(E75-10197) USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION, AND MAPPING OF SALT-AFFECTED SOILS IN CALIFORNIA Final Report, 15 Jul. 1972 - 15 Jul. 1973 (California Univ.) 18 p HC $3.25 CSCL 08B G3/43

N75-21722

Unclas 00197

SPACE SCIENCES LABORATORY

01 STIF E7.5-10.1.9.7 III

USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION AND MAPPING OF SALT-AFFECTED SOILS IN CALIFORNIA (UN327)

CR-142383

A report of work done by scientists at the Department of Soils and Plant Nutrition, University of California, Davis, under NASA Contract No. NAS 5-2187

1317I

Final Report
14 July 1973

UNIVERSITY OF CALIFORNIA, BERKELEY

Final Report

USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION, AND MAPPING OF SALT-AFFECTED SOILS IN CALIFORNIA (UN327)

Co-Investigator: Gordon L. Huntington

Contributors: James Thayer, Eugene L. Begg, Fred W. Herbert
Jack K. Clark, William E. Wildman, Hays Fisher

Department of Soils and Plant Nutrition, Davis Campus

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION AND MAPPING OF SALT-AFFECTED SOILS IN CALIFORNIA

5. Report Date
14 July 1973

6. Performing Organization Code

7. Author(s)
Gordon L. Huntington, et al.

8. Performing Organization Report No.

9. Performing Organization Name and Address
Department of Soils and Plant Nutrition
University of California
Davis, California 95616

10. Work Unit No.

11. Contract or Grant No.
NAS5-21827 , Task 9

12. Sponsoring Agency Name and Address
Goddard Space Flight Center
Greenbelt, Maryland 20771

13. Type of Report and Period Covered
Type 3: 15 July 1972- 15 July 1973

14. Sponsoring Agency Code

15. Supplementary Notes Originally prepared as Chapter 10 in "An Integrated Study of Earth Resources in the State of California Based on ERTS-1 and Supporting Aircraft Data", Robert N. Colwell, principal Investigator, Space Sciences Laboratory, Univ. of Calif., Berkeley, Calif.

16. Abstract
The co-investigator received ERTS-1 imagery of the Great Valley of California for each 18-day cycle for the purpose of investigating the usefulness of satellite imagery for extensive, periodic mapping of salt-affected soils in the state. Study involved 4 selected areas within the Great Valley that contained typical salt and/or alkali-affected soils. Over-flight and on-site field studies were used to relate ground-truth to visible features on the imagery that could be recognized and interpreted by experienced soil scientists. Characteristic features of saline-alkali or alkali soils, "haloblems", were recognizable and provided a rough indication of location and extent of these soils. Variable patterns of infrared reflectance from vegetation on salt-affected lands were investigated as additional means of identification and delineation. Imagery resolution of these patterns not totally adequate for infallible recognition at this stage. May require larger scale imagery from future satellites for practical recognition of saline soils lacking "haloblems".

17. Key Words (Selected by Author(s))
Mapping
Saline soils
Alkali soils
Infrared reflectance
Soil Survey

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	17	

PREFACE

The object of this investigation has been to explore the effectiveness of ERTS-1 imagery as a means for extensively identifying and delineating salt-affected lands within California. The work entailed a photo-interpretive study of imagery received for each 18 day period covering the Great Valley of California. A search was made for distinctive patterns and tonal differences that would reliably identify image areas of salt-affected soils on either B&W transparencies or infrared color composites.

Studies to this point are encouraging, but indicate the need for at least an additional year's set of imagery to select the best time, or times, to identify the various diagnostic features. Irregular areas essentially devoid of normal vegetation because of saline, saline-alkali, or alkali soil conditions ("haloblems") were readily detectable in natural areas by experienced interpreters. Detection was less reliable on cultivated, partially reclaimed lands. A new method in electronic image enhancement, not developed in this project, showed promise of improving detection in the cultivated areas.

Springtime was thought to be the best period for identifying salt-stressed vegetation on affected soils. Inconclusive results with color infrared images suggested a lack of resolution of tonal patterns that otherwise would be useful to distinguish certain areas of salt-affected soils.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1 INTRODUCTION

The pressure of an increasing population has brought about a diversion of much of the better land in the state from farm use to urban, suburban, or industrial use. The economics of land value under these conditions and the geography of the state have forced agriculture in many areas to move to poorer lands, including those affected by salts or alkali. In spite of this, California agriculture has continued to grow, and successful reclamation of salt-affected soils has been accomplished in many areas through the application of present knowledge.

Over 70 percent of the salt-affected soils mapped in the state are located in the Great Valley of California -- the combined Sacramento and San Joaquin Valleys. A wide variety of these soils exist here under varying conditions of climate and land use. For these reasons, this centrally located region was selected for preliminary studies with ERTS-1 imagery.

Most of the salt-affected soils are located in the drier San Joaquin Valley. Very generally speaking, saline-alkali and alkali soils exist east of the axial trough of the San Joaquin Valley, while saline soils are more prevalent in the trough and on the west side of the Valley. In the Sacramento Valley, nearly all salt-affected soils are west of the Sacramento River and are saline-alkali in character. Extensive development of cropland in both valleys in recent years has drastically and extensively altered the concentration of salts and the character of thousands of acres of soils previously mapped as salt-affected. Examples of such areas lie in the naturally saline soil region west of the San Joaquin Valley trough, which have been partially or wholly reclaimed within the past 30 years. In places, some of these soils are again becoming saline as a result of rising local water tables from increased irrigation on higher parts of the alluvial fans.

Over many years, soil surveys of segments of the state have laboriously gathered information concerning the nature, location, and extent of a large portion of the salt-affected soils in California. However, due to the short time-variable nature of salt related properties of these soils there is no current, reliable record on the present over-all status of saline and alkali soils in California. This has drawn attention to the need for a more rapid means of inventory and evaluation of these soils for both short and long-range land use planning and management. The potential of satellite imagery as a means of extensive, periodic monitoring of these soils was pursued in this investigation. ERTS-1 imagery was used to evaluate this potential.

2 PROCEDURE

ERTS-1 imagery in all 4 bands of the MSS was requested to cover California's Great Valley throughout the year. All images, as received, were immediately inventoried, cataloged, and filed to be available to this investigation and to other co-investigators of the University ERTS-1

Project. Eighteen-day cycle maps showing the location and extent of coverage of each set of images were prepared and keyed by their observation ID. The 9 x 9 inch positive transparencies from channels 4, 5 and 7 were used to make Fisher-Wildman Diazochrome infrared color composites. (See Wildman, et al. Use of ERTS-1 Data in the Educational and Applied Research Programs of Agricultural Extension, Task 8 of Contract NAS5-21827 for ERTS-1 Investigation).

Intensive field study has been focused on four selected areas known for their saline-alkali soil conditions. These are:

1. Willows-Colusa region. Ricelands and water fowl refuge areas in the westside basin lands of the central Sacramento Valley.

2. The Dozier area. Salt-affected grasslands on the westside basin rim of the lower Sacramento Valley, northwest of Rio Vista and east of Travis Air Force Base.

3. Firebaugh-Mendota region. East and west basin rim lands and basin lands of the central San Joaquin Valley, west and northwest of Fresno.

4. Tulare Lake-Lost Hills regions. Basin and basin rim lands in the southern San Joaquin Valley.

Imagery taken in late summer and early fall of 1972 and in late spring of 1973 was studied by experienced soil scientists in the laboratory, in the field, and in flight. Visible features on the imagery of areas known to have salt-affected soils were compared with selected aerial photogaphy and recent soil maps of the same areas, and the analysts have drawn on their own past experience with the surface appearances of salt-affected soils.

A special laboratory study was undertaken to investigate the effects of low resolution on the image product from complex patterns of infrared reflection due to complex patterns of healthy and stressed vegetation normally associated with salt-affected soils. The study determined 7 vegetation cover classes representative of cropland or natural areas associated with these soils in California. Patterned diagrams were prepared to represent these classes and each was subjected to photographic distortion to approximate low resolution imaging. The products were compared to ERTS-1 images of known areas.

3 FINDINGS

3.1 B&W Patterns and Tones

Only a very few images on B&W positive transparencies taken of the study areas between early October 1972 and late March 1973 have been useful due to excessive cloud and/or fog cover. Images of areas free of clouds and fog during this period were found to be only of limited value due to darkness of the positives (presumably a function of low sun angle). During this period, the greatest contrasts were found on band 7. During the spring and summer when better imagery was available, band 5 was found to be most useful for field inspections.

The most notable pattern signatures found on the ERTS-1 imagery, indicative of salt-affected soils, was found to be the contrasting, light toned, irregularly shaped clusters of small, barren soil areas. These are popularly known as "scald spots", "slick spots", or "puff spots". The first two names commonly refer to hard, barren areas of surface soil that are high in exchangeable sodium, and may either lack or have slight to moderate amounts of soluble salts. "Puff spots" may or may not be high in exchangeable sodium, but do have high amounts of soluble salts (more than 1 percent). In addition, somewhat rounded, barren depressions are often associated with the aforementioned irregular, light toned areas. These are playas. They range in size from less than an acre to about 80 acres and seasonally collect and hold shallow bodies of water that eventually evaporate. They are also alkali or saline-alkali affected and contribute to the identification of salt-affected soil areas. Within limits of resolution, these light toned areas are all detectable on ERTS-1 imagery, but the several conditions involved are not distinguishable.

The term "haloblem" is proposed to identify these areas or spots. It is derived from two elements: "halo-", of or pertaining to salt; and "blem" from blemish. It is similar in construction to the newly accepted term "astroblem" that refers to meteor impact patterns on the earth's surface.

Haloblems are best identified on band 5 images of unreclaimed areas of salt-affected soils, but they are also recognizable on partially reclaimed and cropped lands. They are important surface features to use in determining the extent of affected areas, particularly saline-alkali soils. The irregular, light and dark patterns can be used to class alkali or saline-alkali soils on the basis of percent of surface area affected. Care must be exercised to distinguish haloblems from droughty sand streaks or exposed light colored subsoils in leveled lands that are not salt-affected. The distinction by image interpretation is not infallible, but knowledge of the local geomorphology and landform relationships involved is helpful.

On the ground, haloblems range from about 1 to 2 feet up to as much as 400 to 500 feet in diameter. They occur singly or in varied clusters. The resolution limit for visibility of single blemishes or clusters on ERTS-1 imagery is about 300 feet. In clusters at the limit of detectability, about 50 percent of the area is barren soil and the remainder a cover of sparse, darker toned vegetation. Verification of these patterns on the ERTS-1 imagery has been accomplished by use of low-oblique photos taken from approximately 5,000 feet, and from on-site field investigations. The most extensive areas of these haloblems are observed in the basin rim lands on the east side of the San Joaquin Valley in Fresno, Merced, and Madera Counties. (See Figures 1, 2, and 3). Few or no haloblems were identified on images of westside basin rim lands with saline soils, but many are to be seen near Lost Hills where the soils are saline-alkali. In the Dozier area, south of Dixon and east of Travis Air Force Base, rounded playas are a part of the haloblem patterns. They range in size from less than an acre to about 80 acres. On the 9 x 9 inch transparencies, one large playa is visible without magnification, while others down to about 5 acres appear as individual entities under low power magnification. (See Figures 4 and 5).

Samulson and Sakrison (co-investigators on the ERTS-1 Investigation entitled "Digital Handling and Processing of Remote Sensing Data", Task 7 of Contract NAS5-21827), in cooperation with this investigation, prepared a trial electronic enhancement of a large area of saline-alkali soils in Madera County, including lands that had been recently reclaimed and cropped to alfalfa, cotton, and irrigated pasture. Cultural patterns were tending to confound detection of known haloblems on the ERTS-1 imagery. The enhancement, which deemphasized straight-line patterns, recreated an image strikingly similar to 1950 aerial photography of the same area taken long before its current stage of development. Identification of existing haloblems was improved and a better interpretative evaluation was able to be made of reclamation changes in the salt-affected soils.

3.2 Color Infrared Patterns and Tones

Diazochrome infrared color composites prepared in the laboratory, and ERTS-1 infrared color prints received on special order, have been studied. To date, no consistent detection has been made of reduced infrared reflectance from fields of irrigated crop plants growing in known areas of salt-affected soils in comparison to the same kinds of crops growing in soils known to be non-salt-affected. Infrared color composites from early fall ERTS-1 imagery were compared, area for area, with low-oblique infrared color transparencies taken over portions of Fresno and Madera Counties in early October, 1972. The latter showed some reduced reflectance from alfalfa growing in slightly salt-affected soils, but patterns were not consistent. At that time of year, near the end of the irrigation season, growing plants are subject to normal moisture stresses that reduce vigor under most circumstances so that pattern consistency should not be expected. This was an early indication of the importance of image timing and seasonal plant growth in this work.

Late summer imagery showed some slight variations in the tonal character of the infrared reflectance signatures detectable from rice in the Sacramento Valley. Another season's imagery and closer ground checking would be necessary to determine whether these variations were soil borne - nutrient deficiencies, or soil salinity - or were due primarily to varietal or crop maturation differences.

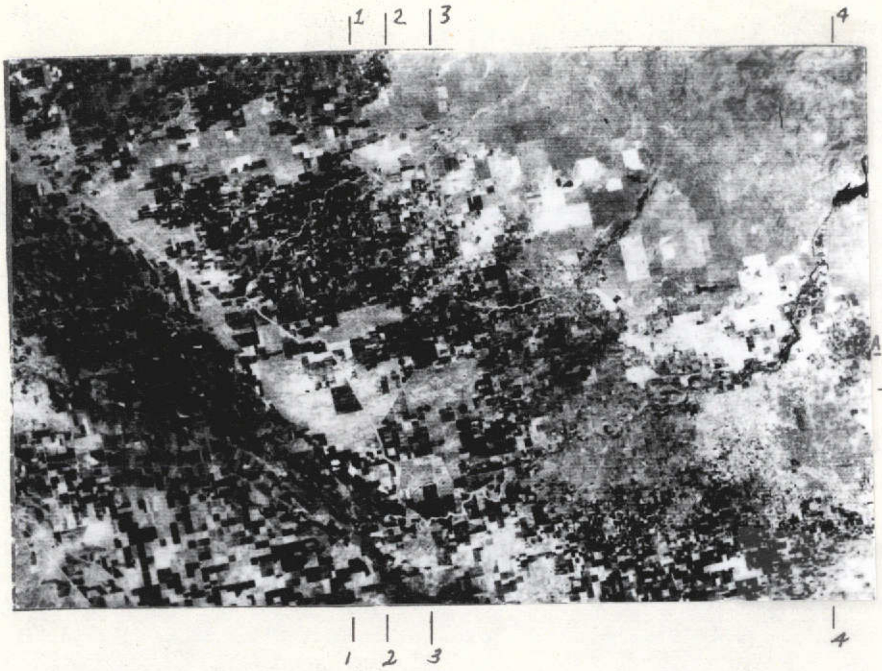

Figure 1. Portion of ERTS-1 image 1056-18114-5, Firebaugh -Mendota region. (A1 - location of Figure 2; B2 - location of Figure 3; A3 - "haloblems"; B4 - City of Fresno).

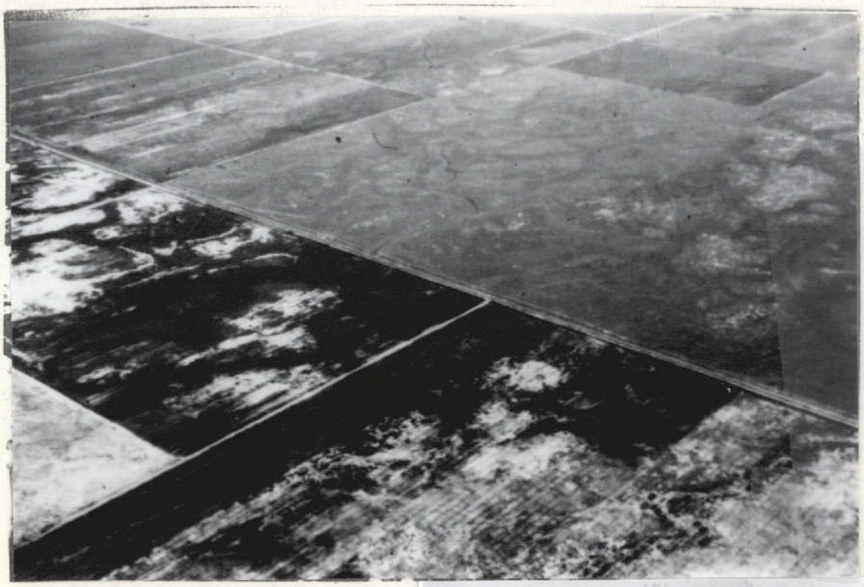

Figure 2. Low oblique taken in Fall 1972 depicting "haloblem" patterns associated with cultivated lands.

Figure 3. Low Oblique taken in the Fall 1972. Native alkali alkali pasture lands typical to the San Joaquin Valley. Reclaimed land under irrigation in the background.

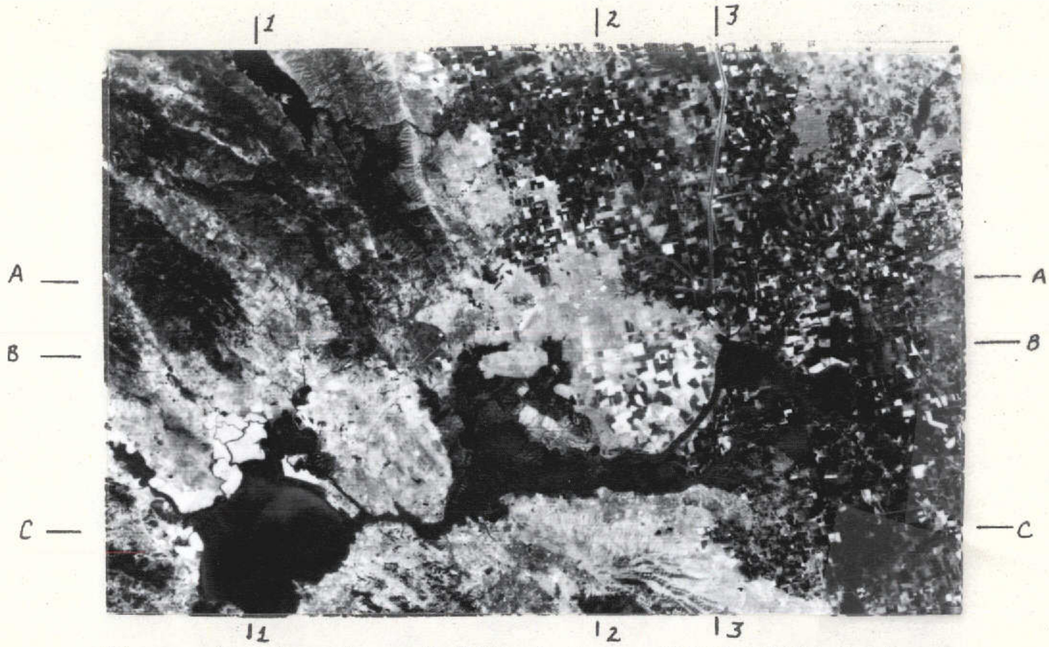

Figure 4. Portion of ERTS-1 image 1003-18175-5, Dozier area, Sacramento Valley. (C1 - San Pablo Bay; A2-80 acre playa SW of Dozier; B3 - Town of Rio Vista on the Sacramento River)

Figure 5. Low oblique taken late Spring 1973. Native grasslands west of Dozier with 80 acre salt playa and smaller scattered playas in the background.

After studying many of the infrared color composites and reflecting on the nature and variability of salt-affected soils and of the normally associated patterns of vegetation, it was apparent, notwithstanding the clarity of the ERTS-1 imagery and apparent sharpness of certain lines and field boundaries, that the imagery had less than the needed resolution for a reasonably detailed detection of salt-affected soils. This statement refers only to the use of infrared color as a means of detection of salt-affected soils, particulary for saline soils and for classes of alkali or saline-alkali soils that are affected only in their subsoils, or that may lack haloblems as an alternate means of detection.

If the variability of infrared reflectance, known to occur from vegetated areas of salt-affected soils because of variability in plant vigor, could be reliably detected and interpreted on the satellite imagery, better mapping of these soils could be accomplished than is possible presently by means of haloblem recognition alone. One means of obtaining this would be through higher resolution imagery from longer focal length sensors, such as may become available in SKYLAB, or in succeeding environmental and resource monitoring satellites. Lacking these resources, further laboratory study was undertaken, as outlined under PROCEDURE, to delve further into the capability of the existing imagery.

After review of the existing soil and vegetation patterns in the four areas under study, it was determined that 7 vegetation cover classes would provide adequate and meaningful groupings for all crop-soil and natural vegetation-soil patterns to be encountered. The classes provided an orderly means of analyzing and comparing land areas and images of the same. They reflected the general vegetation cover and bare ground patterns seen from overhead on lands variably affected by salt.

Vegetation Cover Classes:

1. Full cover -- healthy plants only.

   Complete cover of the soil by healthy plants; no bare ground visible from overhead; IR reflectance essentially uniform from whole area of units of this class; soils non-salt-affected.

2. Full cover -- healthy and stressed plants.

   Complete cover of soil by healthy plants and by plants of less vigor because of salt stress; IR reflectance from whole area of units of this class, but variable in intensity; units have complex of salt-free soils and soils with slightly affected surfaces or salt-affected subsoils only.

3. Full cover -- stressed plants only.

   Complete cover of soil with plants of low vigor; no bare ground visible from above; IR reflectance from whole area of units of this class, but low intensity; all soil slightly affected in the surface or in subsoil.

4. Partial cover -- healthy plants and bare ground.

   Healthy, vigorous plants cover only a part of units in this class; bare ground visible from above; IR reflectance from plants only, not from ground; usually a salt-free soil area.

5. Partial cover -- healthy plants, stressed plants, and bare ground.

   Plants cover only a part of units in this class, some are healthy and vigorous, some are low in vigor; bare ground visible from above; IR reflectance from plants only, but variable - not from bare ground; complex of salt-free and salt-affected soils.

6. Partial cover -- stressed plants and bare ground.

   Plants cover only a part of units in this class; all plants low in vigor; IR reflectance from plants only, but low intensity; moderately to strongly salt-affected soils.

7. Barren -- bare ground only.

   No significant plant growth, only bare ground visible from above; no IR reflectance; strongly salt-affected soils, or very droughty area, or fallowed land.

Giving consideration to these groupings, which are a simplification of possible cover combinations, it is evident that there are many possible patterns of different IR reflectance energy levels. When seen on low resolution imagery, these patterns may become mixed or smudged and confounding patterns or inconsistent color intensities result. Class 1 and Class 7 offer the least problems, so long as resolution is sufficient to image minimum desired units of the classes. The latter is dependent upon the desired scale of mapping. Rice or alfalfa fields or other closed canopy crops on salt or alkali free soils would be representative of Class 1. Class 7 has a few interpretive options within the assumptions used to define the classes. In natural areas, a unit would likely indicate an area of strongly salt-affected soils. In cultivated areas, it would likely represent a fallowed field of salt-free or salt-affected soils if boundaries were regular; if irregular, it would likely represent an area of strongly salt-affected soil.

Geometric and random number controlled patterns have been prepared in the laboratory to resemble, on a small scale, cropping patterns such as plant settings in orchards or vineyards and field crops, or natural patterns of vegetation. These geometric and random patterns have been applied to vegetation cover classes 2 through 6. Optically degraded images of each have been prepared for comparison with areas on Diazochrome color composites in an attempt to predict the actual detailed vegetation patterns, stressed or unstressed, of the selected areas.

Two examples of these patterns are given in Figure 6. Both have about 50 percent red on blue. Figure 6(a) is one of several geometric patterns approximating open planting in orchards or vineyards. This would be placed in cover class 4 showing only healthy plants and bare ground. Figure 6(b) has been degraded to simulate a lowering of resolution. Note the paler appearance of the "tree or vine" rows. This is strikingly similar to the pale reddish appearance of most healthy orchards or vineyards observed on ERTS-1 color infrared imagery at hand., indicating the diluting effect of the low, or no IR reflectance from the closely intermingled areas of bare ground with the strong IR reflectance from the scattered trees or vines. The paler color in Figure 6(b) may also be due in part to the effect of the thin white borders around each red square.

Figure 6(c) also represents a cover class 4 pattern, but a random one presumably of healthy vegetation and bare ground. At lower resolution (Figure 6(d)) there appears to be a change in the proportion of bare ground, and the appearance of a class 5 cover with some stressed vegetation is suggested. This indicates greater care may be needed in interpreting these images for areas of salt-affected soils. Further study is needed to pursue this phenomena to minimize the potential error.

3.3 Limitations and Problems

The darkness of the imagery and the high probability of cloud or fog cover over the Great Valley during the winter months make this a poor time to select for the purposes of this investigation. The imagery received during this reporting period and the understanding gained from it as to its nature and potential for our purposes has strongly indicated the need for a longer period of coverage. An additional cropping season or longer is needed to study the variation in infrared reflectance from common, salt-tolerant crops growing on both salt-affected and unaffected soils. This guideline imagery is necessary for basic interpretive aids and would also determine more clearly the best time, or times, of the year to select imagery for future periodic surveys.

The correlation of ERTS-1 imagery with ground truth information secured from low altitude flights and on-site observations is time critical, particularly during the spring months. It was unfortunately hampered during the spring by adverse weather and longer than usual delays between the ERTS overpass and actual receipt of imagery.

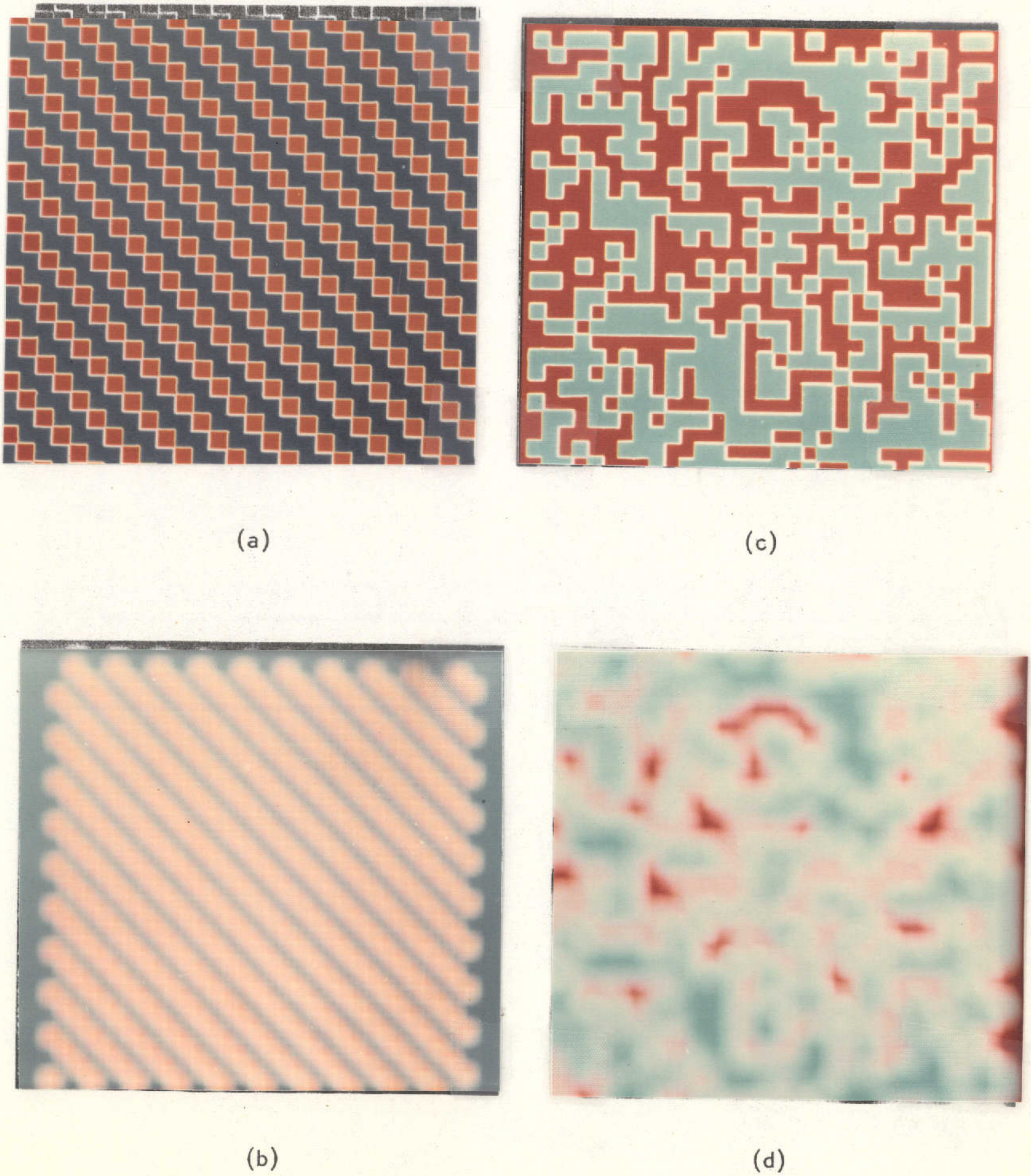

Figure 6. Examples of vegetation cover class patterns prepared to study the effect on color infrared imagery of complex, contrasting ground patterns with dimensions less than the limit of resolution of the imagery.

4 CONCLUSIONS

The study of the proposed method of periodic inventory of salt-affected soils by use of satellite imagery is encouraging in some aspects. A complete evaluation is not possible at this point.

The recognition and delineation of haloblems on given imagery offers a rough approximation of the locations of salt-affected soils, particularly saline-alkali or alkali soils. More accurate delineations of all areas of salt-affected soils would be achievable with certainty-of-recognition of the varied infrared reflectance patterns ascribable to vegetation growth responses on these soils. It may be that higher resolution, larger scale imagery will be necessary.

From a general viewpoint, studies of ERTS-1 imagery for a period of time are most convincing of the tremendous value such regular, continuing coverage has for a wide range of earth studies.

5 GLOSSARY OF TERMS

*SOIL - A natural body at the immediate surface of the earth that consists of unconsolidated mineral matter that has been subjected to, and influenced by, genetic and environmental factors of: parent material, climate (including moisture and temperature effects), macro- and micro-organisms, and topography, all acting over a period of time and producing a product - soil - that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics.

*SALT-AFFECTED SOIL - Soil that has been adversely modified for growth of most crop plants by the presence of certain types of exchangeable ions or of soluble salts.

*ALKALI SOIL - A soil with a high degree of alkalinity (pH of 8.5 or higher), or with a high exchangeable sodium content (15% or more of the exchange capacity), or both.

*SALINE SOIL - A nonalkali soil containing sufficient soluble salts to interfere with plant growth or impair the productivity of crop plants.

*SALINE-ALKALI SOIL - A soil containing sufficient exchangeable sodium to interfere with the growth of most crop plants and containing appreciable quantities of soluble salts. The exchangeable-sodium percentage is greater than 15, the conductivity of the saturation extract is greater than 4 millimhos per centimeter at 25°C and the pH is usually 8.5 or less in the saturated soil.

*After - Glossary of Soil Science Terms. 1970. Soil Sci. Soc. Am., 677 S. Segoe Road, Madison, Wisconsin 53711, USA

HALOBLEM (proposed) - An area of soil incapable of supporting a significant vegetative cover because of a very high degree of alkalinity, a very high exchangeable sodium content, and/or very high quantities of soluble salts. Often irregular in shape with uneven microrelief; includes salt-affected playas. Surface color often high in value when dry. In addition to "playa", may be locally known as "salt spot", "scald spot", "slick spot", "puff spot", or "bull tether site".