0.400-0.475 μm and 0.625-0.675 μm.

The lack of correlation between the airborne multispectral scanner data and yield was likely due to a combination of factors, which are still under investigation.

VI. SUMMARY

Some correlations between vine spectral reflectance and both yield and clusters per vine are statistically significant, however they are inadequate for developing a reliable yield prediction model. Canopy reflectance was strongly influenced by available nitrogen and stage of crop growth. Future sampling can emphasize specific wavelength regions, but these depend on several factors, including stage of growth and agronomic treatment.

VII. ACKNOWLEDGMENT

This study was supported by NASA Grant NGL 33-010-171. Cooperation and assistance were provided by researchers at the State Agricultural Experiment Station, in Geneva, N.Y., the Vineyard Laboratory, in Fredonia, N.Y., the Taylor Wine Company, Inc., in Hammondsport, N.Y., Michael Duggin, of the College of Environmental Science and Forestry, at Syracuse, and by Chain-Chin Yen and other staff of Cornell's Remote Sensing Program.

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Reprinted from **Applied Optics,** Vol. 21, page 2833, August 1, 1982

Field measurement of reflectance: some major considerations

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M. J. Duggin and W. R. Philipson

Success in determining when, whether, and in what conditions to acquire remote sensing data for describing a given target (e.g., vegetation) is contingent on understanding the reflectance properties of the target and its surroundings. Unfortunately, relatively little information on the reflectance properties of the earth's surface exists in the literature. Field measurements of a target's reflectance are usually made with single-beam instruments by sequentially viewing the target and a white standard reflector, which is assumed to be Lambertian. Because variations in atmospheric transmission can occur between the times of measuring the target and reflector, substantial errors in reflectance calculated from these measurements may result. To avoid these errors the irradiance on and radiance from the target must be measured simultaneously. Measurements of the spectral hemispherical–conical reflectance of vegetative canopies were made by simultaneously measuring irradiance and radiance with pairs of portable spectroradiometers. The procedures for calibrating the instruments and for collecting and analyzing spectral reflectance data are described. Major instrumental sources of error and their magnitude are discussed as are problems involved in making such measurements.

I. Introduction

The spectral reflectance indicatrix is normally asymmetrical and dependent on target and wavelength.[1-17] Moreover, the variability of target reflectance (blur of the indicatrix), atmospheric transmission, and path radiance for any set of angular conditions between the sun, target, and sensor will limit discriminability (see, e.g., Figs. 1 and 2). Therefore, the bandpasses, overflight conditions, and sensor geometry (field of view and maximum look angles) that will provide optimum target discrimination can be determined only from spectral reflectance measurements made for various sun–target–sensor geometries supplemented by model calculations which can be checked against field data.[3,4,15-22]

The accurate measurement of ground reflectance properties is critical to the design of future sensors and to the determination of imaging conditions. At present ground reflectance data to satisfy these needs are scanty and in some cases of uncertain accuracy. While there have been many measurements of the reflectance properties of the earth's surface,[23] there are considerable differences in the methods used to obtain these measurements. Most were made with single-beam instruments by sequentially measuring the target of interest and a reference, usually a white spectrally flat Lambertian standard reflector. This method is subject to error due to irradiance variations that can occur between the times of target and reference reflector measurements.

An attempt to simultaneously measure radiance and irradiance using two portable spectroradiometers is reviewed in this paper. The problems encountered are described to point out the difficulties of making such measurements and to show that data in the literature must be viewed with an understanding of the limitations of the methods available to experimenters. Recommendations are given for improved procedures and instrumentation.

II. Measurement Techniques

A. Sequential Measurements of Radiance and Irradiance

As noted, most reflectance measurements in the literature were derived with a single radiometer, obtaining sequential measurements of the spectral or fixed band radiance from a target and from a spectrally flat (e.g., barium sulfate) standard reflector.[2,4,5,15,16,24-27] The

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Received 6 October 1981.
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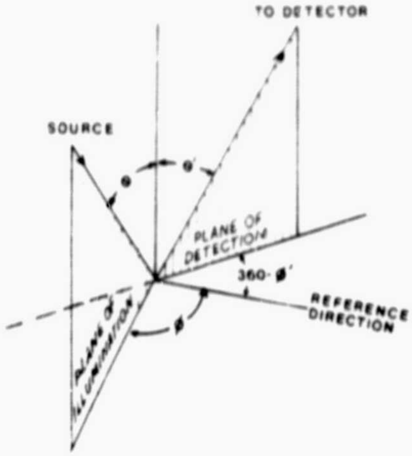

Fig. 1. Sun–target–sensor geometry.

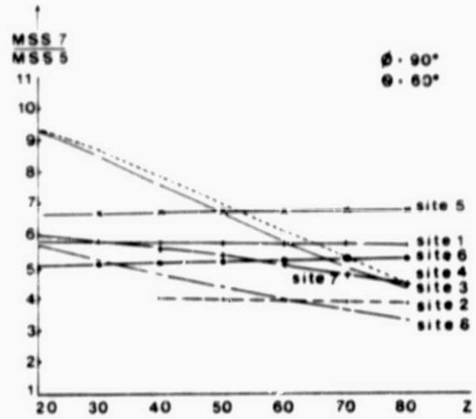

Fig. 2. Variation of reflectance ratio MSS 7/5 with solar zenith angle for nadir-pointing sensor viewing various pasture targets.

reflectance may be calculated using a formula such as

$$R_r = \left(\frac{V_{tr} - D_r}{V_{sr} - D_r}\right) \times K_r, \tag{1}$$

where V_{tr} = reading obtained in bandpass r when recording radiance from the target,

V_{sr} = reading obtained in bandpass r when recording radiance from the standard panel,

D_r = dark current (detector noise) in bandpass r,

K_r = measured reflectance of standard reflector in bandpass r, and

R_r = hemispherical–conical reflectance factor[28] in bandpass r.

A radiometer which uses an optical chopper has an output measured relative to the dark current $V'_{tr} = (V_{tr} - D_r)$ or $V'_{sr} = (V_{sr} - D_r)$:

$$R_r = \left(\frac{V'_{tr}}{V'_{sr}}\right) \times K_r. \tag{2}$$

The assumption with the sequential measurement procedure is that the intensity and spectral distribution of irradiance on the target is invariant during readings of the target and standard reflectors. When a scanning spectroradiometer is used, for example, the length of time taken to scan the spectrum from 400 to 1100 nm at 10-nm intervals is typically 3 min. This is obviously a problem when clouds are present; however, irradiance variations also occur on clear days.

A typical rate of diurnal variation in irradiance with solar zenith angle measured for a clear sky is shown in Fig. 3. In addition to this predictable variation, random variations of at least 5–10% can also occur, even on apparently clear days.[29] The relative shift in spectral composition of irradiance (i.e., irradiance in a selected bandpass divided by the sum of the irradiances in all bandpasses) with solar zenith angle is shown in Fig. 4. Although methods have been proposed to monitor the total global irradiance (broadband) to detect and possibly correct for such fluctuations while collecting data from which the reflectance is calculated, these methods only show where the data may contain artifacts; they do not collect data with which to exclude the artifacts.

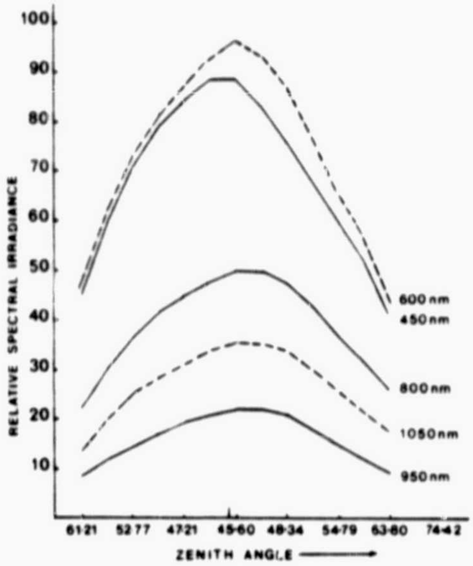

Fig. 3. Solar zenith angle dependence of spectral global irradiance.

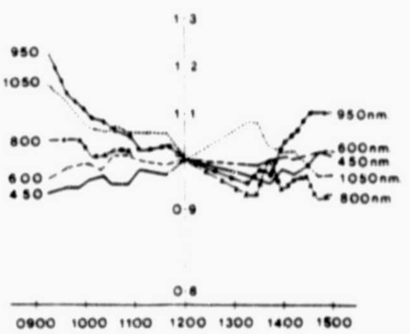

Fig. 4. Solar zenith angle dependence of spectral composition of global irradiance.

B. Simultaneous Measurements of Radiance and Irradiance

Duggin[30] reported a method of calibrating two 4-band radiometers (Exotech type GTR-100) with the same nominal bandpasses. One radiometer measured radiance reflected from a white Lambertian standard reflector, while the other measured irradiance. The calibration factor C_r in bandpass r was

$$C_r = \left(\frac{V_{2r} - D_{2r}}{V_{1r} - D_{1r}}\right)_{cal} \cdot \quad (3)$$

where V_{1r} = voltage from the downlooking radiometer (measuring reflected radiance from standard reflector),

V_{2r} = voltage from the uplooking radiometer (measuring irradiance),

D_{1r} = dark current from radiometer 1, and

D_{2r} = dark current from radiometer 2.

The reflectance factor in bandpass R_r was obtained from

$$R_r = \left(\frac{V_{1r} - D_{1r}}{V_{2r} - D_{2r}}\right) \times \hat{C}_r \times K_r, \quad (4)$$

where V_{1r} = voltage measured from radiometer recording radiance reflected from the target,

V_{2r} = voltage measured from radiometer recording irradiance,

$\hat{C}_r$ = estimate of the calibration factor from a regression fit of C_r (from successive measurements made at different times of day) against a function of solar zenith angle, and

K_r = reflectance of a standard reflector determined in the laboratory with a spectrophotometer.

For the work reported here the authors used three portable spectroradiometers manufactured by the Instrument Specialty Co. (ISCO model SR). Two of the instruments were used to measure radiance from different targets or different areas of the same target, while the third instrument was used to obtain measurements of irradiance. Because the cosine receptors supplied with the instruments were known to give rise to considerable sun-angle dependence,[29] measurements of irradiance were obtained indirectly by measuring radiance reflected from a field-portable white Lambertian reflectance target.

The fiber-optic probes of all instruments were modified to receive radiance via 30° cone receptors. The instrument used for measuring the standard reflector had a 90-cm (3-ft) long fiber probe, while those used for viewing the targets had 180-cm (6-ft) probes.

Measurements from the three spectroradiometers were made by three operators taking readings as close to simultaneously as possible at each wavelength setting. The instruments covered the 400–1150-nm spectral range, with a bandpass of ~25 nm in the visible range (400–750 nm) and 50 nm in the reflected infrared (750–1150 nm). Readings were, therefore, taken at 25-nm intervals over the 400–750-nm wavelength range and at 50-nm intervals over the 750–1150-nm range.

For calibration all instruments view the standard reflector. In calculating the calibration factors for the ISCO spectroradiometers no correction is required for the dark currents. The instruments have optical choppers and give output readings for the detector recording radiance compared with the detector recording no radiance (i.e., when covered by the chopper). Therefore, if spectroradiometer 1 is the reference instrument and spectroradiometers 2 and 3 are the target instruments, Eq. (3) becomes, for each wavelength setting (λ), for the two radiometer pairs

$$C_1(\lambda) = \left[\frac{V_1(\lambda)}{V_2(\lambda)}\right]_{cal} \cdot \quad (5)$$

$$C_2(\lambda) = \left[\frac{V_1(\lambda)}{V_3(\lambda)}\right]_{cal} \cdot \quad (6)$$

The calibration factors $C_1(\lambda)$ and $C_2(\lambda)$ were found to vary with the time elapsed since the instruments were switched on, presumably due to different instrumental drift rates. Because all three instruments view the same standard reflector during calibration, it is not surprising that there was no apparent dependence of $C_1(\lambda)$ or $C_2(\lambda)$ on solar zenith angle as would be expected if one of the instruments had a cosine receptor.

Calibration measurements were made repeatedly over two days with three instruments simultaneously viewing the standard white reflector placed horizontally. Regression equations developed to predict the calibration factors at each wavelength were of the form

$$\hat{C}(\lambda) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4. \quad (7)$$

where t is time in minutes since switch on.

For determining the spectral reflectance of any target simultaneous measurements were obtained of the standard reflector (with spectroradiometer 1) and the target of interest (with spectroradiometer 2 or 3 or both). The spectral reflectance of a target measured with spectroradiometer 2 was calculated using the expression

$$R_1(\lambda) = \hat{C}_1(\lambda) \times \left[\frac{V_2(\lambda)}{V_1(\lambda)}\right] \times K(\lambda), \quad (8)$$

and target reflectances measured with spectroradiometer 3 were calculated with the expression

$$R_2(\lambda) = \hat{C}_2(\lambda) \times \left[\frac{V_3(\lambda)}{V_1(\lambda)}\right] \times K(\lambda). \quad (9)$$

$K(\lambda)$ is the spectral reflectance of the standard reflector measured in the laboratory with a spectrophotometer. (We wish to acknowledge with gratitude the courtesy of E. Whitemen and F. Grum of the Eastman Kodak Research Laboratories, Rochester, N.Y., in making the spectrophotometric measurements.)

As a regular check on the instruments a series of calibration measurements with the standard reflector was made before and after any field-target measurements. That is, all instruments used to collect target reflectance data were checked against the standard re-

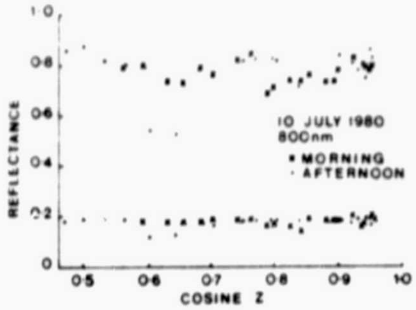

Fig. 5. Calibration data for one day from which estimates of $C_1(\lambda)$ and $C_2(\lambda)$ may be made using regression Eq. (7) for the calibration factors given in Eqs. (5) and (6).

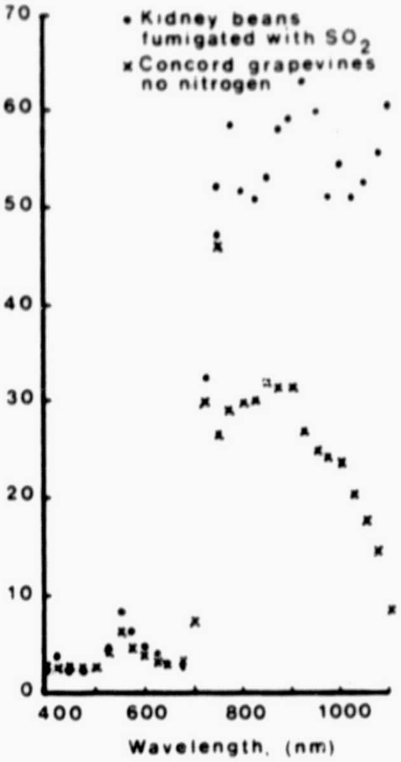

Fig. 6. Typical spectra obtained for two crop canopies using the calibration and measurement methods described.

flector and their calibration factor reexamined. In addition, as one means of assessing the accuracy of the field measurement technique, simultaneous radiance and irradiance measurements were made of a standard target whose optical properties approximate those of vegetation as determined in the laboratory.[31]

III. Results

Values of $C(\lambda)$ calculated from Eqs. (5) and (6) were based on measurements made at different times after switch on for one day as shown in Fig. 5. The wavelength shown is 800 nm, although thirty other determinations of $C_1(\lambda)$ and $C_2(\lambda)$ were made for other wavelengths.

Estimates of the calibration factors $\hat{C}_1(\lambda)$ and $\hat{C}_2(\lambda)$ obtained using regression equations of the form of Eq. (7) provided reliable calibration of target reflectance data as long as calibration measurements made before and after the target measurements gave values consistent with the estimates. Variability in the calibration data showed that 10% was a realistic criterion for agreement between estimated calibration factors and values calculated from field data.

It was found necessary to measure the battery voltages of each of the ten batteries in each instrument before and after measurement sessions. There was no other way to be aware of instrumental errors caused by day-to-day or during-day variations in battery voltage.

During measurements the fiber-optic probe on spectroradiometer 1, the instrument used to measure the standard reflector, was damaged. This problem was found when ambiguities appeared in the calculated reflectance factors. The infrared reflectances $R_1(\lambda)$ and $R_2(\lambda)$ exceeded 100% due to the decreased readings obtained from spectroradiometer 1. Replacement of the damaged probe required all calibrations to be redone. Following this difficulty a problem arose in the amplifier of one of the instruments. Rather than invest several more days in collecting measurements from which new values of $\hat{C}_1(\lambda)$ and $\hat{C}_2(\lambda)$ would be determined, it was decided to recalculate $\hat{C}_1(\lambda)$ and $\hat{C}_2(\lambda)$ from each day's measurements. As noted, because all three instruments view the same standard reflector during calibration, there is no apparent dependence of $C_1(\lambda)$ or $C_2(\lambda)$ on solar zenith angle. Consequently the calibration measurements obtained from the standard reflector before and after each measurement session were used as input to a simple linear regression equation against time since switch on.

Typical spectra obtained using these methods are shown in Fig. 6 for the crop canopies measured. Errors in these spectra would arise from parallax in reading the wavelength scale, from time-dependent variations in calibration between the instruments, and from errors in calibrating the instruments. As described one method of finding the error in measurements of the spectral reflectance of surfaces using field targets is to measure the spectral reflectance properties of a standard target whose optical properties approximate that of the target of interest. Table I shows the reflectance properties of a standard target whose spectral reflectance properties approximate those of vegetation as measured in the laboratory[31] and as measured by a pair of scanning field protable spectroradiometers (ISCO) simultaneously measuring radiance and irradiance. Errors for the spectroradiometer pair are <4% in the visible part of the spectrum and <8% in the infrared part of the spectrum. An overall estimate of error in a spectral reflectance value is approximately ±10%.

IV. Discussion

The above procedure may be employed to obtain *in situ* spectral reflectance values with portable battery-powered spectroradiometers of the ISCO type. These

Table I. Spectral Reflectance of the Artificial Target Simulating Vigorous Vegetation Measured in the Laboratory[31] and in the Field Using a Pair of ISCO Spectroradiometers

Wavelength (nm)	Lab. measurement	ISCO spectroradiometers	Wavelength (nm)	Lab. measurement	ISCO spectroradiometers
450	0.057	0.065	770	0.491	
460	0.063		775		0.505
470	0.071		780	0.508	
475		0.082	790	0.522	
480	0.08		800	0.532	0.548
490	0.091		810	0.541	
500	0.103	0.107	820	0.546	
510	0.113		825		0.570
520	0.117		830	0.552	
525		0.120	840	0.559	
530	0.109		850	0.561	0.600
540	0.093		860	0.565	
550	0.076	0.084	870	0.566	
560	0.063		875		0.642
570	0.054		880	0.569	
575		0.053	890	0.571	
580	0.052		900	0.571	0.615
590	0.049		910	0.571	
600	0.046	0.048	920	0.572	
610	0.043		925		0.558
620	0.042		930	0.573	
625		0.044	940	0.572	
630	0.044		950	0.568	0.574
640	0.044		960	0.567	
650	0.045	0.047	970	0.563	
660	0.044		975		0.601
670	0.045		980	0.56	
675		0.047	990	0.557	
680	0.049		1000	0.554	0.590
690	0.059		1010	0.548	
700	0.077	0.074	1020	0.54	
710	0.126		1025		0.577
720	0.188		1030	0.533	
725		0.180	1040	0.527	
730	0.264		1050	0.524	0.567
740	0.349		1060	0.518	
750	0.422	0.401	1070	0.514	
760	0.464		1075		0.530
			1080	0.509	

may be used in support of or in feasibility studies preceding remote sensing surveys. The intercalibration of the spectroradiometers to obtain $\hat{C}_1(\lambda)$ and $\hat{C}_2(\lambda)$ may be achieved through a simple linear regression of calibration measurements (y) made at the start and finish of each measurement day against time (x) since switch on of the instruments. A more accurate calibration method was used initially but abandoned when instrumental problems caused changes in the calibration. Although the method is complex and time-consuming, the accuracy of such measurements should be within approximately ±10% provided that care is exercised in all the procedures outlined above. Each instrument is subject to mechanical and electronic problems, and the use of two instruments necessitates the employment of at least two operators, producing errors or biases in reading and recording. The manual recording of data from an analog meter is clearly potentially less accurate and more time-consuming than automated digital recording.

It is worth noting that Milton[27] is critical of the two-radiometer method proposed by Duggin[30] for the simultaneous measurement of irradiance and radiance. He performs some very simple hypothetical calculations for a scene and concludes that there is a 25% change in the reflectance factor of a scene under clear sky compared with cloudy conditions. This is at variance with the observations of Duggin *et al.*[32] who found only a 10% change in the reflectance factors of pasture in the Landsat bandpasses for up to a factor of 3 change in the incident light level. It is also at variance with the reflectance data obtained in the Landsat bandpasses for a uniform barley field one month before harvest shown in Table II. A two-radiometer method (e.g., Duggin[30]) was used. Table II (see also Ref. 33) shows the output of the radiometer measuring irradiance. It is seen that changes in irradiance to over a factor of 3 affect the reflectance factor generally by <10% in the infrared bandpasses (MSS 6 and 7) and by <20% in the visible part of the spectrum (MSS 4 and 5). In fact, for a

Table II. Reflectance and Irradiance Spectra in the Landsat Bandpasses for Varying Illumination Conditions[33]

Solar zenith angle	Reflectance MSS 4	Irradiance MSS 4[a]	Reflectance MSS 5	Irradiance MSS 5[a]	Reflectance MSS 6	Irradiance MSS 6[a]	Reflectance MSS 7	Irradiance MSS 7[a]
42.08	0.0717	1.140	0.0812	1.796	0.220	1.642	0.291	2.15
41.67	0.0637	1.179	0.0754	1.861	0.245	1.692	0.343	2.23
40.86	0.0569	0.328	0.0662	0.453	0.223	0.455	0.323	0.592
40.65	0.0761	0.364	0.0842	0.509	0.297	0.501	0.413	0.647
40.45	0.0706	1.207	0.0788	1.906	0.262	1.747	0.350	2.30
40.04	0.0694	1.146	0.0775	1.805	0.263	1.654	0.358	2.18
39.84	0.0689	1.223	0.0756	1.941	0.251	1.785	0.338	2.37
39.44	0.0667	0.338	0.0730	0.471	0.280	0.477	0.396	0.621
39.23	0.0603	0.631	0.0676	0.942	0.229	0.876	0.314	1.139
35.24	0.0555	0.288	0.0597	0.390	0.245	0.406	0.346	0.533
34.85	0.0719	0.280	0.0816	0.375	0.271	0.387	0.371	0.508
34.65	0.0721	0.276	0.0785	0.368	0.259	0.378	0.353	0.493
34.46	0.0551	0.303	0.0626	0.411	0.209	0.415	0.288	0.541
34.07	0.0681	0.765	0.0738	1.167	0.269	1.075	0.374	1.397
33.87	0.0648	1.296	0.0734	2.063	0.235	1.878	0.323	2.49
33.49	0.0639	1.334	0.0684	2.133	0.219	1.945	0.303	2.58
33.10	0.0599	0.907	0.0687	1.402	0.221	1.302	0.312	1.694
32.71	0.0684	0.434	0.0765	0.631	0.245	0.630	0.331	0.830
32.52	0.0739	0.396	0.0825	0.569	0.261	0.578	0.354	0.762
32.33	0.0640	0.392	0.0724	0.563	0.241	0.572	0.341	0.763
Mean	0.0661	0.7114	0.0739	1.088	0.247	1.020	0.341	1.341
S_x[b]	0.00615	0.4157	0.00670	0.689	0.0233	0.6086	0.0325	0.806
CV (%)[c]	9.3	58.4	9.1	63.4	9.4	59.7	9.5	60.1

[a] These values are voltage output from the radiometer measuring global hemispherical irradiance in the Landsat bandpasses.
[b] S_x, sample standard deviation using $n - 1$.
[c] CV, coefficient of variation; standard deviation/mean value expressed as a percentage.

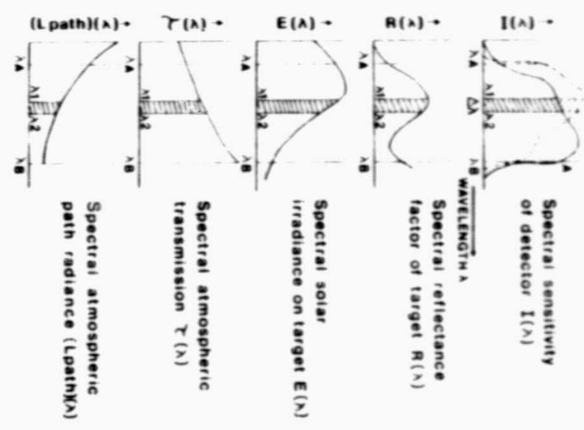

Fig. 7. Spectral dependence of factors controlling sensor output.

coefficient of variation (standard deviation divided by the mean) of 45% in the global irradiance for a series of spectra, the coefficient of variation of the reflectance factor is 10% or less in the visible bands and in the reflected infrared bandpasses.

For an apparently uniform target viewed from nadir the coefficient of variation in reflectance factor values was rarely <6% even on apparently clear days. Thus the coefficient of variation in the reflectance factor caused by substantial irradiance changes is likely to be <10% when the two-radiometer method is used.

In general spectroradiometric measurements, high instrumental stability, and accurate monochromation are needed to minimize errors due to calibration between the instruments. Monochromation should be the same for each spectroradiometer (i.e., the effective bandpass at each wavelength setting should be the same for the two units).

For fixed bandpass radiometers it is also necessary that both the standard (measures irradiance) and target radiometers have the same spectral response function for any given nominal bandpass. This is especially important because of the interaction between the spectral response of the target and that of the sensor.[34-36] This point may be best appreciated by considering the equation

$$NS(\lambda) = \frac{\frac{1}{\pi}\int_{\lambda_1}^{\lambda_2} \{I(\lambda) \times [R(\lambda) \times E(\lambda) \times \tau(\lambda) + L_{\text{path}}(\lambda)]\} d\lambda}{\int_{\lambda_1}^{\lambda_2} I(\lambda) \cdot d\lambda}, \quad (10)$$

where $NS(\lambda)$ = the normalized signal recorded by the sensor,
$I(\lambda)$ = instrument response,
$R(\lambda)$ = spectral directional reflectance factor of the target,
$E(\lambda)$ = spectral global irradiance at the target,
$\tau(\lambda)$ = spectral atmospheric transmission, and
$L_{\text{path}}(\lambda)$ = spectral atmospheric path radiance.

The wavelength dependence of the above functions is shown in Fig. 7. For ground measurements $L_{\text{path}}(\lambda)$ will be negligible. For different sensors with the same nominal bandpass but different instrument responses (e.g., A and B in Fig. 7) $NS(\lambda)$ can vary from channel to channel if $R(\lambda)$ varies across the sensor bandpass. In those cases where the half-power bandwidth of the sensor's response is relatively wide, say, 30 nm or more, the interaction of the spectral responses of the sensor and target significantly affects the recorded signal. It is imperative in these cases to calibrate with standards whose reflectance properties approximate those of the targets of interest, which are seldom spectrally flat. With the Landsat multispectral scanner (MSS), for example, differences between detectors in band 5 (600–700 nm) can be up to 18% for a vegetation target[31] but may be only 6% or less for a spectrally flat target such as barium sulfate. In other words, for fixed bandpass radiometers the two-beam method is reliable only when the instrument response functions of the two instruments are the same. This can be determined only by measuring the spectral response of the sensor and calculating or measuring its interaction with the spectral response of the target across the sensor bandpass using a method such as that proposed by Duggin *et al.*[31]

One further consideration which affects all reflectance measurements is the sun–target–sensor geometry.[1-5,8-15,21,22] Duggin,[9] for example, found changes in the reflectance of wheat of the order of 50%, with a 30° change in solar zenith angle. Similarly, unless the diameter of the viewed area is 1 m or more, variation in the targets viewed can produce large variations in the collected reflectance data.[37] The field of view and look angle of instruments used to obtain spectral reflectance measurements are often not stated, making it difficult to estimate the effect of sun–target–sensor geometry on the reported data.

V. Conclusion

The ground reflectance varies with surface conditions and depends on the angular geometry between the sun, target, and sensor. When measuring ground reflectance it is essential that the angle dependence be determined for each wave band and that the surface variability be assessed. This will produce the best chance of finding the dependence of the reflectance factor on wavelength (λ), look angle (θ'), solar zenith angle (θ), and solar azimuth (ϕ) (Fig. 1). Studies of the sun–target–sensor geometry dependence of target discriminability will lead to optimization of data acquisition conditions.

If measurements are to be made of the variation in the reflectance factors of surface features, it is essential that errors due to atmospheric and irradiance fluctuations be excluded. This necessitates a two-beam measurement. That is, the irradiance on the target and the radiance reflected from the target must be recorded simultaneously. From such measurements optimum sensor bandpasses and overflight conditions (sun elevation, look angle, azimuth) may be determined, taking into account the natural limitations on target discrimination posed by surface variability.

Major difficulties with present equipment are either that the problems of stability, calibration, and robustness are complex or that the equipment operates excellently in a laboratory but is not sufficiently portable to be transported to field sites (mobile laboratories are restricted for reasons of access to a fraction of those sites which are of interest). The technology exists to fabricate novel small rugged portable two-beam field spectroradiometers with a variable field-of-view and digital data logging. Calibration procedures could be easily shown in instruction manuals so that users who have little time to learn the complexities of electrical engineering or optics could use the equipment and obtain repeatable data. Data reduction could be simply achieved by reading the digital cassette or floppy disk on a computer terminal following simple procedures which could be detailed in a manual supplied with the instrument.

Until this step is taken ground reflectance data cannot easily or even reliably be compared. Therefore, until this step is taken there will be inadequate data to refine sensor design, plan optimum overflight times and ground track, determine spacecraft ephemeris, or place limits on sensor-look angle. Without these data the effect of surface reflectance variability on target discriminability for various sun–target–sensor angles will not be known. Most important, without these data it will not be possible (except in an *ad hoc* manner, using possibly nonoptimal imagery) to determine whether and which remote sensing variables are so correlated to resource variables of interest that they can be used as predictors of those variables.

In all cases the field measurement of a calibrated spectrally varying standard reflector is recommended as a means of assessing field reflectance factor measurement errors.

We wish to acknowledge partial support from NASA grant NGL 33-010-171 to the Cornell University School of Civil and Environmental Engineering, from NASA grant 9-16331 to the College of Environmental Science & Forestry, SUNY, Syracuse, N.Y., and from the McIntire-Stennis Fund, U.S. Department of Agriculture. Thanks are due the following for their cheerful cooperation in field measurements: Lisa Balliett, William Hafker, Karen Jahn, Katsutoshi Kozai, Sandra Matulonis, David Smith, John Stanturf, William Teng, and especially Katherine Minden and Thomas Erb. Special acknowledgements are also due Chain-Chin Yen for her efficient help with the reduction of the data, and John Yost and Glenn Darling for their efforts in preparing the standard reflector and fiber-optic receptors. The authors would like to acknowledge Ronald Clayton of Cornell's Department of Agronomy, Donald Warholic of Cornell's Department of Vegetable Crops, and Richard Mandl of the Boyce Thompson Plant Research Institute at Cornell for their cooperation in making the spectroradiometers available. We would also like to thank Melanie Johnson for typing assistance and Maggie Duggin for drafting.

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TECHNICAL PAPERS

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AN ANALYSIS OF SEASAT SAR FOR DETECTING GEOLOGIC LINEARS

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BIOGRAPHICAL SKETCHES

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ABSTRACT

The value of Seasat synthetic aperture radar (SAR) imagery for detecting geologic linears was assessed in a study of an 89,000 km^2 section of New York's Adirondack Mountains. A photographic print of optically processed, 1:500,000 scale SAR imagery (one look direction) was analyzed visually, and the detected linears were compared to those recorded on a 1:250,000 scale geologic map. Eighty percent of the 4,170 km of mapped, geologic linears were detected with the SAR imagery. Moreover, nearly 6,900 km of unmapped linears were also detected. Of these, an estimated 90% could be observed on high altitude aerial photographs. The relationship between SAR image detection of linears and the different types of indicators (e.g., straight valleys or shorelines) is reported.

INTRODUCTION

Launched on 26 June 1978, NASA's Seasat-1 satellite failed four months later, on 10 October 1978. During Seasat's short lifetime, its synthetic aperture radar (SAR) produced

a comparatively large sample of excellent imagery. Although intended primarily for oceanographic applications, the Seasat SAR data were thought to be applicable in a number of terrain studies (Matthews, 1978). One proposed application was assessing linears.

Linears appearing on remotely sensed imagery are of potential importance to engineers and geologists since they may represent jointing, other fracturing, or major or minor faulting (Lattman, 1958). On the other hand, linears may represent topographic features of little significance, or they may represent cultural or other features having no relation to the geology (Isachsen, 1973; Wise, 1977). This study set out to test the value of Seasat SAR for detecting geologic linears.

The development of radar for geologic applications has been reviewed by MacDonald (1980). Of particular interest for the present study is work by Ford (1980), who showed that major and minor topographic linears could be easily mapped from Seasat SAR imagery. Ford's study, while comprehensive, placed emphasis on comparing linears derived from Seasat SAR with those derived from digitally enhanced Landsat imagery; it did not provide an objective test of the validity of the observed SAR linears.

METHODS AND MATERIALS

Seasat and Study Area

The Seasat SAR, an L-band (23.5 cm) system, was flown in a circular, near-polar orbit at an altitude of 800 km. The system was pointed to the starboard side of the spacecraft, 20.5° off nadir, where it imaged a 100 km swath with an optimum resolution of 25 m.

For this study, photographic prints of the optically processed imagery from one look direction were analyzed. The image scale was approximately 1:500,000. The study area was an 89,000 km^2 section of the Adirondack Mountains of New York State (Fig. 1). This area has been mapped in detail and its linears studied with Landsat and various types of photographic imagery (Isachsen, 1973; Isachsen and McKendree, 1977).

Linears Mapping with Seasat SAR

The Seasat SAR imagery was examined with no prior review of maps, photographs or other background information on the study area. Linear features were traced directly from the imagery onto a matte acetate overlay. Linears from the 1:250,000 scale, Geologic Map of New York (Adirondack Sheet, Isachsen and Fisher, 1970; Hudson-Mohawk Sheet, Fisher et al., 1970) were visually transferred to a second acetate overlay at the scale of the SAR imagery. The linears from the SAR imagery and geologic map were compared and categorized into one of four classes (Table 1): class I linears were observed independently on both the imagery and the map; class II linears were observed on the imagery, but only after they were first observed on the map; class III linears were not observed on the imagery, even after they were observed on the map; and class IV linears were observed on the imagery but not on the map. Together, class I, II and III linears include all linears recorded on the geologic map, while class I, II and IV linears include all linears observed on the imagery--though class II linears were not observed on the first look.

Linears Analysis
An objective test of the validity of class III and class IV linears was conducted by randomly checking the linears with aerial photographs. Linears in each class were numbered consecutively. A random number generator was used to define a sufficient sample of linears to obtain 95% confidence in their interpretation. These specific linears were located, if possible, and assessed on color infrared, high altitude aerial photographic films (1:250,000 scale), using a zoom stereoscope and light table (Table 2).

The imagery and geologic map were then examined to categorize the types of indicators that were relied on for visually detecting each linear (Table 3). In addition, rose diagrams were prepared to depict the cumulative lengths of each class of linear in each 15° increment of direction (Fig. 2). These were compared to the SAR look direction, approximately N63°W.

RESULTS AND DISCUSSION

As reported in Table 1, 4,170 km of linears were recorded on the 1970 New York State Geologic Map (i.e., classes I, II and III). Of these, 80% were detectable with the Seasat SAR imagery (class I and II), though about half of these (class II) were not observed on the first analysis.

Of further significance in Table 1 is that nearly 6,900 km of linears detected on the SAR imagery were not recorded on the map. A random sample of these class IV linears was

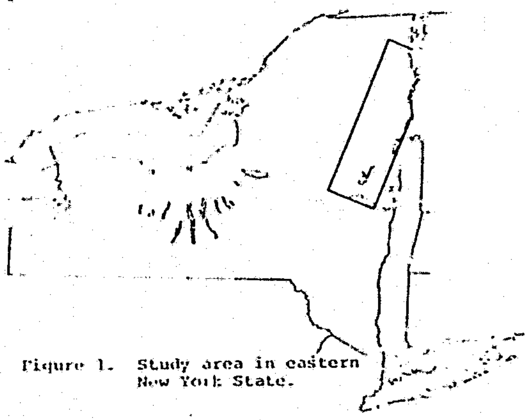

Figure 1. Study area in eastern New York State.

Table 1. Classification of linears observed on Seasat SAR imagery and geologic map.*

CLASS	LINEAR RECORDED ON MAP?	LINEAR OBSERVED ON IMAGERY?	TOTAL NUMBER	TOTAL LENGTH (km)
I	YES	YES, without checking map	213	1,719
II	YES	YES, after checking map	286	1,625
III	YES	NO	115	826
IV	NO	YES	630	6,851

*Photographic prints of Seasat synthetic aperture radar imagery, approx. 1:500,000, and 1970 New York State Geologic Map, 1:250,000.

checked with high altitude aerial photographs, and 90% were "confirmed" (Table 2). In contrast, an aerial photographic check could locate only 50% of the class III linears--mapped linears which were not detectable on the SAR imagery. Those class III linears that could be located were defined on the aerial photographs by scarps, faceted spurs, straight valleys or other features which were judged to be too short or too low in relief to be observed, or associated with a linear, on the Seasat SAR imagery. Some of these features could also have been oriented parallel or nearly parallel to the SAR look direction, causing them to be less amenable to detection (MacDonald et al., 1969). Overall, however, relatively few of the mapped linears (classes I, II and III) in the study area were oriented parallel to the SAR look direction (Fig. 2).

Lastly, the features relied on for detecting linears with Seasat SAR imagery are categorized in Table 3. As with the features used with the aerial photographs, the SAR imagery indicators included "line" features (straight valleys, straight shorelines, scarps, dark linear tones) and "point" features (ridge offsets, faceted spurs, passes, elongated lakes), the difference being defined by image scale. The numbers in Tables 2 and 3 refer to the occurrence of a specific type of feature with a linear. A count of one is added when the detection of a linear relied on one or more of the same feature (e.g., a linear defined by three passes would be tallied as one pass). If two different features were associated with the same linear, both would be counted.

In conclusion, the value of Seasat SAR imagery is apparent. Continuing study is examining the physical basis for class II and III linears, as well as the interactions with other SAR look directions. Further analysis of class IV linears would require field investigation.

Table 2. Photo-identified features associated with class III and IV linears identified on high altitude aerial photographs.

FEATURE	CLASS III No.	CLASS III %	CLASS IV No.	CLASS IV %
Straight valley	6	19	24	16
Straight shoreline	3	10	15	10
Scarp	13	42	36	24
Dark-tone line	0	0	0	0
Ridge offset	0	0	0	0
Faceted spur	7	23	23	16
Pass	1	3	36	24
Elongated lake	1	3	14	9
Linears identified / Linears sampled	20/40	50%	54/60	90%

ACKNOWLEDGMENT

This study was supported in part by Grant NGL 33-010-171 from NASA to the Cornell University School of Civil and Environmental Engineering.

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Table 1. Seasat SAR image-identified features associated with class I, II and IV linears.

FEATURE	CLASS I No.	CLASS I %	CLASS II No.	CLASS II %	CLASS IV No.	CLASS IV %
Straight valley	99	24	84	17	120	8
Straight shoreline	39	9	35	7	119	8
Scarp	72	17	67	14	105	7
Dark-tone line	54	13	101	21	356	25
Ridge offset	13	3	7	1	57	4
Faceted spur	79	19	144	30	472	34
Pass	18	4	27	6	107	8
Elongated lake	41	10	19	4	78	6

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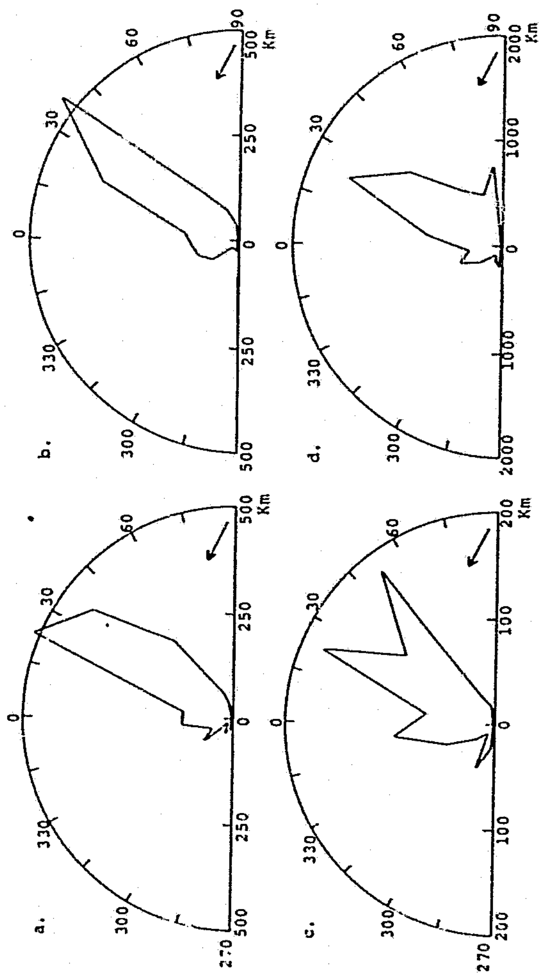

Figure 2. Rose diagrams showing cumulative lengths of (a) class I, (b) class II, (c) class III, and (d) class IV, linears, in each 15° increment of direction. SAR look direction (N63°W) is indicated by arrows. Note the different lengths of radii.

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APPENDIX D

NEWSLETTER RECIPIENTS
(June 1982)

CORNELL REMOTE SENSING NEWSLETTER

LIST OF RECIPIENTS

CAMPUS GROUPS AND INDIVIDUALS*

1. Administration

F.H.T. Rhodes	(President, Cornell)
W.K. Kennedy	(Provost, Cornell)
J.W. Spencer	(Vice Provost, Cornell)

2. Aerospace Studies (Air Force R.O.T.C.)

3. Agricultural Economics

O.D. Forker	(Chair.; Prof.)
D.J. Allee	(Prof.)
H.E. Conklin	(Prof.)
K.V. Gardner	(Sr. Ext. Assoc.)

4. Agricultural Engineering

L.H. Irwin	(Assoc. Prof.)
G. Levine	(Prof.; Dir., Center for Envir. Research)

5. Agricultural Library

6. Agronomy

R.F. Lucey	(Chair.; Prof.)
R. Bryant	(Asst. Prof.)
W.F. Croney	(Sr. Ext. Assoc.)
M. Drosdoff	(Prof. Emer.)
G.W. Olson	(Assoc. Prof.)
J.H. Peverly	(Assoc. Prof.)
T. Setter	(Asst. Prof.)
A.R. Van Wambeke	(Prof.)

7. Anthropology

8. Applied and Engineering Physics

A.F. Kuckes	(Prof.; Assoc. Dir.)

9. Architecture

H.W. Richardson	(Assoc. Prof.)

*Newsletters are sent to the main office of each department listed as well as to various individuals within the department. In addition, Newsletters are provided to graduate and undergraduate students, upon request.

10. Astronomy

F.D. Drake	(Dir., Nat'l. Astronomy & Ionosphere Center; Prof.)
C. Sagan	(Dir., Planetary Studies; Prof.)
Y. Terzian	(Chair.; Prof.)
J. Veverka	(Prof.)

11. Atmospheric Sciences (Agronomy)

B.E. Dethier	(Prof.)
W.W. Knapp	(Assoc. Prof.)
A.B. Pack	(Sr. Ext. Assoc.)

12. Biological Sciences

13. Boyce Thompson Institute

E.H. Buckley	(Plant Biochemist)
J.S. Jacobson	(Plant Physiologist)

14. City and Regional Planning

S. Saltzman	(Chair.; Prof.)
B.G. Jones	(Prof.)
K.C. Parsons	(Prof.)

15. Civil and Environmental Engineering

R.N. White	(Dir.; School of C.E.E.; Prof., Structural Eng'g.)
J.J. Bisogni	(Assoc. Dir.; Assoc. Prof., Environ. Eng'g.)
J.F. Abel	(Assoc. Prof., Structural Eng'g.)
D.J. Belcher	(Prof. Emer.)
W.H. Brutsaert	(Prof., Environ. Eng'g.)
R.I. Dick	(Prof., Environ. Eng'g.)
L.B. Dworsky	(Prof., Environ. Eng'g.)
G.P. Fisher	(Prof., Environ. Eng'g.)
P. Gergely	(Prof., Structural Eng'g.)
J.M. Gossett	(Asst. Prof., Environ. Eng'g.)
M.D. Grigoriu	(Assoc. Prof., Structural Eng'g.)
S.C. Hollister	(Prof. Emer.)
A.R. Ingraffea	(Asst. Prof., Structural Eng'g.)
I. Ishibashi	(Assoc. Prof., Structural Eng'g.)
G.H. Jirka	(Assoc. Prof., Environ. Eng'g.)
F.H. Kulhawy	(Prof., Structural Eng'g.)
T. Liang	(Prof., Remote Sensing Program)
J.A. Liggett	(Prof., Environ. Eng'g.)
L.W. Lion	(Asst. Prof., Environ. Eng'g.)
P. Liu	(Assoc. Prof., Enviro. Eng'g.)
D.P. Loucks	(Prof., Environ. Eng'g.)
G.B. Lyon	(Assoc. Prof., Environ. Eng'g.)
W.R. Lynn	(Prof., Environ. Eng'g.)
W. McGuire	(Prof., Structural Eng'g.)
A.H Meyburg	(Chair., Environ. Eng'g.; Prof.)
A.H. Nilson	(Chair., Structural Eng'g.; Prof.)

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15. Civil and Environmental Engineering (Cont.)

N. Orloff	(Assoc. Prof., Environ. Eng'g.)
T.D. O'Rourke	(Assoc. Prof., Structural Eng'g.)
T. Pekoz	(Assoc. Prof., Structural Eng'g.)
W.R. Philipson	(Assoc. Prof., Remote Sensing Program)
W.D. Philpot	(Asst. Prof., Remote Sensing Program)
R.E. Schuler	(Assoc. Prof., Environ. Eng'g. and Economics)
C.A. Shoemaker	(Assoc. Prof., Environ. Eng'g.)
F.O. Slate	(Prof. Structural Eng'g.)
J.R. Stedinger	(Asst. Prof., Environ. Eng'g.)
G. Winter	(Prof. Emer.)
C.C. Yen	(Data Analyst, Remote Sensing Program)

16. College of Agriculture and Life Sciences

D.L. Call	(Dean)

17. College of Engineering

T.E. Everhart	(Dean)

18. Computer Graphics

D.P. Greenberg	(Dir.; Prof., Arch.)

19. Computer Science

20. Computer Services

D. Gale	(Dir.)

21. Design and Environmental Analysis

22. Ecology and Systematics

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P.D. Bogdanoff	(Computer Progr.)
G.E. Likens	(Prof.)
P.L. Marks	(Assoc. Prof.)

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M. Kim	(Prof.)
W.H. Ku	(Prof.)
S. Linke	(Prof.)
P.R. McIsaac	(Prof.)
C. Pottle	(Prof.)
G.J. Wolga	(Prof.)

25. Entomology

26. Entomology Extension

27. Geological Sciences

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A.L. Bloom	(Prof.)
A. Gibbs	(Asst. Prof.)
D.E. Karig	(Prof.)
J.E. Oliver	(Prof.)
J. Ni	(Res. Specialist)
W.B. Travers	(Assoc. Prof.)

28. International Agricultural Development

J.F. Metz	(Dir.; Prof., Marketing)
L.W. Zuidema	(Assoc. Dir.)

29. International Studies Center

30. Landscape Architecture

M.I. Adleman	(Prof.)
A.S. Lieberman	(Prof.)
L. Mirin	(Assoc. Prof.)
P.J. Trowbridge	(Asst. Prof.)

31. Materials Science and Engineering

32. Mechanical and Aerospace Engineering

33. Military Science (Army R.O.T.C.)

34. Modern Languages and Linguistics

E.J. Beukenkamp	(Dir., Intensive English Program)

35. Natural Resources

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T.A. Gavin	(Asst. Prof.)
R.A. Malecki	(Asst. Prof.)
R.J. McNeil	(Assoc. Prof.)
L. Mudrak	(Ext. Assoc.)
R.T. Oglesby	(Prof.)
M.E. Richmond	(Assoc. Prof.)
B.T. Wilkins	(Prof.)

36. Naval Science (Navy R.O.T.C.)

37. N.Y.S. Agricultural Experiment Station, Ithaca

T. Hullar	(Act. Director)

38. Operations Research and Industrial Engineering

T.J. Santner	(Assoc. Prof.)
A. Schultz	(Prof. Emer.)
B.W. Turnbull	(Assoc. Prof.)

39. Plant Pathology

40. Pomology

41. Public Information

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42. Resource Information Laboratory

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E.M. Barnaba (Manager, Tech. Service)
R. Senykoff (Sr. Ext. Assoc.)

43. Rural Sociology

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44. Sociology

45. Sponsored Programs

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47. University Archives

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48. U.S. Plant, Soil and Nutrition Laboratory

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APPENDIX E

RECENT NEWSLETTERS

The Newsletter, a bimonthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

THE REMOTE SENSING PROGRAM

The Remote Sensing Program began in June 1972 with a grant from the National Aeronautics and Space Administration to the Cornell University School of Civil and Environmental Engineering. Although funding sources have broadened over the years, NASA is still a primary sponsor. Since the Program's inception, its staff has endeavored to strengthen instruction and perform research in remote sensing, building on Cornell's 30 years of experience in aerial photographic studies; to establish communication links among persons interested or active in remote sensing; and to conduct applied research projects. Certain projects that involve unique benefit- or action-producing applications of aircraft or satellite remote sensing in New York or the Northeast are performed under the NASA grant with little or no charge to the user.

Topics being examined under the NASA grant include vineyard yield estimation, vegetable crop acreage in mucklands, plant spectral response to sulfur dioxide, and natural gas exploration. In addition, the National Science Foundation is sponsoring a study of radiative transfer in non-homogeneous waters, and the Environmental Protection Agency is sponsoring work on remote sensing methods for characterizing the contents of chemical storage drums. *(Continued, p2)*.

AN OPERATIONAL LANDSAT

Landsat-4 was launched successfully on 16 July 1982. In contrast to the first three experimental Landsats, launched in 1972, 1975 and 1978, Landsat-4 is intended to provide an operational Earth-sensing capability. This will be achieved with a second generation sensor system, the thematic mapper; a multispectral scanner system similar to those on previous Landsats; and improved ground processing.

The sun-synchronous, near-polar orbit of Landsat-4 is similar to, but lower than, that of earlier Landsats, 705 km (431 mi) versus 920 km (570 mi). From the lower orbit, the spacecraft covers the entire Earth (except poles) in 233 orbits every 16 days instead of 18 days, and the orbital cycle is incompatible with the 251-orbit path/row scheme used with the other Landsats. Consecutive orbits of Landsat-4 are 2,752 km apart, and the adjacent swath to the west is covered seven days later instead of one. *(Continued, p2)*.

FALL SEMESTER COURSES

Courses in Aerial Photographic Studies and Remote Sensing that will be offered during the fall by Cornell's School of Civil and Environmental Engineering include: "Remote Sensing--Fundamentals" (Philipson), "Image Analysis I--Landforms" (Liang), and "Image Analysis II--Physical Environments" (Liang). All are 3-credit hour courses. Three variable credit hour courses, "Project,""Research," and "Thesis," will also be offered on demand. In addition to these regularly scheduled courses, William Philpot will offer a new, 3-credit hour course, "Special Topics-Introduction to Digital Image Processing." This course will emphasize image processing techniques that are widely used in remote sensing applications. Approximately half of the course will consist of lectures on image enhancement, pattern recognition, image analysis and classification, using a largely non-mathematical approach. The remainder of the course will be devoted to gaining image processing experience with batch and interactive systems. Each student will complete several projects. For information about these courses, contact Profs. Philpot or Philipson, 464 Hollister Hall, tel. 256-4330, or Prof. Liang, 453 Hollister Hall, tel. 256-5074.

ARGOS USERS CONFERENCE

Service Argos, representing CNES (Centre National d'Etudes Spatiales), NASA and NOAA, is organizing an Argos users' conference at Annapolis, Maryland, 14-15 December 1982. The conference is open to anyone, including those interested in but unfamiliar with the Argos satellite-based data collection and platform location system. A call for papers requested contributions in seven areas: meteorology, oceanography, offshore, glaciology, hydrology, biology or equipment. Abstracts of 200-300 words were due by 6 September at Service Argos, Centre Spatial de Toulouse, 18, avenue Edouard-Belin, 31055 Toulouse Cedex, France.

Cornell Remote Sensing, cont'd.

During the summer, members of the Program staff were involved in three international projects. Ta Liang spent five weeks on a soil mapping project in the Northwest Province, Zambia, where he was a consultant to the Spectral Data Corporation, working through the Regional Remote Sensing Facility in Nairobi, Kenya. Warren Philipson spent one month in the Xinjiang Region of the People's Republic of China, providing remote sensing consultations to a livestock development project; and he also spent one month in Syria, coordinating a project on developing remote sensing applications for agriculture. Both of Philipson's projects were conducted for the Food and Agricultural Organization of the United Nations, and both are continuing.

The staff of the Remote Sensing Program includes Warren Philipson, principal investigator, Ta Liang and William Philpot, co-investigators, William Teng, research specialist, and Chain-Chin Yen, computer data analyst. Donald Belcher, Arthur McNair and Ernest Hardy are general consultants to the Program, and for specific projects, assistance has been provided by many Cornell and non-Cornell personnel. Students who contributed to the Program efforts over the summer include Katherine Minden and Ellen Weeks.

LARS CALL FOR PAPERS

The 9th International Symposium on Machine Processing of Remotely Sensed Data, with special emphasis on resource evaluation, will be held at Purdue University, 21-23 June 1983. Authors interested in contributing papers should submit four copies of a 500-1000 word summary to D.B. Morrison, Purdue Univ./LARS, 1220 Potter Dr., W. Lafayette, IN 47906 (tel. 317-494-6305) by 17 December. Opportunities for reporting more recent research results will be available via one-page abstracts of poster papers, due by 25 February 1983.

Landsat-4, cont'd.

Both the thematic mapper (TM) and the multispectral scanner (MSS) scan 185-km swaths. The TM is a seven-band scanner whose spectral ranges were selected for specific applications: band 1 (0.45-0.52 μm), blue-green for water penetration, soil versus vegetation, and deciduous versus coniferous flora; band 2 (0.52-0.60 μm), green peak reflectance for vegetative vigor; band 3 (0.63-0.69 μm), chlorophyll absorption in the red for vegetation discrimination; band 4 (0.76-0.90 μm), infrared for biomass and water body delineation; band 5 (1.55-1.75 μm), infrared for vegetation moisture content, soil moisture, and snow versus clouds; band 6 (10.4-12.5 μm), thermal infrared for vegetation stress, soil moisture and thermal mapping; band 7 (2.08-2.35 μm), rock type discrimination and hydrothermal mapping. Compared to the MSS, the TM has a higher radiometric sensitivity and a higher spatial resolution--30 m in all but band 6 which is 120 m.

The MSS is essentially the same as those on previous Landsats, however, the optics have been modified to maintain a pixel size of approximately 80 m from the lower altitude. Although spectrally unchanged, bands 4, 5, 6 and 7 have been redesignated bands 1, 2, 3 and 4, respectively.

INSTRUCTIONAL VIDEOTAPES

Purdue University announces the availability of a set of five tutorial videotapes under the overall title, "Introduction to Quantitative Analysis of Remote Sensing Data." Authored and presented by staff associated with the Laboratory for Applications of Remote Sensing, the tapes run for just under 30 minutes each, with individual presentations on: The Remote Sensing Information System, The Role of Pattern Recognition in Remote Sensing, Correction and Enhancement of Digital Image Data, Spectral Properties of Soils, and The Role of Numerical Analysis in Forest Management. Accompanying each tape is a printed Viewing Notes which contains key illustrations and quotations from the tapes, as well as self-administered tests, with answers. To obtain an 8-page descriptive brochure or borrow the 10-minute preview tape, "Keep Pace with Remote Sensing," contact Mr. G.W. O'Brien, 116 Stewart Center, Purdue Univ., W. Lafayette, IN 47907 (tel. 317-474-7231).

CONFERENCES AND SYMPOSIA

Operational Interpretation of Remote Sensing Data and Outlook for Use of Future Satellite Systems (Int'l. Soc. Photogrammetry & Remote Sensing, Commission VII); 13-17 Sept; in Toulouse, France; Contact: GDTA, 18, avenue Edouard-Belin, 31055 Toulouse Cedex, France.

Fall Technical Mtg., Amer. Soc. Photogrammetry; 19-23 Sept; in Fort Lauderdale-Hollywood, Fla.; Contact: 1982 ACSM-ASP Fall Convention, 3152 Coral Way, Miami, Fla 33145 (tel. 305-446-3511).

Thermosense V, An Int'l. Conf. on Thermal Infrared Sensing Diagnostics; 25-27 Oct; in Detroit; Contact: SPIE/Thermosense V, P.O. Box 10, Bellingham, WA 98227.

3rd Asian Conf. on Remote Sensing; 4-7 Dec; in Dacca, Bangladesh; Contact: Dr. Shunji Murai, Inst. of Industrial Science, Univ. of Tokyo, 7-22, Roppongi, Minatoku, Tokyo, Japan.

Remote Sensing for Exploration Geology (ERIM 2nd Thematic Conf.); 6-10 Dec; in Fort Worth, Tex.; Contact: Remote Sensing Center, ERIM, P.O. Box 8618, Ann Arbor, Mich. 48107 (tel. 313-994-1200).

SELECTED ARTICLES AND PUBLICATIONS

Amer. Soc. Photogrammetry. 1983. Manual of remote sensing. 2nd Ed., 2 vols., 36 chaps., approx. 2400 p. Amer. Soc. Photogrammetry, 210 Little Falls St., Falls Church, VA 22046 (Prepublication prices through 15 Oct: $57.50, member; $42, student member; $77.50 nonmember; postage/handling: $3 in U.S., $6 in Canada, $10 elsewhere).

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The Newsletter is made possible by a grant from the National Aeronautics and Space Administration to Cornell's School of Civil and Environmental Engineering. Address comments to Dr. W.R. Philipson, Cornell University, Hollister Hall, Ithaca, N.Y. 14853 (tel. 607-256-4330).

The Newsletter, a bimonthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

LANDSAT FOR MONITORING VEGETABLES IN NEW YORK MUCKLANDS

Mucklands are important vegetable-growing areas in New York State. The feasibility of applying Landsat multispectral scanner data for inventorying vegetable acreage in these variably shaped and variably sized fields is being tested by the Cornell Remote Sensing Program in a study with the New York Crop Reporting Service.

An 11 July 1981 Landsat computer-compatible tape for central New York was selected on the basis of a crop calendar and the available Landsat scenes. This tape--provided by the USDA/SRS--was analyzed using a 1977 version of ORSER, modified and supplemented for operation on Cornell's IBM 370/168 computer. The remotely sensed data were related to field crop records supplied by the cooperator. The pilot area encompassed 26 fields in Madison County, N.Y. *(Continued p2)*.

LAND USE AND COVER INVENTORY IN NORTH YEMEN

The Resource Information Laboratory of the N.Y.S. College of Agriculture and Life Sciences is continuing its land use/cover project in the Yemen Arab Republic (Newsletter, Nov 1980). The objectives are to inventory and map the country's agricultural land use, develop institutional capabilities for using the resource information, demonstrate the general value of satellite remote sensing for lesser developed countries, and refine low-cost photographic image enhancement techniques.

Landsat color composites were prepared using diazo and a masking technique. The imagery included at least two dates of each of the ten scenes required to cover the country. Visually interpreted land use and cultural data from other sources were recorded in a 1:250,000 scale geographic reference system, based on the U.T.M. projection. In developing the map series, a regional geographic analysis approach was adopted, with mapping efforts planned, coordinated and executed at the national level. *(Continued p2)*.

SIR-A DATA

Data from the Shuttle Imaging Radar-A, launched on NASA's second space shuttle on 12 November 1981, are now available. The SIR-A was a synthetic aperture, L-band (1278 MHz, 23 cm) system, which imaged a 50-km swath width with a 50° incidence angle and a resolution of approximately 40 m. Imagery was acquired at selected locations--approx. 10 million sq. km.--between 36°S and 41°N latitudes. The data were optically correlated onto 13 cm film at a scale of 1:500,000. Inquiries regarding specific data availability should be directed to: NSSDC Request Coordination, Code 601, NASA/GSFC, Greenbelt, MD 20771 (tel. 301-344-6695). For general information, contact: Annie L. Holmes or Don L. Harrison, SIR-A Data Center, MS 183-701, Jet Propulsion Lab., Pasadena, CA 91109 (tel. 213-354-2386).

LATE CALL FOR POSTER PAPERS

The 17th International Symposium on Remote Sensing of Environment will be held in Ann Arbor, Mich., 9-13 May 1983. Conventional sessions and multidisciplinary poster sessions will address: new or innovative techniques; advanced sensor and data acquisition system design; advanced data processing and analysis capabilities; earth resources, environmental monitoring and information system requirements; and discipline or mission oriented projects. Persons interested in contributing a paper for a poster presentation should submit 20 copies of a 300-1000 word summary to Dr. J.J. Cook, ERIM, P.O. Box 8618, Ann Arbor, Mich. 48107 (tel. 313-994-1200), before 1 November.

CALL FOR PAPERS

The 8th Canadian Symposium on Remote Sensing will be held in Montreal, 3-6 May 1983. The general theme is the integration of remote sensing in resources management. In addition, a special session will be devoted to simulation of data from future satellite programs, such as SPOT or Radarsat. Contributors should send a 600-word abstract to Dr. F. J. Bonn, Laboratoire de Teledetection, Dept. de Geographie, Universite de Sherbrooke, Sherbrooke, Quebec, Canada J1K 2R1 (tel. 819-565-4523), before 15 November.

Vegetable Monitor, cont'd.

Supervised classification was performed using a Euclidean distance classifier ("CLASS"). Four fields each of corn, potato and onion were used for training, and two fields of each crop were used for testing. In addition, six abandoned fields were included as training data and two abandoned fields were used for testing. The best results were obtained by treating the training data for corn, potato and onion as representing two categories of each crop (i.e., bimodal distributions), with two fields each. Abandoned fields were treated as representing three categories with two fields each. The resulting accuracies ranged from 60 to 100% for the training data and 54 to 89% for the testing data. In an effort to improve these results, the spectral data were subjected to principal component and canonical transformations prior to classification; however, these transformations produced no increase in accuracy.

The work to date has been conducted by Min-hui Zhu, Shou-yong Yan and Chain-chin Yen, under the direction of Warren Philipson. Partial support has been provided by NASA grant NGL 33-010-171. For further information contact Dr. Philipson. (*see bottom p4*).

CONFERENCES/SHORT COURSES

"Remote Sensing for Exploration Geology," thematic conference; 6-10 Dec.; in Fort Worth, Tex.; $275; Contact: Remote Sensing Center, ERIM, P.O. Box 8618, Ann Arbor, Mich. 48107.

"Remote Sensing and the Atmosphere," annual technical conference of Remote Sensing Society; 15-17 Dec.; in Liverpool, England; contact: Dr. A. Anderson-Sellers, Geography Dept., Univ. of Liverpool, P.O. Box 147, Liverpool L69 3BX, England (tel. 051-709-6022 X2707/ telex 627095).

11th Alberta Remote Sensing Course; 21-25 Feb. 1983; $175; course is intended to develop practical expertise in using remote sensing for earth resource surveys and management; Contact: Alberta Remote Sensing Center, 11th Floor, 9820-106 St., Edmonton, Alberta, Canada T5K 2J6 (tel. 403-427-2381).

"The Application of Remote Sensing Techniques to Aid Range Management," international conference of Remote Sensing Society; 21-23 Sept. 1983; Contact: Mrs. Pam Cook, Short Course Secretary, National College of Agricultural Engineering, Silsoe, Bedford, England MK45 4DT.

Landsat in Yemen, cont'd.

A special training program oriented to technology identification and transfer was implemented along with, and as an integral part of, the project. Early in 1983, the Resource Information Laboratory will be conducting several workshops in Yemen. These will focus on the Landsat project as a means for collecting baseline data, while demonstrating the utility of land resource data for national planning.

Project support has been provided through the Near East Bureau of the U.S. Agency for International Development, in cooperation with the Yemen Ministry of Agriculture. For details, contact Dr. Ernest E. Hardy, Director/Principal Investigator, or Dr. Donald Senykoff, Yemen Program Manager, Box 22 Roberts Hall, Cornell Univ., Ithaca, NY 14853 (tel. 607-256-6520).

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CALL FOR POSTER PAPERS

A Symposium on the Application of Remote Sensing to Resource Management will be held in Seattle, Washington, 22-27 May 1983. Sponsored by the American Society of Photogrammetry in cooperation with the Renewable Natural Resources Foundation and its member societies, the symposium is intended to bring remote sensing technology to the resource manager or technician. Poster papers addressing case applications of remote sensing to natural resource management are solicited. Proposals should include a title, the author's name and affiliation, and a 100-word paragraph describing the application, time frame in which the application was applied, and its current status. Proposals should also include the general topic of interest (forestry, wildlife, vegetation damage, etc.). Submit proposals to Dr. Peter A. Murtha, Faculty of Forestry, Univ. of British Columbia, Vancouver, B.C. V6T 1W5 Canada.

SELECTED ARTICLES AND PUBLICATIONS

Heat Capacity Mapping Mission user's guide & data availability catalogs. Requests from U.S.: NSSDC, Code 601, NASA/GSFC, Greenbelt, MD 20771 (tel. 301-344-6695); foreign requests: World Data Center A for Rockets & Satellites, same address.

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The Newsletter is made possible by a grant from the National Aeronautics and Space Administration to Cornell's School of Civil and Environmental Engineering. Address comments to Dr. W. R. Philipson, Cornell University, Hollister Hall, Ithaca, N.Y. 14853 (tel. 607-256-4330).