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USE OF ERTS-I DATA TO ASSESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA (UN070)

(E75-10216) USE OF ERTS-1 DATA TO ACCESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA Final Report, Jul. 1972 - Jul. 1973 (California Univ.) 70 p HC $4.25 G3/43
N75-21741
Unclas
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A report of work done by scientists at the Department of Geography, University of California, Santa Barbara, under NASA Contract No. NAS 5-21827

13/7E

UNIVERSITY OF CALIFORNIA, BERKELEY

Final Report
15 September 1973

USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA (UN070)

Co-Investigator: John E. Estes

Contributors: L.W. Senger, R.R. Thaman,
D. Brunelle, D. Cottrell, F. Evanisko,
S.P. Kraus, B. Palmer, J.M. Ryerson,
T. Soper, K. Thaman

Department of Geography, Santa Barbara Campus

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA5-21827 (ERTS-A)		

4. Title and Subtitle	5. Report Date
USE OF ERTS-1 DATA TO ASSESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA	July, 1973
	6. Performing Organization Code
7. Author(s) Co-Investigator: John E. Estes, Geography Dept., Univ. of Calif., Santa Barbara	8. Performing Organization Report No.
9. Performing Organization Name and Address Geography Remote Sensing Unit University of California Santa Barbara, California 93106	10. Work Unit No. Task 5 Inves. #317E 11. Contract or Grant No. NASA 5-21827 Estes 4/73
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland	13. Type of Report and Period Covered Final Report July 1972-July, 1973 14. Sponsoring Agency Code

15. Supplementary Notes Originally prepared as Chapter 6 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, University of California, Berkeley, Calif.

16. Abstract

The Geography Remote Sensing Unit (GRSU) at the University of California, Santa Barbara was responsible for investigations with ERTS-1 data in the Central Coastal Zone and West Side of the San Joaquin Valley. Results of the investigations discussed in this report indicate that ERTS-1 type data can be a valuable source for environmental resource information needs. Resource information concerning such topics as land use, crop identification, drainage and landform mapping, kelp mapping, forest fire damage and vegetation mapping were investigated and conclusions concerning type amounts and optimum bands for data extraction were arrived at. The resolution of the ERTS-1 data places constraints upon the detail to which specific environmental phenomena can be investigated. Furthermore, the resolution limitations create certain problems for the investigation of environments where a high diversity of phenomena are localized in small areal units, such as the coastal portion of the Central Region of California. However, these limitations are mitigated to a large degree through the synoptic perspective afforded by ERTS-1.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Regional Change, Earth Resources Surveys, Central California Coastal Zone, San Joaquin Valley, Land Use Data Base.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	63	

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0 INTRODUCTION

The Geography Remote Sensing Unit (GRSU) at the University of California, Santa Barbara was responsible for investigations with ERTS-1 data in the Central Coastal Zone and West Side of the San Joaquin Valley. The nature of these investigations concerned the inventory, monitoring, and assessment of selected parameters that characterize the natural and cultural resources of the two areas. The determination of land use and the identification of agricultural crops, drainage networks and basins, landforms, and natural vegetation with the aid of ERTS-1 images were the principal subjects for investigation. These parameters are the key indicators of the dynamically changing character of the two areas. Monitoring of such parameters with ERTS-1 data provides the techniques and methodologies required to generate the information needed by federal, state, county, and local agencies to assess change-related phenomena and plan for management and development.

Progress reports submitted during the course of the ERTS-1 investigation primarily emphasized an analysis of ERTS-1 data for specific environmental information in selected sites. The purpose of this approach was to identify and develop workable solutions to interpretation and classification problems, in order that "set" methodologies and techniques could be defined preparatory to the construction of finalized data base maps for the selected resource parameters under investigation.

The construction of the various data bases required that two decisions be made: (1) where the boundaries should be drawn to define the area for which mapping would be accomplished; and (2) what specific ERTS-1 images should be used as the data sources for mapping. The mapping area, designated as the Central Region, was finally determined on the basis of including a wide range of environmental habitats, encompassing a sufficiently large area to demonstrate the significance of ERTS-1 type data, and having high quality ERTS-1 coverage. The resultant Central Region test site covers approximately 52,213 square kilometers of land area, with boundaries extending from Monterey in the extreme northwest; east through Hanford to the Sierra Nevada foothills; south along the Sierra Nevada foothills and across the Tehachapi Mountains to the western end of the San Fernando Valley; west to Point Concepcion, along coastal portions of Los Angeles, Ventura, and Santa Barbara counties; and finally, north-northwest along the coastline to Monterey. Included within the site are several million people and ten counties (all of Kings, San Luis Obispo, Santa Barbara and Ventura counties; and portions of Fresno, Kern, Los Angeles, Monterey, San Benito, and Tulare counties). The selection of ERTS-1 images to be used for mapping was based on cloud cover, image quality, and seasonal enhancement of environmental phenomena. The images from which interpretations were performed included the following frame numbers/dates: E1002-18140/25 Jul 72; E1018-18010/10 Aug 72; E1019-18062/11 Aug 72;

E1073-18064/04 Oct 72; E 1074-18123/05 Oct 72; E 1234-18021/14 Mar 73; E 1235-18073/15 Mar 73; E 1235-18075/15 Mar 73; and E 1255-18190/04 Apr 73.

The remainder of this final report, sections 1 - 7, is concerned with an evaluation of the utility of ERTS-1 data for inventorying, monitoring, and assessing specific resource parameters. Discussion centers on methodologies, data analysis, problems encountered, and detailed results. Section 1 presents the findings of land use investigations. ERTS-1 data were effective for general land use mapping, delineatinc transportation networks, and delimiting boundaries of cropped agricultural land; difficulty was encountered in consistently identifying urban boundaries. Section 2 discusses a method for crop identification from ERTS-1 data based on the presence or absence of vegetation in a given field, which may have significant implications for the development of computerized crop surveys. Section 3 deals with drainage and landform mapping. Drainage networks and basins can be accurately determined from ERTS-1 data, while only macro-level landform features could be consistently identified. Section 4 documents the capability to identify and measure kelp beds on ERTS-1 imagery, with important implications for routinely inventorying kelp resources.

In similar fashion, the feasibility of determining forest fire damage with high accuracy from ERTS-1 data is treated in Section 5. Section 6 is concerned with natural vegetation mapping. It was possible to map vegetation at the association level with reasonable accuracy, using only limited ground truth information.

Conclusions regarding the utility of the ERTS-1 system as a data source for resource information are presented in Section 7, based on significant results achieved in the investigations conducted by GRSU. ERTS Image Descriptors are also included. The key words used to describe the itemized ERTS-1 images represent a preliminary evaluation of information content by GRSU personnel.

1 LAND USE

This section represents a final evaluation of ERTS-1 as a source for a land use data base for the entire Central Region test area. The Central Region Land Use Data Base Map (see Figure 1), operational Land Use Classification Key (see Table 2), and analysis of the ERTS system presented herein are the result of both extensive and concentrated research conducted during previous reporting periods. This final evaluation, however, differs from earlier ones in that: (1) the region is mapped in its entirety; and, (2) an overall evaluation of the usefulness of ERTS as a land use identification tool is presented. The sections which follow are concerned with: (1) a brief review of earlier research methodologies and goals; (2) a description of the final construction of the complete test region land use map and operational data base

CENTRAL REGION LAND USE DATA BASE

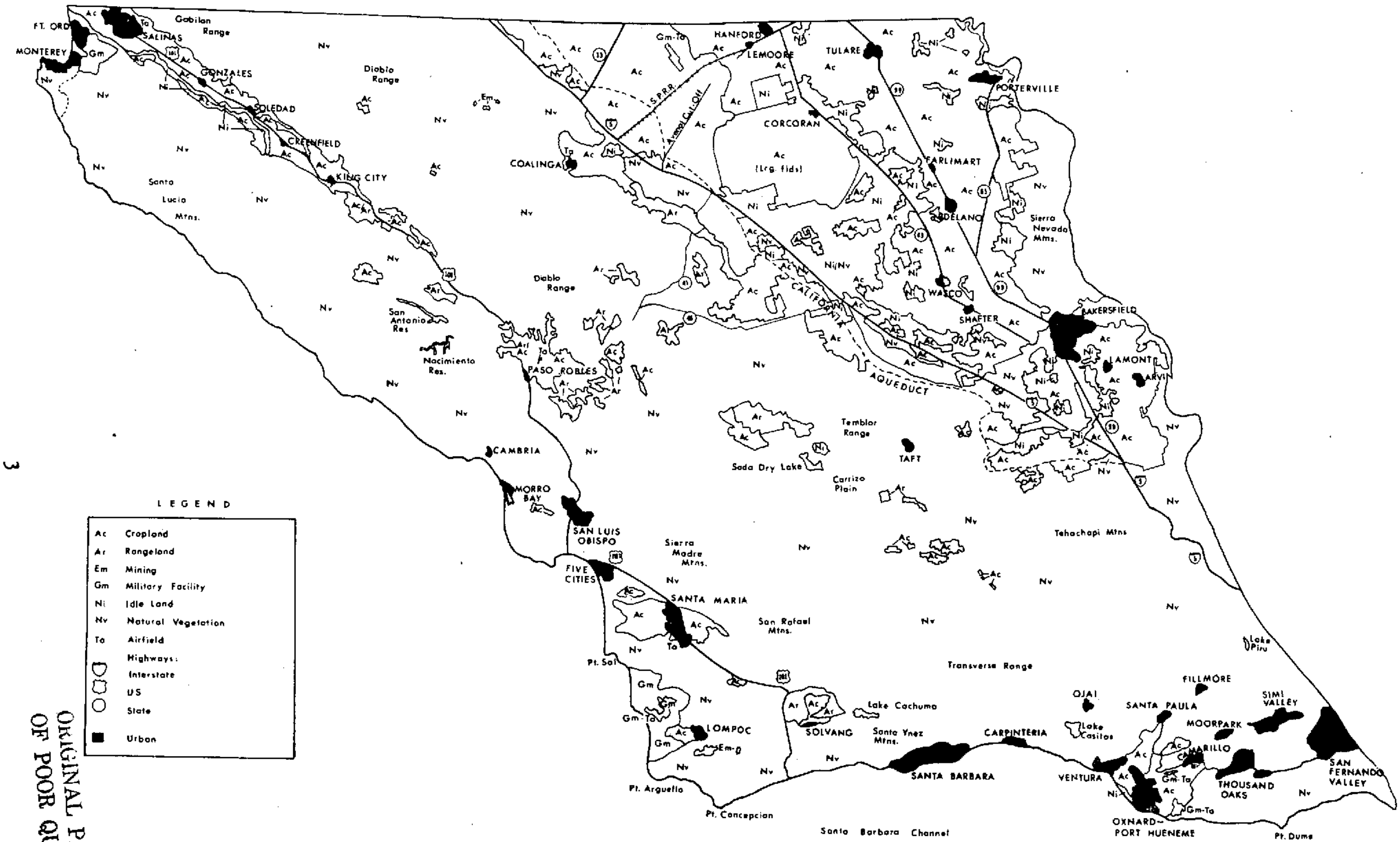


Figure 1. ERTS-1 central region land use map.

classification key; and (3) an overall analysis of earlier research and the utility and application of ERTS for future land use mapping.

1.1 Earlier Research Methodologies and Goals

During previous reporting periods our evaluation of land use features, using ERTS-1 imagery concentrated on determining the feasibility of ERTS as a data source for land use analysis. The methodology employed involved the use of individual 9.5 x 9.5-inch black-and-white transparencies (MSS bands 4-7), of selected areas within the Central Region test site, as source imagery for the identification, delimitation, evaluation, and mapping of various type land uses. In order to assess the capability of ERTS-1 as a data source for providing meaningful land use information within a working data base context, the investigations focused on identifying specific land use parameters within diversified cultural and environmental (physical) settings. The cultural features examined were: (1) spatial extent and location (both absolute and relative) of urbanized areas; (2) transportation routes and networks; and (3) agricultural development and extent.

Three sets of ERTS-1 MSS band positive transparencies (frame numbers: 1002-18140, North Central Coastal Région; 1073-18064, South Central Coastal Region; and 1019-18062 Central Valley Region) were used initially to evaluate specific land use information potential of ERTS data for diverse environments. For each of the three (3) ERTS-1 frame numbers utilized, MSS bands 4-7 were evaluated for total information content and application to land use studies. The results of these evaluations were summarized in the first three progress reports in the form of individual maps and comprehensive tables.

1.2 Land Use Map and Data Base Classification Methodology

The basic methodology employed in constructing a land use map and data base key for the entire Central Region test site involved: (1) determining the boundaries of the area; (2) selecting the optimal imagery for evaluation of land use features; and (3) examining and revising the land use classification scheme developed at the beginning of the project to reflect the interpretability of ERTS-1 imagery.

To insure compatibility of the land use data base map with other environmental maps presented in this report (e.g., natural vegetation, hydrology, etc.), a uniform boundary for the test area was defined. In addition to the previously mentioned North Central Coastal, South Central Coastal, and Central Valley Regions mapped earlier, portions of Ventura and Los Angeles counties, not previously mapped, were included. In order to effectively evaluate the suitability of ERTS-1 as a land use resource identification tool, it was deemed advisable to have a wide range of optimal test area imagery, flown during several periods. Therefore, nine 9.5 x 9.5-inch black-and-white transparencies imaged on various dates were selected. This was done to insure overlapping of multiple frames at any point in the test area, and to allow for analysis of possible seasonal tonal signature differences.

Before actual mapping commenced, each band of each numbered image was evaluated for tone, texture and contrast, and those affording the best potential for land use analysis (usually bands 5 and 7) were used in preparation of the final map. Once the broad Central Region test area boundary had been outlined on clear mylar (acetate), actual land use mapping from the selected 9.5 x 9.5-inch transparencies began.

The procedure involved first examining each image for recognizable land use features. Once these features were identified, their extent was traced onto clear mylar placed over the image. To provide verification of an initial analysis, or further delimit land use features, overlapping images of different dates were then examined. Where additional land use signatures were discovered, this information was traced onto the acetate. In this manner (i.e. through the use of overlapping images), a detailed and comprehensive Central Region Land use data base map was constructed. Whereas earlier maps relied on imagery from a single date only, the final map made use of multiple date, overlapping imagery.

Preparatory to the commencement of the ERTS-1 program in July, 1972, GRSU devised a classification key for use in land use mapping (see Table 1). The key was purposely designed with built-in flexibility. Once actual analysis and interpretation of the imagery began, modifications to expand it (i.e., make it more specific), or collapse it (i.e., make it more general) could then be made. After extensive evaluation of various ERTS images, using both 9.5 x 9.5-inch transparencies and contact print enlargements from these transparencies, a considerably "collapsed" operational classification key (see Table 2), was devised to replace the earlier one.

1.3 Overall Analysis of the Utility and Application of ERTS for Land Use Evaluation

This section deals with an overall analysis of the utility and application of ERTS for land use mapping. The discussions which follow are concerned with use and applications in: (1) determining extent and location (both absolute and relative) of urbanized areas; (2) locating and tracing transportation routes and networks; (3) delimiting agricultural extent and development; and (4) measuring land use change.

It should be pointed out at this time that the ability to identify and delimit land use features is very dependent on several major factors, including: (1) ERTS image resolution and quality; (2) seasonal variations, and (3) the location of the particular feature in relation to

TABLE 1. INITIAL LAND USE CLASSIFICATION (JULY, 1972)

KEY:

General Category, ex. A (Agriculture)
Type within Category, ex. t (tree crops)
Specific Type, ex. c (citrus)
Total Code: Atc

Note: The more specific notation depends upon ability to identify, and additional types and specific types can be added to the system as they are encountered.

	CODE
AGRICULTURE	A
Grain Crops	Ag - (type)
Horticulture	Ah - (type)
Pasture (improved)	Api
Pasture (unimproved)	Apu
Row Crops	Ar - (type)
Stock farming (beef)	Asb
Stock farming (sheep)	Ass
Stock farming (dairy)	Asd
Tree Crops	At - (type)
EXTRACTIVE	E
Seawater mineral recovery	Es - (type)
Petroleum production fields	Ep - (type)
Construction materials	Ec - (type)
Mining Operations	Em - (type)
PUBLIC FACILITIES	G
Governmental - administrative	Ga - (type)
Governmental - Military	Gm - (type)
Cemeteries	Gc
Protection - Police & Fire	Gf - (type)
Hospitals	Gh
Prisons	Gp
Waste disposal (solid & liquid)	Gd - (type)
Education	Ge - (type)

TABLE 1. (Continued)

	Code
PARKS & RECREATION	P
Campground	Pc
Golf Course	Pg
Park	Pp
Stadium	Ps
Marinas	Pm
Resort	Pr
INDUSTRIAL	I
Power Plant (fossil, hydro, nuclear)	Ib - (type)
Warehousing	Id - (type)
Commercial fishing (docking & canneries)	If - (type)
Port facilities	Ip
Shipbuilding & repairs	Is
Heavy manufacturing	Ih - (type)
Light manufacturing	Il - (type)
Saw mills (or pulp)	Iw
Power substation & transmission	It
TRANSPORTATION	T
Airports	Ta - (type)
Highways (roads, etc.)	Th - (type)
Railroads & yards	Tr - (type)
Canals	Tc - (type)
COMMERCIAL	C
Clustered	Cc - (type)
Strip	Cs - (type)
RESIDENTIAL	R
Single family	Rs
Multi-family	Rm - (type)
NON-DEVELOPED	N
Natural vegetation	Nv - (type)
Idle land	Ni - (type)
Barren land	Nb - (type)
Water bodies	Nw - (type)

TABLE 2. OPERATIONAL LAND USE CLASSIFICATION (MAY, 1973)

KEY:
General Category, ex. A (Agriculture)
Type within Category, ex. c (crops)
Specific Type, ex. g (grain)
Total Code: Acg

General Category	Code	Comments
AGRICULTURE	A	
Field Crops	Ac - (type)	may include row type (r); grain type (g); and tree/orchard (t). Additional sub-types could be added.
Range Areas	Ar - (type)	grasslands differentiated from surrounding vegetation and often showing signs of fencing (square borders). May include improved (i) or unimproved (u).
EXTRACTIVE	E	
Mining Operations	Em - (type)	may include open pit (o) etc., and additional sub-types.
Petroleum Production Fields	Ep	usually identified by maze of crossing access roads.
PUBLIC FACILITIES	G	
Governmental-military	Gm - (type)	may include air bases (ta), army installations (indicated by Fort ______), etc.
PARKS AND RECREATION	P	
Golf Course	Pg	readily identifiable on MSS Band 7 if of eighteen hole variety.
Marinas	Pm	identifiable due to geometrical signature along coastlines.
INDUSTRIAL	I	
Port Facilities	Ip	as Pm, but larger.
TRANSPORTATION	T	
Airports	Ta	signature depends on locational context to other features and runway material.

TABLE 2. (Continued)

General Category	Code	Comments
Highways (roads, etc.)	Th*	*roads are normally mapped using their federal, state or county number (e.g., 101 rather than the code).
Railroads	Tr*	*railroads are usually mapped using the abbreviations for their operating company (e.g., S.P.R.R. - Southern Pacific Railroad Co.).
Canals	Tc*	*canals are normally identified by name (e.g., California Aqueduct).
URBAN	U*	*urban areas, undifferentiated commercial Residential areas normally identified by the city name (e.g., OJAI) in bold type and their extent shaded in.
NON-DEVELOPED	N	
Barren Land	Nb	includes extensive sand or bare rock areas.
Idle Land	Ni	land within or bordering agricultural or urban areas which has been cleared but not used for commercial purposes.
Natural Vegetation	Nv	see natural vegetation data key and map for specific vegetation associations.
Water Bodies	Nw* - (type)	*normally indicated by lake (l), river (r), or ocean (o) name on map.

others. Often a land use feature exhibits a slightly different tonal or textural signature when one or more of the above factors changes. For instance, U.S. 101, a major four-lane highway, was inconspicuous and difficult to trace between Santa Barbara and Santa Maria on ERTS image number E1073-18064 for October, 1972. However, five months later, using ERTS image number E 1235-18075 for March 1973, the highway was easily traced. The reason for the variation between the two frames of the same area, was that the October 1972 image was taken at the end of the Southern California dry season, while the March 1973 image was taken after unseasonably heavy rainfall. Thus U.S. 101, with its light tonal signature, blended completely with the light toned surrounding grassland during the earlier period, but contrasted sharply against the dark, even textured, moist grassland in the latter period. Therefore, the following analysis, while applicable to the ERTS imagery used, may be subject to further modification in the future.

Urban Areas

In addition to extensive macro-scale evaluations made of individual urban concentrations in the three regional sectors analyzed earlier (see Table 6.3. "Evaluation of MSS Bands 4-7: Urban Concentrations"), a micro-scale analysis of the application of ERTS imagery to accurately delimit and measure urban areal extent was also conducted.

The results of both the macro- and micro-scale analysis would seem to indicate that ERTS is an excellent general purpose data source for the identification of urban area location. This is with particular reference to populated areas of over 4,000 inhabitants. The final map (see Figure 1) includes forty-two urban areas (see Table 4), with Atascadero (pop. 10,290) and Carmel (pop. 4,525), the only cities/areas over 4,000 pop., which were not identified on the imagery used. In part, this was due to inadequate tonal contrast in the former and constant cloud cover over the latter. Identification, in most cases, was facilitated by locating the characteristic light grey tonal signature and mottled texture of the urban area, as contrasted with the different signatures of surrounding non-urban areas. The contrast was best defined in areas of extensive agricultural production (e.g., San Luis Obispo). Also, location along transportation (road) networks further aided in identification. While ERTS-1 has proven a useful tool in the identification of urban area location, its value in determining actual urban areal extent is still to be proven. The previously mentioned micro-scale analysis, conducted in an earlier reporting period, compared known area figures from 1972 NASA High Flight (scale 1:120,000) and predicted area measurements from enlarged ERTS imagery (approx. scale 1:150,000). The results showed the latter to be relatively inaccurate, with an error of at least ± ten percent for ten sites that were sampled. The major source of error on ERTS occurred at the boundaries of the study areas, where urban and non-urban features merge as a result of population/building density

TABLE 3. EVALUATION OF MSS BANDS 4-7: URBAN CONCENTRATIONS

Location/City	Band 4	Band 5	Band 6	Band 7
Salinas Valley (U.S. 101)	Good to excellent. All five cities are well defined (vary from white to light grey) against dark background.	Fair to good. Urban response not as clear as Band 4. While Greenfield and Gonzales are identifiable by shape and tone/texture (white-light grey and slight mottling). Soledad and King City blend with surrounding agricultural land. Salinas easily located by white signature of CBD. However, boundaries tend to fade at interface with non-urban.	Poor to fair. None of 4 smaller cities south of Salinas defined. Salinas, however, has strong signature.	Poor to fair. Four smaller cities again are undifferentiable, owing to lack of tonal contrast. Salinas, with light to medium grey tone and mottled texture, also shows some street patterning. Border between urban and non-urban is well defined owing to tonal differences.

TABLE 3. (Continued)

Location/City	Band 4	Band 5	Band 6	Band 7
U.S. 99 Area - including cities east of 99: Arvin, Bakersfield, Delano, Earlimart, Lamont, McFarland, Porterville, Tulare, and Visalia	Fair to good delineation; Dark grey mottled appearance. Contrast well with surrounding agricultural land and/or linear patterns of the highways.	Good to excellent. Dark grey mottled tone/texture stands out against agricultural surroundings.	Poor to fair. Urban areas show a light spectral response against light signature of surrounding agricultural land. Bakersfield, Porterville, Tulare and Visalia give fair response including lightly defined street patterns.	Poor to good. Definition same as Band 6. Street patterns have better (darker) contrast.
Calif. 43/198: Hanford, Lemoore, Shafter, Wasco	Fair response, as above.	Same as Band 4.	Poor to fair. Same as above. Hanford is only city to give fair response (as Bakersfield, etc.)	Same as Band 6.
Coalinga	Poor definition; area of limited agriculture; urban grey spectral response blends with surrounding signatures.	Fair identification; dark, mottled against lighter toned surrounding area.	Poor.	Same as Band 6.
Taft	Not visible.	Poor - dark response against light toned idle land response.	Poor.	Same as Band 6.
San Luis Obispo	Poor to fair. Tends to blend with surrounding grassland lighter tone and mottled texture are evident but not obvious.	Fair. Urban area is evident as mottled texture contrasts strongly with uniform texture of surrounding land.	Poor. Urban blends with surrounding grassland.	Poor to fair - CBD displays medium grey signature, which contrasts well with light grey of radiating urban area.

TABLE 3. (Continued)

Location/City	Band 4	Band 5	Band 6	Band 7
Lompoc, Santa Maria, and Vandenberg AFB	Fair to good. Lompoc and Vandenberg are well defined. In Lompoc area light grey tone contrasts well with surrounding mixed agricultural signatures. Vandenberg's urban strip contrasts well with surrounding scrubland and the large adjacent concrete flight ramp and runways. Santa Maria elicits a fair tonal signature with the light grey response contrasting well with the agricultural field patterns to the west. However, the response fades in other directions where it blends with extensive grassland.	Good. Lompoc and Vandenberg as in Band 4. Santa Maria gives a strong response due to a mottled textural signature and dark grey tones which contrast with both the regular field boundaries and irregular grassland/rangeland.	Poor to good. Lompoc and Vandenberg as in Band 4. However both tend to lose some clarity where adjacent grasslands blend with the urban response. still possible to distinguish the distinctive mottled urban texture in most cases. Santa Maria, for an unknown reason, gives a very poor response with a general blending of tone and texture between urban, field agriculture and grassland.	Fair to good. As in Band 4. In addition, the main street linear networks are visible in Lompoc and Santa Maria.
NEW CUYAMA	Poor. Very small, urban settlement, mainly an agricultural and oil extractive area. Sparse population.	Poor.	Poor.	Poor.

TABLE 3. (Continued)

Location/City	Band 4	Band 5	Band 6	Band 7
VENTURA COUNTY - Camarillo, Ojai, Oxnard-Pt. Hueneme, Santa Paula, and Ventura	Fair to good response. Except for Ojai, all cities are in an area of extensive agriculture. Light grey spectral response of urban areas contrasts well with linear pattern and dark response of surrounding fields.	Good. Urban areas show a dark grey, distinctively mottled response which is easily differentiated from surrounding agricultural land.	Poor to fair. Difficult to determine juncture of urban and agricultural boundaries due to a wide variety of light and dark grey tonal signatures. Areas tend to merge.	Poor to fair Same as band 6.
SANTA BARBARA COUNTY - Santa Barbara and Carpinteria	Fair to good. Santa Barbara's tonal signature fair but tends to blend with lower elevation foothill slopes. Both urban response and foothill/grassland have light grey tone with similar pictures. Carpinteria gives a good response with light grey urban spectral signature contrasting well be between the coast and mountains.	Good for both cities. Still a slight problem in differentiating urban and foothill boundaries in some instances.	Poor to good. Santa Barbara shows good response with dark grey tonal signature and a mottled texture These aid in distinguishing urban-grassland boundaries. However, on this band Carpinteria tends to blend with the grassland and scrub vegetation of its adjacent hillsides making identification poor.	Fair. Same problem as in Band 5.
SANTA YNEZ VALLEY	Poor. Small urban settlements of Santa Ynez, Solvang and Buellton with dispersed population densities make identification nearly impossible. No positive response, either textural or tonal.	Poor.	Poor.	Poor.

TABLE 4. URBAN AREA POPULATION DATA

CITY	COUNTY	AREA POPULATION*
Arvin	Kern	5,199
Bakersfield	Kern	69,515
Camarillo	Ventura	19,219
Cambria	San Luis Obispo	1,716
Carpenteria	Santa Barbara	6,982
Coalinga	Fresno	6,161
Corcoran	Kings	5,249
Delano	Kern	14,559
Earlimart	Tulare	3,080
Fillmore	Ventura	6,285
Five Cities (including Arroyo Grande, Grover city, Nipomo, Oceano and Pismo Beach)	San Luis Obispo	27,840
Fort Ord	Monterey	26,128
Gonzales	Monterey	2,575
Greenfield	Monterey	2,608
Hanford	Kings	15,179
King City	Monterey	3,717
Lamont	Kern	7,007
Lemoore	Kings	4,219
Lompoc	Santa Barbara	25,284
McFarland	Kern	4,177
Monterey (including Seaside and Pacific Grove)	Monterey	77,819 (est.)
Moorpark	Ventura	3,380
Morro Bay	San Luis Obispo	7,109
Ojai	Ventura	5,591
Oxnard-Pt. Hueneme	Ventura	85,520 (est.)
Paso Robles	San Luis Obispo	7,168

TABLE 4. (Continued)

CITY	COUNTY	AREA POPULATION*
Porterville	Tulare	12,602
Salinas	Monterey	58,896
San Luis Obispo	San Luis Obispo	28,036
Santa Barbara (including Goleta and Montecito)	Santa Barbara	128,215 (est.)
Santa Maria	Santa Barbara	32,749
Santa Paula	Ventura	18,001
Shafter	Kern	5,327
Simi Valley	Ventura	61,327
Soledad	Monterey	6,843
Solvang	Santa Barbara	2,004
Taft	Kern	4,285
Thousand Oaks	Ventura	36,334
Tulare	Tulare	16,235
Ventura	Ventura	57,964
Visalia	Tulare	27,482
Wasco	Kern	8,269

* 1970 U.S. Census Bureau figures

decreasing towards the perimeter. However, this may have been the result of resolution and seasonal variation, as August 1972 imagery was used. Initial examination of March 1973 imagery, following an extensive rainy season, shows differences both in urban signature and extent, with boundaries of the test areas better defined. A re-evaluation of ERTS as a data source for urban extent analysis, using the improved March 1973 imagery, may yield more accurate results.

ERTS-1, then, is a valuable data source for urban area identification, and a possible tool for accurate delimitation of urban areal extent. Unfortunately, attempts to identify smaller land use features (e.g., commercial and residential structures) within urbanized areas using ERTS have proved unsuccessful. Regardless, there are significant planning implications of applying the ERTS synoptic view as a monitoring tool for gross urban expansion and development.

Transportation Routes and Networks

An extensive evaluation of individual transportation features (e.g., highways, secondary roads, canals, airports, railroads, etc.) for the various test region sectors is contained in Table 5. "Evaluation of MSS Bands 4-7: Transportation Features." In general, ERTS has proven an accurate tool in locating, identifying, and tracing various transportation features, especially in those areas of extensive agricultural production where contrasts are greater. Thus, two lane and four lane highways are clearly traced in the agriculturally rich San Joaquin and Salinas Valleys, as are other transportation features such as the California Aqueduct (especially on bands 6 and 7.) However, as with urbanization, in locations with extensive grassland or natural vegetation regime characteristics (e.g., most of the Coastal Central Region), the typical light tonal, linear signature of highways and railroads readily blends with the similar light-toned, mottled texture of surrounding features. In addition, the relatively narrow width of transportation features such as roads and railroads, renders their identification even more difficult given the resolution capabilities of ERTS. Furthermore, seasonality has a marked effect on signature response, especially, where tonal contrasts between vegetative features and transportation arteries are highlighted. The earlier example of U.S. 101 between Santa Barbara and Santa Maria illustrates this point.

Regarding other transportation features (e.g., airports and railroads), the results have been less encouraging. In the case of airports, the main factors seem to be runway construction material, size of the facility, and contrast with surrounding land uses. The extensive concrete runway surfaces of Vandenburg and Oxnard Air Force Bases and Lemoore and Pt. Magu Naval Air Stations, were easily identified and mapped. However, the only civilian airports delimited were at Salinas, Paso Robles, Santa Maria and Coalinga where, for still undetermined reasons, there was good contrast between them and their surrounding environments. Unidentified

TABLE 5. EVALUATION OF MSS BANDS 4-7: TRANSPORTATION FEATURES

LOCATION	BAND 4	BAND 5	BAND 6	BAND 7
U.S.99- 4 lane	Good response along entire route except when passing thru urban areas, where road signature blends with urban. Stands out well in areas of intensive agriculture, as well as areas of low-lying, sparse natural vegetation. Linear regularity aids in identification as does light signature.	Fair to good. Same as for Band 4, except that signature fades to the Northwest in an area of small fields and bare soil (highway and fields both display light tone).	Poor to fair. Road shows dark response which tends to blend very subtly with surroundings.	Fair to good. Dark, linear response against lighter agriculture signature. Also, unlike Band 5, it is well defined along entire ERTS-1 image.
Interstate 5- 4 lane	Poor to good. Major portion of route well defined. However, as much of the surrounding land remains undeveloped, the signature tends to fade when this occurs on both sides of Interstate 5. Light response of road good against agriculture (dark), but poor against open land (also light).	Poor to fair. Generally same as Band 4. However more fade out in undeveloped areas.	Poor. Tends to blend with light signature of surrounding land along majority of route.	Poor. Light signature against light background--majority of route traced on Figure 1 not visible.
Calif. 43- 2 lane	Poor to fair. Irregular response. Visible in areas of agriculture where regular field patterns lend good contrast. However, in several large sections identified as Ni areas or Ac with bare soil, the road tends to blend.	Same as Band 4	Not visible.	Fair. Dark response is well defined against agricultural regular patterned background. Slight loss of resolution in bare soil and idle land areas.
Calif. 198- 2-4 lanes	Poor. Visible thru Hanford although small field patterns tend to disrupt signature. Contrast is poor. Cannot be traced thru the idle land east of Hanford and west of U.S. 99.	Same as Band 4.	Not visible.	Poor. Dark tone only visible against agricultural background with great difficulty.
Avenal cut-off- 2 lane.	Poor to fair. Light pattern contrasts in areas of varying toned agriculture. Fades when encountering homogeneous light responses of bare soil, etc.	Same as Band 4.	Poor to fair, due to dark, linear pattern against lighter signature of agriculture.	Good. Dark linear response against regular agricultural patterns.

TABLE 5. (Continued)

LOCATION	BAND 4	BAND 5	BAND 6	BAND 7
U.S. 101	Poor to good. White linear signature appears best against dark grey or near black, especially in agricultural region of Salinas Valley and Mountain region north of San Luis Obispo. Tends to fade and blend with light grey in San Luis Obispo area and disappear into Salinas. Most of the highway is not visible from Santa Barbara to San Luis Obispo except where it transverses agricultural fields.	Poor to good. Tend toward a light grey response. Not evident in San Luis Obispo Area nor within Salinas. Also, tends to blend into Salinas River signature. Not visible from Santa Barbara to San Luis Obispo except where it transverses agricultural fields.	Very Poor to poor. Very poor except in the Salinas Valley from Salinas-Soledad. Even here the grey signature tends to merge with other greys around it. Not visible at all from Soledad to Santa Barbara.	Poor to good. Good through the Salinas Valley- presents a dark tone in contrast to lighter agricultural areas. Response fairly good south of King City but again fades. Visible through mountains north of San Luis Obispo, but fades from San Luis Obispo to Santa Barbara.
U.S. 1	Poor. Tends to blend with light grey tones of San Luis Obispo-Morro Bay. Invisible along most of the coast from Morro Bay northward and from Santa Maria southward.	Poor to fair. Along coast, portions are visible. Bend at Cambria especially apparent as are portions along raised sea platform to the north between Monterey-Cambria.	Very Poor.	Poor to excellent. Excellent through Morro Bay proper. Fair from Morro Bay-San Luis Obispo, through grassland. Not well defined along rest of coast.

TABLE 5. (Continued)

LOCATION	BAND 4	BAND 5	BAND 6	BAND 7
Calif. 126- 2-4 lanes	Good. Linear pattern and light tonal signature contrast well with surrounding pattern of fields.	Poor to good. Good contrast and response from Ventura to Santa Paula through area of agriculture. From NE of Santa Paula where agriculture is more irregular the contrast and response of the road are quite poor (especially as it borders the Santa Clara River).	Not visible	Not visible
Calif. 154- 2 lanes	Poor to good. Highway connects Santa Barbara with the Santa Ynez Valley via the Santa Ynez Mountains and Lake Cachuma. Response is nonexistent except for a small portion bisecting an agricultural area, which contrasts well (mainly due to the linear nature of the Highway response against the field patterns).	Same as Band 4	Not visible	Not visible

TABLE 5. (Continued)

LOCATION	BAND 4	BAND 5	BAND 6	BAND 7
Other Roads	Poorly defined.	Road patterns visible in some urban areas and some field boundaries.	Poor to fair. Street patterns visible in large cities.	Good to excellent. Street patterns in large cities detectable as dark linear response against mottled grey urban.
S.P.R.R.- Southern Pacific Railroad Line	Poor to fair between Interstate 5 and Hanford. Fair definition when crossing vegetated fields- contrast evident. Poor response between NAS Lemoore and Hanford, due to small fields and poor contrast. Not visible from Hanford to U.S. 99 or Interstate 5 to Coalinga.	Same as Band 4.	Same as Band 4.	Poor to good. Good east of the California Aqueduct. Contrasts well with agricultural land. Poor contrast to the west.
Canals- California Aqueduct	Fair to good along entire route. White tone and linear pattern. Water visible.	Same as Band 4.	Good to excellent. Water gives very dark response and contrasts with lighter agricultural land.	Same as Band 6.
Other Canals	Poor to fair located between Interstate 5 and U.S. 99 for main part. Light tone and linear pattern visible. Difficult to differentiate from roads.	Same as Band 4.	Same as above.	Same as Band 6.

TABLE 5. (Continued)

LOCATION	BAND 4	BAND 5	BAND 6	BAND 7
Airports	Poor to good-NAS Lemoore. Runways show white signature and good contrast with surrounding agriculture. Wasco-poor but visible. Light response. Coalinga- poor, dark signature. Vandenberg AFB, in an area of homogenous natural vegetation gives a good, light response.	Fair to good-NAS Lemoore. Wasco- same as Band 4. Coalinga- Poor to fair. Shows dark against light signature of surrounding land. Shafter- poor but visible. Vandenberg and Santa Maria exhibit good tonal responses. NAS Pt. Mugu and Oxnard AFB (SE of Camarillo) give a fair response, tending to blend periodically with surrounding agriculture.	NAS Lemoore- good. Coalinga- good. Others are not visible.	NAS Lemoore- good. Coalinga- poor. Others are not visible.
Harbors	Poor to fair. Several harbors along the coast at Santa Barbara, Ventura and Oxnard to Pt. Hueneme are visible due to distinctive patterns. However, it is not possible to discern much detail.	Same as Band 4.	Same as Band 4.	Same as Band 4.

were several airports with 4,000'+ runways, including San Luis Obispo, Santa Barbara, Monterey, King City, Oxnard-Ventura, Shafter, and Bakersfield-Meadows.

Railroads proved even more difficult than airports. The only trackbed identified was a S.P.R.R. Spurline from Coalinga toward Hanford, through extensive agricultural land. Here contrasts with the surrounding environment facilitated identification. The main reasons for the inability to identify other tracks, including coastal and Central Valley mainlines, are: (1) the narrowness of the trackbed; and, (2) the common procedure of highway and railroad right of ways running adjacent to one another, so that the latter's trace blends with the former's.

In summary, ERTS has utility and applications as a resource tool to accurately identify, locate, and trace transportation networks. It should prove particularly relevant for highway planning and spatial network inventory analysis by federal, state, and county agencies. Furthermore, in conjunction with urban area uses, it could substantially aid not only in identifying existing networks, but in locating and evaluating future routes.

Agriculture

One of the most successful applications of ERTS-1 to land use identification in the Central Region test area was in agriculture. Results were achieved in: (1) identifying agricultural areas; and, (2) accurately measuring their extent. It was possible to recognize land now in agricultural use owing to rectangular field signatures and/or the presence of extensive, regular vegetation tone/texture. Idle land was identified on the basis of the absence of field boundaries and the presence of uniform vegetation/soil tonal responses. However, it should be noted that it is possible that small areas of fallow land may have been included in the classification, where field boundaries blended with the similar light signature of the bare soil. Table 6 "Evaluation of MSS Bands 4-7: Agricultural Features" illustrates these results.

Regardless, a high degree of mapping accuracy is possible, and the following specific example is an indication of the reliability of the rest of the mapped data for the study area. During the summer, 1972, an agricultural land use map of a portion of Kern County (radiating from Bakersfield N, W, and S) was constructed from 1971 NASA High Flight 70 mm black-and-white negatives (enlarged to a scale of 1:290,000), and crosschecked with 1:120,000 scale CIR imagery. This was sent to the Kern County Water Agency (K.C.W.A.) for verification of agriculture acreage estimates. When K.C.W.A. figures were received, the same area was mapped from ERTS-1 with the following results:

TABLE 6. EVALUATION OF MSS BANDS 4-7: AGRICULTURAL FEATURES

cation	Band 4	Band 5	Band 6	Band 7
roughout st Region	Poor to excellent. Depends on field size, distribution of crop types (tones), etc. Where crops show a homogeneous tone (e.g., light or dark grey), field boundaries are poorly defined and individual fields tend to blend together. Also, occurs in areas of small, compact fields. Larger field patterns result in better boundary definition, although heterogeneity of crop types (giving different tonal responses in adjacent fields) seems to be more important in determining contrast.	Poor to excellent. Field definition depends on contrast. Light response of perimeter roads (normally dirt) gives good contrast to generally darker tone of field crops. Only exception (poor) is when fallow, bare soil, or other light response situations tend to blend with the individual fields.	Poor to fair field definition. Very irregular in quality and difficult to discern when small fields exist. Ability to define boundaries improves with tonal contrasts.	Poor to good field definition. Same basic comments as Band 6. However, tonal signature of perimeter roads is better. Dark grey response tends to delimit borders rather well. However, homogeneous field responses tend to present similar problems as those experienced with Band 4.

Source	Agriculture Acreage Estimate (acres)
1. NASA High Flight (70mm) - 1971	753,369
2. K.C.W.A. - 1971	795,280 (including fallow)
3. 1969 Crop Survey (Kern County)	746,104 (excluding fallow)
4. ERTS-1	748,050

For future agricultural land use feature investigation, ERTS shows excellent possibilities as a relatively inexpensive, highly accurate tool for delimiting and measuring agricultural development in the Central Region test site. Particularly relevant would be its use by Federal, State and County agriculture officials to measure changes in agricultural extent, both on a regional and local basis.

Land Use Change

In order to evaluate the potential of ERTS-1 imagery as a tool for land use change identification and mapping, land use maps of the West Side of the San Joaquin Valley were constructed for 1971 and 1972. This particular section of the Central Region test site was selected for study since it has been an area of continuing land use transformation. This is primarily related to the mitigating effects of better quality water (available since 1968 via the California Aqueduct) and the construction of a major transportation link along its entire length (interstate Highway 5, completed in 1972). Furthermore, excellent quality high altitude photography, flown in 1971, was available of the West Side and afforded an opportunity for a detailed comparison with 1972 ERTS-1 imagery.

For mapping purposes, four general land use categories were selected as land use change indicators. These were considered compatible with ERTS-1 imagery resolution, and included: (1) cropland; (2) grazing (including pasture); (3) oil extraction; and, (4) non-productive. Urban area change, which was insignificant for the period, was excluded.

Using the four gross land use classifications listed above, two types of maps were produced to measure the nature and degree of land use change. The first type consisted of a pair of maps showing total West Side land utilization for the years 1971 and 1972. The second type comprised a pair of maps depicting the specific areas that had undergone change during the same one year period (1971 - 1972). Of this latter pair, the first map showed the areas that had changed and their land use in 1971, while the second map delimited the same areas, but indicated their new land use for 1972. In determining land use type, where multiple use was evident (e.g., oil extraction and grazing occurring together), the highest economic utilization (in dollars) served as the basis for final classification. Oil extraction was considered the highest economic use, followed by cropland, grazing, and non-productive.

Once the mapping had been completed, the total acreage of the mapped area was computed, using a compensating polar planimeter, and a quantitative estimate was then made of the acreage within each land use category. Thus, by using the two sets of maps, and the resulting quantitative measures derived from them, it was possible to evaluate the changes that had occurred in the West Side between the years 1971 and 1972.

The actual 1971 and 1972 gross land use patterns for the West Side are illustrated by the two maps in Figure 2. A quantitative estimate of land use acreage, by category, was obtained using a compensating polar planimeter, and the results appear in Table 7. For both years (1971 and 1972), the predominant land uses were grazing and cropland. In 1971, 90.09 percent (2,572,452.8 acres) of all land use types occurred in these categories, while in 1972 the total had increased slightly to 90.39 percent (2,580,793.8 acres). Oil extraction, as a primary land use, had declined slightly during the one year period, from 6.11 percent (174,352.6 acres) to 6.03 percent (172,278.6 acres). This was to be expected in an area where long term production had finally begun to deplete an exhaustible economic resource. Non-productive land also declined, from 3.80 percent (108,619.8 acres) to 3.58 percent (102,352.8 acres) of the total.

In terms of net change, grazing land alone increased in areal extent, by some 2.0 percent (26,894 acres) over the period 1971 - 1972, while cropland decreased 1.5 percent (18,553 acres), non-productive 5.8 percent (6,267 acres), and oil extraction 1.2 percent (2,074 acres). Approximately 3 percent (81,543 acres) of the total area (2,855,425 acres) underwent a conversion from one land use category to another.

In terms of actual change, Figure 3 and Table 8 present comprehensive breakdown of the changes, by category and areal distribution, from 1971 - 1972. The dominant trend was a conversion of marginal cropland to grazing (49,152 acres), while grazing to cropland, the other major change, accounted for another 22,258 acres. Non-productive to cropland (7,163 acres), oil extraction to cropland (2,074 acres), and cropland to non-productive (896 acres), were the only other changes.

This trend of converting sections of existing cropland to grazing, as well as the lesser trend of converting grazing to cropland, is probably attributable to water availability. While the California Water Plan (via the California Aqueduct) has significantly increased the volume and quality of water in the West Side, it has not brought in unlimited supplies. With restrictions enforced on the amount available to individual property owners, and the tenuous cost/benefit of

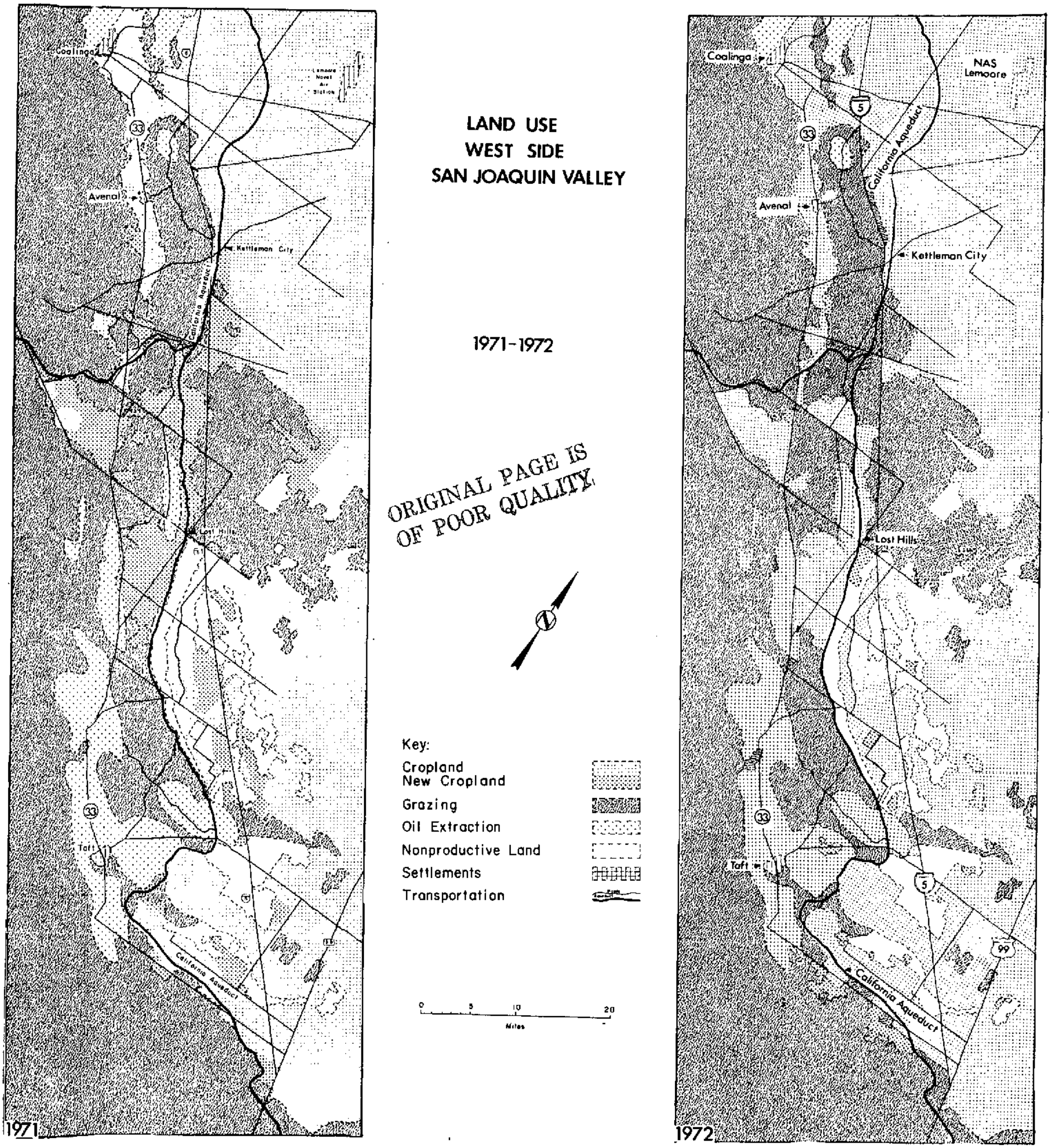


Figure 2. Land Use maps for the West Side of the San Joaquin Valley, California constructed from high altitude photography (1971) and ERTS-1 data (1972).

TABLE 7. NON-URBAN LAND USE 1971 AND 1972, WEST SIDE SAN JOAQUIN VALLEY

LAND USE CATEGORY	1971 (ACRES)	1972 (ACRES)	NET CHANGE (ACRES)
CROPLAND	1,233,063.9	1,214,510.9	-18,553.0
GRAZING	1,339,388.9	1,366,282.9	+26,894.0
OIL EXTRACTION	174,352.6	172,278.6	- 2,074.0
NON-PRODUCTIVE	108,619.8	102,352.8	- 6,267.0
TOTAL	2,855,425.2	2,855,425.2	

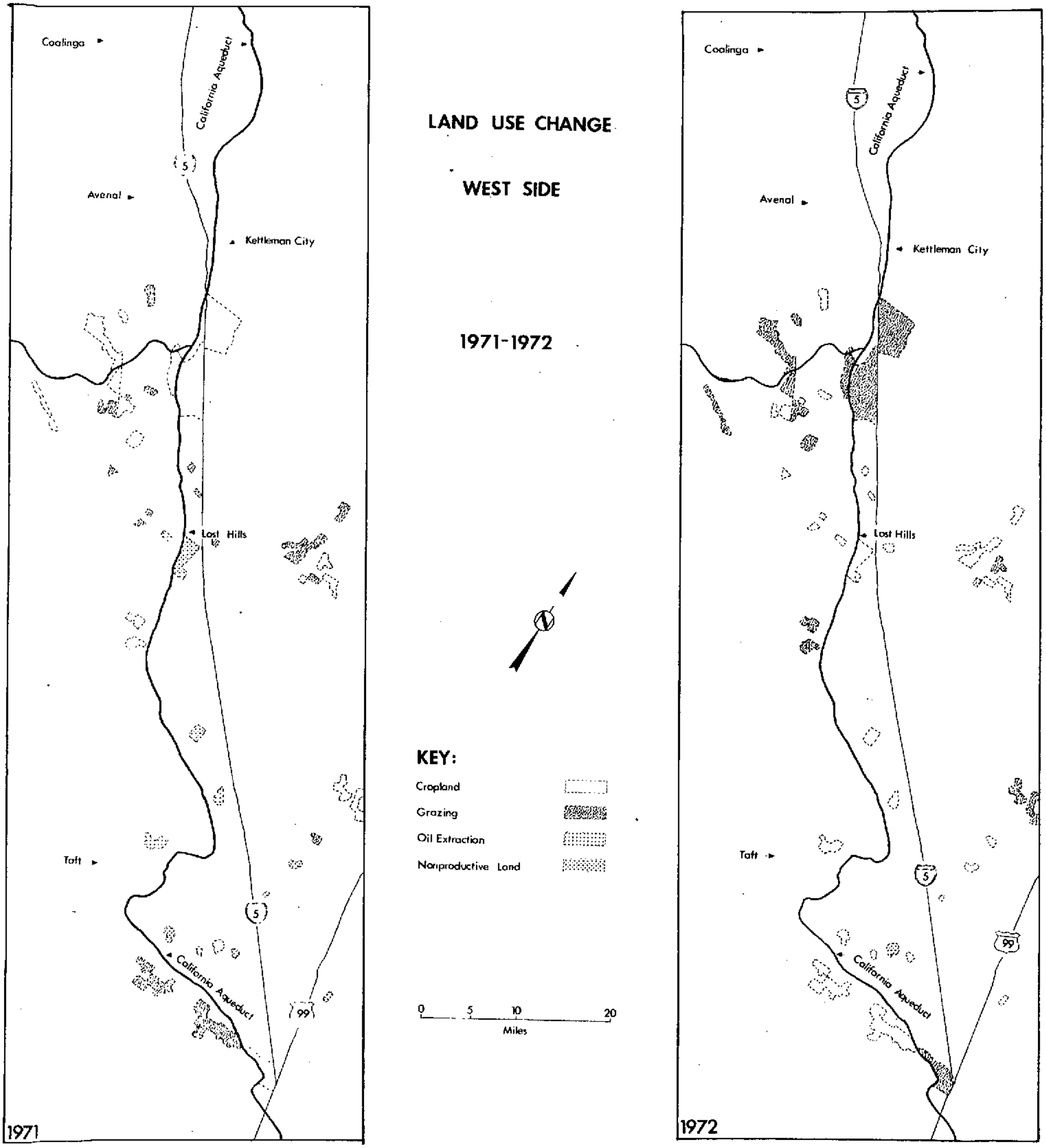


Figure 3. Map showing land use change from 1971 to 1972 in the West Side of the San Joaquin Valley, California.

TABLE 8. LAND USE CHANGES 1971 - 1972

1971	1972 LAND USE CHANGES (IN ACRES)				
	CROPLAND	GRAZING	OIL EXTRACTION	NON-PRODUCTIVE	TOTAL
CROPLAND		49,152		896	50,048
GRAZING	22,258				22,258
OIL EXTRACTION	2,074				2,074
NON-PRODUCTIVE	7,163				7,163
TOTAL CHANGE IN LAND USE ACREAGE	31,495	49,152		896	81,543

NET CHANGE IN LAND USE CATEGORIES (ACRES)

CROPLAND	GRAZING	OIL EXTRACTION	NON-PRODUCTIVE
Loss: 50,048	Loss: 22,258	Loss: 2,074	Loss: 7,163
Gain: 31,494	Gain: 49,152	Gain: N/A	Gain: 896
Change: -18,553	Change: +26,894	Change: -2,074	Change: -6,267

providing water to marginal holdings, agriculturalists have resorted to: (1) taking marginal land out of crop production and converting it to grazing land; (2) postponing actual planting in fields which were already surveyed and graded for production (in anticipation of water availability); or, (3) initiating a program of "shifting" cultivation, in which established fields are allowed to go fallow and new fields are opened for production, when individual water quota limitations do not permit full irrigation of all available arable land.

The interpretation of the four land use categories was accomplished with little difficulty from ERTS-1 data. Tonal and textural signatures for cropland and grazing were readily identifiable owing to field boundary outlines, distinct patterning, and/or pronounced contrasts with adjacent land uses. Non-productive and oil extraction areas were more difficult to identify owing to the similarity of their signatures (usually, due to lack of extensive vegetative cover and poor contrast). However, oil extraction could be consistently identified where extensive access road networks were visible. In cases where the roads were not detectable (owing to insufficient resolution), it was necessary to supplement ERTS-1 data with high altitude supporting photography and limited ground truth.

The results of this evaluation of ERTS-1, as a data source for monitoring land use change, show a definite potential for the use of satellite imagery in monitoring and mapping the macro-scale changes discussed above. Few interpretation problems were experienced, and the overall maps constructed (e.g., the 1972 maps found in Figures 2 and 3) correspond closely to: (1) ground truth data collected for the area; and, (2) coincident NASA high altitude photography imaged in 1972.

1.4 Summary

Based on the research which has been accomplished, ERTS-1 data will have useful applications for the identification and measurement of land use features at a macro-level. While not lending itself to micro-analysis and identification of very small features (i.e., urban residences), ERTS-1 does offer valuable potential as a tool for land use planning based on regional analyses of gross features (i.e., urban areal extent, transportation features, agricultural acreage, etc.).

The potential value for regional planning purpose of the synoptic view afforded by ERTS, is evident. This is illustrated by the Central Region Land Use Data Base Map, both in the extent (52,213 square kilometers) and the nature (transcending artificially created political boundaries) of the coverage which is provided. Land use information is essential for determining present levels of land development and evaluating future directions that development should take. These considerations are becoming increasingly regional in scope, and ERTS provides a mechanism whereby regional planning efforts can be coordinated on a large scale. As this trend becomes more firmly established, ERTS-1 type data for land use should play a more substantial role in the planning process and facilitate regional level decision-making activities.

2 CROP IDENTIFICATION

The difficulty in consistently identifying crop types with any degree of accuracy from single date satellite imagery is widely recognized. However, it has been determined that vegetated/non-vegetated field conditions can be accurately identified from ERTS-1 data. Since non-vegetated (bare soil) conditions signal the beginning and end of any given growing season, it was hypothesized that this information could be extracted from ERTS-1 data and correlated with a conventional crop calendar to generate crop acreage statistics.

The methodology to evaluate this concept consisted of three (3) proposed phases. The first phase would involve the collection of vegetated/non-vegetated data on a field-by-field basis over a year-long growing cycle. These data would be extracted from ERTS-1 imagery solely on the basis of tonal changes in fields. In the second phase, these data would be examined to determine the discrete periods during the year when a field is in a vegetated condition. The third phase would involve the correlation of these discrete temporal tonal patterns (for vegetated conditions) with a conventional crop calendar to identify characteristic tonal signature patterns that may be directly associated with the growing season of a specific crop type.

At the completion of this investigation, it was anticipated that it would be possible to make some but not all pertinent conclusions concerning: (1) the types of crops for which this technique is particularly suitable; (2) the amount of error which might be anticipated if the technique is made operational; (3) any peculiarities of crops or field conditions that restrict the use of the technique; and, (4) the times of the year when it may be expected that image acquisition will be difficult to accomplish.

The last consideration mentioned above precluded completion of the investigation beyond the first phase. It proved possible to document the vegetated/non-vegetated condition of individual fields from ERTS-1 data with a high degree of accuracy (nearly 100 percent). However, a problem of unforeseen magnitude developed in the area of ERTS-1 image acquisition. It was anticipated that atmospheric conditions might preclude acquisition of usable data for a few months of the year, particularly during the rainy season. In the case of our Central Valley study area, such conditions prevailed for approximately six (6) consecutive months for most of the sites. The time period extended from late September through early March, and represented one-half of the annual growing season for which no data could be obtained. The major cause of the problem was extensive and complete cloud cover, although for January the difficulty could be attributed to processing (imagery was too dark to be usable).

Because of the lack of sufficient data for long and critical time periods during the growing season, we found it impossible to complete the proposed study. However, the portion of the investigation which was completed (phase one) did produce two significant findings. The first of these relates to the fact that vegetated/non-vegetated field conditions could be accurately identified from ERTS-1 data. Since these data are the most critical inputs to the technique under investigation, it is expected that such data collected over a larger part of the annual growing season would validate the technique. The second finding concerns the problems encountered in data acquisition. If the problem reflects an unfortunate series of coincidences, then its magnitude might be expected to be of significantly less importance for future data acquisition missions. If such is not the situation, then more study will be required to attempt to optimize the actual timing of data acquisition. In either case, closer investigation of this problem will be required before the technique suggested in this section can be scientifically validated and put into operational use.

3 DRAINAGE AND LANDFORM MAPPING

As elements in the data base approach being utilized to more fully evaluate the potential of ERTS-1 data, drainage and landform characteristics of the Central Coastal Zone and San Joaquin Valley are being mapped. These phenomena are significant for several reasons including the following: (1) watershed management; (2) determination of potentially hazardous areas; (3) identification of possibly unique environmental features or habitats; and, (4) assessing the potentials and limitations for planned area development.

3.1 Drainage Networks and Basins

As stated in prior reports, preliminary analysis of ERTS-1 data indicated a definite potential for compiling drainage network and basin maps. In order to more fully evaluate this potential, drainage characteristics of the Central Region were mapped from ERTS-1 data and then compared to 1:250,000 U.S.G.S. topographic maps to determine the accuracy of mapping and the feasibility of using ERTS-1 data to update existing small scale drainage maps.

The methodology for mapping drainage characteristics consisted of four basic steps: (1) tracing all clearly defined stream flowlines on the ERTS-1 images; (2) delimiting drainage basins on the basis of the stream flowlines and topographic characteristics; (3) delimiting drainage basins on 1:250,000 U.S.G.S. topographic maps; and, (4) comparing the

ERTS-derived drainage data with data determined from the topographic maps. Mapping was performed at actual ERTS-1 scale, using acetate overlays. Interpretation was facilitated by utilizing different dates of ERTS-1 imagery for the same area, since this procedure provides a capability for stereoscopic viewing.

The accuracy of identifying drainage networks and basins from ERTS-1 data was determined by comparing three selected areas on 1:250,000 topographic maps with corresponding areas on the completed EPTS-1 Central Region Drainage Data Base map (see Figure 4). The comparison indicated that major streams (third order or greater) could be identified with 100 percent accuracy, while the accuracy for minor streams (second order or smaller) dropped to approximately 77 percent. There were no problems in accurately identifying drainage basins for the areas compared; stereoscopic viewing made it a simple task to delimit these features from ERTS-1 data.

The major difficulties in interpreting drainage data from ERTS-1 imagery were encountered in areas of: (1) arid environments; (2) valley bottoms; and, (3) slopes where a larger number of streams flow into a higher order stream system. Arid environments presented the problem of deciding the proper flowline to trace. Water flow is so intermittent that the course of a given stream channel may vary considerably, depending upon the amount of rainfall received in a particular season. In the case of valley bottoms (such as may be found in the San Joaquin Valley), field patterns associated with agricultural land usage exhibit a tendency to mask natural lines of water flow; inferrences must be made in these situations. Finally, certain areas (particularly steep-sloped ones) posed problems related to storm conditions. Heavy water flow during storms causes stream channels to vary their courses, and it is often difficult to establish what the proper flowline should be.

Despite the problems cited, ERTS-1 imagery appears to be a very useful source for mapping drainage networks and basins. Major stream courses could be delimited with 100 percent accuracy and, in several instances, flowlines could be identified on ERTS-1 imagery that did not appear on 1:250,000 topographic maps. Drainage basins could be delimited with no problems. Consequently, it should be feasible to employ ERTS-1 data for the construction of new drainage maps or to update existing ones. This would be an invaluable aid to government agencies charged with this responsibility, and to those groups involved in watershed management and planning.

3.2 Landform Mapping

Previous analysis of ERTS-1 data had indicated a definite potential for use in regional landform mapping. In order to evaluate this potential, a landform data base map for the Central Region was prepared directly from ERTS-1 imagery (see Figure 5). Review of the specific difficulties involved in the preparation of this map provides a perspective

Central Region Drainage Data Base

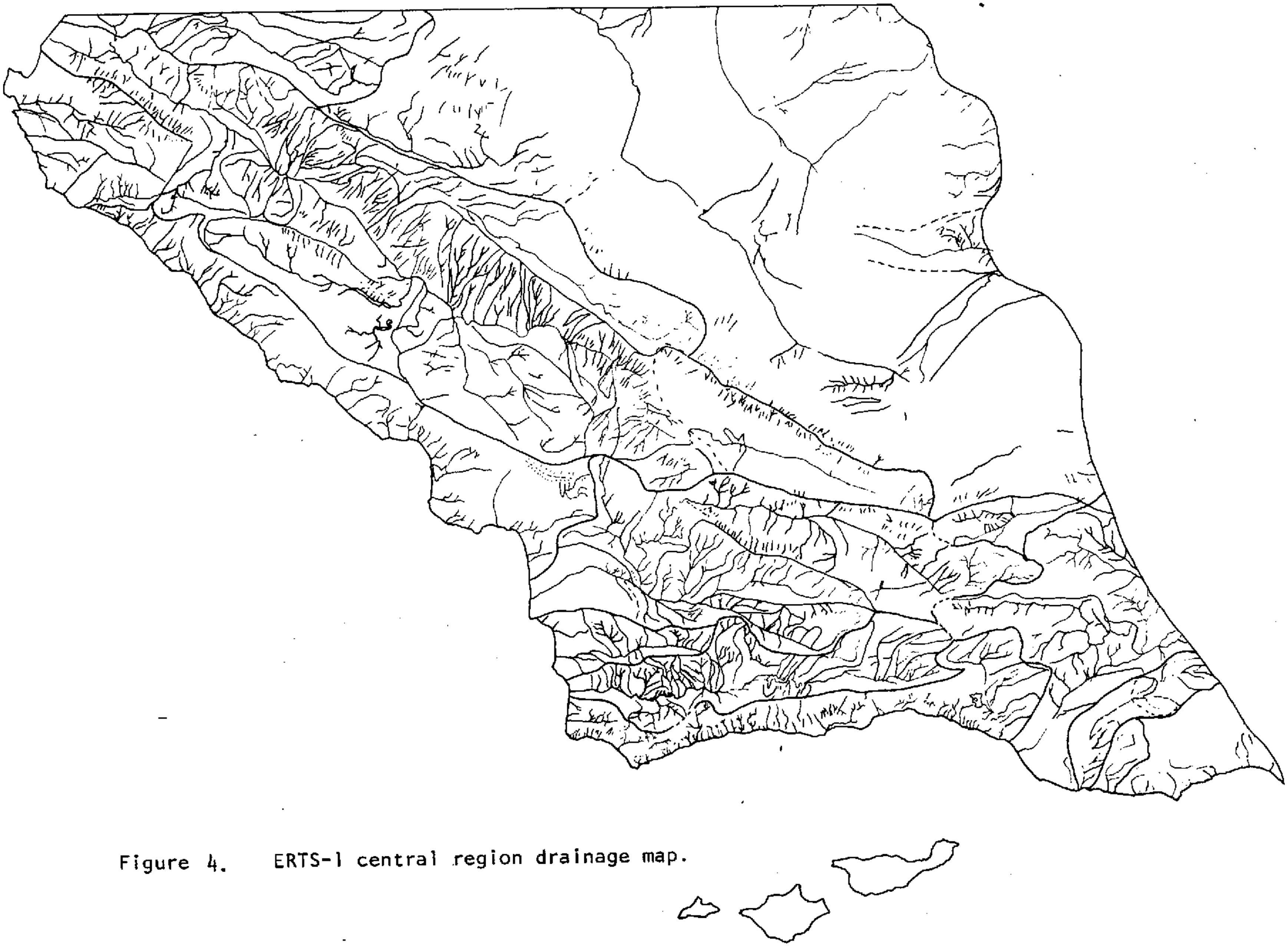
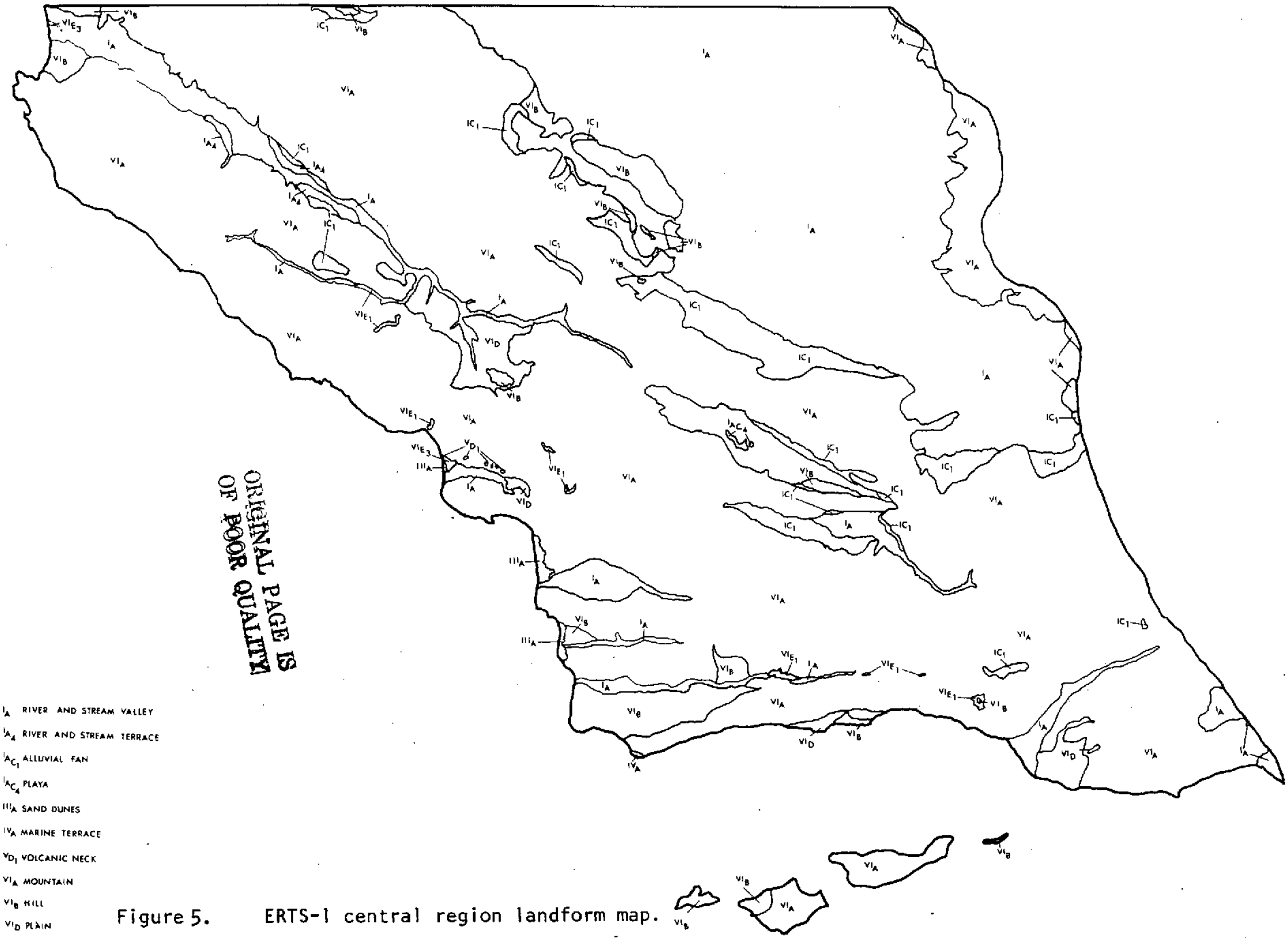


Figure 4. ERTS-1 central region drainage map.

CENTRAL REGION LANDFORM DATA BASE



I_A RIVER AND STREAM VALLEY
I_{A_4} RIVER AND STREAM TERRACE
I_{AC_1} ALLUVIAL FAN
I_{AC_4} PLAYA
III_A SAND DUNES
IV_A MARINE TERRACE
V_{D_1} VOLCANIC NECK
VI_A MOUNTAIN
VI_B HILL
VI_D PLAIN
VI_E LAKE
VI_{E_3} ESTUARY

Figure 5. ERTS-1 central region landform map.

concerning the feasibility of constructing actual landform maps or revising existing maps using ERTS-type data.

ERTS-1 landform mapping procedures involved several basic steps. These included the choice of area to provide for a wide variety of landforms and to correspond with existing landform map coverage. The latter was desired to facilitate evaluation. Once mapping locations were chosen, a landform classification scheme was organized. This is shown in Figure 5. Actual mapping was performed on cellulose acetate overlays to ERTS-1 9.5 x 9.5-inch positive transparencies. The interpretation of specific landform categories was accomplished from several ERTS-1 images taken on different dates. This procedure provided a capability for stereoscopic viewing, which is necessary for specific landform identification.

Some of the more significant problems encountered during mapping included occasional difficulty in locating boundaries between categories, delimiting narrow beaches and terraces and partial obscuring of features by vegetation cover or urban areas. In addition, some misclassification resulted from the inability to recognize certain subtle differences between similar appearing features, which might give clues regarding the exact nature of the landform. For example, some volcanic landforms were classified as "hill" simply because ERTS-1 imagery did not provide sufficient resolution capability to determine any significant difference between the two. This type of error reflects the fact that the classification scheme which was used is probably too specific for ERTS-type data. The greatest difficulty was experienced in relation to the problem of locating certain category boundaries. It was very difficult to draw a precise line separating low hills from fan categories, and fans from valley classes. This problem was most commonly encountered along areas in the West Side of the San Joaquin Valley. The hill-fan-valley floor relationship may change in the course of a single storm, and is consequently too variable to be accurately identified from ERTS-1 imagery.

These problems do not greatly detract from the potential use of ERTS data for large scale regional mapping, however. The problems cited are, for the most part, local and can be resolved with minimum ground truth operations. All major landform categories were identified with a high degree of accuracy, and without a need for supporting ground truth information. The inability to map very specific categories in the landform classification scheme would probably have little importance to users of macro-scale regional maps (state, national, or global levels).

4 INVENTORIES OF SEA KELP (MACROCYSTIS) OFF THE COAST OF CALIFORNIA

Studies of ERTS-1 MSS imagery have indicated that it may be of value for the assessment and monitoring of kelp concentrations off the coast of California.

The role of kelp (Macrocystis) in the Coastal marine ecology is significant. Kelp beds provide habitats and a source of nutrients for marine flora and fauna. It is also important that the occurrence and growth of kelp is related to many environmental factors such as water temperature, depth, sub-strata, turbidity, currents, meteorological conditions, and waste disposal.

The resource potential of kelp and associated fauna has been recognized for many years. The utilization of kelp resources by harvesting, sport, and fishing industries is a multimillion dollar market operation.

Several environmental problems related to the distribution and depletion of kelp include: (1) the effects of waste disposal from sewage outfalls; and, (2) the effects of kelp cutting by commercial and pleasure craft.

Increased kelp harvesting activities and the utilization of coastal waters for waste disposal have demonstrated a need for proper inventories and management of existing kelp resources. The problems of inventorying kelp have been studied using both ERTS-1 imagery and conventional color infrared aerial photography. The purpose of this study was to: (1) evaluate the interpreter's ability to locate, delimit, and conduct areal estimations of Macrocystis, using ERTS-1 imagery; and, (2) determine if ERTS-1 can provide reliable input for the monitoring of coastal kelp on a regular basis.

4.1 Methodology

ERTS-1 imagery was analyzed for an area off the California coast from the Monterey Peninsula in the north to Morro Bay in the south. Optimum contrast between kelp and the background water was obtained using ERTS-1 MSS image number 1002-18140, band 6 (0.7 - 0.8 micrometers). Maps were constructed from positive and negative transparencies (scale = 1:1,000,000) enlarged by projection to a scale of 1:290,000. Conventional color infrared aerial photographic coverage of the same area was obtained by NASA in April 1971 at scales of 1:60,000 and 1:120,000. Maps of the kelp were constructed using the CIR 9" x 9" transparencies. These maps were then compared with the maps prepared from the ERTS-1 imagery to determine the usefulness of the ERTS-1 data.

Discrimination of kelp was based on uniform light tonal signatures (on band 6) of the kelp canopy; for the purposes of interpretation, three general classes of kelp concentration were selected: (1) continuous cover; (2) mottled cover; and, (3) sparse cover.

All contiguous concentrations of kelp were delineated, and artificial breaks in beds resulting from extreme boat traffic were also considered. Each discrete kelp concentration ("kelp island") was assigned an identification number and measured in areal extent. Measurements of the total surface area (km^2) were made with a compensating polar planimeter and a millimeter square grid. Excellent correlation between the two systems provided a dependable check of measurement accuracy.

Using maps constructed from ERTS-1 imagery, and employing a similar system of classification and quantification of surface features, one should find it possible to monitor coastal kelp beds on a regular 18-day basis.

4.2 Analysis

The map in Figure 6 shows the individual kelp beds that were mapped along the coast of California. Figures for the quantitative estimations of the surface area of the kelp are found in Table 9.

Initial analysis of areal estimations reveal that the relative surface area of each kelp bed is small. Only one of the individually delimited areas exceeded an estimate of 5.0 square kilometers. The majority of the areas measured were between 0.7 and 5.0 square kilometers. These results, when converted to a total estimated surface area of 34.44 square kilometers, reveal the relative discontinuity of coastal kelp beds along the California coast. This figure may also have bearing on the difficulty encountered by harvesting activities and the fact that only 5 percent of the total biomass is harvested annually. There also seemed to be some correlation between the size of kelp beds and their location relative to the littoral zone. In certain areas (e.g., 34-40 on Figure 6) kelp cutting from non-commercial marine traffic has contributed to the separation of individual concentrations from the main body.

In the analysis of the surface cover of the individual beds, no apparent attenuation of kelp from south to north is revealed. A general clumping of individual beds was observed for most locations along the coast. A breaking up of individuals (e.g., 53-57) was noted along the Monterey Peninsula.

Apart from the effect of cutting on the surface area of kelp, many of the changes observed between individual concentrations may be attributed to storms, wave action, surface winds, or currents. The effects of sewage disposal were not observed in this study owing to the location of the test site.

Some of the complications inherent in the monitoring of coastal kelp from ERTS-1 MSS imagery include the above mentioned effects of environmental forces. While quantitative estimations of kelp biomass considered observable surface coverage, a large portion of the kelp biomass remains submerged and undetected by remote sensing techniques. The value of systems using ERTS-1 imagery rests in the ability to locate and map surface features on a regular basis, thus, providing a system that can

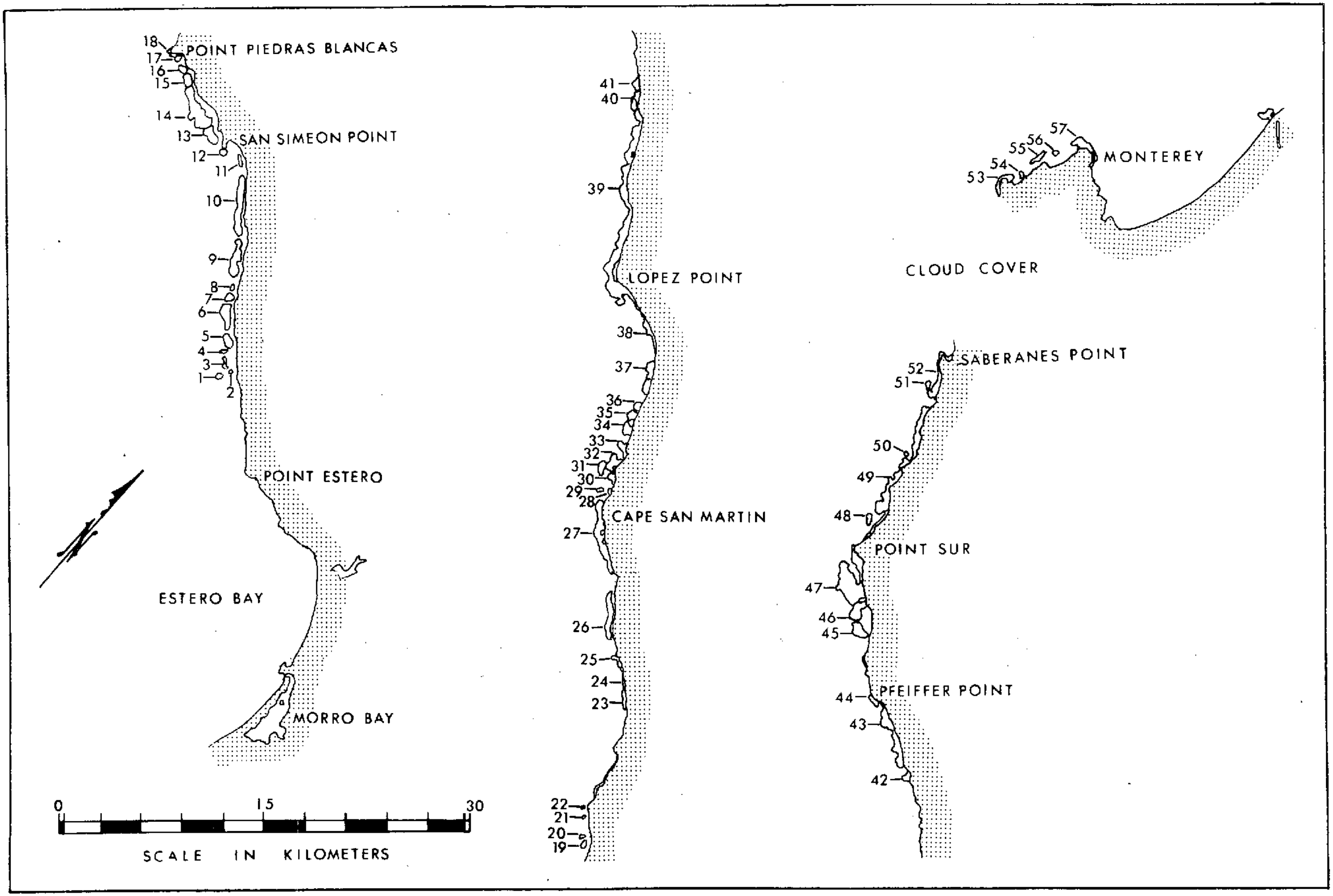


Figure 6. Map showing the areal extent and location of Kelp beds (Macrocystis) along the California coast from Morro Bay north to the Monterey Peninsula. Land area is shown by stippled pattern, while individual kelp concentrations are indicated by number (1-57). Data for the map was derived from ERTS-1 MSS image number 1002-18140, band 6 (July, 1972).

TABLE 9. QUANTITATIVE ESTIMATES OF SURFACE AREA OF INDIVIDUAL KELP BEDS FROM MORRO BAY TO MONTEREY PENINSULA, CALIFORNIA FROM ERTS-1 MSS BAND 6 IMAGERY

Numerical Designation	Kelp (*Macrocystis*) Area Km^2	Numerical Designation	Kelp (*Macrocystis*) Area Km^2
1	.1282	31	.2860
2	.0673	32	.7500
3	.0013	33	.2940
4	.1002	34	.4370
5	.4205	35	.3280
6	.8831	36	.1680
7	.2520	37	.8490
8	.0841	38	.3780
9	.9672	39	6.510
10	1.261	40	.1770
11	.1282	41	.2350
12	.1282	42	.2270
13	.6308	43	.1250
14	2.712	44	.1850
15	.3364	45	.5720
16	.1513	46	.6810
17	.1010	47	3.458
18	.1282	48	.1680
19	.0757	49	2.882
20	.0421	50	.0674
21	.0421	51	.1090
22	.1682	52	.7460
23	.2607	53	.5130
24	.0873	54	.0841
25	.2103	55	.2020
26	.8831	56	.9250
27	1.808	57	.6900
28	.0925		
29	.0757		
30	.1700		
		TOTAL KELP AREA	34.4432

monitor the movement and fluctuations of kelp boundaries. Eventually, it may be possible to relate the total surface area, as delimited on ERTS-1 imagery, to the total kelp biomass.

4.3 Summary

Data obtained from maps and quantitative measurements indicate that accurate delimitation of kelp may be done using ERTS-1 MSS band 6 imagery. The use of descriptive categories based on uniform tone responses may prove to be a reliable indicator of surface characteristics within kelp boundaries. Observable surface patterns and estimations of kelp area may be applicable to other environmental parameters such as canopy density, standing crop, and biomass availability. The ability to observe the behavior of sea kelp may provide a system to monitor the location and migration of offshore "kelp islands," while at the same time affording a basis for the assessment and management of the earth's total kelp resource.

5 DELIMITATION OF THE EXTENT OF FOREST FIRE DAMAGE

Investigations have been conducted to determine the effectiveness of delimiting fire damage areas on ERTS-1 imagery. Within the California Coastal Range area near Santa Barbara, there recently have been two extensive forest fires: (1) the "Romero Fire," just east of Santa Barbara in October, 1971 which burned an area of approximately 16,000 acres; and, (2) the "Bear Fire," just north of Santa Paula in August, 1972 which burned approximately 17,260 acres of scrubland and forest vegetation. Both fires offer excellent test sites for the study of fire damage and vegetation regeneration using ERTS-1 imagery.

It is a common practice of the U.S. Forest Service to delimit the area of each major fire using conventional aerial photography and ground reconnaissance techniques. These techniques have inherent limitations in that: (1) they require the preparation of large photo-mosaics; and, (2) the cost of the acquisition of such photography generally provides for only single date coverage, thus making time-dimensional studies difficult. Acquisition of ERTS-1 imagery in early August, 1972, afforded an opportunity to study the Bear Fire area before the fire, and two subsequent opportunities to study the extent of fire damage just after the fire and before the first major rains of the 1972 winter.

5.1 Analysis of ERTS-1 Data

In order to evaluate the ERTS-1 imagery, a data base was built up using: (1) conventional aerial photo-mosaics and already delimited U.S.G.S. topographic maps of the Romero Fire; and, (2) NASA high altitude color infrared photography (approximate scale 1:90,000) and topographic maps of the Bear Fire. Using these data sources, exact delineations of the fire areas were prepared and the areal extent for each burn area was calculated.

Upon receipt of ERTS-1 imagery, it was determined that band 7 (0.8 - 1.1 micron band) provided excellent data for the identification and delimitation of the fire areas. Figure 7 shows an enlargement of MSS frame number 1054 - 18010, band 7, of the area of the Bear Fire. Analysis of the NASA high altitude imagery indicated that the boundary delineations and area estimations generated from ERTS-1 imagery are more accurate than the results obtained by the U.S. Forest Service, as are the areal estimates of unburned, vegetative "islands" within the fire boundaries.

In addition to the capability demonstrated for accurate delimitation of the extent of fire damage for the Bear Fire, it also proved feasible to utilize ERTS-1 imagery (band 7) for delimiting the extent of the Romero Fire (which had occurred almost a year prior to the acquisition of October ERTS-1 imagery). This ability to document the effects of a former burn indicates that 18-day repetitive ERTS-1 coverage is of considerable value for monitoring changes in an area which has been burned more than one year before. Such monitoring could have considerable utility for: (1) studying the rate of natural vegetation regeneration; (2) investigating the detrimental effects of a burn, such as increased erosion, flooding, mudslides, land slides, etc.; and, (3) monitoring the success of revegetation programs (the area burned by the Bear Fire has been aerially seeded with rye grass, as a deterrent to erosion).

5.2 Conclusions

In summary, the synoptic view and multi-date acquisition aspects of ERTS-1 imagery provide a means, with respect to forest fires, to: (1) clearly define the boundaries of the burned area; (2) allow for rapid calculation of the areal extent of the damage; (3) eliminate the need for preparing large aerial photo-mosaics; (4) supply a valuable temporal dimension to the study of the effects of large scale forest fires; and, (5) determine the extent of like vegetation remaining within a fire perimeter.

6 VEGETATION MAPPING

The objective of the vegetation mapping study was to determine the extent to which ERTS-type imagery might be used for the generation of base data concerning vegetation associations found in the Central Region of California. Attainment of this objective would be achieved by the construction and evaluation of a vegetation data base map for the entire region, based on ERTS-1 imagery obtained throughout the 1972-1973 growing season.

Figure 7. ERTS MSS band 7 (0.8 - 1.1 microns) image showing the Bear Fire area as a dark island (owing to low infrared reflectance) amidst the surrounding vegetation.

6.1 Approach

The evaluation of ERTS-1 imagery for purposes of vegetation mapping entailed nine interrelated phases: (1) formulation of a system for classifying the characteristic vegetation associations of the Central Region; (2) construction of a Central Region vegetation verification data base from ground truth and high altitude photographic data; (3) selection of sample test sites within the region; (4) familiarization with the image characteristics of ERTS-1 imagery; (5) preliminary interpretation of ERTS-1 imagery for the sample test sites; (6) evaluation of the preliminary maps; (7) selection of optimal dates of ERTS-1 images to be used in a multidate mapping approach; (8) interpretation of ERTS-1 imagery for the entire region and the completion of the vegetation data base map; and, (9) final analysis of the data base map and the utility of ERTS-1 imagery for vegetation mapping.

6.2 Formulation of a System of Vegetation Classification

Before a preliminary evaluation of the utility of ERTS imagery for vegetation mapping purposes could be performed, it was necessary to prepare a suitable vegetation classification scheme. The scheme was designed so that it: (1) included major plant communities found in the Central Region; and, (2) was flexible enough so that it could be expanded or contracted for use with variable photographic scales and/or resolutions.

In order to prepare such a classification scheme, a thorough examination of literature on California natural vegetation was carried out. The resultant scheme was derived, for the most part, from five sources (California Parks and Recreation, 1971; Critchfield, 1971; Kuchler, 1964; Munz and Keck, 1970; and, Nash, 1970). It consisted of a hierarchical classification of the natural vegetation associations of the Central Region and was divided into three basic levels (see Table 10). The first and most general level is divided into aquatic vegetation and terrestrial vegetation; the second level comprises major vegetation groups on a physiognomic basis (e.g., grassland, scrub vegetation, forest, etc.); and, the third level breaks down these general physiognomic classes into individual vegetation communities. (A fourth level is provided in some cases where characteristic species tend to be dominant in some associations.)

Symbols were developed for use on vegetation maps and indicate both the physiognomic and community affiliation of each vegetation type. The system is open-ended, thus making it feasible to add or subtract symbols depending upon the precision required for vegetation mapping.

6.3 Construction of a Verification Data Base

The information content of any remote sensing imagery can be effectively evaluated only if an accurate data base for the area under

TABLE 10. NATURAL VEGETATION CLASSIFICATION SCHEME

Plant Community	Code
I. Aquatic	
A. Marine (Aquatic)	M
1. Nearshore (Kelp and seaweed)	Mn
2. Intertidal	Mi
B. Freshwater (Aquatic)	Fw
C. Marsh	Ma
1. Salt Marsh	Ma_{sm}
2. Freshwater Marsh	Ma_{fm}
II. Terrestrial	
A. Barren	Ba
B. Strand	Sr
C. Grassland	G
1. Coastal Prairie	Gcp
2. Valley Grassland	Gvg
3. Meadows	Gme
D. Woodland-Savanna	Ws
E. Scrub	S
1. North Coast Shrub	Snc
2. Coastal Sagebrush (soft chaparral)	Scs
3. Cut-over Forest	Scf
4. Chaparral (hard chaparral)	Sc
5. Scrub-Hardwood	Shw
6. Desert Scrub	Sd
a. Mesquite	
b. Sagebrush	
c. Saltbush	
F. Forest	F
1. Hardwood	Fhw
2. Mixed Evergreen	Fme

TABLE 10. (Continued)

Plant Community	Code
3. Coniferous	Co
a. Redwood	Co_{rw}
b. North Coast	Co_{nc}
c. Douglas Fir	Co_{df}
d. Pine	Co_{pc}
G. Riparian	R
H. Agriculture	A

consideration is available. With this in mind, data base maps of the vegetation in the entire Central Region were prepared. The preparation of these maps entailed the use of 1:60,000 and 1:120,000 scale high-altitude color infrared photography taken in April, 1971. Stereo coverage was available in most cases and the overall quality of the imagery was excellent. The actual data base maps were constructed on cellulose acetate overlays. Site locations of representative plant communities were selected and ground truthed in order to evaluate interpretation accuracy. Herbarium specimens of dominant plant species within each community were also collected to relate physiognomic characteristics (e.g., leaf structure and plant geometry) to variations in tonal response apparent of the imagery.

6.4 Preliminary ERTS-1 Vegetation Mapping

Two representative test areas were selected within the Central Region for preliminary evaluation of ERTS-1 imagery for vegetation mapping purposes. One test area was situated along the coast (in the vicinity of Morro Bay), and the second was in the more arid San Joaquin Valley (northeast of Bakersfield). The test area near Morro Bay included a representative sample of most of the major vegetation associations characteristic of the coastal portions of the Central Region. The area near Bakersfield included a representative sample of most of the characteristic vegetation associations in the more arid portions of the Central Region.

A time period of approximately one week was allotted to the study of ERTS-1 imagery to permit familiarization with its unique tonal, textural, and scale qualities. All seven MSS and RBV bands and the bulk color composite for frame number 1002-18140 (Monterey area) were examined with the aim of selecting the most appropriate band for vegetation studies. The results indicated that, of the seven black-and-white bands, MSS band 5 was most suitable for vegetation mapping purposes.

Through the use of both the color composite and band 5 (imaging in the red portion of the spectrum from .6 - .7 microns), vegetation boundary delineations were drawn using cellulose acetate overlays. These maps were then compared with the 1:120,000 and 1:60,000 vegetation data base maps prepared from high altitude color infrared photography.

After the ERTS-1 imagery had been compared with the conventional photography and vegetation data base maps, it was possible to determine relevant tonal ranges, textural characteristics, shapes, and locational parameters for each vegetation community under consideration. From these data, a descriptive interpretation key was prepared (see Table 11), which was utilized for the preliminary interpretation of ERTS-1 data.

Preliminary interpretation and mapping for both sample test sites was performed utilizing photographic enlargements of ERTS-1 images

TABLE 11. VEGETATION INTERPRETATION KEYS

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Barren	Ba	white to light grey	continuous		In man-induced and naturally disturbed areas.	Mostly lacking or devoid of vegetation.
Coastal Strand	Sr	light grey to grey	continuous to streaked		Dunes and sandy beaches dispersed along entire coast with community variability from north to south.	Consists of low prostrate vegetation, often succulent woody perennials. Genera include: *Atriplex*, *Franseria*, *Lupinus*, and *Abronia*.
Coastal Salt Marsh	Ma_{sm}	dark grey to black	continuous		Coastal habitats, sea level to 10 feet, most extensive on tidal flats and lagoons.	Lacking perennial grasses. Mostly succulents, herbs or shrubs and prostrate vegetation. Characteristic genera include *Salicornia*, *Suaeda*, and *Distichlis*.
Coastal Sagebrush (Soft Chaparral)	Scs	Grey	mottled		Transverse, peninsula and South Coast Ranges to Baja, California. Mostly below 3,000 feet between the ocean and chaparral communities.	Occurring on dry and semi-rocky moderate to steep south and west facing slopes. Shrubs 1-5 feet in height with fasciculate leaves. Fairly continuous ground cover although less dense than chaparral. Characteristic genera include *Salvia*, *Artemesia*, *Baccharis*, and *Eriogonum*.

TABLE 11. (Continued)

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Chaparral	Sc	dark grey to black	mottled to patchy		Coast Ranges from southern California to Mexico, notably in San Luis Obispo and Santa Barbara counties. Occurring in dry, rocky slopes and ridges often north facing on lower altitudes and south facing on higher altitudes to 6,000 feet.	Pyrophytic and evergreen shrubs. Dense, broad-leaved, and sclerophyll vegetation, 3 to 15 feet in height. Occurring as a continuous, often impenetrable cover. Characteristic genera include: *Adenostoma*, *Ceonothus*, and *Arctostaphylos*.
Desert Scrub	Sd	light grey to grey	mottled	some fence-lines along edges.	Throughout the San Joaquin Valley in arid lowland environments; primarily in sites not suitable for agriculture.	Sparse low vegetation characterized by dominant shrubs such as *Prosopis*, *Atriplex*, *Artemesia*, *Allenrolfia* and *Suaeda* plus an understory of annual grasses such as *Bromus*, *Schismus*, etc.
Grassland	G	light grey	continuous		Low hot valleys of coast ranges on clay soils from sea level to 3,000 feet.	Uncultivated grasses and low associated herbaceous plants. Characteristic genera include indigenous *Stipa*, *Poa*, and *Aristida*, and replacement genera including *Bromus*, *Avena*, *Festuca*.
Woodland Savanna	WS	light grey to grey	mottled to patchy		Occurring in areas of mergent grass and woodland from sea level to 6,000 feet.	Open stands of broad-leaved trees and evergreen with intermittent grass and herbaceous vegetation. Refer to Forest Hardwood and Grassland.

TABLE 11. (Continued)

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Scrub-Hardwood	Shw	dark grey to black	mottled		Refer to Hardwood Forest.	Open stands of broad-leaved trees with open spaces occupied by sagebrush, chaparral, and low herbaceous vegetation.
Forest Hardwood	Fhw	Black	continuous to mottled		Semi-rocky to clay soils on foothills and in valleys. Inner coast ranges from sea level to 4,000 feet.	Mixed or homogeneous stands of broad-leaved species 15 to 70 feet in height forming a closed or nearly closed canopy. Characteristic genera include: *Quercus*, *Pinus*, and *Umbellularia*
Forest-coniferous	Fco	Black	mottled		Coastal ranges from sea level to 12,000 feet.	Dense stands of homogeneous or mixed coniferous trees ranging from 10 to over 100 feet in height. Closed or nearly closed canopy. Characteristic species include *Pinus muricata*, *P. radiata*, and *Cupressus sargentii*.
Riparian	R	Dark grey to black	mottled to patchy	thin streamers, sometimes patchy	Species of trees and shrubs restricted to streambank environments from sea level to 6,000 feet.	Broad leaved trees 10 to 70 feet in height forming a dense crown cover. Understory consisting of low shrub and herbaceous growth (generally phreatophytic) along stream course. Characteristic genera include: *Platanus*, *Acer*, *Alnus*, *Populus*, and *Salix*.
Agriculture	Ag	dark grey to black	continuous	rectangular	Coastal and mountain regions.	Regularly cut hay lands, cultivated and irrigated fields.
Water body	WB	black	continuous		Marine and terrestrial.	

1002-18140 (July 25, 1972) of the Morro Bay area, and 1091-18064 (October 22, 1972) of the San Joaquin Valley area. The resultant scales were approximately 1:290,000 and 1:250,000 respectively.

Through use of the information contained in the photo interpretation key in Table 11, plus an *a priori* knowledge of the vegetation associations of these areas, complete vegetation maps for the two sample areas were prepared on acetate overlays.

After completion, the maps of the sample areas prepared from ERTS-1 data were compared to maps constructed from high altitude photography and ground truth data. The comparison and subsequent evaluation indicated that some vegetation categories were too detailed for interpretation from ERTS-1 data, while others were not identifiable with any reliable degree of consistency. Consequently, the initial vegetation classification system was modified preparatory to the construction of the Central Region Vegetation Data Base. The revised system comprised 17 categories (see Table 12), and reflected an assessment of what categories would be most compatible with ERTS-type data based on the preliminary mapping that was accomplished.

Coincident with the testing of the classification system, an evaluation of the optimum dates for interpretation of particular vegetation association categories from ERTS-1 data was performed. The purpose of the evaluation was to effectively utilize the opportunity for a multidate mapping approach afforded by ERTS-1 data. Five image dates, representative of seasonal variations, were selected for each vegetation association category. Each vegetation association was interpreted on band 5 for the five dates, and a final assessment was made as to the optimum time period for differentiating a particular vegetation association from its surrounding environment. The results of this testing can be seen in the Cross-Evaluation chart in Table 13. This table formed the basis for selecting particular images to be used in the construction of the Central Region Vegetation Data Base.

6.5 Central Region Vegetation Data Base

The actual interpretation and mapping of the vegetation in the Central Region was done by three skilled interpreters, who were familiar with the characteristic vegetation types in the area. The interpretation was done on the original black-and-white, 1:1,000,000 scale, 9.5 x 9.5-inch transparencies. For each scene or area imaged on a given frame, at least two bands (generally bands 5 and 7) were interpreted in concert to fully utilize the significant information from both the visible and infrared portions of the spectrum. Two or more dates were also utilized for each scene to exploit seasonal variations that might improve identification and delineation accuracy. The actual identification of the different vegetation associations was based solely on tonal differences, macrotextural differences, and locational data on the ERTS-1 imagery.

TABLE 12. VEGETATION CLASSIFICATION USED FOR VEGETATION DATA BASE MAPPING OF THE CENTRAL REGION TEST SITE

1. Barren
2. Strand
3. Marsh
4. Grassland
5. Soft Chaparral
6. Hard Chaparral
7. Scrub
8. Scrub Grassland
9. Scrub Hardwood
10. Woodland Savanna
11. Hardwood Forest
12. Coniferous Forest
13. Desert Scrub
14. Riparian
15. Agriculture
16. Urban
17. Waterbodies

TABLE 13. CROSS-EVALUATION CHART SHOWING OPTIMUM MONTHS FOR DIFFERENTIATING VEGETATION ASSOCIATIONS ON ERTS-1 IMAGERY

	Barren	Strand	Marsh	Grassland	Soft Chap.	Hard Chap.	Scrub	Scrub Gras.	Scrub Hrd.	Wild Sav.	Hrd. Forest	Riparian	Agriculture	Urban
Barren		5	5	10	10	10	10	10	10	10	10	5	5	5
Strand	8		8	8	8	8	8	8	8	8	8	8	8	8
Marsh	10	8		10	10	10	10	10	10	10	10	10	10	10
Grassland	10	10	10		3	10	8	8	3	3	1	5	8	N
Soft Chap.	10	8	10	3		8	3	3	3	10	10	5	5	5
Hard Chap.	10	8	10	10	8		3	3	3	8	1	8	8	8
Scrub	10	8	10	8	3	3		1	N	N	3	8	8	8
Scrub Gras.	10	8	10	8	3	3	1		3	3	1	8	8	8
Scrub Hrd.	10	8	10	3	3	3	N	3		3	8	8	8	8
Wdl. Sav.	10	8	10	3	10	8	N	3	3		1	8	8	8
Hrd. Forest	10	8	10	1	10	1	3	1	8	1		8	8	8
Riparian	5	8	10	5	5	8	8	8	8	8	8		8	8
Agriculture	5	8	10	8	5	8	8	8	8	8	8	8		8
Urban	5	8	10	N	5	8	8	8	8	8	8	8	8	

N - no optimum
1 - Jan.
3 - Mar.
5 - May
8 - Aug.
10 - Oct.

The interpretation was carried out utilizing hand magnifiers and Zeiss stereoscopes (when reinforcement and/or combination of images was desired, or when limited stereoscopic viewing was possible). The original mapping was completed on individual acetate overlays and later transferred to a single map base.

The minimum mapping unit, i.e., the smallest area that was classified as to given vegetation association, was 2.641 square kilometers. At a scale of 1:1,000,000, 2.641 square kilometers equals approximately 0.026 square centimeters on the image. Accordingly, it was felt that units smaller than 2.641 square kilometers would be comparatively insignificant, and unmappable, at a scale of 1:1,000,000. As a consequence of the selection of this minimum mapping unit, certain vegetational features (such as the kelp concentrations and areas of riparian vegetation) were too limited in areal extent to merit mapping at the ERTS-1 scale. However, it has been possible to map and determine the areal extent of these areas (as documented in section 4 and 5), using five to ten times (5x to 10x) enlargements of the ERTS-1 imagery.

Upon completion, the 1:1,000,000 data base map of the vegetation association of the Central Region test site (Figure 8) was evaluated by: (1) comparing the mapping accuracy (i.e., delineation of vegetation boundaries) with similar maps constructed utilizing 1972 NASA High Altitude photography; (2) viewing analagous areas on color and color infrared high altitude photography (at scales of 1:60,000, 1:120,000 and 1:390,000) on which a majority of the mapping categories could be consistently identified; and, (3) selectively ground truthing areas to determine variable species composition in the major associations throughout the region.

The major problem encountered in working with the ERTS-1 imagery was the difficulty in differentiating between woody and arborescent vegetation, such as hard chaparral, hardwood forests, and coniferous forest. Based on tonal variations alone, these associations tend to range from dark grey to black and are very difficult to differentiate. Nevertheless, some differentiations can be made based on geographical location (i.e., proximity to the coast or location in mountainous areas). The Cross-Evaluation chart (Table 14) shows the relative ease of differentiation between the vegetation associations. The ratings are based not only on tonal, macrotextural differences, and locational factors, but also on the use of the multidate and multiband aspects of ERTS-1 images. The ratings indicate that there is reasonably high accuracy for differentiating between some of the individual categories. However, in attempting to differentiate between a given category and all other possible categories, the identification accuracy is considerably reduced owing to the similar signature and geographic distributions of different vegetation association. Table 15 provides a list of vegetation associations, or groups of vegetation associations, which can be accurately differentiated from each other, but within each group

CENTRAL REGION VEGETATION DATA BASE

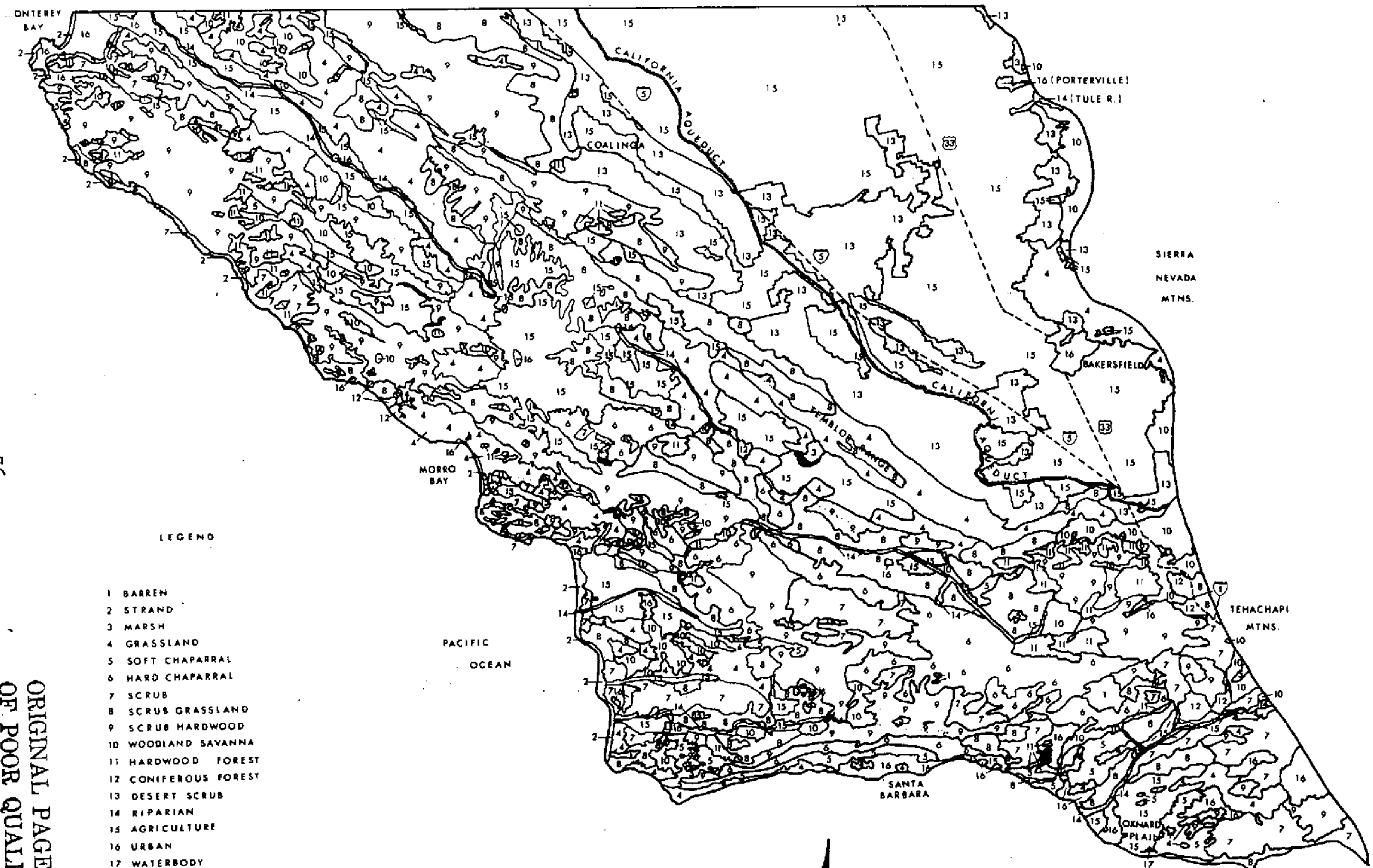


Figure 8. ERTS-1 central region vegetation map.

TABLE 14. CROSS-EVALUATION CHART SHOWING THE RELATIVE EASE OF DIFFERENTIATING BETWEEN VEGETATION ASSOCIATIONS ON ERTS-1 IMAGERY BASED ON INTERPRETATIONS PERFORMED USING MULTIBAND-MULTIDATE ERTS-1 DATA

	Barren	Strand	Marsh	Grassland	Soft Chaparral	Hard Chaparral	Scrub	Scrub Grassland	Scrub Hardwood	Woodland Savanna	Hardwood Forest	Coniferous Forest	Desert Scrub	Riparian	Agricultural	Urban	Waterbodies	Composite
Barren		+	++	++	++	++	++	++	++	++	++	++	+	++	++	++	++	++
Strand	+		++	++	++	++	++	++	++	++	++	++	++	++	++	+	++	++
Marsh	++	++		++	-	+	+	++	++	++	++	++	++	+	++	++	-	-
Grassland	++	++	++		++	++	++	-	++	+	++	++	+	++	+	++	++	++
Soft Chaparral	++	++	++	++		--	--	+	+	+	-	+	++	+	++	++	++	--
Hard Chaparral	++	++	+	++	--		--	+	--	++	--	-	++	+	++	++	++	--
Scrub	++	++	+	++	--	--		+	--	+	--	-	++	++	++	++	++	-
Scrub Grassland	++	++	++	-	+	+	+		+	--	++	++	-	++	++	++	++	-
Scrub Hardwood	++	++	++	++	+	--	--	+		+	--	--	++	-	++	++	++	+
Woodland Savanna	++	++	++	+	+	++	+	--	+		+	++	+	++	++	++	++	+
Hardwood Forest	++	++	++	++	-	--	--	++	--	+		--	++	-	++	++	++	--
Coniferous Forest	++	++	++	++	+	-	-	++	--	++	--		++	+	++	++	++	--
Desert Scrub	+	++	++	+	++	++	++	-	++	+	++	++		++	++	++	++	+
Riparian	++	++	+	++	+	+	++	++	-	++	-	+	++		-	++	++	-
Agricultural	++	++	++	+	++	++	++	++	++	++	++	++	++	-		+	++	++
Urban	++	+	++	++	++	++	++	++	++	++	++	++	++	++	+		++	++
Waterbodies	++	++	-	++	++	++	++	++	++	++	++	++	++	++	+	++		++

++ Excellent Differentiation (approximately 100%)
\+ Good Differentiation (limited confusion)
\- Limited Differentiation (often confused)
-- Poor Differentiation (undifferentiable in most cases)

TABLE 15. VEGETATION ASSOCIATIONS OR GROUPS OF VEGETATION ASSOCIATIONS WHICH HAVE SIMILAR SPECTRAL SIGNATURES AND LOCATIONAL CHARACTERISTICS

The members within each group are generally very difficult to differentiate from one another.

I	II	III	IV	V	VI	VII	VIII	IX	X
Barren	Strand	Marsh	Grassland	Desert Scrub	Woodland Savanna	Soft Chaparral	Riparian	Agricultural	Urban
		Waterbodies			Scrub Grassland	Hard Chaparral			
						Scrub			
						Scrub Hardwood			
						Hardwood Forest			
						Conifer Forest			

VI
Woodland Savanna
Scrub Grassland

correct identification is generally very difficult. The major difficulty is in differentiating between woody vegetation types (comprised of tree and woody shrubs). Grassland associations, or areas having relatively high concentrations of grass, can generally be easily differentiated from the more woody associations. Despite the difficulty of differentiating between woody vegetation associations, it should be emphasized that ten distinct vegetation categories can be identified with a relatively high degree of accuracy. The most significant of the results of the vegetation mapping using ERTS-1 imagery may be summarized as follows: (1) the realization of its value as a mapping base on which accurate, continuous boundaries of major vegetation units can be delineated; (2) the ability to improve identification and delineation results with multidate imagery received on a regular basis; and, (3) the use of ERTS-1 imagery for the selection of optimal areas for verification of interpretation results, either by utilizing limited conventional aerial photography or ground reconnaissance techniques.

6.6 Conclusions

The completion of the vegetation data base map for the entire 52,213 square kilometer Central Region area showed that the use of multidate, multiband ERTS-1 imagery permitted rapid and accurate delineation of major vegetation associations. An evaluation of the map (see Figure 8) indicated that most of the major physiognomic vegetation groupings (e.g., forest, scrubland, grassland, savanna, etc.) can be mapped with an accuracy comparable to that obtained using conventional high altitude photography. Through the use of ERTS-1 imagery, it should be possible to rapidly update valuable vegetation resource data on a regional basis. With varying degrees of accuracy, 17 different vegetation units could be identified (see Table 12). These 17 different vegetation units comprise the modified vegetation classification scheme, which resulted from the previously mentioned preliminary mapping studies. Each of these different vegetation units represents basic differences in site characteristics. In most cases these may indicate either the developmental potential of an area or the effect, favorable or unfavorable, that man has had on the area.

The time saving resulting from the interpreter's ability to continuously map large areas eliminates difficulties commonly encountered when utilizing conventional aerial photomosaics. The time required to map the entire 52,213 square kilometer area was approximately 10 man-days. A large proportion of this time included familiarization with the small scale imagery, the selection of optimal dates, and general familiarization with the variable tonal characteristics of the different vegetation types over time. Given present expertise, the completion of vegetation maps of similar size, scale, and areal extent should require no more than 3-5 man-days.

The major drawbacks of utilizing ERTS-1 data for vegetation mapping seem to be: (1) the broad classification systems used with ERTS imagery (i.e., grouping more specific units into more general categories) may be of only marginal use for land use planning purposes; and, (2) in order to achieve an acceptable level of identification accuracy, the mapping must be performed by interpreters who are well acquainted with the vegetation associations and their geographic distribution. An alternative would be the utilization of a well-coordinated program of high altitude photography and ground reconnaissance to verify identifications. There is still a need for some reliance on ground reconnaisance, selective use of coincident conventional aerial photography, or a priori knowledge of the vegetation in order to accurately identify the vegetation units that are detectable on ERTS-1 imagery.

7 CONCLUSIONS

The results of the investigations discussed in the preceding sections indicate that ERTS-1 type data can be a valuable source for environmental resource information needs. The resolution of ERTS-1 data places constraints upon the detail to which specific environmental phenomena can be investigated. Furthermore, the resolution limitations create certain problems for the investigation of environments where a high diversity of phenomena are localized in small areal units, such as the coastal portion of the Central Region of California. However, these limitations are mitigated to a large degree through the synoptic perspective afforded by ERTS-1. ERTS-1 data provide a capability to inventory resources over extremely extensive areas (e.g., the 52,213 square kilometer area of the Central Region), and generate data for these areas at essentially a single point in time. Although the detail of information may be insufficient for specialized user requirements, the advantage of this synoptic view is that large scale environmental resource information can be: (1) obtained within a standardized format for a single date; and, (2) monitored and updated with comparative ease and frequency to reflect changing resource conditions. This is not feasible utilizing conventional data collection methods.

With respect to the specific studies which the Geography Remote Sensing Unit has conducted, the following conclusions can be made:

Land Use

1. Urban areas can be differentiated best on MSS bands 4 and 5.

2. Transportation linkages (highways, roads, airports, canals) are most readily defined from MSS band 7.

3. Agricultural field boundaries are adequately identifiable on MSS bands 4 - 7, and most clearly defined on band 7.

4. Cultivated land can be mapped accurately (under 5 percent error) from MSS band 5. Fallow land identification explains the majority of error.

5. Land use is difficult to map in the California coastal environment because many individual use categories occupy very small areal units; land use mapping is easier and capable of more sophisticated refinements in the arid California Central Valley.

6. Macro-level land use change can be identified, mapped, and measured with a high degree of reliability.

Crop Identification

1. Non-vegetated (bare soil) field conditions are identifiable with almost 100 percent accuracy (negligible errors of omission or commission).

2. It is difficult to identify specific crops on a single date because of signature overlap.

3. Identification accuracies can be improved by a multidate analytical approach, since crop growth cycles are reflected in progressively changing tonal signatures on ERTS-1 imagery over time.

Drainage and Landform Mapping

1. Drainage networks and basins can be mapped with sufficient accuracy to permit updating of U.S.G.S. 1:250,000 topographic maps.

2. Macro-scale landform mapping is feasible.

Kelp (Macrocystis)

1. Kelp concentrations can be identified and located accurately.

2. Boundaries of kelp concentrations can be delimited accurately and good areal estimations made.

3. Internal variations within kelp concentrations are detectable (probably related to density) and may, in conjunction with estimates of areal extent, provide an indication of biomass.

Forest Fire Damage

1. The perimeter of forest fire damage can be accurately delimited.

2. "Islands," or pockets of unburned vegetation, can be identified and mapped.

3. Burn area of previous forest fires (at least one year in the past) can be identified and mapped.

Vegetation Mapping

1. Barren land, Coastal Strand, Coastal Salt Marsh, Grassland, Scrub Hardwood, and Agricultural vegetation exhibit good differentiation.

2. Coastal Sagebrush, Chaparral, Woodland-Savannah, Forest Hardwood, and Riparian vegetation exhibit limited differentiation.

3. Coniferous forest is difficult to differentiate.

4. Individuals, with comparatively minor training in photo interpretation and vegetation identification, can perform vegetation mapping at reasonable levels of accuracy; more specifically, at the association rather than the community level. This indicates that ERTS-1 type technology should be transferable into operational usage for this type of resource inventory.

5. Some problems in the interpretation of specific vegetation associations may be mitigated through selective use of ground or light aircraft reconnaissance.

The successes resulting from these specific investigations are primarily attributable to the multiband (opportunity to view phenomena that are highlighted in different bands) and multidate (certain phenomena are more observable during particular seasons of the year) aspects of ERTS-1 data. Perhaps most significantly, it is estimated that each of the Central Region data base maps (encompassing an area of approximately 52,213 square kilometers) could be constructed for a different time period in approximately one man-week. These considerations indicate that ERTS-1 type data should provide significant input to resource management and planning at regional, or larger, scales.

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GSFC ______________________

ORGANIZATION ______________________

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Land-use	Veg.	Geology	
1251 17565M				Clouds
1256 18242M				Clouds, Bay
1287 17564M				Clouds
1269 17565M	X	X	X	
1291 18182M	X	X	X	Bay
1291 18184M	X	X	X	
1273 18183M	X	X	X	Bay
1273 18185M	X	X	X	
1289 18081M	X	X	X	Islands
1289 18072M	X	X	X	
1289 18074M	X	X	X	
1290 18124M	X	X	X	
1290 18130M	X	X	X	
1290 18133M	X	X	X	
1274 18241M	X	X	X	Bay
1305 17563M				Clouds, Haze
1252 18021	X	X	X	Clouds, Urban Area
1252 18023				Islands
1272 18131	X	X	X	
1272 18133	X	X	X	Sand Dunes
1272 18924	X	X	X	Snow, Urban Area, Sedimentation
1292 18240				Haze, Bay, Urban Area
1306 18015				Clouds, Haze
1306 18021				Clouds
1323 17562				Fog, Haze
1324 18014	X	X	X	Fog, Desert
1324 18020				Clouds

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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