1 up

Fall as PB 204 741

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

INTERAGENCY REPORT USGS-222

STUDIES IN REMOTE SENSING OF SOUTHERN CALIFORNIA AND RELATED ENVIRONMENTS

by

Leonard W. Bowden
Department of Geography
University of California
Riverside, California 92502

August 1971

Work performed by the University of California for the USGS Geographic Applications Program under USGS Contract No. 14-08-0001-10674 and for the National Aeronautics and Space Administration (NASA) under NASA Contract No. W-12570, Task No. 160-75-01-32-10.

602
N72-12341 (NASA-CR-124842) STUDIES IN REMOTE SENSING OF SOUTHERN CALIFORNIA AND RELATED ENVIRONMENTS Final Report L.W. Bowden (California Univ.) Aug. 1971 21 p G3/13
Unclas 09891 CSCL 08G 124842
(CATEGORY)

Table of Contents

Introduction

At a meeting in 1966, with the advisory committee to the National Research Council on Remote Sensing of the Environment, the concept of a southern California test site for geographic application of remote sensing for earth resources was first presented. As a result of the above meeting, a proposal titled "Remote Sensing of Southern California and Related Environments" was submitted to the United States Department of Interior (USDI) and was funded by the Geography group (later to become Geographic Applications Program - GAP) as part of the National Aeronautics and Space Administration's (NASA) discipline program in Earth Resources.

The original project involved research to be performed at the University of California, Riverside and the University of California, Los Angeles. It was believed that the southern California test site was well suited for such undertakings because of the environmental diversity of the region which enabled investigators to examine remotely sensed data of a multitude of conditions and landscapes. The prime, but not sole, source of data was the Earth Resources Aircraft Program at NASA's Manned Spacecraft Center, Houston, Texas (NASA/MSC).

The objective of the supported research was loosely defined for good reason. The tasks were exploratory and experimental. It was not fully understood whether meaningful geographic information was obtainable in an area already well documented or if the techniques and methodology could be transferred to related environments. Many of the aircraft (and later spacecraft) sensors had not been used before by Geographers in southern California - especially those sensors collecting data in the non-visible portion of the electromagnetic spectrum.

Several broad characteristics of the regional geography of southern California were investigated with regards to their feasibility to be studied by aircraft and spacecraft sensors. The investigations were conducted for two general purposes: (1) to better inventory and understand the resources and environmental circumstances of southern California, and; (2) to serve as models for future geographic analysis of other regions when using remote sensing devices.

Sample activities described in detail in this report are drawn from a heterogeneous collection of operations and tests.[1] The entire series of tests was designed to apply the technology of remote sensing to the science of Geography. In the opinion of the principal investigator, there were three geographically pertinent experiments that produced worthwhile results. The three experiments were published under the following titles:

1. Minnich, R. A., L. W. Bowden and R. W. Pease, Mapping Montane Vegetation in Southern California with Color Infrared Imagery, Status Report III, Technical Report III, April 1969, 53 pp.

[1] Described and annotated under the title Published Papers at the end of this report.

2. Mullens, R. H. Jr., Analysis of Urban Residential Environments Using Color Infrared Aerial Photography: An Examination of Socioeconomic Variables and Physical Characteristics of Selected Areas in the Los Angeles Basin, with addendum by L. W. Senger III, An Application of the Concepts of the Los Angeles Residential Environment Study to the Ontario-Upland Region of California, Status Report III, Technical Report IV, May 1969, 175 pp.

3. Johnson, C. W., L. W. Bowden and R. W. Pease, A System of Regional Agricultural Land Use Mapping Tested Against Small Scale Apollo 9 Color Infrared Photography of the Imperial Valley (California), Status Report III, Technical Report V, November 1969, 94 pp.

They will be discussed in the Experiment section later in this paper.

A technological breakthrough was produced by Dr. Robert W. Pease in his work on use of Aero Ektachrome Infrared, Type 8443, for high altitude photography. Pease's work was published under the following titles and has continued under USDI Contract 14-08-0001-11914. The papers and documentation have previously been submitted to GAP under the following titles:

1. Pease, R. W. and L. W. Bowden, Making Color Infrared a More Effective High Altitude Sensor, Status Report II, Technical Report I, March 1968. Also published as Technical Letter NASA-117, May 1968, 31 pp. and in Remote Sensing of the Environment: An Interdisciplinary Journal, Vol. 1, No. 1, January 1969, 30 pp.

2. Pease, R. W., Predicting the Relative Dye Layer Densities of Color Infrared Transparencies, Status Report III, Technical Report I, January 1969, 33 pp.

3. Pease, R. W., More Information Relating to the High Altitude Use of Color Infrared Film, Remote Sensing of the Environment: An Interdisciplinary Journal, Vol. 1, No. II, April 1970, pp. 123-125.

One experiment offered a variety of successful accomplishments. A description of it was prepared by Pascucci and North in Technical Letter NASA-132, Mission 73 Summary and Data Catalog (Pascucci and North, 1968). In retrospect, Mission 73 was scientifically weak in performance but successful in training of United States, Brazilian, and Mexican scientists and a useful demonstration of what could be undertaken as a massive regional exercise. There is no doubt that several of the professional publications and technical reports in the field of remote sensing are directly and/or indirectly influenced by the data acquisition and imagery interpretation that grew out of Mission 73. For example, the urban studies performed at Northwestern University and the University of California, Los Angeles, the studies of agricultural land use at the University of California, Riverside and Berkeley, the radiation studies at Stanford and Menlo Park, atmospheric studies at the University of California, Riverside and Barringer, Inc., the television traffic monitoring study at the University of Tennessee and East Tennessee State University, are but a few of the inputs assisted by Mission 73.

Many individual studies and small test projects were performed by the three investigators, sixteen research assistants and twenty-one lab helpers that were involved.

Experiments

Some specific goals of the research were to correlate multisensor and ground truth observations and evaluate the feasibility of sensor and sensor combinations as data-gathering components in aircraft and spacecraft. Tests conducted in three subregions, San Bernardino Mountains, Metropolitan Los Angeles, and the Coachella-Imperial Valley have shown the most promise. All three eventually determined Aero Ektachrome Infrared was the best available sensor package. In the San Bernardino Mountains the concern was for energy balance determination and vegetation association with mapping. Mr. Richard Minnich, using 1/16,000 Aero Ektachrome Infrared was able to map 1500 mi^2 of vegetation at a scale of 1/62,500. (Eight USGS quadrangles.)[2] Using a practical combination of physionomic and floristic classes he developed himself, field check verifies that Minnich mapped the total vegetation at a higher accuracy per unit area than had ever been done before. (Minnich, Bowden, Pease, 1968). The total project was completed in less than eight months. Other scales of color infrared photography were available as well as color, black and white panchromatic, radar, and thermal infrared, (TIR) imagery. Only the color infrared (CIR) was usable for high accuracy because vegetation tone, texture and class differences were not uniformly apparent in the other sensor images. However, temperature inversion lines and pockets of air drainage were detectable on some TIR. Minnich's work represents a "breakthrough" in the geographic application of remote sensing in southern California in that he developed a scientifically useful classification from the sensor image that is probably more accurate than any ground based vegetation mapping. (The test also demonstrated the practicality of CIR film-filter combinations developed by Dr. Robert Pease.)

Traditionally, remote sensing tests have been designed to take an existing classification or category or task and determine if it could be performed as well as or faster than was accomplished by direct sensing. The new projects on hazard prediction and coastal studies have adopted the lateral thinking of Minnich as a model and are striving to perfect lateral systems to older geographic work rather than duplication of updated systems. Mapping, digitalizing, storage of information, classification, etc., will be performed in the context of the sensed image or data rather than always converting back to ground-developed geographic data banks. Hopefully, therein lies a new generation of remote sensing experiments. For years we have tied our classification systems to methods compatible to "old time" field party techniques. Hopefully, new classification systems developed for Geography by remote sensing will lead to a significant input to future "Geographic Information Systems."

---

[2] Refer to Minnich, Bowden and Pease (1969), Mapping Montane Vegetation with Color Infrared Imagery, Status Report III, Technical Report III, for reproductions of eight maps.

A second study, involving the Coachella-Imperial Valley, took many months to develop. One hundred miles inland from the Pacific Coast lies an area of irrigated agriculture, small towns, and desert surrounding the Salton Sea. The Salton Sea has been a favored remote sensing test site since the days of rocket photography in the 1950's. Almost always cloud-free, the area lies at 33°N. Lat., which has often placed it within manned satellite observation range. The Imperial Valley, at the south side of the sea is 54 kilometers east-west and 77 kilometers north-south and encompasses over 600,000 acres (± 260,000 hectares) between the irrigation canals which bound the east and west sides. Flat, mostly below sea level, the cadastral pattern is a near-perfect township and range grid to test against X-Y models of machine readable sensor data. Immediately to the south is the randomly patterned Mexicali Valley of Baja California with a different economy, land tenure, land use and techniques which produces an equally attractive test contrast.

After many aircraft-borne experiments that used cameras, films, filters, thermal radiometers, radar scanners, passive microwave radiometers, etc., a final test came with the Apollo 9 Mission when near vertical multispectral and color infrared 70 mm imagery was obtained of the Imperial Valley. Mr. Claude Johnson, and others working on models designed from earlier aircraft missions, set about to verify and extrapolate the benefit of spacecraft imagery to obtain detailed, usable, i.e., machine readable, agricultural land use data. (Plate 1.) In addition he tested the applicability to both mapping and computer storage. (Johnson, Bowden, Pease, 1969.) The results show that a regional agricultural land use information map of 10 acres or smaller can be obtained from spacecraft with 3 to 4 digit Standard Land Use Codes from spacecraft providing:

1. A priori knowledge is present in the form of "crop calendars."

2. Random field survey can be used to correct anomalies.

3. The interpreter has control of the design in order to quantify the techniques.

4. Resolution of 100 meters or better is obtained.

5. Color infrared film is used.

A study differentiating the quality of residential neighborhoods in the Los Angeles area was carried out by Bowden (1968) using high altitude 1:60,000 (Missions 42 and 56) scale color infrared photography. The study contained about 400 census tracts covering the entire range of income levels and housing types in the city and compared the classification of residential areas based on the 1960 census with that developed by interpreting the CIR imagery obtained in 1967. The census data was based on mean income and mean home value per census tract while the imagery utilized a photo key involving the size and shape of houses, yard condition, swimming pools, roof color, number of automobiles, parking, street pattern, and utility services. Four broad cateogries of housing quality were delineated.

NOT REPRODUCIBLE

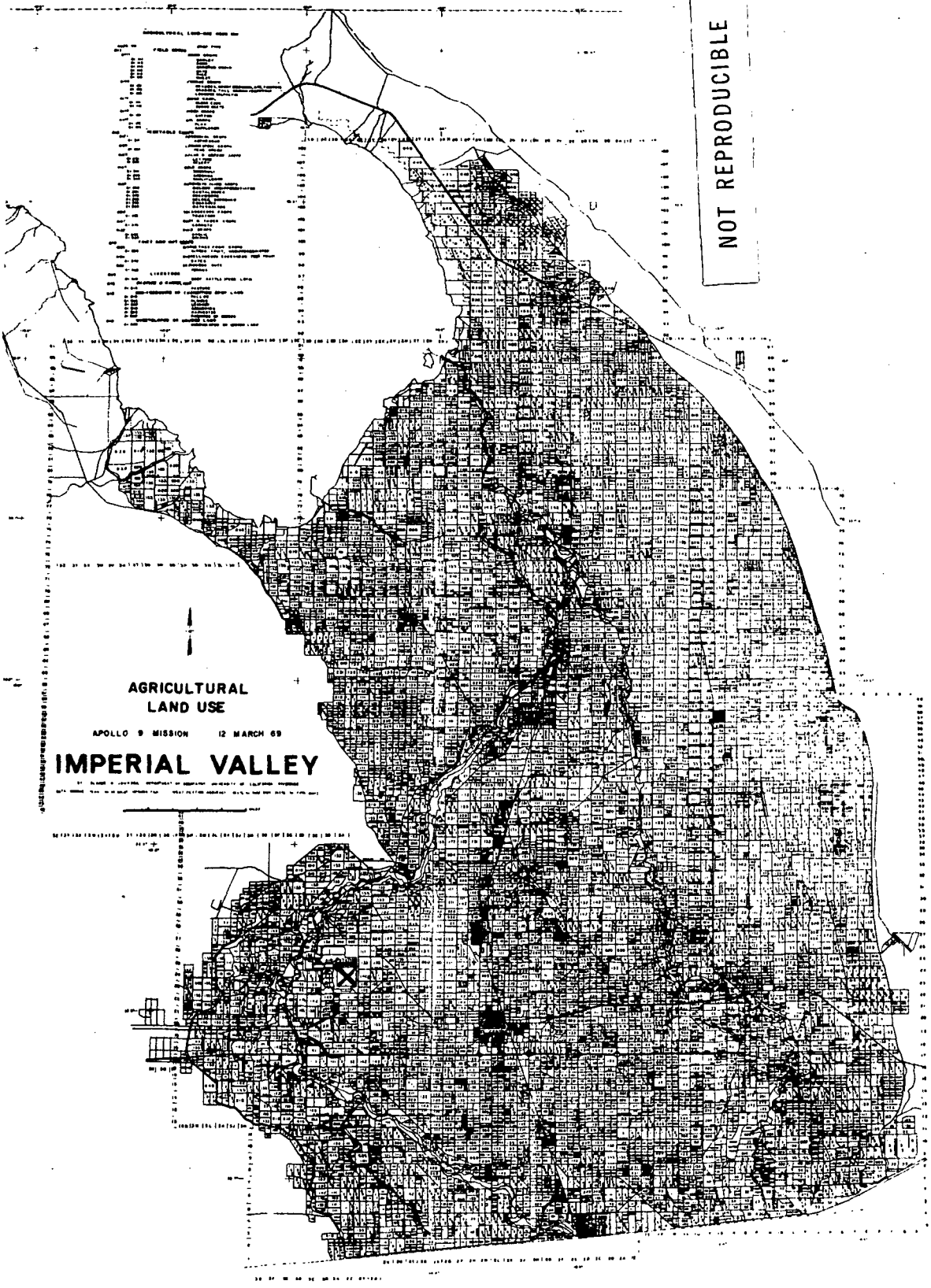


PLATE 1

Mullens (1969) used a nine category set of surrogates of housing quality derived from low altitude, 1:6,000 scale (Mission 73), color infrared photography based upon a mixture from those developed by Wellar at Northwestern University and by Bowden. Mullen's categories were dwelling type, (single or multiunit), vegetation quality, litter, vacant land, land use, location, presence of pools and patios, lot and home size, and street quality and character. He correlated these photographic surrogates employing a numerical scale from 1-5 with census variables using the Kendall Rank Correlation technique. Consistently a triplet of variables comprising quality of vegetation + the presence of litter + amount of vacant land served as the best indicators of low housing quality and correlated at values up to .86 with census tract data, despite the fact that Mullens' sample was in a very homogeneous area of Los Angeles and did not contain as wide a variation in housing quality as tests such as this would require. He also correlated the triplet surrogates from air photo interpretation (vegetation + litter + vacant land) with social rank based on occupation, income, and educational level, and with morbidity, mental health, arrests and other data from local authorities. The ranking of all categories from all areas by unweighted sums of socioeconomic variables compared with sums of all surrogate variables gave an overall correlation of .83 indicating a close association between residential area quality as identified on the color infrared aerial photographs and the socioeconomic factors identified in this study. Senger, in an addendum to Mullen's report, found similar results in a study of the Upland-Ontario area. In concluding his study Mullens noted that Wellar's surrogates need further testing in other cities to establish the limits of their applicability. While Mullens seemed less certain than Wellar that they would be consistently quantifiable, the present fragmentation of data collection between numerous federal, state, and city and county agencies does not make for consistency either.

A land use map of west and central Los Angeles using high altitude (1:60,000) color infrared photography was constructed with Mission 42 imagery (Bowden, 1968). The maps were based entirely on the imagery and ground checks indicate they were more accurate than those compiled by the Los Angeles County Planning Agency during the same year. Both land use maps were completed in two weeks as compared to several months for the Los Angeles County Planning Agency maps.

Evaluation of Sensors

Research undertaken involved the comparison and evaluation of sensor capability and extraction of information. Individual instruments and sensors were used for specific studies and reported in numerous technical reports, articles, and papers throughout the period of the contract. (See Appendix A for annotated bibliography of published and unpublished reports.) Diverse sensors such as UV absorption spectroscopy for NO_2 and SO_2 "smog" detection; Airborne Light weight Optical Tracking System (ALOTS) for high altitude, large scale imagery; Sony Portable Television for monitoring traffic flow, Bendix 3.5 to 5.5 μ Thermal Infrared Imager for air drainage patterns, and a host of black and white, color, color infrared, black and white infrared, and 8-14 μ infrared

scanner imagery was acquired. Table 1 lists an abbreviated summary of the quality of information for geographic purposes as obtained from several sensors. A qualified judgment is made (1-good, 2-fair, 3-poor, and 4-not applicable) for selected regional resource data acquisition in the most useful form (digital, scan, film, etc.).

In many ways the above table is an unfair judgment of sensor capabilities because each sensor was designed to perform special functions. The large number of 4's (which means not applicable) are indicative of the weakness of such a table. The type of information of most value to Geographers bias' the table strongly toward visible and near infrared film as the most useful sensor package. On the other hand, the table may be useful to a Geographer or resource manager without experience in remote sensing because certain sensors can be eliminated early in analysis without undue expense paid for inadequate data. In addition, some sensors have not reached peak performance because of expense of analysis or lack of interpretative understanding of the environment being recorded. It would be fair to call the table "an evaluation of sensor data as received and analyzed for resource data by selected Geographers in southern California during the late 1960's."

TABLE 1

SENSOR EVALUATION IN SOUTHERN CALIFORNIA

(Assumes Mid-Altitude Platform)

		Ultraviolet		Visible			Near IR		Intermediate IR			Microwave		
		Scanner .29-.5	Absorption Spectroscope	B/W Film	TV Camera	Color Film	B/W	Color	Scanner 3.5-5.5μ	Scanner 8-14μ	Side Looking Radar (K band)	Scanner (K band)	Scatterometer	Passive Radiometer 9.3+15.86Ghz	Passive Imager 19.35Ghz
Land Use	Rural	3	4	2	2	2	3	1	3	3	2	4	4	4	2
	Urban	3	4	2	2	2	3	1	3	2	2	4	4	4	3
	Other	3	4	2	3	2	3	1	3	3	3	4	4	4	3
Transportation	Network	3	4	2	2	2	3	2	3	2	2	4	4	4	3
	Surveillance	3	4	3	2	3	3	2	3	2	2	4	4	4	3
	Volume	4	4	3	2	3	3	3	3	3	2	4	4	4	3
Hazard Prediction	Forest Fire	3	3	3	3	2	3	1	3	2	3	4	4	4	3
	Flood	3	4	2	3	2	3	2	3	2	2	4	4	4	3
	Earthquake	3	4	3	3	3	3	3	3	3	3	4	4	4	3
Land Forms	Pattern	3	4	2	2	2	2	1	2	2	2	4	4	4	2
	Relief	3	4	2	3	2	3	2	3	3	3	4	4	4	3
	Structure	3	4	3	3	2	3	2	3	2	2	3	3	3	3
Shore Areas	Form	3	4	2	2	1	2	2	3	2	2	4	4	4	2
	Change	3	4	2	2	2	2	2	3	2	2	4	4	4	2
	Energy	2	2	4	4	4	4	3	2	2	3	3	4	4	1
Vegetation	Type	3	4	3	3	2	3	1	3	3	3	3	3	3	3
	Distribution	3	4	2	2	2	2	1	3	2	2	4	4	4	2
	Health	3	4	3	3	3	2	2	3	2	3	4	4	4	4
Soil	Class	3	4	2	3	2	2	2	3	3	3	3	4	4	3
	Distribution	2	4	2	2	2	2	2	3	3	2	4	4	4	2
	Surface Moisture	3	4	3	3	3	3	2	3	2	2	2	3	3	3
Water	Drainage Pattern	3	4	2	2	2	2	1	2	2	2	4	4	4	3
	Ground Water	3	4	3	3	3	3	3	3	2	3	3	3	3	3
	Sea State	3	4	3	3	3	3	3	3	3	2	4	3	3	2

(Source: Bowden, Leonard W., "Remote Sensing of Southern California: An Attempt to Inventory a Geographic Region," Proceedings of the Association of American Geographers, San Francisco, Vol. 2, 1970, pp. 17-21.)

Published Papers

Bowden, L. W., "Remote Sensing of the World's Arid Lands," IGU/UNESCO Symposium Sobre Desiertos Costeros, Lima, Peru, April 1967, (Univ. of Arizona Press), (in press). No abstract.

Bowden, L. W., N. J. W. Thrower and C. E. Tiedemann, Status Report on Remote Sensing of Southern California and Related Environments; Test Site 130, October 1967, 105 pp. No abstract.

Contents

Alexander, R. H., L. W. Bowden, D. F. Marble, and E. G. Moore, Remote Sensing of Urban Environments, reprinted from Proceedings of the Fifth Symposium on Remote Sensing of Environment, 16, 17, 18 April 1968, University of Michigan, Ann Arbor, pp. 889-911.

Abstract

The cities of the world are afflicted with a variety of pressing problems such as blighted neighborhoods, overloaded transportation systems, and pollution of the air and water surrounding them. The tensions and strains arising from the clustering of heterogeneous population groups within urban environments of highly variable quality places the solution of these problems high among the goals of our society. Remote sensing, it is felt, can play an important role in the study of cities and the search for solutions to urban problems, and can thus become a major component in the metropolitan information systems of the future.

Major tasks for future applications of urban remote sensing systems include (1) the delimitation of urbanism, and monitoring of its growth and decline,

(2) the determination of urban land use and internal structure, and (3) the study of urban dynamics, including rapidly-changing elements within the city and forces of the physical environment acting upon it. Recent advances in the application of photographic, thermal infrared, radar, and microwave sensors indicate that each can be used as sources of valuable data about urban environments when coupled with an appropriate information system.

Pease, R. W. and L. W. Bowden, Making Color Infrared a More Effective High Altitude Sensor, Status Report II, Technical Report I, March 1968. Also published as Technical Letter NASA-117, May 1968, 31 pp. and in Remote Sensing of the Environment: An Interdisciplinary Journal, Vol. 1, No. 1, January 1969, 30 pp.

Abstract

Although Kodak Ektachrome Infrared Aero Film, type 8443 transparency film, has long been recognized as a useful remote sensor, recent high-altitude and spacecraft images indicate that its potential is curtailed by as little as one atmospheric mass between the camera and target. Examination of the unique properties of the film indicates that significant improvement can be made by using auxiliary minus-visual filters with the necessary minus-blue filtration recommended. Although not a panacea for all uses of color infrared film, the auxiliary filter technique makes a substantial "break-through" in the use of the film at high altitudes and gives the individual investigator many more research options that utilize the near infrared.

Pascucci, R. F. and G. W. North, Technical Letter NASA-132, Mission 73 Summary and Data Catalog, August 1968, 277 pp.

Abstract

During the spring of 1968, the USGS/NASA Remote Sensing Mission 73 was carried out at the Southern California test sites in the Los Angeles Basin, the Indio Hills, the Coachella Valley, the Imperial Valley, the Salton Sea, and the Anza-Borrego Desert. The present report is concerned with the Geographic Applications sites in Los Angeles, the Coachella Valley, and the Imperial Valley.

The objective of the program was to acquire data by means of airborne sensors over an area the properties of which were being measured on the ground.

As a result of the program, remote sensing data were acquired by thirteen sensors mounted in seven aircraft. The sensors included: 1) The AAS-5 ultraviolet scanning radiometer; 2) The Barringer ultraviolet absorption spectrometer; 3) The DVC television camera; 4) A twelve-inch focal length aerial camera (using color infrared film); 5) 8 three-inch focal length Hasselblad cameras (using color and color infrared film); 6) The Raytheon microwave radiometer; 7) The Reconofax IV infrared scanning radiometer; 8) The Ryan scatterometer; 9) The Aerojet General scanning microwave radiometer; 10) An RC-8 metric camera (using black-and-white and color infrared film); 11) The Nimbus medium resolution infrared scanner; and 12) The Barnes IT-3 infrared thermometer.

Ground truth activities conducted before, during, and after the flights resulted in the acquisition of the following data: 1) Soil moisture samples; 2) Thermometric and radiometric surface temperatures at several frequencies; 3) Surface reflectance measurements; 4) Land use maps; 5) U. S. Geological Survey and U. S. Weather Bureau hourly weather readings; 6) Hourly readings of atmospheric SO_2 and NO_2; 7) Multi-spectral ground photography; 8) Urban data; 9) Calibrated test target readings; 10) Atmospheric particle counts; 11) Soil bearing strength measurements; and 12) Soil electrical resistivity measurements.

Preliminary reports based on initial examination of results have indicated several tentative conclusions. Some of the more important are: 1) Infrared Aero Ektachrome film, used with 15+80B or 15+82B filters, is the single most effective sensor for land use determination; 2) The scatterometer demonstrated potential for agricultural land use discrimination; 3) The thermal IR scanner is superior for land use determination to the ultraviolet scanner and passive microwave scanning radiometer, which show only gross correlation; 4) Several criteria for determining housing quality can be identified on black-and-white and color photography; 5) Surrogates of neighborhood quality can be identified on CIR photographs and correlations established between them and socioeconomic variations; 6) Ultraviolet absorption spectroscopic measurements correlate reasonably well with ground measurements of atmospheric NO_2 and SO_2; 7) Urbanized areas can be located on passive microwave imagery; 8) The passive microwave scanning radiometer can detect wind disturbance, hence horizontal energy transfer, over large bodies of water; 9) The MR62 and MR64 passive microwave radiometers, because of their long integration time, are of little use in determining soil moisture concentrations; 10) The scanning microwave radiometer shows potential for soil moisture determination.

Contents

Introduction

In order to appreciate the spirit and intent with which this report was prepared, it is necessary to understand the following points: 1) The report is a follow up to Status Report II, Technical Report I.* In the former, based on experiments conducted by Dr. Robert W. Pease, the emphasis was on technical aspects of using Aerial Ektachrome Infrared Type 8443 for geographic research. The latter is a demonstration of the usefulness and application of the techniques exploited in previous research. Included in the captions are references to the scientific implications of either the image or the method of sensing or both; 2) A variety of environmental situations and geographic locations are illustrated. Each caption explains the circumstances and conditions under which the image was taken and gives a cursory interpretation. In no case is the caption and description a full or detailed analysis. The amount of data that can be extracted from the photos in terms of land use, seasonal changes, descriptive landscape, geomorphic expression, vegetation identification, atmospheric and hydrologic conditions would fill many volumes and require more manhours than available to the present researchers or their assistants; 3) Most images were taken under less than ideal conditions. The majority were taken from commercial and private aircraft, often crowded with people and flying flight lines completely uncontrolled by the photographer. All of the images were photographed by either Dr. R. W. Pease, Dr. L. W. Bowden, or Mr. Richard Minnich, are obliques and all airborne imaging was through window glass. The prints were made from "inter-negatives" produced from original transparencies. The processing of transparencies was performed in the Department of Geography photo lab but most of the prints were produced by Kodak. The "inter-negative" prints are generally inferior to the original transparencies or to the few prints produced in our own darkroom. Captions occasionally describe a scene that is clearly visible on the original transparency but may be masked in the reproduction (an effort has been made to reduce this conflict as much as possible, and in no case is the caption or description all inclusive); 4) It is our belief these illustrations simulate the results obtainable from manned earth orbit missions when 70 mm or larger size film is used.

The format of this report is standard manuscript form with the description or annotation of each image preceding the image plate on opposite but facing pages. In order not to deface the images, no numbers, letters or arrows are used on the pictures themselves. The descriptions are arranged in sequence and are keyed to the images on a "left to right - upper to lower" style. For example, a appears on the upper left, b on the upper right, c on the lower left, and d on the lower right of the page of illustrations. If only two or three images are used the same left to right, top to bottom sequence applies. Most of the images were photographed in a north facing manner except for those appearing in the section on the Salton Sea Region. In each case, direction is stated in the caption if necessary for orienting the reader.

The report represents close to 1,000 hours of effort when the total time for imaging, processing, analyzing, editing, mounting, and typing is considered. In addition to Pease, Minnich and the author's effort in taking the pictures --credit is due Steven Pease for film processing; Gary Harris, R. Anthony Van Curen and Tad Widby for image interpretation; Conrad Bahre and Stephen Sandlin

for editorial assistance; Caroline Kuinius for typing and Dorothy Lewis for plate construction and report construction.

*Also distributed as Pease, Robert W. and Leonard W. Bowden, Making Color Infrared Film a More Effective High Altitude Sensor, Technical Letter NASA-117, May 1968.

Pease, R. W., Predicting the Relative Dye Layer Densities of Color Infrared Transparencies, Status Report III, Technical Report I, January 1969, 33 pp.

Abstract

A graphical method is presented whereby relative dye-layer densities of color infrared image elements can be derived from known reflectance curves. The response of each dye-forming layer in 50 nanometer wavebands across the CIR spectrum are totaled and plotted on a D log E diagram for type 8443 film, a diagram modified to fit an illumination with constant intensity for all wavelengths. From the relative dye-layer densities so derived, hue and tone of image elements can be inferred.

Application of the method is made for some common image targets showing (1) how plant reflection yields a red record, (2) the unbalancing effect of air luminance on the color of the image, (3) the reshaping of the spectral distribution of energy reaching the film with auxiliary filters to overcome this imbalance, and (4) the nature of the record for certain targets other than vegetation both at close range and aloft.

In addition an analysis is made using the method to show the effect of spectral characteristics of certain spacecraft windows on possible CIR photography through them. Space-deteriorated coatings will not yield a satisfactory CIR image whereas non-deteriorated or uncoated windows will do so.

Pease, R. W., Plant Tissue and the Color Infrared Record, Status Report III, Technical Report II, February 1969, 13 pp. No abstract.

Foreward

A number of explanations have been proposed for the photographic reaction of infrared films to the near-infrared reflection from plants. Some have held that chlorophyll is endowed with a high reflectance in these wavelengths. Another has attributed it to water included within plant tissue. Dr. Pease has combined his background in botany with an intimate knowledge of color infrared film to analyze the nature of infrared reflectance of plant tissue, particularly as it applies to the red record of color infrared film. Conclusions have been checked with spectroradiometric measurements of both living plant tissues and tissue that has been subjected to a variety of purposely controlled laboratory modifications:

Color infrared film is one of the most useful tools for remotely sensed land use analysis, particularly for crops and natural vegetation. An understanding of the physiological causes of the record it yields should be of use in the analysis.

Pease, R. W., Color Infrared Film - A Boon to Geographers Who Fly, Annals of the Association of American Geographers, Vol. 59, No. 1, March 1969, Abstracts of Papers Presented at the 64th Annual Meeting of the AAG, Washington, D. C., August 18-22, 1968, pp. 198-199.

Abstract

Geographers who attempt color slides from commercial airliner windows are frequently disappointed with results. The surface is obscured by air luminance which reduces color hues and detail to the point where they are barely distinguishable. Color infrared transparency film, commercially available in the familiar 35 mm cassettes as Kodak Ektachrome Infrared Aero type 8443, overcomes these problems and allows the geographer to realize the photographic potential of his high altitude perspective. A system of auxiliary filters developed under a NASA funded inquiry makes the system as reliable and foolproof as normal color.

In use, a G filter (Wratten 12 or 15) is used over the camera lens. By rejecting unwanted blue, the film has great haze penetrating capabilities. The suggested additional auxiliary filters are a Wratten CC30B, an 80B, or an 82B. Only one of these should be used with the basic G, not all. The use of one of the auxiliaries enhances the record of infrared reflection, removes an objectionable cyan cast of the image, and gives the film better exposure latitude.

By rendering colors falsely, the film creates color signatures that are easy to differentiate through great thicknesses of atmosphere and thereby facilitate analysis of the surface. Growing vegetation is rendered in various shades of red, urban patterns show as neutral tones of gray, and harvested crops as yellow to green. Only a little experience is necessary to make meaningful interpretations.

When the auxiliary filters are used, exposure must be approximately doubled from the ASA 100 recommended by the manufacturer (for behind-the-lens meters use ASA 160). The only drawback is that Eastman Kodak at present will not process the film. It must be done by independent labs using the E-3 system or by the user, himself.

Minnich, R. A., L. W. Bowden and R. W. Pease, Mapping Montane Vegetation in Southern California from Color Infrared Imagery, Status Report III, Technical Report III, April 1969, 53 pp.

Abstract

Geographers and other earth scientists need large area maps of contemporary vegetation in order to understand the landscape better. The requirement is difficult to fulfill because general disagreement among scientists as to whether floristic, physiognomic or similar classifications are best suited to the widest range of application. Identification through the media of remotely sensed photos and imagery partially solves the problem because classes have to be designed that are compatible to data extracted. Mapping a large area in California, such as the San Bernardino Mountains, also demonstrates that color infrared is a suitable sensor package for detailed mapping and offers potential for quantitative mapping in future systems. The level of information presented is comparable or superior to the most tedious mapping by ground survey and was accomplished in a fraction of the time.

Mullens, R. H. Jr., Analysis of Urban Residential Environments Using Color Infrared Aerial Photography: An Examination of Socioeconomic Variables and Physical Characteristics of Selected Areas in the Los Angeles Basin, with addendum by L. W. Senger III, An Application of the Concepts of the Los Angeles Residential Environment Study to the Ontario-Upland Region of California, Status Report III, Technical Report IV, May 1969, 175 pp.

Abstract

Aerial photographs have been widely used by urban planners and researchers as a valuable source of information about the urban environment since the end of World War II. Recent research sponsored by the United States government as part of the Earth Resources Survey Program has resulted in the development of a variety of new photographic techniques. The use of color infrared film (Kodak Aero Ektachrome, type 8443) has been greatly expanded as a result of improved capabilities and has shown great potential in the analysis of urban environments.

The images produced a color infrared film, (CIR) present a very detailed and informative picture of the urban environment. In this study aerial photographs taken with CIR film have been used to differentiate various types of residential areas in the Los Angeles basin, using characteristics of the physical environment which vary from one type of residential area to another. Residential areas of varying quality have been classified based on these characteristics.

The socioeconomic characteristics of large urban populations are also associated with specific types of residential environments. It is thus possible to associate the characteristics of the physical environment with socioeconomic variables within these residential environments. Features of the physical environment, identifiable on CIR aerial photography of Los Angeles are examined to determine which of these are the best indicators of "quality of residential areas" or "social areas" as determined by the socioeconomic characteristics of the inhabitants of the selected areas. Association between several physical features and the socioeconomic variables was found to exist with considerable regularity.

Alexander, R. H., L. W. Bowden, D. F. Marble, D. S. Simonett and J. E. Wilson, "Geography: Comparison of Apollo 6 and 7 Photographs," Science Screening Report of Apollo 7 Mission, NASA TM-X 58029, June 1969, pp. 49-56.

Abstract

Scientists representing disciplines related to earth resources present preliminary interpretations of the 70-millimeter photography taken by the crew of the Apollo 7 spacecraft. The photographs are compared with photographs taken at conventional aircraft altitudes and are evaluated regarding applications. The individual photographic frames were examined with reference to important interpretation parameters. Uses and benefits in the areas of land-use planning, cartographic production, weather forecasting, oceanographic studies, regional geology, hydrological analyses, and agricultural surveys are described.

Johnson, C. W., L. W. Bowden and R. W. Pease, A System of Regional Agricultural Land Use Mapping Tested Against Small Scale Apollo 9 Color Infrared Photography of the Imperial Valley (California), Status Report III, Technical Report V, November 1969, 94 pp.

Abstract

Interpretation results of the small scale CIR photography of the Imperial Valley (California) taken on March 12, 1969 by the Apollo 9 earth orbiting satellite have shown that world wide agricultural land use mapping can be accomplished from satellite CIR imagery if sufficient a priori information is available for the region being mapped. Correlation of results with actual data is encouraging although the accuracy of identification of specific crops from the single image is poor. The poor results can be partly attributed to only one image taken during mid-season when the three major crops were reflecting approximately the same and their CIR image appears to indicate the same crop type. However, some incapacity can be attributed to lack of understanding of the subtle variations of visual and infrared color reflectance of vegetation and sorrounding environment. Analysis of integrated color variations of the vegetation and background environment recorded on CIR imagery is discussed.

Problems associated with the color variations may be overcome by development of a semi-automatic processing system which considers individual field units or cells. Design criteria for semi-automatic processing systems are outlined.

Pease, R. W., More Information Relating to the High Altitude Use of Color Infrared Film, Remote Sensing of the Environment: An Interdisciplinary Journal, (in press).

Abstract

Use of EA-4 processing for color infrared film and observed deviations from normal sensitometric characteristics modify the previously made recommendations for the use of auxiliary minus-visual filters with the film system. With this processing, the need to equalize dye-forming layer sensitivities to combat the color shift due to air luminance can be met with filters that attenuate less the visual wavelengths. Loss of cyan sensitivity due to aging, on the other hand, increases the attenuation need. Simple tests are suggested whereby the user can ascertain the sensitometric characteristics of his film.

Presented Papers

Bowden, L. W., Alexander, Marble and Moore, Remote Sensing of Urban Environments, Invitational Paper, 5th Symposium on Remote Sensing, U. of Michigan, Ann Arbor, April 1968.

Bowden, L. W. and R. W. Pease, "Remote Sensing and Its Relation to the Earth's Budget," Invitational Paper, IGPP, University of California, Riverside, May 1968.

Bowden, L. W., "Remote Sensing of Natural Resources," Invitational Paper, Instrument Society of America, San Diego, California, December 1968.

Bowden, L. W., "Remote Sensing of the World's Arid Lands," IGU/UNESCO Symposium Sobre Desiertos Costeros, Lima, Peru, April 1967, (University of Arizona Press), (in press).

Bowden, L. W., "Mission 73: An Experiment in Remote Sensing in Southern California," Association of Pacific Coast Geographers, Annual Conference, San Fernando Valley State College, Northridge, California, June 13, 1969.

Minnich, R. A., "Mapping Montane Vegetation with Color Infrared Imagery," Association of Pacific Coast Geographers, Annual Conference, San Fernando Valley State College, Northridge, California, June 13, 1969.

Johnson, C. W., "Land Use of the Imperial Valley: Determined from Apollo IX Color Infrared Imagery," Association of Pacific Coast Geographers, Annual Conference, San Fernando Valley State College, Northridge, California, June 13, 1969.

Mullens, R. H., "Analysis of Urban Residential Environments in the Los Angeles Basin Using Color Infrared Aerial Photography," Association of Pacific Coast Geographers, Annual Conference, San Fernando Valley State College, Northridge,California, June 13, 1969.

Johnson, C. W., "Agricultural Land Use of the Imperial Valley as Determined from Apollo IX Color Infrared Imagery," Program Review, NASA Manned Spacecraft Center, Houston, Texas, September 1969. (to be published).

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. USGS-DO-71-Ø17	2. Gov't Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
Studies in Remote Sensing of Southern California and Related Environments

5. Report Date
August 1971

6. Performing Organization Code

7. Author(s)
Leonard W. Bowden, University of California

8. Performing Organization Rept. No.
IR-USGS-222

9. Performing Organization Name and Address
U.S. Geological Survey
Geographic Applications Program
Washington, D.C. 2Ø242

10. Project/Task Work Unit No.
16Ø-75-Ø1-32-1Ø

11. Contract/Grant No.
NASA W-1257Ø
USGS 14-Ø8-ØØØ1-1Ø674

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 2Ø546

13. Type of Report & Period Covered
Final report

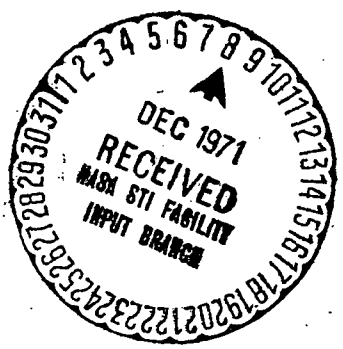
14. Sponsoring Agency Code

15. Supplementary Notes
Work performed by the University of California for the USGS Geographic Applications Program under USGS contract no. 14-Ø8-ØØØ1-1Ø674

16. Abstracts This report summarizes the research activities in southern California to determine whether meaningful geographic information was obtainable by use of remote sensing in an area already well documented or if the techniques and methodology could be transferred to related environments. Several broad characteristics of the regional geography were investigated with regards to their feasibility to be studied by aircraft and spacecraft sensors to improve the inventory and understanding of resources and environmental circumstances and to serve as models for future geographic analysis of other regions when using remote sensing devices. Sample activities are described in detail and three experiments producing worthwhile results are highlighted: mapping montane vegetation with color IR imagery, analysis of urban residual environment using color IR aerial photography, and regional agricultural land use mapping tested against color IR photography. Bibliography

17. Key Words and Document Analysis. (a). Descriptors
Sensors characteristics, Color infrared photography, Urban land use, Land use mapping, Infrared mapping, Terrain intelligence

This is DRA
CR # 124647
W/12-71



17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 8F

18. Distribution Statement	19. Security Class (This Report)	21. No. of Pages
Unclassified - Unlimited	UNCLASSIFIED	22
	20. Security Class. (This Page) UNCLASSIFIED	22. Price $3.00/$0.95

FORM NBS-867(1-70)