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MONITORING CALIFORNIA'S FORAGE RESOURCE USING ERTS-1 AND SUPPORTING AIRCRAFT DATA

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Throughout the western United States, large livestock operators, livestock associations, county farm advisors, state statistical reporting services and federal land resource managers have expressed the need for improved techniques for regional monitoring of the forage resources associated with rangelands and wildlife habitats. The new techniques they desire should provide more accurate and timely information regarding the distribution and availability of forage, the health or condition of the forage, the duration of the green-feed period (the time period the forage plants are green), and the amount of forage produced. This information is essential for determining: (a) the animal carrying capacity for the range; (b) the time when grazing animals can begin grazing and the time when they should be removed from the range to minimize damage to the forage plants; (c) the location and condition of alternative sources of forage once the forage at a given range site has been fully utilized; and (d) the fire hazard created by unutilized forage once it has dried and become combustible.

NASA's Earth Resource Technology Satellite (ERTS-1) launched July 23, 1972, offers for the first time the unique capabilities for regional monitoring of forage plant conditions. The repetitive coverage every 18 days, the synoptic view and the real-time recovery of the imagery for immediate analysis, combine to make the ERTS satellite a valuable tool for improving the evaluation of our rangeland resources. Studies presently underway at the University of California, Berkeley (sponsored jointly by NASA and the Bureau of Land Management), seek to determine if imagery obtained from high altitude aircraft and spacecraft (ERTS) can provide: (1) a means for monitoring the growth and development of annual and perennial range plants in California, and for determining the time and the rate of initial plant growth (germination) and terminal plant growth (maturation and senescence; (2) a means for determining or predicting the relative amount of forage that is produced; and (3) a means for mapping rangeland areas having different forage producing capabilities.

Relatively cloud free ERTS imagery for much of California was obtained during the first six cycles: July through October. This imagery has provided an excellent opportunity to monitor the changes associated with the termination of the green-feed period in the perennial rangelands,

and the initiation of the green-feed period in the annual grassland ranges. The perennial rangelands in California are located primarily in the extreme northeastern portion of the state and throughout and east of the Sierra Nevada Mountains. Forage plants associated with the perennial rangelands generally commence growth in late spring or early summer and mature and dry in late summer or early autumn. Thus only the last half of the 1972 growth season of perennial forage plants was monitored during the period of July through October. The annual rangelands in California are located primarily in the foothills of the Coast and Sierra Nevada Mountains. Forage plants associated with the annual ranges generally commence growth during the autumn in response to sufficient rainfall to cause germination of the seeds. Usually a half-inch of rain is required. The first rains of the 1972-73 season fell on September 26 and 27 causing germination of the annuals throughout the northern half of the annual grassland range. The second rains occurred between October 7 and 14 causing further germination to the south over approximately half of the remaining range where germination had not occurred. Finally, during the first and second weeks of November, rainfall caused germination of the remaining annual grassland areas. This southern progression of germination was monitored by the ERTS pass during the first week of October and by the subsequent passes 18 days later.

Analysis of range condition and change has been performed on diazochrome composites of MSS imagery (bands 4, 5 and 7). The diazochrome composites are comprised of a yellow transparency of band 4, a magenta transparency of band 5 and a cyan transparency of band 7. Each of the colored transparencies are made by exposing the 9 x 9 inch black-and-white positive ERTS transparency on the appropriately colored diazochrome film using ultraviolet light. The three colored transparencies are registered (sandwiched) to make the composite which simulates the color renditions of color infrared film. Diazochrome composites were made for each of the first six passes providing a medium on which to compare changes in the vegetation and surface features.

Change detection was also facilitated by employing "positive-negative" masking techniques. This method of detecting change involves superimposing in registration the negative image from one band on one date with the positive image of the same band at a second date. If the two possible composites are made (negative image from the early date with positive image from the later date and vice versa) those features which appear light or white in tone on the composite should depict features which have changed. Because the negative and positive images can also be reproduced on diazochrome colored film transparencies, many combinations of color composites can be created which both show changed features while enhancing feature classification. In any event features which have changed during the interim between passes of the ERTS vehicle can be monitored and their significance evaluated in relation to rangeland environments.

High altitude aircraft data obtained in association with certain of the ERTS overpasses provide verification of many of the conditions of features analyzed. In addition, aircraft data from previous years provide a means for comparing conditions during this growth cycle with previous growth cycles. A network of sample sites located throughout California's rangelands provide ground truth data regarding species composition, growth stage and condition, plant height, degree of utilization, and forage produced. Observations are made at approximately monthly intervals to document the changing forage conditions and provide accurate verification of the conditions analyzed on the ERTS imagery for corresponding areas. Rainfall and temperature data are also collected to correlate with plant development and production.

Significant Results

1. Detailed mapping within rangeland environments is not possible from ERTS data. Gross vegetation types such as forestland, rangeland and meadow land can be discriminated, but the resolution of ERTS imagery does not permit detailed mapping needed for evaluating management problems or making management decisions. This result should be qualified by indicating that the level of information mapped from ERTS imagery would not be useful to the local or district manager of rangelands. Further qualification should emphasize that it is the mapping performed by humans which is not sufficiently detailed to be useful. Automatic classification using the magnetic tape data of ERTS will be tested to determine if refined mapping from ERTS data can be performed.

Vegetation-soil maps derived from high altitude aircraft data generally are detailed enough to be useful to local or district range managers. The comparison of the supporting high altitude aircraft data with ERTS imagery of the same area demonstrates the limiting resolution of ERTS data for detailed vegetation-soil mapping.

2. Most ephemeral lakes within the perennial rangeland can be detected and mapped. Their presence and/or size on a given date provide clues to the climatic variables that directly affect forage production and condition. The ephemeral lakes are best observed on bands 6 and 7.

3. The most important use of the ERTS imagery for evaluating rangelands is for monitoring changes in forage plant condition and development. Annual rangeland containing recently germinated forage species could be differentiated from rangeland where germination had not occurred. Thus the approximate time of germination and the extent of the range where germination has occurred can be determined from analysis of ERTS data. It follows from these observations that the cessation of plant growth in response to insufficient rainfall and soil moisture depletion can also be monitored by ERTS data. A comparison of ERTS images obtained on October 5 and 6, with images obtained 18 days later confirms the

southward spread of germination in the annual grassland of California resulting from the rains during the interim period. From the information obtained through analysis of ERTS data it is possible: to predict when grazing could commence and when it should be terminated at the end of the growth season due to a reduction in nutritive value associated with the drying of range forage species, or to the absence of sufficient forage to maintain the grazing animals; and to determine the length of the green-feed period which is correlated with the amount of forage produced. When the growth season is short forage production will be below normal and the animals will leave the range much earlier and lighter than normal (more supplemental feed or alternative sources of feed will be required). When the growth season is long, forage production will be above normal and the animals will leave the range at a later date and be considerably heavier than normal. They will require less feed supplements.

4. Analysis of the ERTS imagery should reveal the location and size of ranges affected by favorable or unfavorable climatic variables that cause above- or below-normal (respectively) forage condition and production.

5. ERTS imagery can provide the bases for determining the location and extent of rangelands where potential fire hazard exists either by virtue of early drying or by virtue of the presence of abundant forage which when dry creates the flash fuel for spreading fire to more valuable vegetation types.

6. ERTS data does not provide sufficient resolution to determine the cover or condition of forage plants in most perennial range plant communities. A noteworthy exception is that of meadow sites which have a dense cover of vegetation in contrast to the generally sparse cover of plants in other perennial plant communities. Moreover, the drying trend of the meadow vegetation could be monitored from one pass to the next in the perennial rangeland between August and October. Thus meadows and ephemeral lakes can be monitored using ERTS data, and provide indicators to the climatic variables governing forage production and condition throughout the perennial rangelands. It is envisaged that ERTS data will also prove valuable for determining conditions early in the growth season which indicate when grazing can commence without doing damage to the perennial forage plants.

7. ERTS data provide a permanent record of range conditions at a given date and for a given year. A comparison of ERTS images with aircraft data obtained on previous years reveal the relative difference in range condition between years. ERTS data acquired on a year-to-year basis can provide the first and most effective means for comparing changes in range condition from year-to-year for large rangeland areas.

Specific users who stand to benefit from the information obtained

through analysis of ERTS data include: (a) the Bureau of Land Management and the U.S. Forest Service -- both agencies are required to regulate the time and duration of grazing on lands that they administer; (b) the California Crop and Livestock Reporting Service -- an example of a state agency that can use ERTS derived information to account for animal movements, the need for feed supplements, and the determination of range conditions; (c) the California Division of Forestry and other fire control agencies (BLM and USFS) -- these are vitally concerned with acquiring information which permits more accurate and timely allocation of manpower and equipment to prevent potential wild fires; and (d) ranchers, feedlot operators, and others involved in using or supplying feed supplements -- they need timely information regarding availability of green forage, the time of animal movements to and from rangelands, and the availability and demand for alternative sources of feed supplements.

In summary, the data provided by ERTS and high altitude aircraft enables range managers to monitor the development of range lands throughout California. By providing timely and accurate data regarding the availability, distribution and condition of forage, the ERTS satellite can contribute greatly to more effective utilization and management of California's rangelands. To the extent that predictions of forage production can be made from ERTS data (in conjunction with ground and climatic data), range managers, feedlot operators and suppliers of feed supplements can more efficiently predict the time, direction and numbers of animals moving to and from rangelands, and determine the need for feed supplements which will sustain the animals until they are converted to consumable meat products.