Paper L 10

APPLICATION OF ERTS-1 SATELLITE IMAGERY FOR LAND USE MAPPING AND RESOURCE INVENTORIES IN THE CENTRAL COASTAL REGION OF CALIFORNIA

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ABSTRACT

ERTS-1 Satellite imagery has proved a valuable data source for land use as well as natural and cultural resource studies on a regional basis. ERTS-1 data also provide an excellent base for mapping resource related features and phenomena. The investigations reported on here are focused on a number of potential applications which are already showing promise of having operational utility.

INTRODUCTION

The purpose of this paper is to describe the significant findings resulting from an evaluation of ERTS-1 imagery as a data source for land use studies and the inventory and monitoring of selected environmental parameters. The paper will be divided into three sections: 1] a description of research carried out be the Geography Remote Sensing Unit [GRSU], University of California, Santa Barbara, California, from July 1972 to July 1973; 2] a discussion of the significance of the results; and, 3] a brief discussion of envisioned follow-on studies and the uses of ERTS-1 data that, at present, seem to have the most promise on an operational basis.

DESCRIPTION OF RESEARCH

The objectives of the research, performed by the GRSU, were to: 1] determine the feasibility of using ERTS as a data source for the detection, identification and mapping of various land use types; 2] identify specific land use parameters within the diverse environmental and cultural settings constituting these test areas; and, 3] to compile data base maps for land use and other important resources in the Central California test site. Specific features under examination included: natural vegetation, geomorphology, hydrology, and cultural features such as urbanized areas, transportation routes and networks. The areal focus of these studies was on the Central Regional Test Site, California, covers approximately 52,213 square kilometers [see Figure 1]. Included within the site are several million people and all, or portions of, ten California counties.

In order to successfully evaluate ERTS-1 data for generating resource data for this area it was first necessary to: 1] develop flexible classification schemes for both urban and rural terrain features and, 2] to develop a data base for the test site, against which the value of ERTS-1 imagery as a data source could be evaluated.

Figure 1: Central Regional Test Site, California covering approximately 52,213 square kilometers.

Classification Systems

The classification systems were designed so that they could be either collapsed or expanded to accomodate different levels of generalization, e.g., classifications developed would be applicable to either conventional aerial photography or ERTS satellite imagery. Four major classification schemes were devised: 1] land use; 2] land forms; 3] hydrology; and, 4] natural vegetation [see Appendix A]. The land use classification scheme included general categories such as agriculture, extractive industries, public facilities, recreational facilities, industrial areas, transportation networks, commercial areas, residential areas and non-developed land. Each of these categories are, in turn, subdivided for more specific identification of terrain features, e.g., recreation was broken down into campgrounds, golf courses, parks, stadiums, marinas, etc., or as in the case of residential areas, into single family and multi-family dwellings.

The land form [geomorphology] classification scheme included general categories related to fluvial, glacial, eolian, marine, volcanic and other complex geomorphological features. Again these categories were further broken down into more specific land forms.

Hydrologic features were broken down into streams [which were classified according to their "stream orders"], lakes, springs, estuaries, marshes, swamps and man-made hydrologic features such as reservoirs, canals, wells, sumps, etc.

Finally, the natural vegetation classification included both terrestrial and aquatic vegetation. Again, these categories were subdivided into sub-categories such as marine aquatic, freshwater aquatic, strand grassland, woodland-savanna, scrub, forest and riparian. These sub-categories were, in turn, further broken down into more specific vegetation associations such as: salt marsh, valley grassland, coastal chaparral, cut-over forest, desert scrub, hardwood forests, coniferous forests, etc. Again, in all cases the classification systems derived were amenable to application to both conventional high altitude NASA photography and the more generalized ERTS-1 images.

Data Base

In preparation for the analysis of ERTS-1 data, baseline information on the Central Regional Test Site was acquired prior to the acquisition of the first ERTS-1 images. These data were compiled utilizing 1:60,000 and 1:120,000 high altitude photography; 1:600,000 NASA U-2, ERTS-1 support photography; and selective ground reconnaissance. Based on interpretational analysis of these data, GRSU personnel were able to prepare land use, landform, hydrology and natural vegetation maps for almost the entire Central California test site. In all cases, the above mentioned classification schemes were used as guidelines for data acquisition and mapping. The data and maps compiled provided an excellent basis for evaluating the potential of ERTS-1 type imagery for supplying similar or incremental data on either a more timely or, less costly basis than is presently possible.

ERTS-1 Analysis

After the classification systems had been prepared and the data base for the test site completed, the analysis of the ERTS-1 imagery began. The analysis of the ERTS-1 imagery was accomplished in six phases: 1] an initial phase during which the image interpreters familiarized themselves with the unique scale, resolution, contrast and tonal and textural characteristics of ERTS-1 imagery; 2] preliminary interpretation of the imagery for representative test sites to determine the interpretability and classification related information content of the ERTS imagery; 3] evaluation and modification of classification schemes based on the preliminary studies; 4] completion of data base maps for the entire Central California test site; 5] the application of ERTS data to ancillary problems with particular focus on interfacing with and trying to encourage resource management agencies and other user groups to attempt to utilize ERTS-type data on an operational basis; and, 6] a final analysis and summary of the value of ERTS-1 imagery based on the studies performed by the GRSU.

Phase 1: The familization phase entailed intensive study of ERTS images of known areas to determine which features and/or environmental parameters could be consistently identified. An examination was also made of the interpretation techniques which would be most suitable for ERTS analysis. As part of this phase, interpretation and analysis were performed on both the original 9 1/2 x 9 1/2 inch black-and-white transparencies as well as on ten times [10x] enlargements of selected portions of ERTS images. In most cases the analysis performed entailed the study of both conventional high altitude aerial photography and ERTS images of the same area, in concert, to familiarize the interpreter with the relative appearance of the landscapes and to gain a general idea of which features could be detected, identified, mapped, measured, and/or monitored.

Phase 2: The preliminary interpretation of ERTS-1 imagery for selected test sites was again, a phase of the study designed to familiarize interpreters with the problems associated with an overall interpretation of ERTS imagery for specific test areas so that they would be better prepared to complete the data base for the entire 52,213 square kilometer Central Region test site. Furthermore, at this juncture in the study, multidate imagery taken during both summer and winter seasons was unavailable, so a decision was made to delay the production of the final test area maps until additional data from subsequent ERTS over-flights became available, in order to achieve highest mapping accuracy for the finished product.

Preliminary maps were completed for land use, land forms and natural vegetation and formed the basis for modification of the original classification systems to render them more applicable to the information content of ERTS imagery. Figure 2 is an example of one of the preliminary vegetation maps of the area around Morro Bay, California, utilizing ten times enlargements of July 25, 1972 ERTS-1 imagery. Similarly, a preliminary

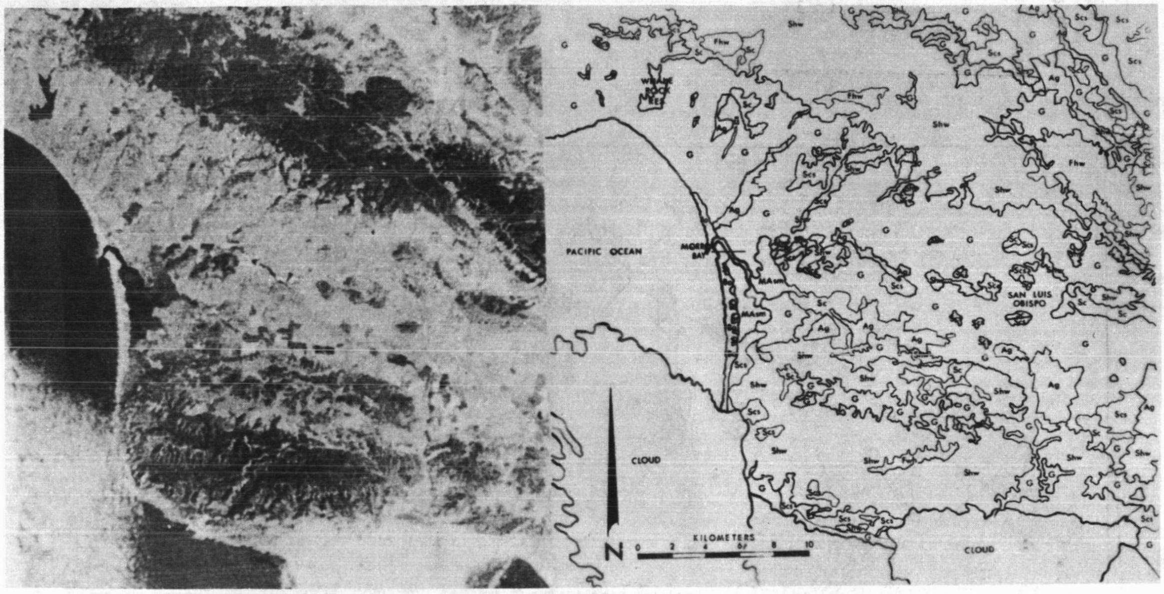


Figure 2. Preliminary natural vegetation maps prepared from ten times [10x] enlargements of July 25, 1972 ERTS-1 satellite imagery of the area surrounding Morro Bay, California.

map of land use is shown in Figure 3 while another preliminary vegetation map is shown in Figure 4. In all cases, the experience gained in preparing these maps was invaluable for the ensuing mapping of the entire test site as well as providing valuable insight for an accurate estimation of the value of ERTS data for such studies.

Phase 3: Based on these preliminary studies, a number of modifications were made in the classification systems to provide for a more generalized type of information [see Appendix B]. For example, urban areas under 4,000 persons in population were very difficult to detect. Consequently, classifications such as single or multiple family dwellings became insignificant as important categories [at least in the California environment]; likewise, certain vegetation categories such as hard chaparral and soft woodland were generally difficult and were modified for the final operational classification. Accordingly, the original detailed classification schemes shown in Appendix A were modified and more generalized categories, such as those shown in Appendix B, became the operational categories utilized for the production of the final data base maps.

Actual completion of the data base maps for the Central Regional Test Site required the use of portions of seven different ERTS-1 images such as those shown below in Figures 5 and 6. For each section of the test site at least two ERTS bands [generally band 5 and either band 6 or 7,

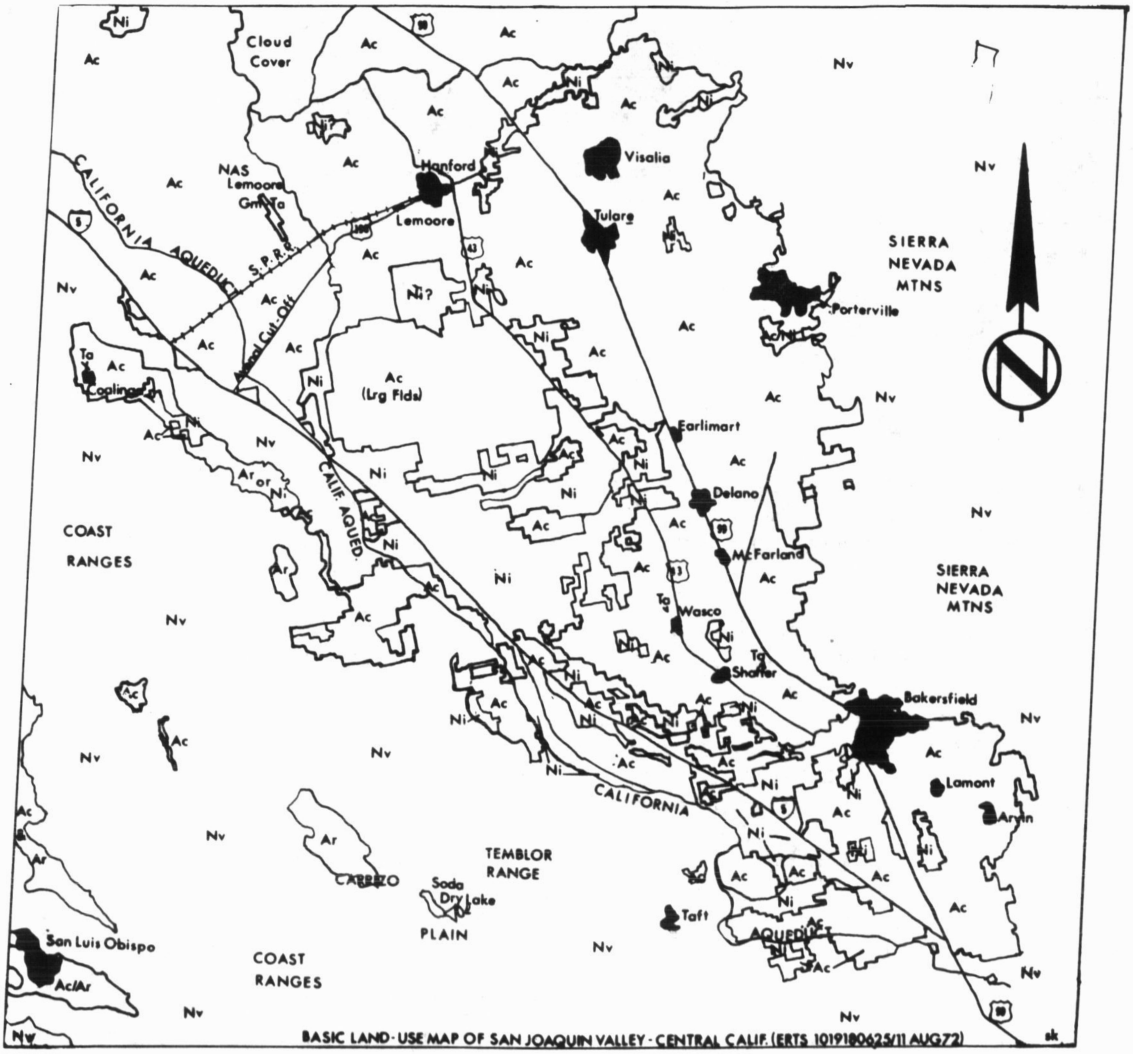


Figure 3. Preliminary land use map constructed using August 11, 1972 ERTS-1 imagery of the southern end of the San Joaquin Valley, California.

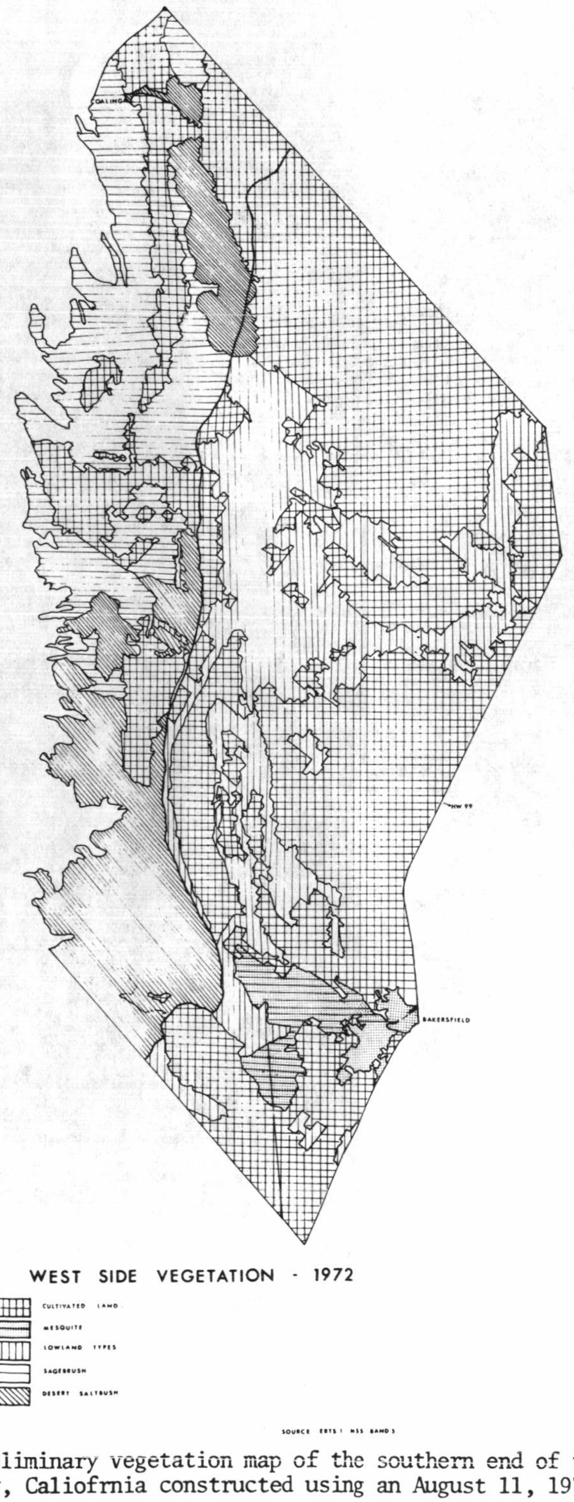


Figure 4. Preliminary vegetation map of the southern end of the San Joaquin Valley, Caliofrnia constructed using an August 11, 1973 ERTS-1 image.

Figure 5. An example of a 9 1/2 x 9 1/2 inch (1:1,000,000) ERTS-1 band 5 image used for the completion of regional data base maps of the Central Regional Test Site. This image is centered on the town of Santa Barbara, California.

Figure 6. An example of a 9 1/2 x 9 1/2 inch (1:1,000,000) ERTS-1 image used for the completion of regional data base maps of the Central Regional Test Site. This image is centered on the Tulare Lake area of the San Joaquin Valley, California.

although in a few instances band 4 was used] were employed to utilize the multiband capabilities of ERTS-1 imagery. Similarly, data from two or more dates were utilized in all cases in order to maximize the potential for discrimination and identification of a given feature. For example, although July imagery was excellent for distinguishing between different major vegetation types, it was almost impossible to locate the city of San Luis Obispo [population of approximately 30,000] at this date. This was a result of the similarity of the light toned urban signature with that of the surrounding annual grassland, which is dry during the summer months. In March, however, when the annual grassland had turned green, the limits of San Luis Obispo showed up clearly against the background annual grassland. In all cases the actual interpretation was carried out using the original 9 1/2 x 9 1/2 inch, 1:1,000,000 scale ERTS images with the maps being constructed on mylar overlays. Interpreters used hand magnifiers and Zeiss stereoscopes [when reinforcement and/or combination of images was desired, or when limited stereoscopic viewing was feasible].

The minimum mapping unit, i.e., the smallest area that was classified, was 2.641 square kilometers. At a scale of 1:1,000,000, 2.641 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.

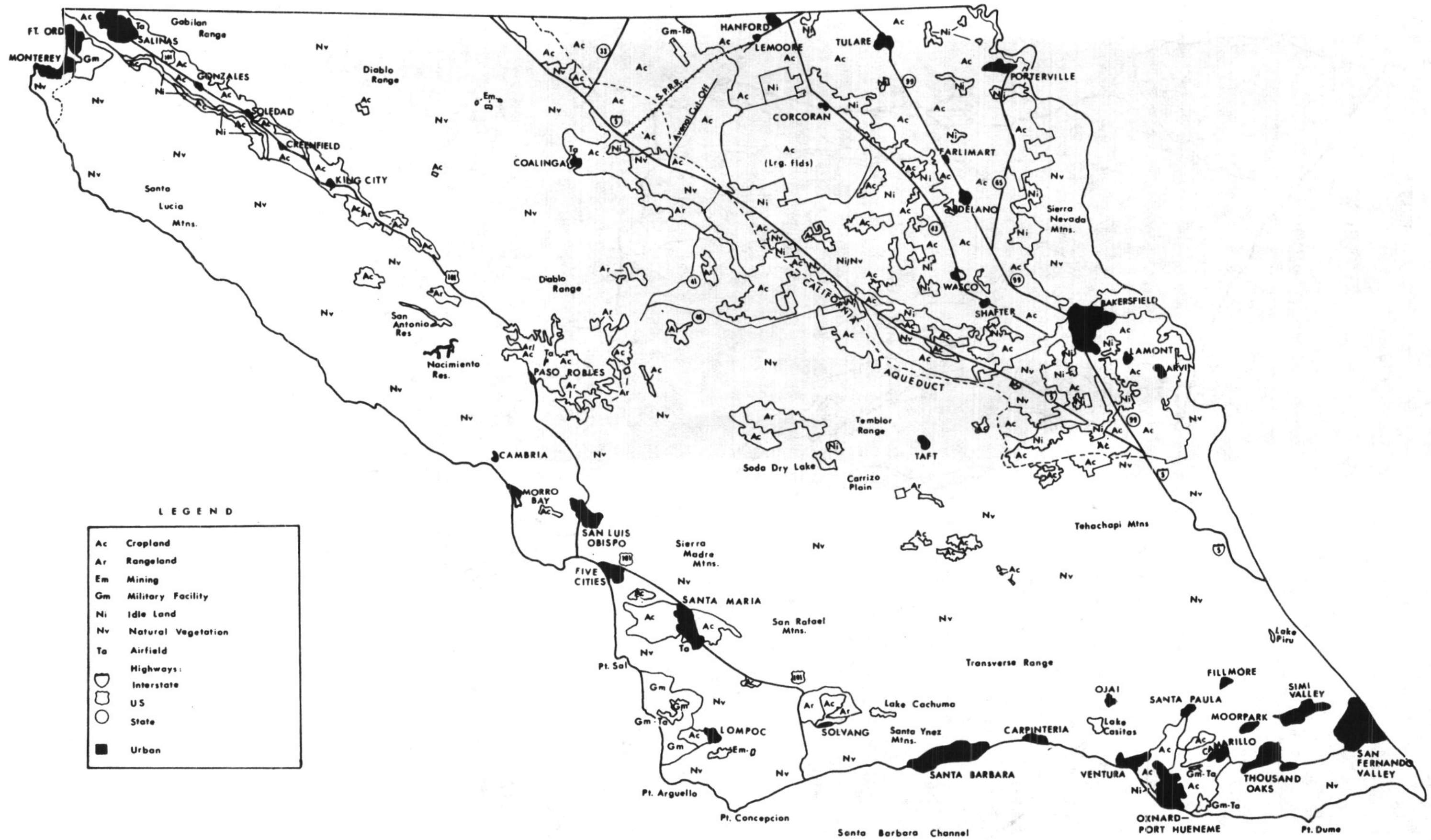
The resultant final land use, land form, hydrology and vegetation data base maps for the Central Region Test Site can be seen on the following pages.

In addition to the completion of the data base maps discussed above, a number of additional studies were performed in an attempt to develop inventory techniques which would have a high probibility of being adopted on an operational basis by various user agencies with area responsibilities. These studies have included: 1] mapping the distribution of kelp [Macrocystis] concentrations along the Central California coast; 2] mapping and monitoring fire damage and recovery rates of a major forest fire; 3] inventory of irrigated agricultural land for Kern County, California; 4] location and delineation of areas of perched water tables in the West Side of the San Joaquin Valley, California; 5] monitoring of land use change; and, 6] identification of agricultural crops.

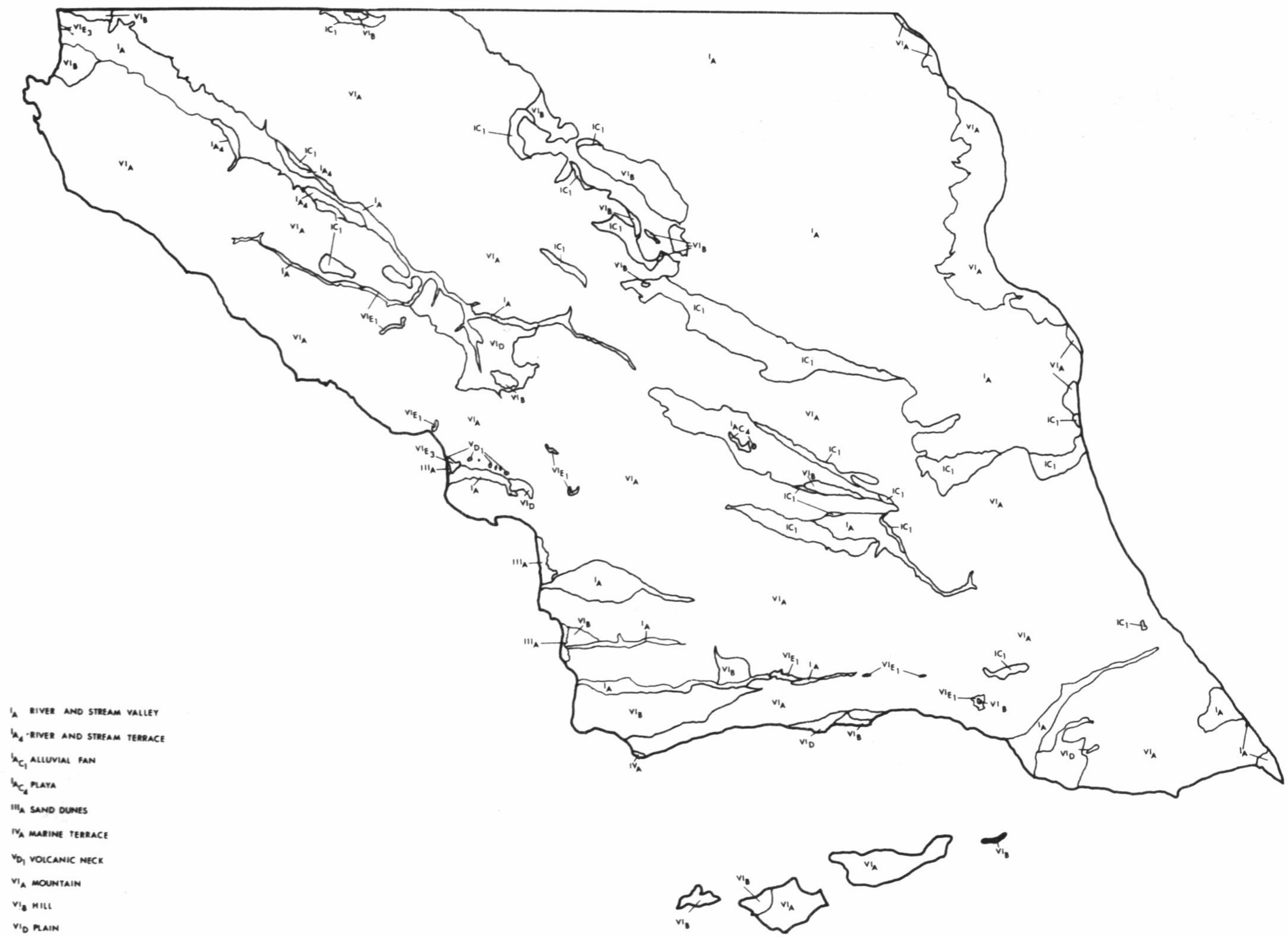
The kelp survey which was carried out using ten times [10x] enlargements of a July 1972 ERTS-1 image of the California coast showed that it was possible to accurately map kelp using ERTS imagery if optimum meteorological, tidal, water temperature, current conditions, etc. occur at the time of overflight. The map showing the areal extent and location of the kelp concentrations and an estimate of their surface area can be seen on the following pages [Figure 7 and Table 1].

The investigation of the usefulness of ERTS-1 data for delimiting fire damage areas was based on the U.S. Forest Service's common practice of delimiting the area of each major fire area using conventional aerial photog-

CENTRAL REGION LAND USE DATA BASE

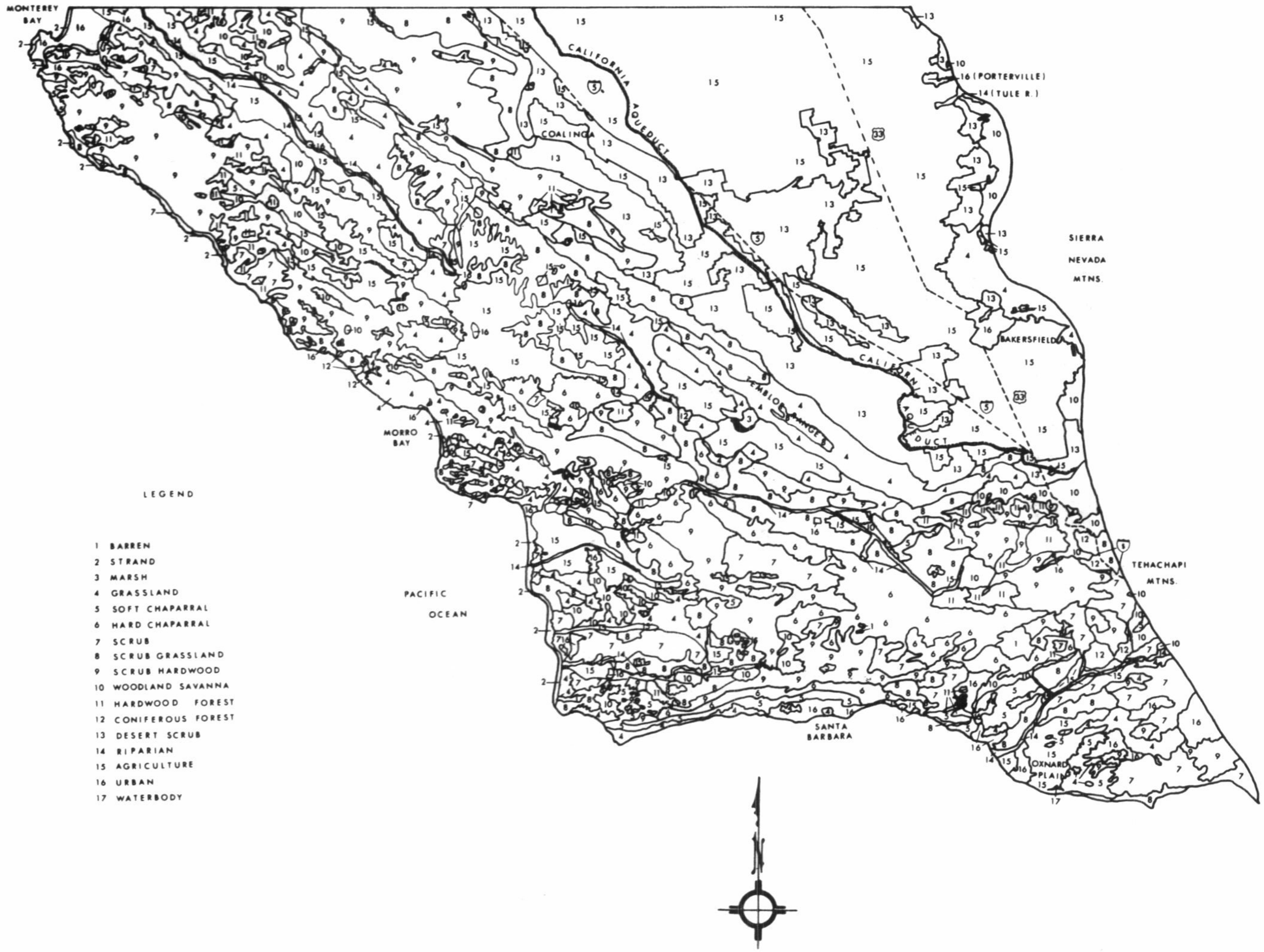


CENTRAL REGION LANDFORM DATA BASE



Central Region Drainage Data Base

CENTRAL REGION VEGETATION DATA BASE



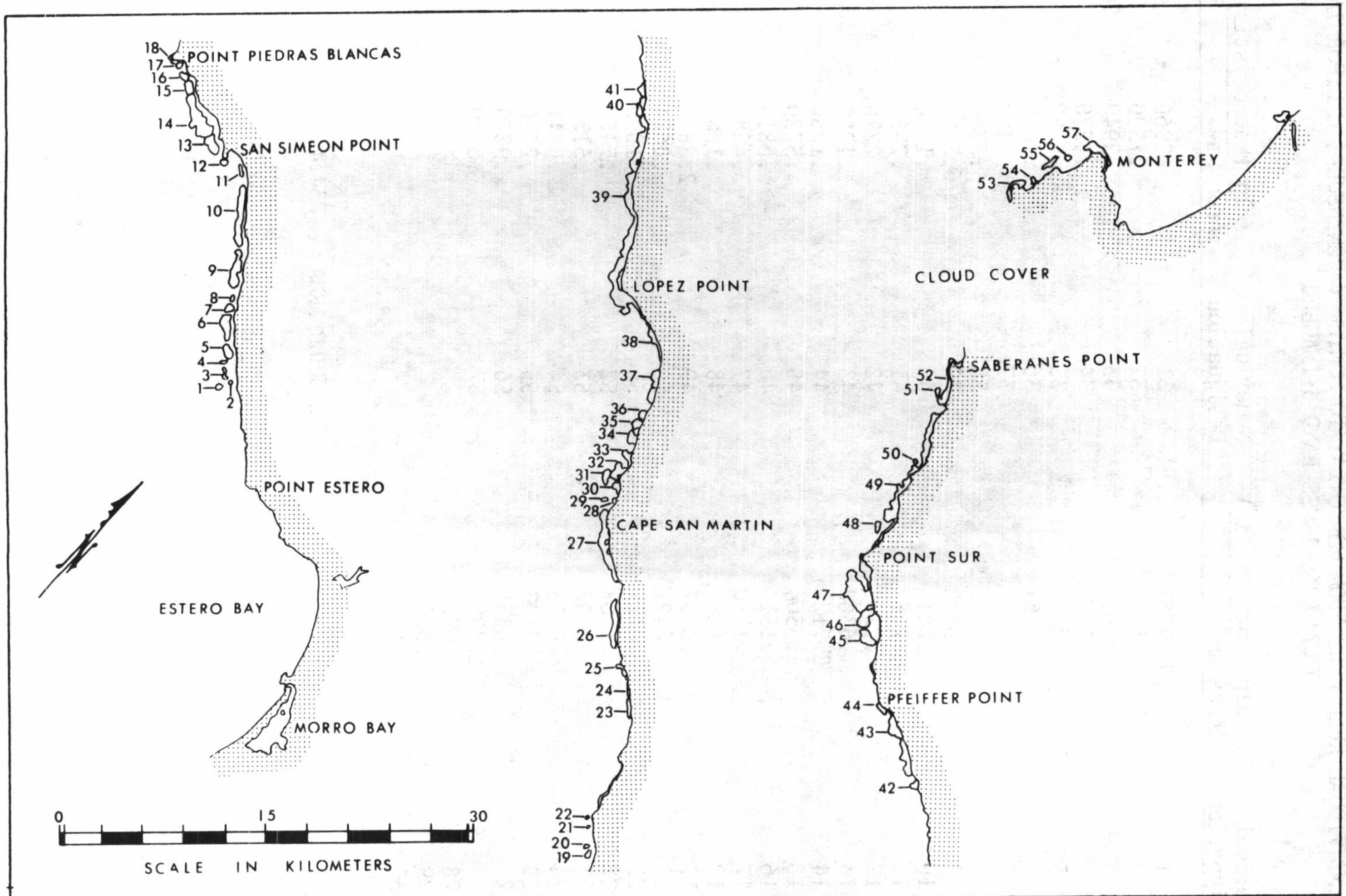


Figure 7. Map showing the areal extent and location of kelp beds (Macrocystis) along the California coast from Morro Bay north to the Monterey Peninsula. Land area is shown by the stippled pattern while individual kelp concentrations are indicated by numbers (1-57).

TABLE 2. 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	5k	.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

graphy. The study was focused on an area west of Santa Barbara burned by the "Bear Fire" in August 1972 which burned approximately 17,260 acres of scrubland and forest vegetation. Upon receipt of the October 1973 ERTS-1 imagery, it was found possible, on band 7, to accurately map the areal extent of the fire as well as unburned islands of vegetation within the fire area at a considerable time savings over the use of conventional areal photography. Furthermore, with the receipt of ERTS data on an 18-day basis it was possible to monitor the vegetation recovery rate of the burned area.

The inventory of irrigated agricultural land using ERTS-1 data has also shown considerable promise. This project entailed the inventory of all irrigated agricultural land in Kern County, California. Data were generated on the acreage of irrigated land in the county and sent to the Kern County Water Agency [KCWA] for verification. The area was first mapped using NASA high altitude photography and later using ERTS-1 imagery. The results of these inventories is shown below in Table 2 along with K.C.W.A. figures for the same area:

Table 2
Comparison of Data on Irrigated Agricultural Land, Kern County, California

SOURCE	AGRICULTURAL ACREAGE ESTIMATE
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

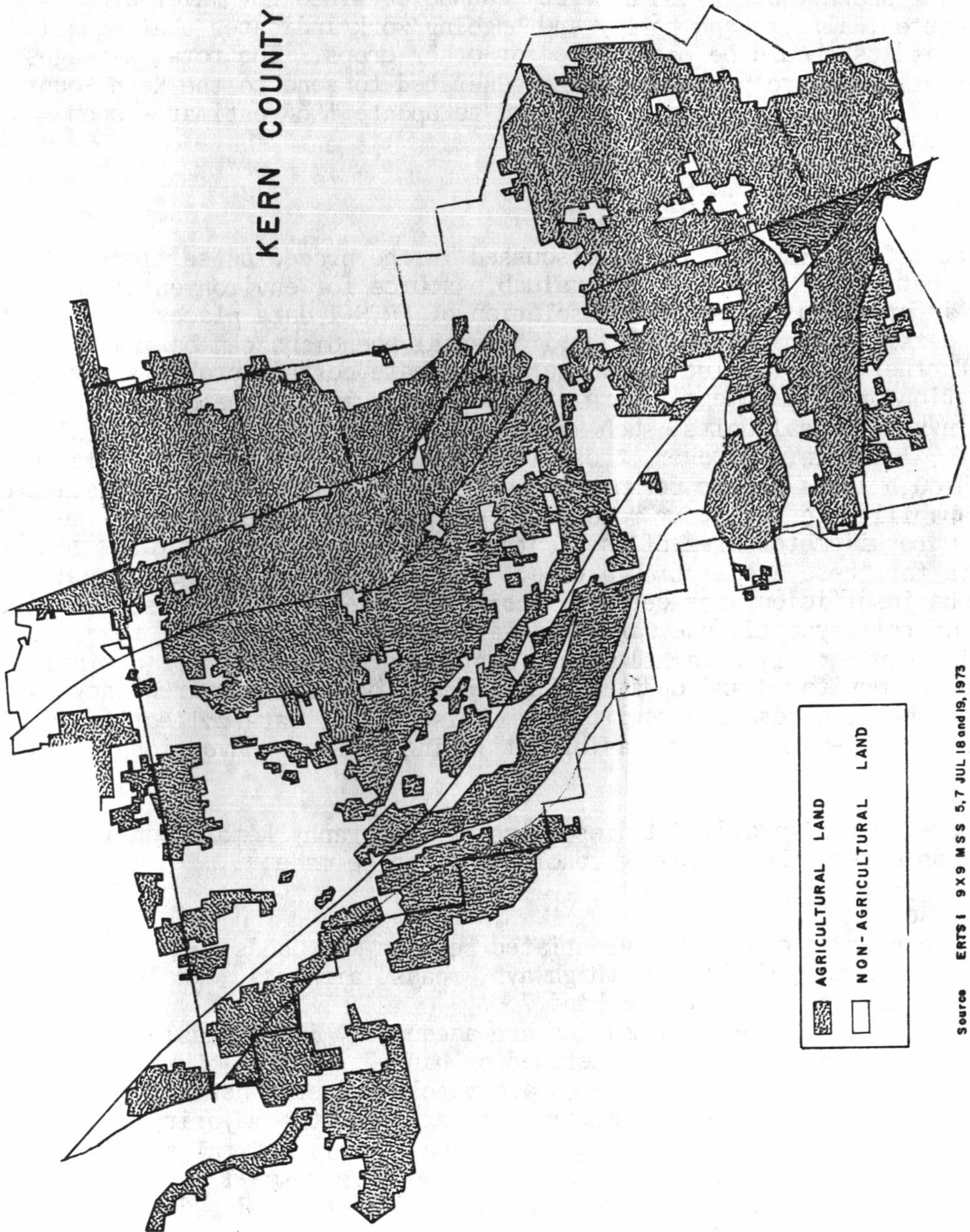
An indication of the accuracy of these figures [less than 1% error when fallow ground is excluded] is the fact that the K.C.W.A is now using ERTS-1 data on irrigated agricultural land supplied to them by the GRSU as data input to their water supply/demand models. The following maps are examples of March and July 1973 inventories of irrigated agricultural land based on ERTS-1 data which are being supplied to the K.C.W.A. on a regular basis.

Other work in progress with K.C.W.A. and the Department of Water Resources of the State of California indicated that areas of perched water tables and excessive soil salinity, both pressing problems in the irrigated lands of the West Side of the San Joaquin Valley, can be monitored effectively using multidate ERTS type imagery.

Land use change studies are also of critical importance to planning agencies because land use changes rapidly, especially in rapidly developing agricultural areas such as the West Side of the San Joaquin Valley, California, and it is important to monitor this phenomena. Accordingly, studies were also conducted to see if ERTS-1 imagery might be suitable for detecting and monitoring land use change. The following map and table show 1971 and 1972 data on land use change in an area of the West Side of the San Joaquin Valley constructed from 1971 high altitude photography and ERTS-1 imagery,

KERN COUNTY

SOURCE: ERTS-1 Imagery MAR 15, 73 MSS 5&7


KERN COUNTY
AGRICULTURAL LAND
NON-AGRICULTURAL LAND
Source ERTS I 9X9 MSS 5,7 JUL 18 and 19, 1973
khf

respectively. In this case, the ERTS-1 imagery provided for adequate monitoring of land use change.

Finally, the use of ERTS-1 imagery, should provide accurate data on the relative acreages of different agricultural crops. Preliminary studies have already shown that 90-95% accuracy can be obtained for major crops such as cotton, alfalfa and barley and ongoing work indicates that equally accurate results should be obtainable for other crops. The total acreages of different crops are presently being generated to send to the Kern County Water Agency so that they can be utilized to update 1960 estimates upon which present water allocations are based.

CONCLUSIONS

The results of the investigations discussed in the preceding sections indicate that ERTS-1 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, resolution limitations create certain problems for the investigation of environments where diverse environmental 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 extensive areas [e.g., the 52,213 square kilometer area of the Central Region], and sequentially generate data for these areas through time. Although the detail of information may be insufficient for certain specialized user requirements, the advantages of this synoptic view are 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 type of data collection does not appear to be economically feasible utilizing present conventional data collection methods.

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

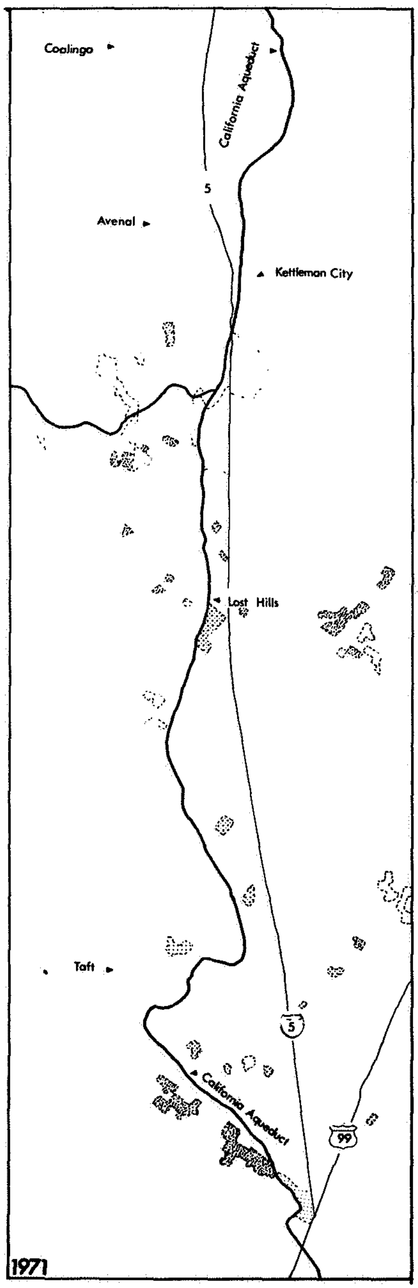
<u>Land Use</u>

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.

LAND USE CHANGE

WEST SIDE

1971-1972



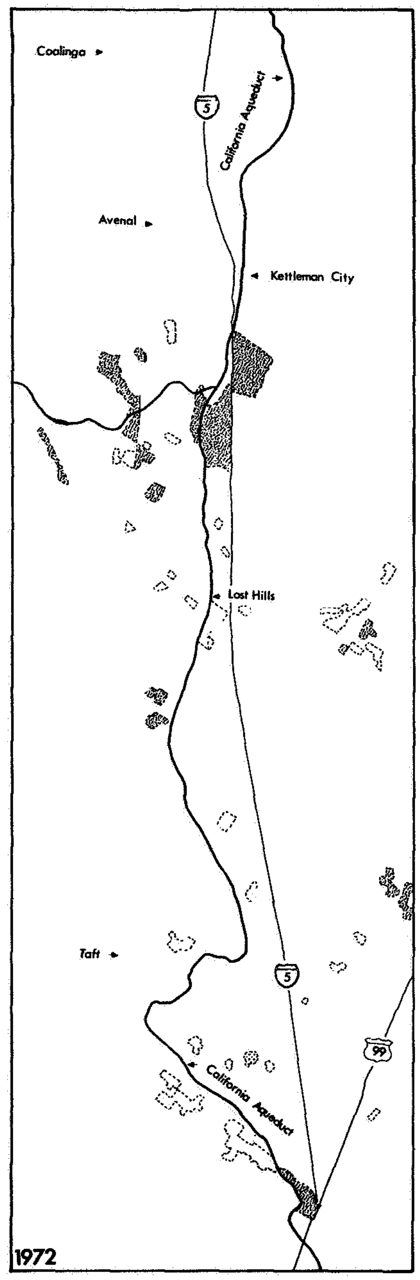


TABLE 3. LAND USE CHANGES 1971 - 1972

1972 LAND USE CHANGES (IN ACRES)

1971	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

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 and approach an accuracy of 90% or higher if multidate analytical approach is used, 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 [Macricystis]

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.

Successes resulting from these specific investigations are primarily attributable to: 1] the multiband [opportunity to view phenomena that are highlighted in different bands[; and, 2] multidate [certain phenomena are more observable during particular seasons of the year] approach which is characteristic 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. Indeed the GRSU is presently actively pursuing the potential planning applications of these data with several local and regional agencies including: the Central California Coastal Commission, State of California Department of Water Resources, Fresno Office, Kern County Water Agency and the Santa Barbara County Planning Department, among others.

In short, the ERTS-1 satellite data provides an excellent mapping base for regional resource inventories utilizing generalized classification systems. In order to achieve high interpretation accuracy, the mapping should be performed by interpreters who are well acquainted with the landscape features and their geographic distribution. The major opportunities for the operational use of ERTS-1 type imagery seem to be in generating more specific, timely and accurate data such as the total acreage if irrigated agricultural land, rates and magnitude of land use change, the monitoring of kelp resources, the inventory of acreages of important agricultural crops or studies of similar critical environmental parameters which provide input for important resource management decisions.

Appendix A. Original Classification Schemes for Land Use, Land Forms, Hydrology and Natural Vegetation

Key:

General Category ex. A [Agriculture]
Type within Category ex t [tree crops]
Specific Type ex c [citrus]
Total Code: Atc

Note that 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
Crops	Ac
Grain Crops	Acg [type]
Horticulture	Ach [type]
Row Crops	Acr [type]
Tree Crops	Act [type]
Livestock	Al
Stock farming [beef]	Alsb
Stock farming [sheep]	Alss
Stock Farming [dairy]	Alsd
Rangeland	Ar
Pasture [improved]	Arpi
Pasture [unimproved]	Arpu
Extractive	E
Seawater mineral recovery	Es [type]
Petroleum production fields	Ep [type]
Mining Operations	Em [type]
Public Facilities	G
Governmental, administrative	Ga [type]
Governmental, military	Gm [type]
Cemeteries	Gc
Protection, Police and Fire	Gf [type]
Hospitals	Gh
Prisons	Gp
Waste disposal [solid & liquid]	Gd [type]
Education	Ge [type]
Parks & Recreation	P
Campground	Pc
Golf Course	Pg
Park	Pp
Stadium	Ps
Marinas	Pm
Resort	Pr

Appendix A cont'd.

	CODE
Industrial	I
Primary Conversion	Ip
Steel mill	Ips
Ship building	Ipb
Saw mills [or pulp]	Ipw
Assembly	Ia
Auto	Iaa
Electronic	Iae
Food Processing	If
Canneries, fish	Ifc
Canneries, fruit	Iff
Storage	Is
Port warehousing	Isp
Rail warehousing	Isr
Transportation	T
Airports	Ta [type]
Highways	Th [type]
Railroads & Yards	Tr [type]
Canals	Tc [type]
Docks	Td
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]

LANDFORM CLASSIFICATION

I. Fluvial
   A. River and stream valley
      1. meander
      2. oxbow lake
      3. meander scar
      4. terrance
      5. channel bar
      6. point bar
      7. delta bar
      8. channel filling
      9. natural levee
      10. crevasses
      11. distributaries, passes, or mouths
   B. Deltas
      1. esturine
      2. arcurate
      3. digitate [birdsfoot]
   C. Other
      1. alluvial fan
      2. alluvial cone
      3. bajada
      4. playa
      5. alkali flat
      6. salinas
      7. washes [wadis]
II. Glacial
   A. Alpine
      1. cirque
      2. tarn
      3. trough valley
      4. hanging valley
      5. steps
      6. pater noster lakes
      7. aretes
      8. moraine
      9. esker
      10. kame
      11. kame terrace
      12. fjords
      13. fiards
      14. ice
   B. Continent
      1. mamillated
      2. till plain
      3. drumlin
      4. kettle
      5. kame

6. kame terraces
7. esker
8. moraine
9. ice

III. Eolian
  A. Dunes
    1. sand shadows
    2. barchan or crescent
    3. longitudianl or seif
  B. Sand sheets
  C. Whole backs
  D. Deflation basins
  E. caves or arches

IV. Waves and Currents
  A. Terraces
  B. Tidal zone
    1. beach
    2. bays
    3. inlet
    4. sea arch
    5. stack
    6. bar
    7. spit
    8. forwland
  C. Offshore zone
    1. tombolo
    2. stack
    3. bar
    4. spit
    5. foreland
    6. island

V. Volcanic
  A. Cones
    1. strata or composite
    2. shield
    3. cinder
    4. spatter
  B. Depressions
    1. craters
    2. calderas
  C. Lava fields or plains
    1. tumuli
    2. squeeze-ups
    3. pressure ridges
    4. lava blisters
  D. Skeletons
    1. neck
    2. plug
    3. dike
    4. sill

LANDFORM CLASSIFICATION [page 3]

VI. Comples and Compound
    A. Mountain
    B. Hill
        1. monadnock
        2. inselberg
        3. other
    C. Ridge
        1. cuesta
        2. hogback
        3. homoclinal
        4. other
    D. Plain
        1. lacustrine
        2. outwash
        3. other
    E. Water body
        1. lake
        2. lagoon
        3. estuary
        4. tidal marsh
        5. tidal flat
        6. other

VII. Other
    A. Karst
        1. sinkhole
        2. uvala
        3. karst plain
        4. bland valley
        5. karst valley
        6. rise pits
        7. hums
    B. Atolla and reefs
    C. Meteorite craters
    D. Carolina bays
    E. Man made forms
    F. Other

C-8

HYDROLOGIC CLASSIFICATION

I. Streams
   A. 1st Order
   B. 2nd Order
   C. 3rd Order
   D. 4th Order
   E. 5th Order
   F. 6th Order
II. Lakes
   A. Permanent
      1. Freshwater
      2. Saline
   B. Ephemeral
      1. Freshwater
      2. Saline
III. Springs
IV. Estuaries
V. Marshes
VI. Swamps
VII. Man Induced Changes in Hydrology
   A. Reservoirs
   B. Canals
   C. Wells
   D. Other

NOTE: Drainage basins would be delimited on the same map, but would not be classified.

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
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

Appendix B. Revised operational land use and vegetation classification schemes which were used for the preparation of regional data base maps from ERTS-1 imagery.

KEY:
- General Category, ex A (Agriculture)
- Type within Cateogry, 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)	grassland 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 content to other features and runway material.
Highways (roads, etc.)	Th*	*roads are normally mapped using their federal, state or county number (i.e., 101 rather than the code).
Railroads	Tr*	*railroads are usually mapped using the abbreviations for their operating company (i.e., S.P.R.R.-Southern Pacific Railroad Company).

Appendix B cont.

General Category	Code	Comments
Canals	Tc*	*canals are normally identified by name (i.e., California Aqueduct).
URBAN	U*	*urban areas, undifferentiated between commercial. Residential are normally identified by the city name (i.e., 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.

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
13. Desert Scrub
14. Riparian
15. Agriculture
16. Urban
17. Waterbodies