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NATURAL RESOURCE INVENTORIES AND MANAGEMENT APPLICATIONS IN THE GREAT BASIN

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ABSTRACT

ERTS-1 resolution capabilities and repetitive coverage have allowed the acquisition of several statewide inventories of natural resource features not previously completed or that could not be completed in any other way. Familiarity with landform, tone, pattern and other converging factors, along with multidate imagery, has been required. Nevada's vegetation has been mapped from ERTS-1 by the following categories: southern desert shrub, salt desert shrub, northern desert shrub, pinyon/juniper woodland, mountain brush, aspen, meadows and marshlands, wheatgrass seedings, phreatophytes and cropland.

Dynamic characteristics of the landscape have been studied. Sequential ERTS-1 imagery has proved its usefulness for mapping vegetation, following vegetation phenology changes, monitoring changes in lakes and reservoirs (including water quality), determining changes in surface mining use, making fire fuel estimates and determining potential hazard, mapping the distribution of rain and snow events, making range readiness determinations, monitoring marshland management practices and other uses. Land use capability classification work is in progress. A wide variety of other uses has been proposed and users identified. Feasibility has been determined, but details of incorporating the data in management systems awaits further research and development. The need is to accurately define the steps necessary to extract required or usable information from ERTS imagery and fit it into on-going management programs.

INTRODUCTION

The synoptic view of the Great Basin afforded by ERTS-1 and especially the repetitive cloud free coverage has proved to be very valuable for the inventory of natural resource features in the Great Basin of the United States. Resource managers can derive considerable useful information from ERTS-1, although the specific procedures for incorporation of the data into management programs is lacking. This investigation has developed a catalog of information derivable from ERTS-1 space imagery as well as an appraisal of new uses and user groups. Problems associated with the use of the imagery have been identified.

The principal objective of our study has been to investigate the usefulness of MSS imagery from ERTS-1 as a supplementary tool for the management of renewable natural resources within the Great Basin. Subsidiary objectives can be listed as follows:

1. To develop a key to broad vegetation units and assess their relation to soil order and landform.

2. To evaluate MSS spectral signatures for vegetation phenology for a complete growing season.

3. To map the natural vegetation of Nevada.

4. To determine the usefulness of specific bands for evaluating a variety of wildland management functions.

METHODS

Initially, our ERTS analysis consisted of identifying different classes of roads, cities, towns, small water bodies, stream channels, fields, landforms, gross vegetation types, and other features that we were familiar with. Our initial finding was that we were able to identify many more features than we first thought possible. This was a matter of gaining experience and familiarity with the imagery.

Secondly, we began to measure the area of water bodies, vegetation types and both natural and man-made vegetation units. Several grids were constructed with different size squares and calibrated to ERTS scale. The grids were generally 0.1 mm square, 1 mm square, and 4 mm square. Very large areas were measured with dot grids having 990 or 3960 dots per square decimeter (64 or 256 dots per square inch). More recently we have used our Zoom Transfer Scope to blow up features for more accurate measurement.

We have used human interpretation techniques almost exclusively. Tone, texture, shape, pattern and size were the main photo interpretation factors utilized. When interpreting certain features, we relied heavily on physiographic location, soil appearance and field experience with these features. Color composites added infinitely to interpretations, especially for vegetation types having greater than 50% cover. Diazochrome transparencies proved useful when of good quality. Even slightly dark transparencies produced poor diazochrome color composites.

A mosaic of the state was constructed using 21 black and white prints at a scale of 1:1 million (8.5 by 12.7 decimeter sheet; 24 by 36 inch sheet) and 1:2

million (4.25 by 6.37 decimeters; 12 by 18 inch sheet). The red band (MSS 5) was used to construct the mosaic because landform features appeared more striking. This mosaic is being used as a base to map resource features and compare changes on other imagery types and dates.

To determine accuracy of ERTS-based vegetation maps, test points were established along highways which traversed the state. These test points were systematically located at 16 kilometer (10 mile) intervals. The vegetation next to the highway was recorded as to type (salt desert shrub, pinyon/juniper, etc.) and physical location. These points were located on a 1:1 million scale topographic map using a Lietz opsometer and USGS topographic maps at a scale of 1:250,000. Accurate point location on the 1:1 million scale map was thus made.

Once the point locations were established, the vegetation map overlays (scale 1:1 million) were superimposed on the base map. At each point the vegetation was recorded as observed in the field and as identified on ERTS. This data was treated as an interpretation test. Known field points became identification cells and the maps became an interpretation of these cells. Two types of error were possible: commission and omission. A commission error occurred when the map identified a cell as being of a certain type when it was not. An omission error occurred when it was not identified correctly, i.e., it was omitted. An interpretation test table was generated from this data.

To correlate satellite imagery with ground events, accurate and often detailed notes were taken at several study sites. Three main factors determined optimum time to record "ground truth". The first factor was the eighteen day overflights. Ground truth must be recorded every eighteen days coinciding with the ERTS overflights.

The second factor was plant maturity. Since much of our ground data was concerned with plant phenology, the period of active plant growth and development was critical. Ground data was obtained for northern Nevada sites between April and October, the active growing season. During the remainder, most vegetation is dormant. Data was obtained for southern Nevada sites year-long due to diverse climatological conditions caused by elevational differences of 3.2 kilometers in 48-64 linear kilometers (2 miles in 30 or 40 linear miles). The greatest growth period for the low elevation southern sites was between February and November.

The third factor was accessibility. Winter storms caused many northern sites to be inaccessable due to road conditions. This was a determining factor in making ground data collection trips.

The dominant species were listed, along with their phenological stage. Soil moisture, snow pack, etc., were also observed. In general, our observations shifted from detailed, small area observations to general, large area observations. It was felt that these generalized observations were more compatable with our project goals and research capabilities. The ability to ascertain ground measurements that correlate with image features was a difficult one due to the great heterogeneity of features that appeared homogeneous on an ERTS-1 image.

A densitometer was used to correlate vegetation reflectance on ERTS with ground phenology data. Only Reno and Las Vegas study areas could be used, however, due to extensive cloud cover over the rest of the state during critical overpasses.

The initial study sites were found to be too small for use with our densitometer. The area which could be "read" with the densitometer was a 1 mm diameter circle on the image, or about 80 hectares (200 acres) on the ground. With this in mind, larger sites were selected such as a large native meadow, a large alfalfa field, an extensive area of mountain brush, and other similarly large areas.

MSS 5 and 7 bands were used, as these are most indicative of vegetation change. Large water bodies were measured to create a standard to compensate for exposure. It was hoped that the MSS 7 image of these water bodies could be transformed to a constant value. Once this constant value was found, the vegetation data was transformed accordingly. This transformed data was then ratioed (MSS 5 ÷ MSS 7) or the differences were found (MSS 5 - MSS 7). The ratios or differences were used to detect vegetation phenology change.

ACCOMPLISHMENTS

Resource Inventories

We have completed ERTS-1 derived maps for the principle Great Basin vegetation types statewide: southern desert shrub, salt desert shrub, northern desert shrub, pinyon/juniper woodland, mountain brush, aspen, meadowland, agricultural and phreatophytic vegetation and wheatgrass seedings. Most other vegetation types, e.g., stands of bristlecone pine, white fir or other specific plant associations, were not mappable with the color composite data available, or the resolution limits of ERTS-1.

Native vegetation has frequently been plowed and planted to introduced grasses in Nevada to increase grazing capacity. Nearly a million acres were found in the state (Figure 1). MSS band 7 was the most useful for identifications. Seedings were delineated by ownership or administration: public, private,

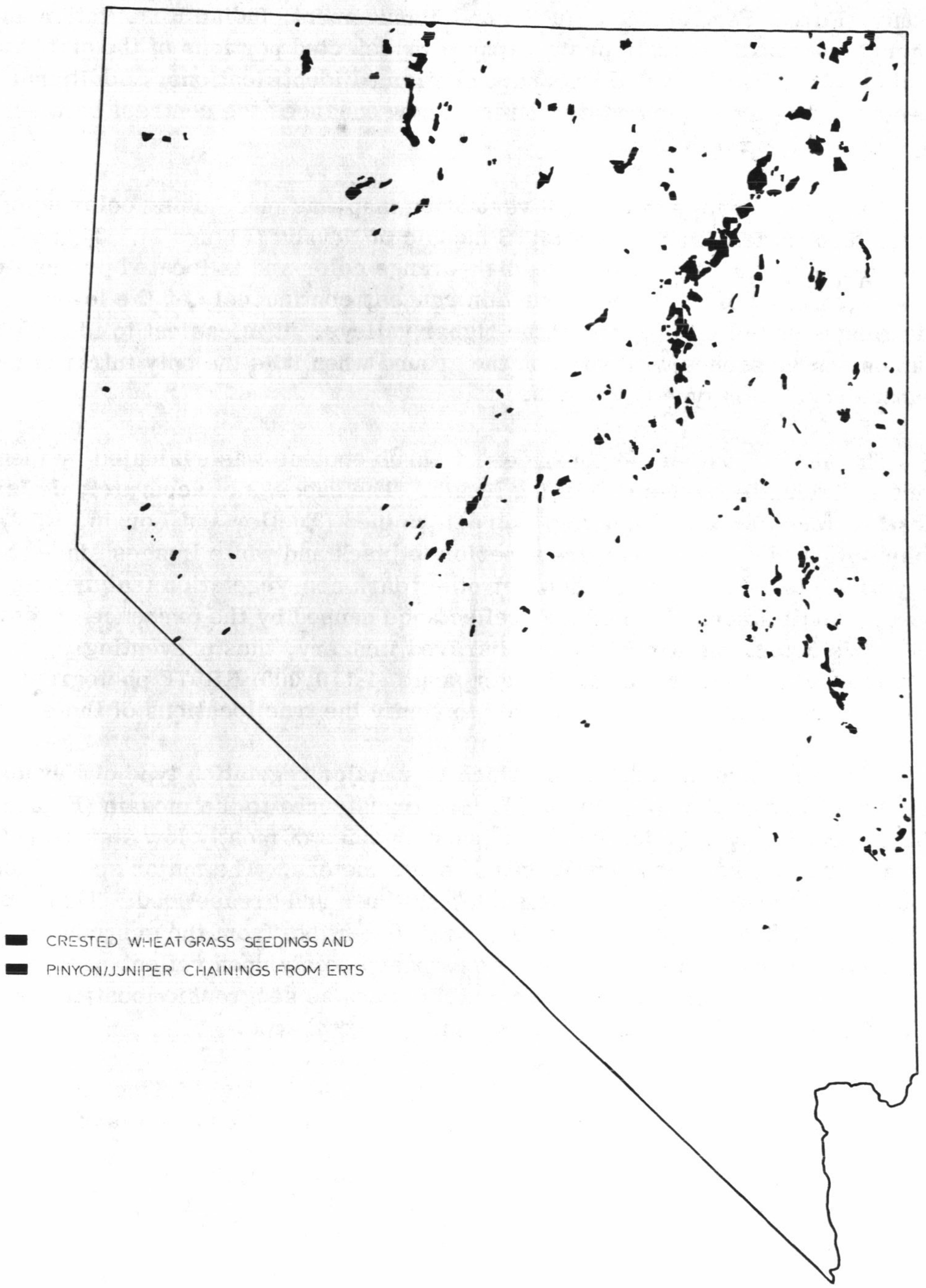

Figure 1. Perennial wheatgrass seedings in Nevada. Their distribution is closely related to the distribution of valleys adjacent to the higher mountain ranges.

county, Forest Service, Bureau of Land Management, Indian Reservation and other. Intermediate scale photography over selected portions of the state and field checking by aircraft flights have confirmed identifications. Additional seedings were located on winter dates. Snow enhanced the contrast between seedings and native brush.

The pinyon/juniper woodland vegetation map was made using color composites, then transferring to the ERTS mosaic of Nevada (Figure 2). This vegetation type is characterized by a reddish-orange color and is located primarily in belts on most of the higher mountain ranges, continuously on the lower mountain ranges and often in some of the higher valleys. It is easiest to identify and map on winter scenes with snow on the ground when it is the only infrared reflective vegetation type (Figure 3).

The pinyon/juniper-northern desert shrub ecotone was evaluated by identifying individual ecotones of varying length. The success of accurately defining these ecotones on ERTS imagery was determined (Tueller and Lorain, 1973). Color infrared composites were superior to black and white images since it was easy to mistake landform shadows or other dark non-vegetation features for ecotones. Small amounts of infrared reflectance caused by the presence of pinyon/juniper is detectable with the color infrared imagery, thus preventing possible confusion with other features. Larger scale (1:110,000) RB57F photography and aerial reconnaissance have been used to verify the true locations of the ecotones.

Salt desert shrub vegetation, which is a major vegetation type of Nevada, was mapped from the color infrared, then transferred to the mosaic (Figure 4). This vegetation type is dominated by brush species of mostly low stature (1/4 to 1/2 meter tall), but occasionally reaches 1-2 meters. The major species in this type are halophytes including shadscale, saltbush and greasewood. This vegetation was difficult, if not impossible, to differentiate from the surrounding northern and southern desert shrub types based solely upon reflectance. Therefore, it was necessary to use other criteria such as geographic location, soil reflectance, and elevation in identifying this vegetal type.

Interpreter experience is very important in identifying this vegetation type as the following criteria all have to be taken into account before a decision is made:

1. It is generally below 1500 meters (5,000 feet), except for some higher, internal drainage basins.

2. It is usually associated with light colored, highly reflective alkali soils where water frequently stands or moves and evaporation is high.

Figure 2. Pinyon/Juniper Woodland in Nevada.

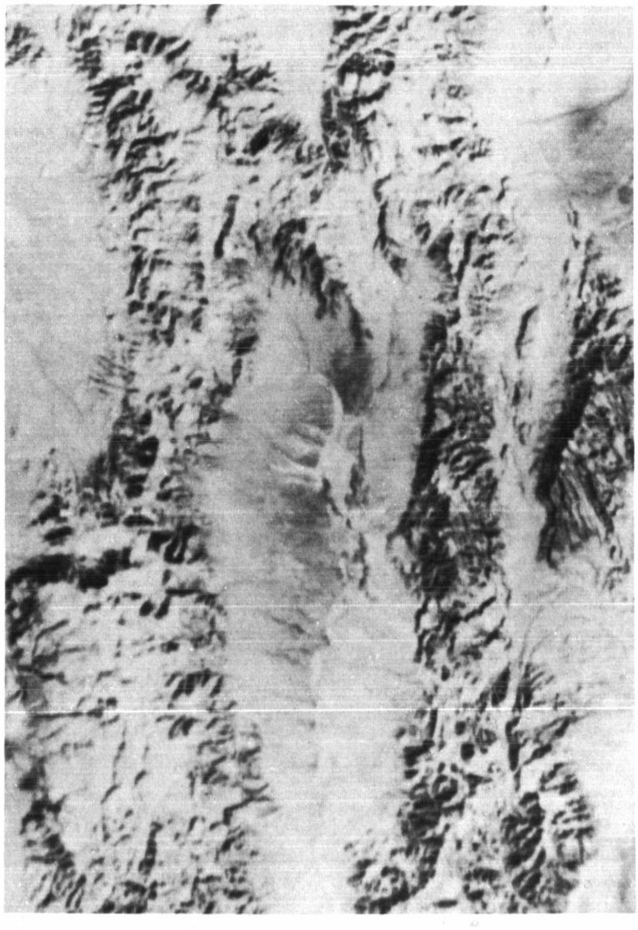

Figure 3. Winter ERTS-1 scene used to map the Pinyon/juniper woodland. Note how the pinyon/juniper woodland is found in belts on the higher mountain ranges (Monitor Range on left) and goes to the top on lower portions of the Hot Creek Range on the right. (Image 1144-18003-4, 5, and 7)

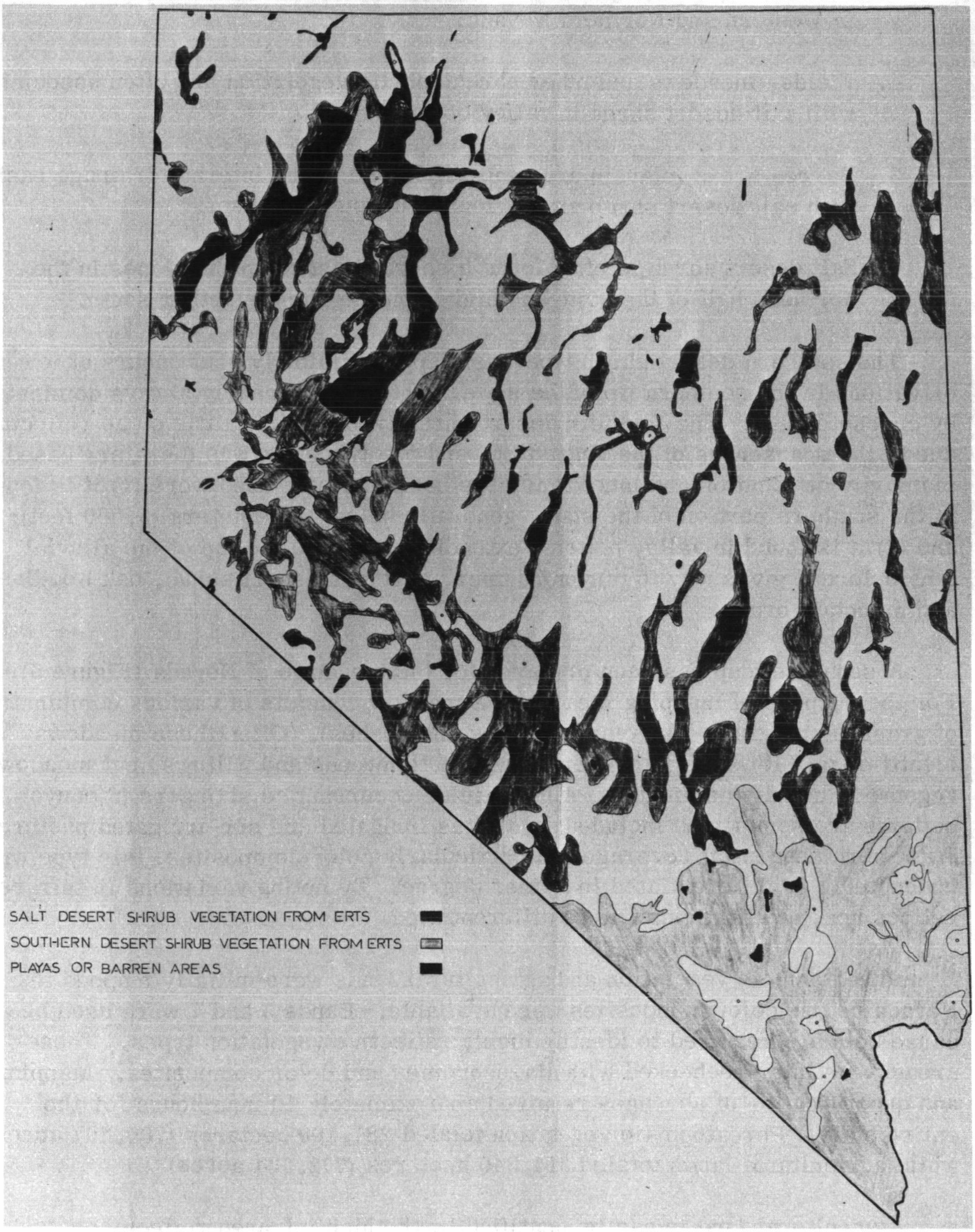

Figure 4. Southern Desert Shrub (Primarily Mojave Desert) and Salt Desert Shrub Vegetation in Nevada.

3. It is closely correlated with the mapped distribution of Pleistocene lakes in Western and Northern Nevada.

4. Fields, meadows and other phreatophytic vegetation are often associated with salt desert shrub in valley bottoms.

5. Barren areas (playas) are generally found in the internal drainage basins with salt desert shrub always found surrounding them.

6. Salt desert shrub is often found a short distance up the slopes in the northern half of the state and higher on the slopes further south.

The southern desert shrub type was mapped similarly, but occurs at lower elevations in the southern tip of the state. This type is nearly always dominated by creosote bush. The southern desert shrub type exhibits little or no reflectance due to the sparseness of the vegetation, and identification was therefore based primarily on location and landform. The basic criteria used were (1) it is found in the southern portion of the state, generally below 1500 meters (5,000 feet); and (2) it is found in valley bottoms extending nearly to the top of the alluvial fans before it gives way to pinyon/juniper, northern desert shrub, oak woodland and mountain brush.

A separate map has been prepared for the meadows of Nevada (Figure 5). For the purpose of mapping meadows, a meadow consists of various combinations of grasses and grass-like plants (sedges and rushes). Often these meadows identified on ERTS are interspersed with cottonwoods and willows, but meadow vegetation usually dominates. Alfalfa fields occurring as stringers in canyon bottoms are sometimes included as well as irrigated and sub-irrigated pastures. With more sequential coverage and particularly color composites, this type will undoubtedly be differentiated to a finer degree. By noting variations in infrared reflectance, alfalfa fields can be differentiated.

Phreatophytic vegetation and agricultural lands were initially mapped in Nevada before color composites were available. Bands 5 and 7 were used because both are required to identify highly reflective vegetation types. These areas were later rechecked with diazochromes and color composites. Mapping and quantification of acreages required approximately 10 man hours for the entire state. Phreatophytic vegetation totaled 287,100 hectares (705,407 acres), while agricultural lands totaled 314,340 hectares (772,334 acres).

Agricultural land is easily identified by the high infrared reflectance during the growing season and the orderly, usually square or rectangular shape of the individual fields. Fallow fields are easily identified by their light tone on all bands including color infrared composites. Phreatophytes were identified by

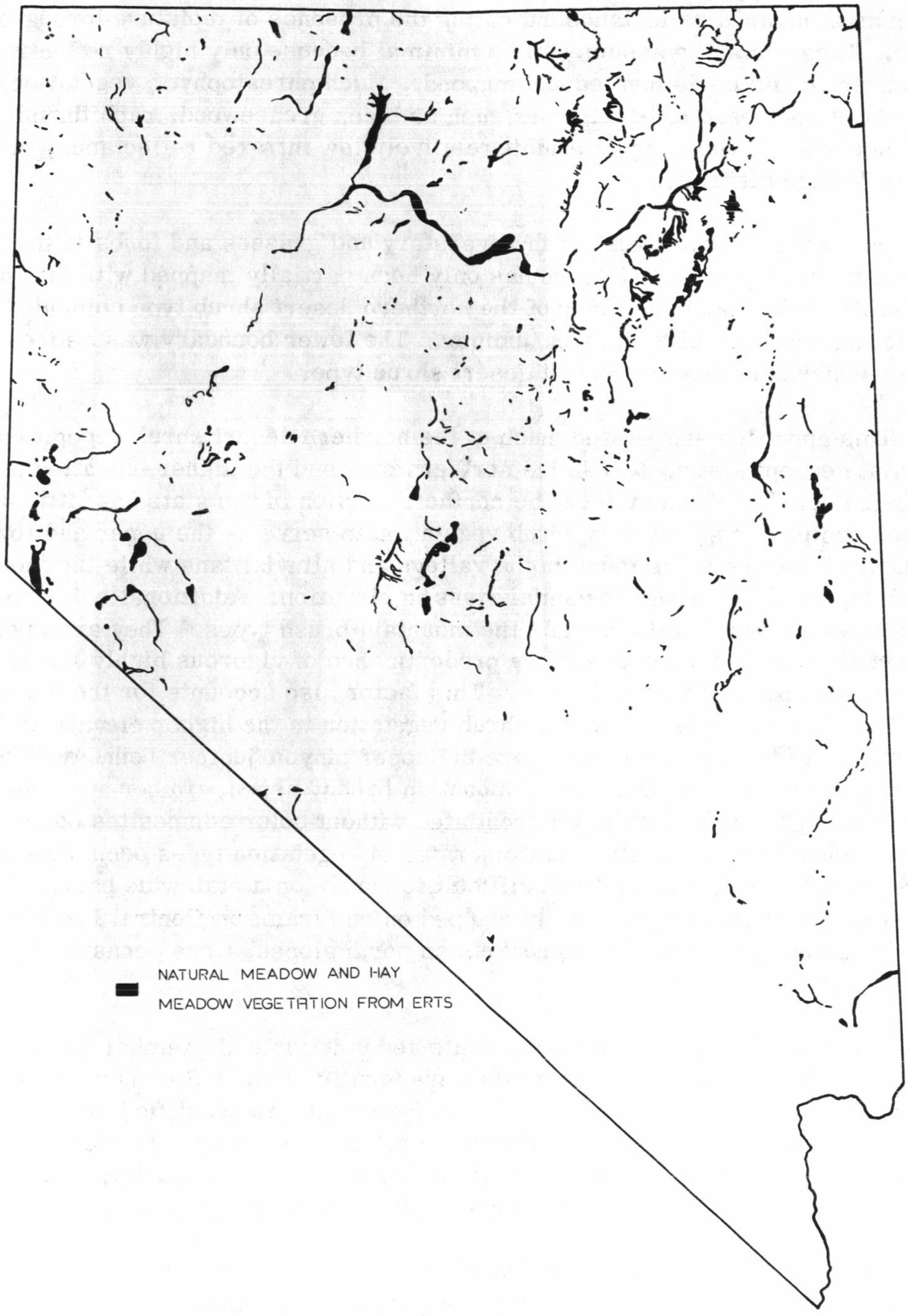

Figure 5. The Distribution of Native and Hay Meadow Vegetation in Nevada as derived from ERTS-1 Color Composites.

their high infrared reflectance indicating the presence of moisture throughout the year. These data are assumed to be minimal because only highly reflective vegetation could be delineated and mapped. Much phreatophytic vegetation in Nevada is composed of brush types such as black greasewood, rabbitbrush and big sagebrush. These types exhibit relatively low infrared reflectance, making quantification difficult.

Dominated by sagebrush in the overstory and grasses and forbs in the understory, the northern desert shrub has only been partially mapped with the imagery available. The upper boundary of the northern desert shrub type coincided with the lower boundary of the pinyon/juniper. The lower boundary was delineated by the upper boundary of the salt desert shrub type.

This approach segregated much of the northern desert shrub vegetation in the state except a strip across the northern part and the higher elevation areas in the remainder of the state. The northern portion of the state has little or no pinyon/juniper or salt desert shrub vegetation to serve as the upper and lower boundary. Sagebrush is found in the valleys and alluvial fans while the mountain brush type is found with substantial rises in elevation. Additional color composites are required to differentiate the mountain brush types. They are highly reflective in the summer due to the predominance of vigorous highly infrared reflective shrubs, grasses and forbs. This factor also accounts for the difficulty of differentiating northern desert shrub vegetation in the higher elevations in the remainder of the state. Areas above the upper pinyon/juniper boundary are a mixture of northern desert shrub, mountain brush, aspen, timber and sub-alpine vegetation. These cannot be differentiated without color composites on additional dates. These types are also conglomerates of vegetation types occurring in fairly small areas, making them difficult to handle on a statewide basis. The aspen type was fairly successfully mapped on one frame in Central Nevada. Timber types, usually occurring in pockets on north slopes, were occasionally identified.

Standing water surfaces were inventoried using mid-September imagery as a base. Reservoirs, lakes and ponds were identified on MSS images and named from existing topographic maps. The surface area was quantified by acreage using a system similar to that described earlier for seedings (Tueller and Lorain, 1973). This water inventory can be updated seasonally or annually. A number of other inventories are underway or have recently been completed.

Soil-vegetation relationships have been considered. Some general relationships specifically oriented to landform-vegetation-soil correlations are readily apparent. For example, there is a close relationship between salt desert shrub vegetation and old beaches, between the mountain brush, pinyon/juniper, mountain mahogany complex and mollisols, and the northern desert shrub vegetation and the distribution of andisols.

Vegetation mapping accuracy results show an overall correct figure of 74% (Table 1). Much of the incorrect results is due to the inability at times to distinguish northern desert shrub from salt desert shrub, and the poor identification of low density pinyon/juniper. Very sparse pinyon/juniper cannot be detected on ERTS imagery and there was a high percentage of omission errors associated with this type. It may have been appropriate to eliminate many pinyon/juniper identification cells because of their proximity to a mapped ecotone, but this was not done. Hence, the results may not correctly describe the accuracy of this vegetation map, but they do give an indication of the types of errors that can be expected in identifying this vegetation type. There was also error associated with the discrimination between small playas and salt desert shrub. Perhaps the salt desert shrub and playa identification cells should be combined due to the fact that not all playas were indicated on the vegetation map.

Analysis of Repetitive ERTS-1 Imagery

Sequential imagery has proved its usefulness for a wide variety of purposes: vegetation mapping, following vegetation phenology changes, monitoring changes in standing water in lakes and reservoirs, evaluating changes in surface mining use, determining freezing and thawing dates for ponds, lakes and reservoirs, determining wet and dry periods on playas in relation to storm events, making fire fuel estimates and hazard estimates, mapping storm and snow distribution patterns in relation to large downstream erosion or flood events, making range readiness determinations, and other uses.

Unique winter scenes provided by ERTS were highly beneficial for identifying and mapping certain features. Color infrared composites from December 14, 1972 (Figure 3) greatly aided the mapping of pinyon/juniper vegetation in Nevada. These frames provided a unique situation in which pinyon/juniper (tree) was the only infrared reflective vegetation type at this time. All other vegetation types were either dormant or were covered with snow at this time. Unfortunately, only two frames in Nevada were available of this unique scene. The lower boundary of pinyon/juniper is easily recognized on summer color composites, but the upper boundary diffuses into other highly infrared reflective types. Pinyon/juniper was very accurately mapped where these winter scenes existed, but was still more accurately mapped where they did not exist than any map available.

Another example of interpretation aided by snow cover is shown at Coils Creek. Coils Creek has been one of our intensive soils/vegetation study sites for the past 6 or 7 years (Blackburn, et al., 1969). Later, the vegetation/soils

Table 1

Results of an ERTS-1 Interpretation Test for Vegetation Type Identification in Nevada.

Vegetation	northern desert shrub	southern desert shrub	salt desert shrub	playas [1]	pinyon/juniper	coniferous	agriculture	seedings	points not used [2]	TOTALS (excluding points not used)	TOTALS (including points not used)
No. Test Cells	31	20	70	3	22	1	9	3	9	159	168
No. Correct	29	17	48	0	10	1	9	3	-	117	-
No. Commission	32	0	7	1	2	0	0	0	-	42	-
No. Indicated	61	17	55	1	12	1	9	3	9	159	168
No. Omitted	2	3	22	3	12	0	0	0	-	42	-
% Omitted	6	15	31	100	55	0	0	0	-	26	-
% Committed[3]	103	0	10	33	9	0	0	0	-	26	-
% Commited[4]	52	0	13	100	17	0	0	0	-	26	-
% Correct	94	85	69	0	45	100	100	100	-	74	-

[1]All playas were not indicated on the map

[2]These points were not used due to problems with ecotones

[3]Based upon no. of type present

[4]Based upon no. of type indicated

map compiled in 1969, plus field trips were used to see if these same vegetation communities could be recognized on color, color infrared, and multispectral photography. Color infrared is available of this entire watershed at a scale of 1:24,000. Multispectral imagery is available at a scale of 1:62,500, from which color composites and enhancements were made to study the vegetation. NASA's RB57F flew the area in the fall with 9 sensors including color, color infrared, and black and white multispectral. These were all intensely studied. One vegetation ecotone, a very sharp boundary between big sagebrush and low sagebrush plant communities, could never be identified, even on the 1:24,000 color infrared. This boundary can now be clearly identified on December 14, 1972 color composites. Optimum snow cover is felt to be the reason for this identification. This could only be accomplished by sequential coverage over the same areas by the ERTS satellite. There is no question that sequential coverage adds invaluable information for vegetation mapping. Obtaining coverage in different winters where snowpack varies will also provide additional information.

As another example, we have evaluated a big sagebrush chemical control project occurring on the northern alluvial fan of Antelope Peak in the Monitor Range. The area is about 2 miles long by 1 mile wide with the chemical control accomplished in strips where sections between strips were left uncontrolled. This area is fairly easy to identify on 1:108,000 color infrared imagery obtained in the fall. This area is not visible on ERTS diazochrome composites in September, but is readily visible on December 14, 1972, ERTS black and white or color composites. The plant succession of this area can be monitored by ERTS from year to year as the area eventually returns to big sagebrush vegetation.

Changes in lakes, ponds and reservoirs are measurable. Determinations can be made of changes in surface standing water and correlated with water availability for irrigation, waterfowl habitat, and similar uses (Figure 6).

Numerous other examples can be cited. Many wildfires occurred in Western Nevada in the summer of 1973. Several of these fire scars were measured in a matter of minutes and compared favorably to Bureau of Land Management records. These fire scars were identified with the greatest ease on MSS 7 (Figure 7). Analysis of imagery before and after a significant storm event in Central Nevada has shown the potential of evaluating erosion features such as the widening or cutting of major washes. The Ruby Marshes are being monitored for waterfowl and fisheries management purposes. Water level controls are correlated with vegetation changes resulting in tone changes on ERTS color composites.

Phenology change has been successfully detected by using a densitometer and ratioing the transformed values for MSS bands 5 and 7. Figure 8 shows the typical phenologic change of a native meadow. The plants are initially green in

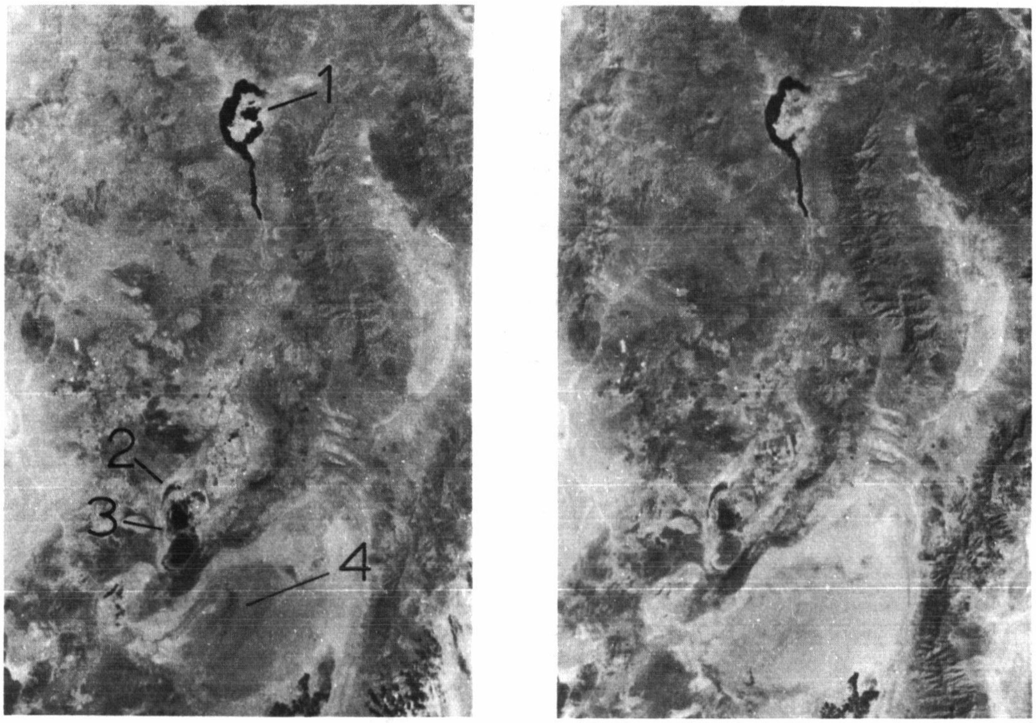

Figure 6. Left - ERTS-1 MSS 7 on August 11, 1972. Note the standing water in Rye Patch Reservoir (1), Toulon Lake (2), Humboldt Lake (3), and the Carson Sink (4). (Image 1019-18050-7)

Right - The same frame September 16, 1972. Note the significant reduction in total standing water. (Image 1055-18050-7)

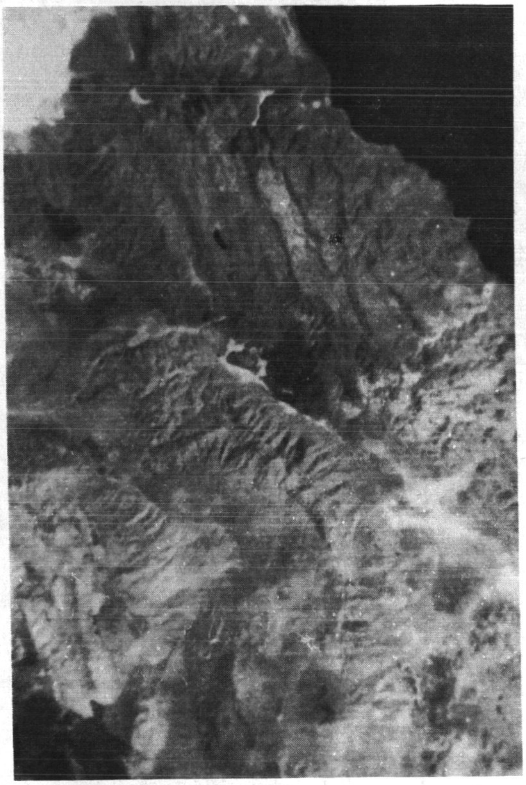

Figure 7. Fire scars, such as these between Pyramid Lake and Reno, can easily be delineated and quantified on ERTS imagery. (Image 1380-18104-7)

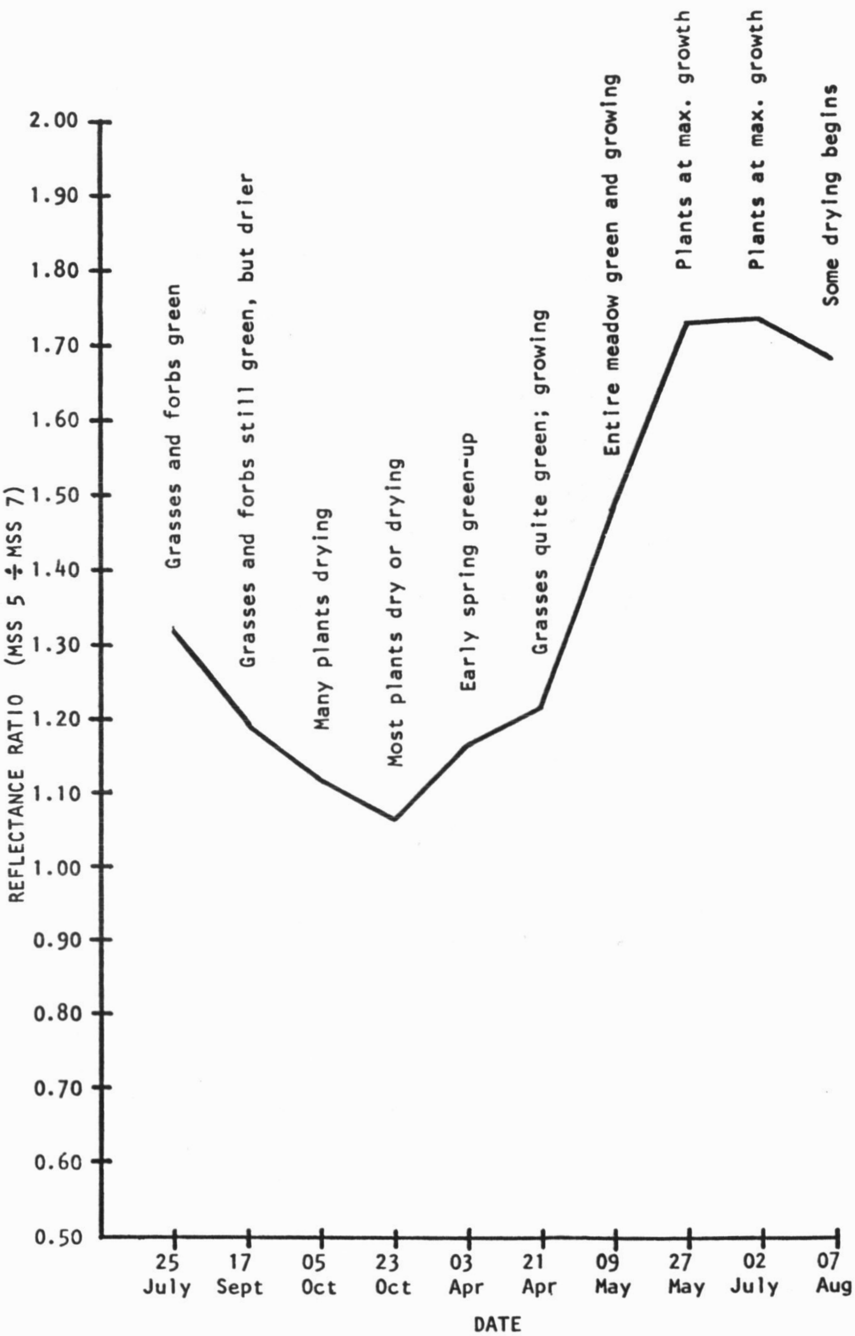

Figure 8. Phenologic Change of a Native Meadow in Washoe County as Detected on ERTS Imagery

the summer and exhibit fairly high infrared reflectance. The MSS 5 band records this as a dark tone, while the MSS 7 band shows it much lighter. Hence, the ratio between these bands is greater than 1. As the year progresses and the plants mature, this reflectance and the ratio decrease. With the onset of spring, the plants green up and the ratio increases. The phenology change is dependent on many factors, especially climate, and will vary from year to year.

Figure 9 shows the phenology change of a mountain brush community. The plants are initially green, but as fall approaches the deciduous species lose their leaves. This lowers the ratio but it still remains above 1. Snowfall covers the remaining leaves and the relfectance ratio drops below 1. Snowmelt, together with the emergence of new leaves, is detected as the ratio again rises above 1.

Similar results were observed for an irrigated field, an alfalfa field, and a marsh area. Annual vegetation such as cheatgrass exhibits the same reflectance properties, although the reflectance is not as easily measured except in the spring. Tests run on sparse vegetation types in the Las Vegas area showed that the phenology cannot be monitored for this type. The soil, not the vegetation, is the main contributing factor to the tone signature or infrared reflectance exhibited on ERTS imagery.

DISCUSSION AND CONCLUSIONS

The data we have extracted from ERTS-1 imagery is proving to be very useful to state and federal agencies and private firms. Many groups that we have worked with in Nevada have already shown an interest in and used these data. Our project has provided inventory information in the kind of detail never before available in Nevada on a statewide basis. The ERTS-1 imagery as a monitoring system is invaluable and only a few of the potential uses have been evaluated. The ERTS imagery has created considerable interest for monitoring water availability in reservoirs, snowpack determinations, fire fuel estimates, and measuring urban sprawl. Various other inventory and monitoring systems have been proposed. However, one important problem is the need for more timely delivery of products.

A tremendous amount of information is available from ERTS-1 imagery that has not been exploited in Nevada due to the sheer bulk of the data and the need for more research, including ground data. New uses are constantly being brought to light by exposing the imagery to different people (e.g., the Nevada Fish and Game Department has suggested and is using ERTS-1 imagery for the following: eagle and hawk inventory planning, aspen mapping in relation to beaver inventories). Our Desert Research Institute is using the imagery to survey sites in the Great Basin that have potential for the placement of solar energy

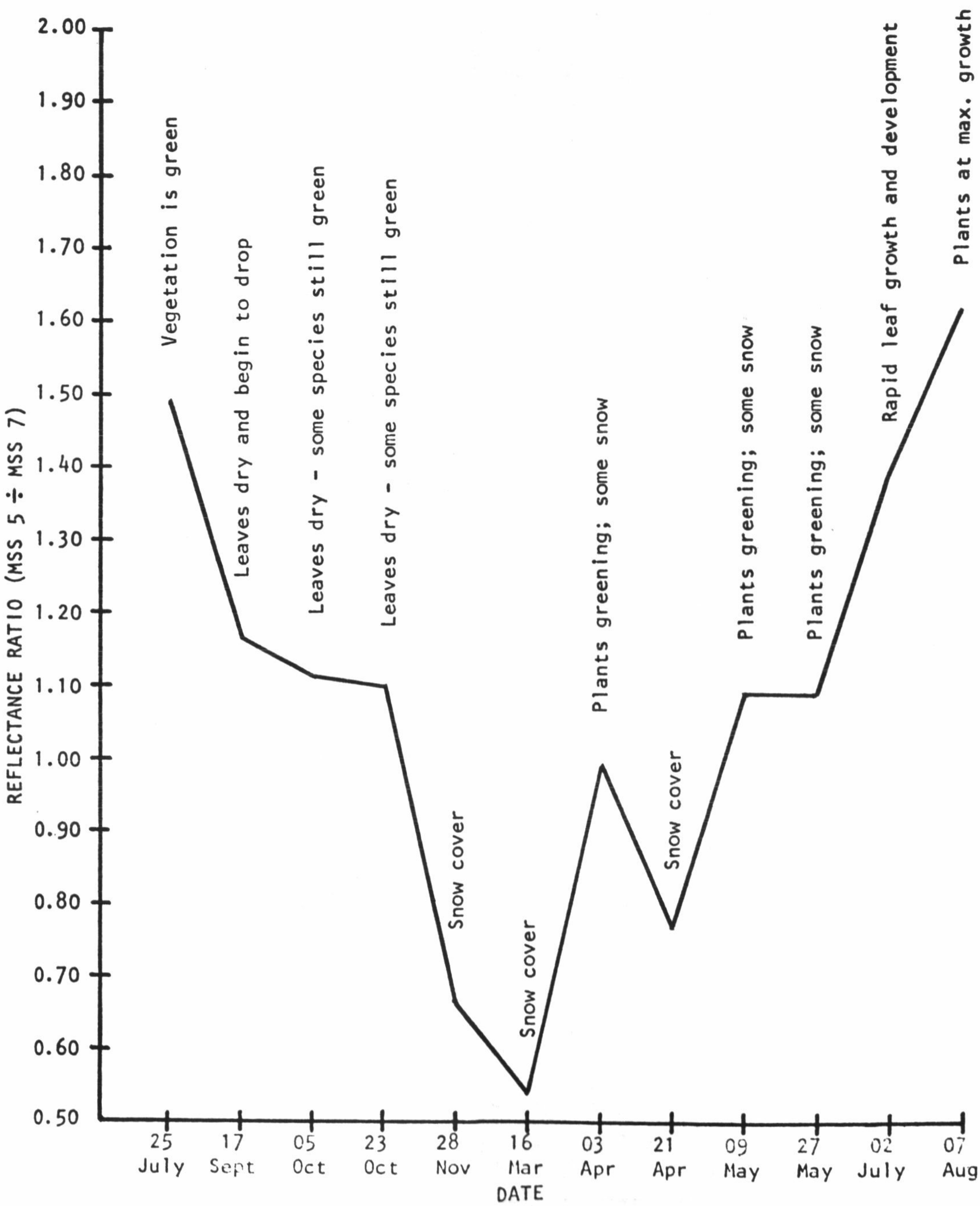

Figure 9. Phenologic Change of a Mountain Brush Community in the Sierras as Detected on ERTS Imagery

panels; The Nevada Division of Water Resources is utilizing updated surface water inventories and surveying the state for potential locations for new atomic energy plants and for inventorying the location and extent of surface mining activities.

The full potential of sequential imagery cannot be fully realized at this time due to factors such as cloud cover and exposure or processing problems. More coverage will undoubtedly show additional uses. The comparison of year to year dates (we are just beginning to evaluate this) will also yield more information on the correlations between precipitation, vegetation production and reflectance on ERTS imagery. Many unique signatures on ERTS have appeared which were not evaluated because we were not aware of their existence at the time field notes were gathered. As these ideas are plugged into our future field work, we can check these unique signatures as ERTS passes over and exploit their values for future uses. Finally, many critical dates for mapping vegetation types were missed due to cloud cover problems. The addition of dates in subsequent years and their related unique conditions will aid further mapping in the state (e.g., pinyon/juniper winter mapping scenes) and for updating maps.

ERTS will have considerable input to Nevada's new land use planning legislation (land use capability classification). County managers will also find it useful for land use planning. For example, we have had a request for a mosaic of Washoe County to be used by the Washoe County Sheriff's Department in their law enforcement planning efforts.

The Bureau of Land Management and Forest Service are finding our vegetation inventories to be useful for management purposes. Measurement of phenological changes in the vegetation has important management implications, e.g., for monitoring grazing management systems, fire hazard estimates and range readiness. Feasibility has been determined, but details of incorporating the data into management systems awaits further research and development.

More information is needed to document vegetation phenology and the means for accurately measuring the appropriate signatures. Additional detailed field notes on specific vegetation types (e.g., meadow and aspen) would be helpful along with larger scale underflights to document signatures as they appear on ERTS. Many variations in reflectance are apparent in seedings. These need further investigation to determine why they occur, and if they can be correlated with grazing management requirements.

The unique ability to infer snow depths and to determine snow distribution by storm event offers great potential for more accurately mapping vegetation types and to map other vegetation units that are not identifiable to date on ERTS-1 data.

There is also further need to describe these uses to state and local agencies, individuals and firms in the Great Basin. Information from our study has not yet been widely disseminated.

ERTS lends itself well to countywide or statewide inventorying and monitoring systems. The resolution was adequate for identifying most major vegetation types or zones in the Great Basin. Higher resolution would definitely be an advantage where more vegetational detail is required. Small stock ponds, critical to the livestock industry, could be monitored with a higher resolution system. The 18-day interval would be adequate for our study if there were no cloud cover, except for the critical growing season. The growing season requires more frequent coverage for optimum information. Cloud cover on only one overpass tends to leave large gaps in the data. For example, two of our study areas had no coverage between January and mid-June, a critical portion of the growing season. For the statewide inventories already described, ERTS-1 has proved its usefulness.

MSS 4 was evaluated routinely, but it was soon determined that this band was of little use to our investigations. MSS 5 and 7 bands were found to be the most useful for our investigation. MSS 5 provided the best resolution while MSS 7 has important uses for evaluating standing water surfaces and certain highly reflective vegetation types. For most of our analyses, MSS 6 offered no additional advantages.

NASA high flight data has been invaluable to us for purposes of supplementing ground data. Additional flights in other areas would also be of benefit in support of ERTS data.

Use of ground data is required in certain instances, but many times one cannot get the perspective from the ground required to accurately interpret ERTS data. We have found difficulty in sampling ERTS-1 signatures on the ground because of the variation found on the ground on seemingly homogeneous sites as viewed on ERTS-1 imagery. This is where NASA high flight imagery and our own 70 mm color and color infrared imagery is useful because it provides the overview and the resolution to see necessary detail and to make comparison.

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