LANDSAT MONITORING OF ALBEDO CHANGES IN NORTHWESTERN ARIZONA, 1977 - 1980

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U. S. Geological Survey Open-File Report 82-14

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ABSTRACT

As part of a cooperative project between the U.S. Geological Survey and the Bureau of Land Management, changes in albedo (percentage of light reflected from the ground) were calculated and mapped from Landsat images for an area in northwestern Arizona for three periods: August 26, 1977, to September 3, 1979; September 3, 1979, to August 28, 1980; and August 26, 1977, to August 28, 1980. The mapped albedo changes were field checked in April 1981. Decreases in albedo were associated with increases in vegetation, primarily the flush of annual vegetation and the regrowth of vegetation in chained areas and sites of past fires. Increases in albedo were due to recent fires.

Continuous monitoring of changes in albedo using current, rather than historical, Landsat images can provide the Bureau of Land Management with a means of monitoring vegetation growth, determining areas of high fire potential, and more efficiently deploying of field personnel to sites where severe changes are occuring in the quality of the land and vegetation resources. For example, an albedo change could be an indication of encroachment by an invader species. Similarly, it could indicate where rangeland is being lost to desertification.

INTRODUCTION

Management of land connotes a responsibility for making decisions on the basis of complete and accurate knowledge of the condition of the land. An accurate and efficient means of monitoring the changes in the land and its renewable resources is vital to updating the factual and practical bases of land management.

Purpose of the Report

The purpose of this report is to document a satellite-based method of monitoring changes in land quality in an area in northwestern Arizona which is representative of lands managed by the U.S. Bureau of Land Management (BLM). An initial evaluation is made to determine whether the method can provide the BLM with up-to-date information on land quality for use in the management process.

Criteria for a Monitoring System

Monitoring of land quality on the ground generally consists of field investigations of change or the extrapolation of data taken in experimental plots, such as vegetation exclosures, to large areas. A sound monitoring system would be capable of (1) surveying large areas in a reasonable amount of detail, (2) detecting changes at a level significant for land management decisions, (3) achieving an observational timeliness and frequencey commensurate with the decisionmaking process, (4) having a low probability of missing significant change, and (5) being relatively inexpensive and cost-effective.

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Field monitoring is expensive in terms of logistics and the cost of labor and transportation, particularly if conducted often. In addition, some areas of change may be overlooked because of the difficulty of access in rugged terrain.

Satellite monitoring has the advantages of a very low unit cost for the data and its analysis, a reasonable frequency of observation, and the ability to cover large areas in sufficient detail for many land management purposes. A method of monitoring the albedo (percentage of light reflected from the land surface) has been developed and initially tested by the U.S. Geological Survey for monitoring arid and semiarid lands (Robinove and others, 1981). It meets the above criteria in general and is being considered by the BLM as a possible routine approach to monitoring changes on public lands in the western United States.

Mapping Terrain Change With Landsat Images

A number of methods may be used to map changes in terrain with Landsat images. The simplest and most straightforward is the visual comparison of two black-and-white or color-composite images taken at different times. This method will successfully pick up gross changes but has a high probability of missing subtle and gradual changes.

Digital change detection may be done by comparing the same single-band scene acquired at two different times and either ratioing the images and analyzing the composite ratio image for change, or classifying land cover on the two images and analyzing the difference in the classifications. Another method is the albedo method, which is used in this report.

The Albedo Method

The albedo method is based on the hypothesis that the percentage of light reflected from the ground (and its cover) will increase if the cover decreases and will decrease if cover increases. In arid regions, an increase in density of vegetation will darken the ground. High soil moisture at the surface will darken the ground, and erosion, as by flash floods, will lighten the ground.

The albedo method is described by Robinove and others (1981) in complete detail, and the reader is referred to that report for derivation of the equations and the computer methodology. The basic theory involves the additive combination of the four bands of a Landsat image to calculate the total amount of light reflected from the ground in the wavelength interval of 500 to 1,100 nanometers (nm). This reflected amount is corrected for atmospheric scattering by subtracting from each pixel the darkest value in each band in the scene and by correcting for solar elevation. The corrected value is ratioed with the incoming solar radiation in the same wavelength interval to arrive at the albedo.

The albedo is calculated for each pixel in each of two Landsat scenes (or subscenes) of the same area at two different times. The images are registered to each other and the earlier image is subtracted from the later image. Each pixel in the resulting image has a plus or minus value showing how much the albedo has increased or decreased. The image analyst then selects threshold values which are significant in the area on the basis of his knowledge and judgment, and prints out maps showing change beyond the threshold values. For example, he may decide to show only those pixels whose albedo has decreased by more than 3 percentage points and those pixels whose albedo has increased by more than 5 percentage points. The objective is to delineate patterns of significant change that correspond either to natural terrain patterns or to land management units.

The resulting binary maps (black equals change, clear equals no change) are superimposed on Landsat images or on base maps for field checking.

Field Checking Albedo Change Maps

The albedo change maps show where change has taken place, in which direction there is change, and the amount of change, but they do not indicate why a change has taken place--this question must be determined in the field or through the knowledge of the field person. The first objective of field checking is to determine if the areas where the albedo has changed are significant in terms of land quality and management. In addition, it is necessary to determine if all areas of significant change in land quality are mapped as areas of albedo change. The approach, then, provides a field check for errors of both commission and omission. Field checks of albedo maps have not been done in a manner that leads to a statistical measure of reliability because of the difficulty of assessing historical changes. For example, if a field check is done in 1981 for albedo changes that have taken place between 1977 and 1979, the present land records and the knowledge of the field person are generally inadequate to determine all of the reasons for change and, particularly, to identify areas of known change that are not mapped. Nevertheless, the areas of albedo change that have been field checked in this and previous projects have, with few exceptions, been satisfactorily explained and shown to be of significance in assessing changes in land quality.

Albedo Change Mapping in the Arizona Strip

Maps of albedo change were made for an area in northwestern Arizona in the BLM Arizona Strip District and adjacent lands to the south. Figure 1 shows the test site area. The dates of the albedo images are August 26, 1977, September 3, 1979, and August 28, 1980. Changes were mapped for the 2-year period 1977-79, the 1-year period 1979-80, and the combined 3-year period 1977-80. Figures 2 to 7 show the 1979 albedo image (used as a base map) and the albedo change maps. Albedo changes are shown in black and are superimposed on the 1979 albedo image.

The change maps were field checked by the authors in April 1981. Twenty-one major areas of change were checked; many minor change areas of only a few acres were not field checked. Many of the small areas that show minor albedo changes may be caused by small errors in registration of the albedo images. The larger areas are of much more importance in land management decisions in the Arizona strip. Table 1 summarizes the changes that took place and provides explanations for them. The authors have been able to explain all the albedo changes with the exception of site number 1 for which a single explanation of the changes is difficult to determine.

The figures and the table indicate that the basic changes taking place are natural, that is, the flush of annual vegetation and revegetation of burned areas. Two actively managed areas showed change; the plowed fields of the Arkansas Ranch (site 14) and the regrowth of vegetation in areas where pinyon pine and juniper had been chained (site 10).

The authors believe that the mapping and explanations of the changes have shown the general usefulness of the method. Its major advantage is that it identifies the areas of change which can then be inspected on the ground, and avoids the expense of surveying the entire area on the ground several times per year to find the areas of significant change. In routine use, this approach will provide significant savings in manpower, time, and cost.

Recommendations

On the basis of previous work (Robinove and others, 1981) and on this test of the albedo change method in the Arizona strip, the authors have several recommendations regarding further testing of the method and for routine operational use for BLM management purposes:

1. Further tests should be conducted with current, rather than historical, data to allow field checking within 2 to 3 weeks of the end of the change period. This approach is feasible given the present rapid delivery times of Landsat computer-compatible tapes from the Earth Resources Observations Systems (EROS) Data Center. Successful tests would provide the Bureau of Land Management with a capability for routine monitoring of vegetation growth and fire potential and would allow rapid deployment of field personnel to areas of severe change.

2. The method of deriving albedo change maps should be made as completely automated as possible on the Interactive Digital Image Manipulation System (IDIMS) computer at the BLM Denver Service Center (DSC). A critical part of this automation is the use of a Sequential Scene Detection Algorithm (SSDA) to eliminate the tedious, time-consuming, and somewhat inaccurate visual selection of ground control points for image registration. Use of the SSDA is the most effective way of speeding up the automated production. This latter technique should also be installed on the DSC system.

3. BLM field offices should be informed of the availability in Denver of the technique and should be encouraged to use the technique in their Districts on appropriate projects.

4. Some experiments should be conducted on a more frequent basis. Experiments to date have monitored only annual changes, but it is believed that changes from vegetation dormancy (early spring) to periods of annual and perennial growth (early summer) may provide useful information on forage conditions in some areas and also on susceptibility to fire.

REFERENCE

Robinove, C. J., Chavez, P. S., Gehring, Dale, and Holmgren, Ralph, 1981, Arid land monitoring using Landsat albedo difference images: Remote Sensing of Environment, v. 11, p. 133-156.

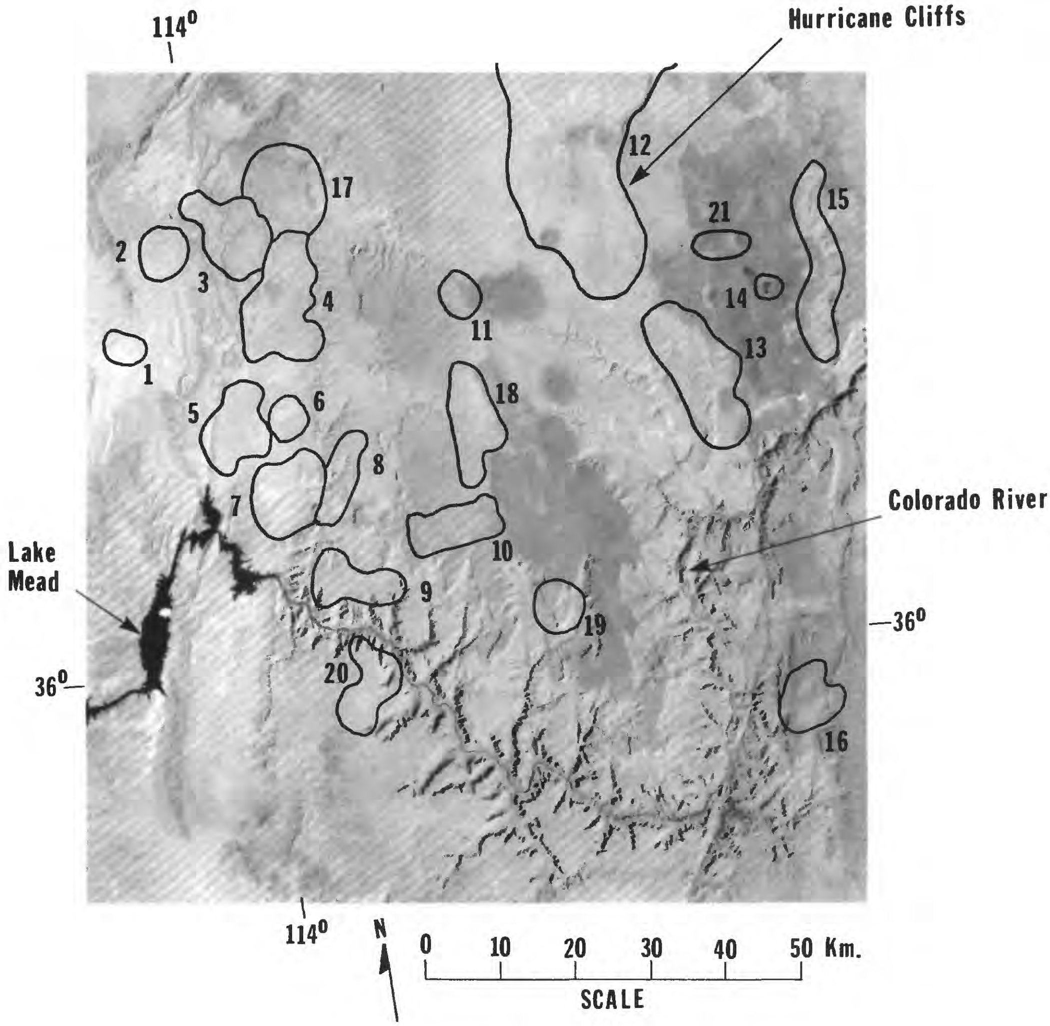

Figure 1.—Albedo image acquired September 3, 1979, of the western Arizona strip. The total area is 6,100 square miles (3.9 million acres). The quantitative albedo image has a gray scale which is proportional to the albedo. The darkest area, in Lake Mead, has an albedo of 1.89 percent; the brightest areas (several locations) have an albedo of 45 percent. The mean albedo of the area is 17 percent with a standard deviation of 4.6 percent.

This is one of the three albedo images used for change mapping in this test. The numbered areas are locations where significant amounts of albedo change took place. They are described in table 1.

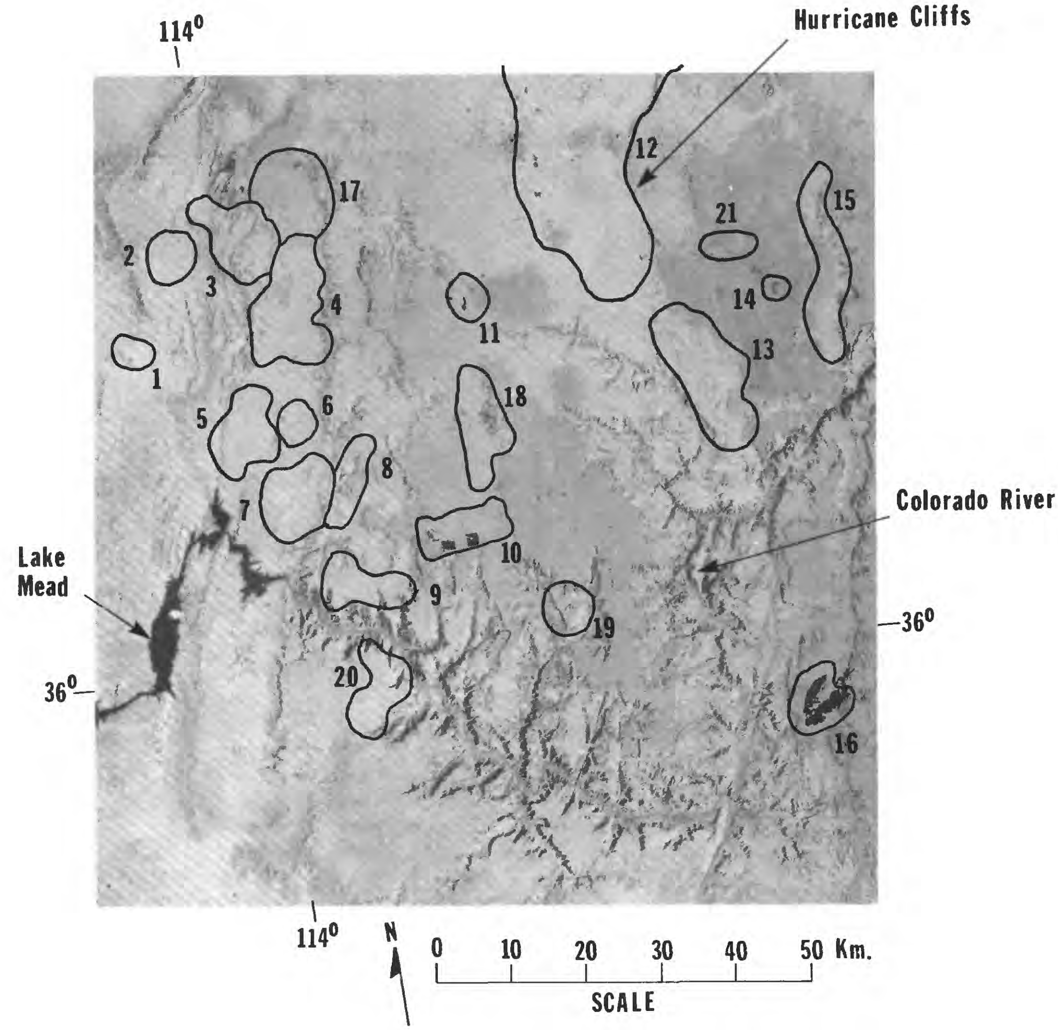

Figure 2.—Areas where albedo increased by more than two percentage points from 1977 to 1979 are shown in black in the numbered locations (11, 16, 18, and 21). See table 1 for explanation.

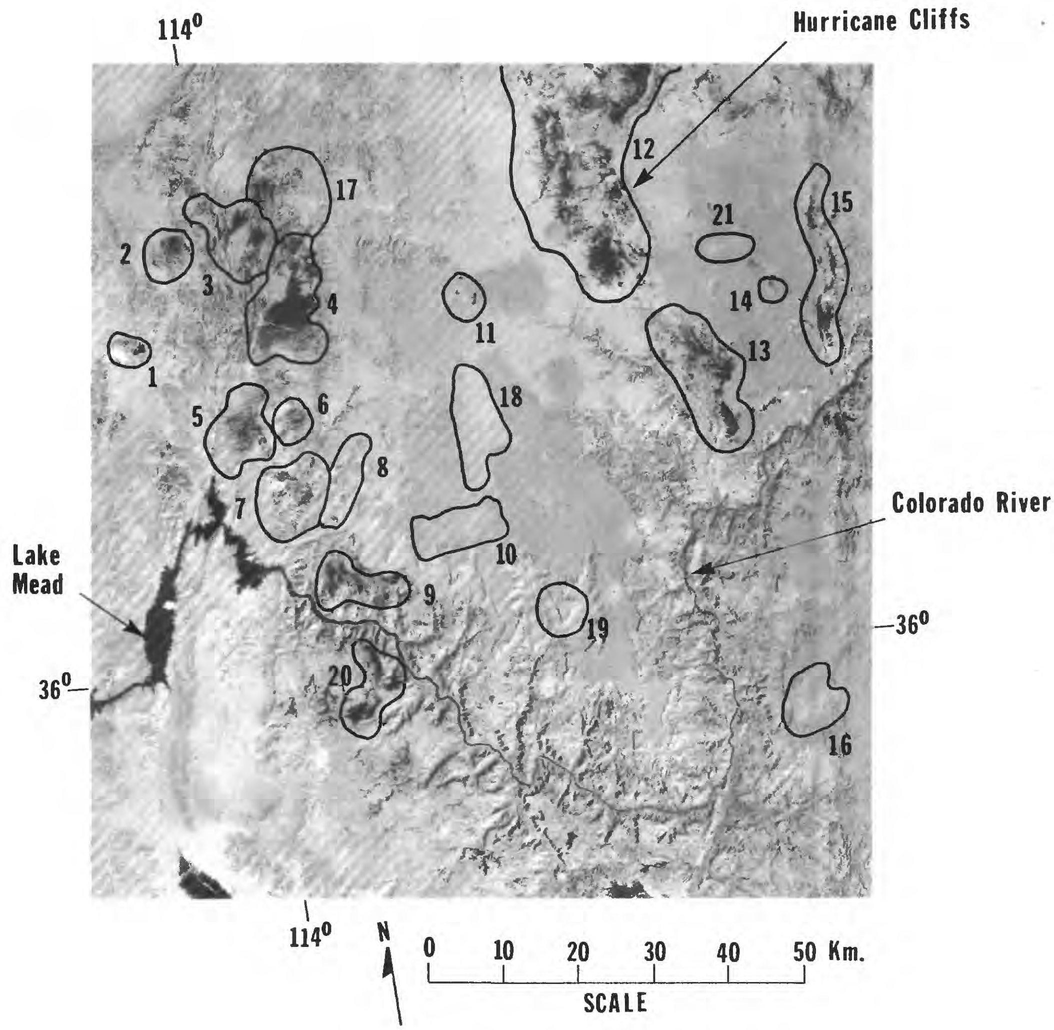

Figure 3.—Areas where albedo decreased by more than two percentage points from 1977 to 1979 are shown in black in the numbered locations (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 17). See table 1 for explanation.

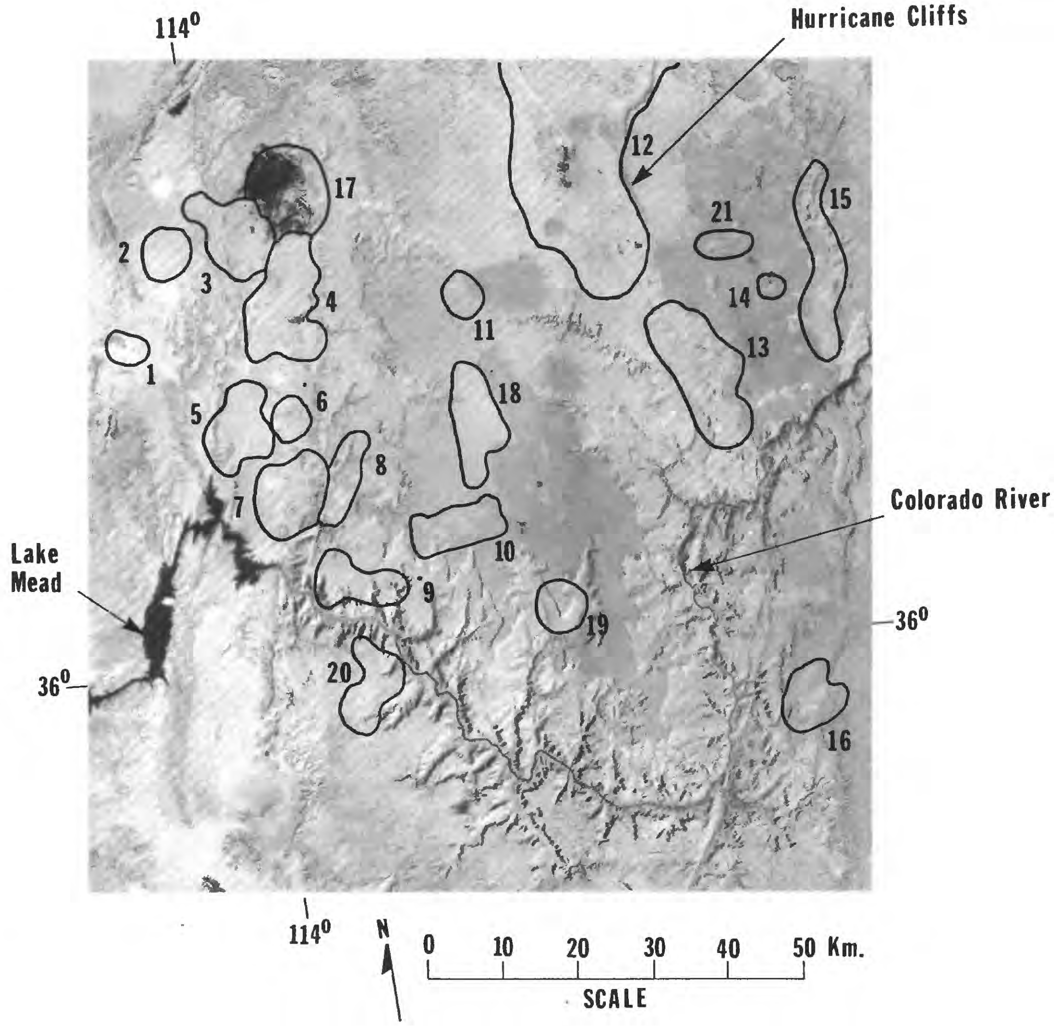

Figure 4.—Areas where albedo increased by more than one percentage point from 1977 to 1979 are shown in black in the numbered locations (10, 12, 13, 17). See table 1 for explanation.

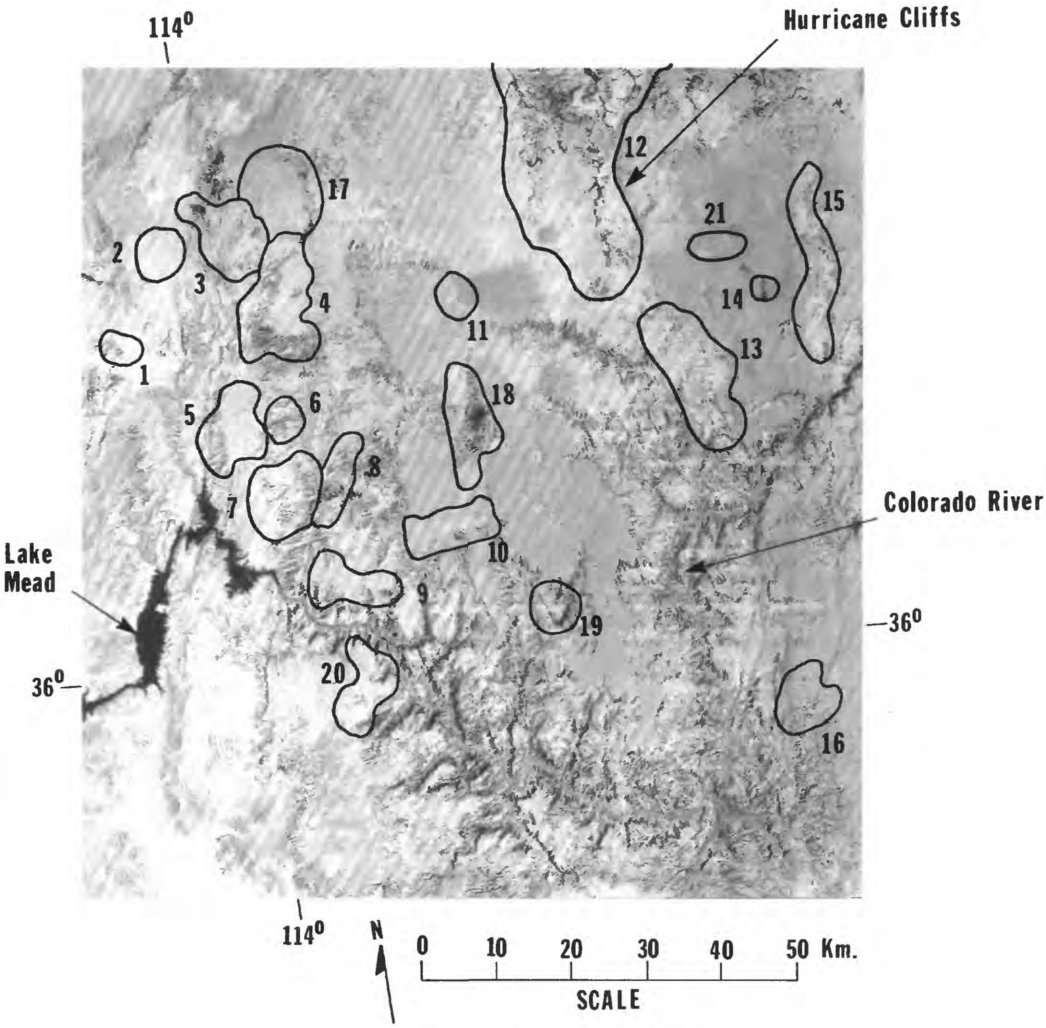

Figure 5.—Areas where albedo decreased by more than three percentage points from 1979 to 1980 are shown in black in the numbered locations (4, 7, 8, 10, 12, 14, 15, 18, 19). See table 1 for explanation.

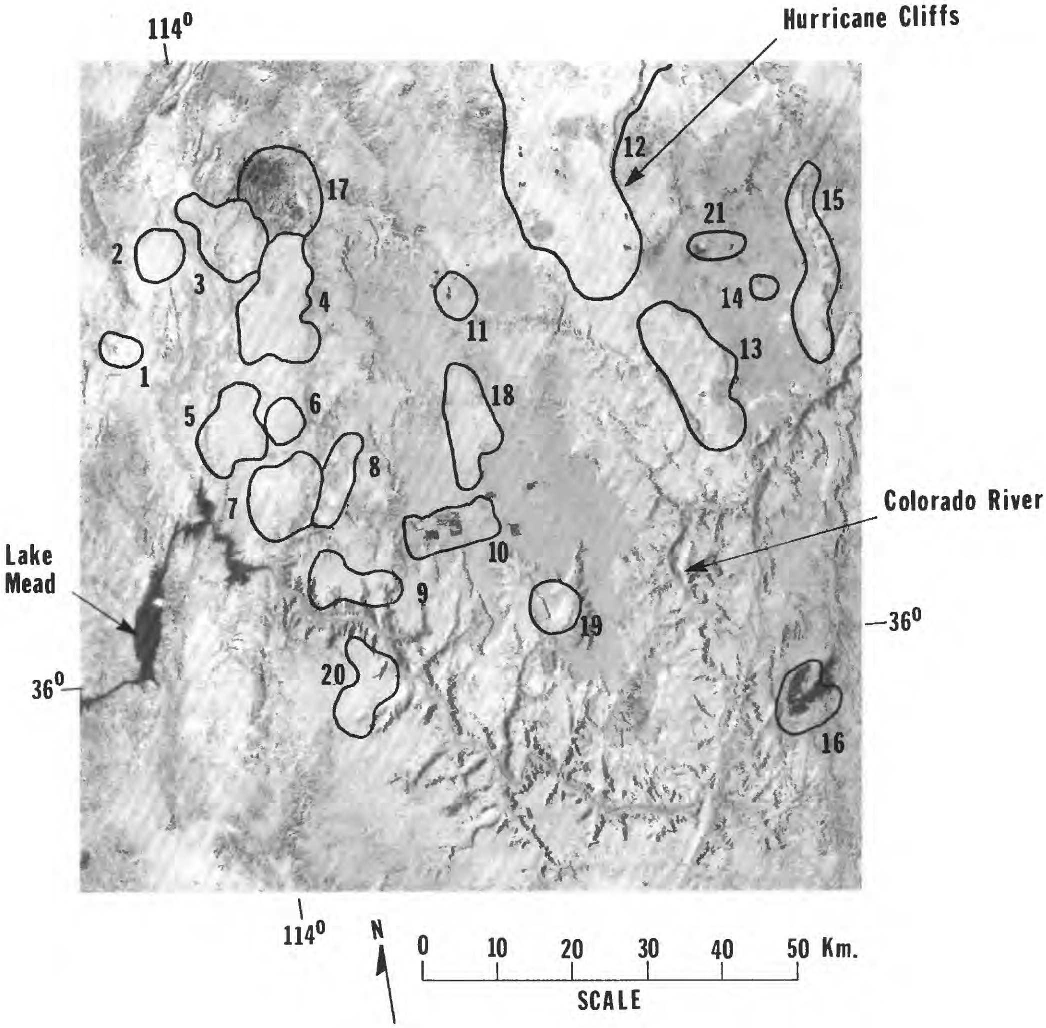

Figure 6.—Areas where albedo increased by more than one percentage point from 1977 to 1980 are shown in black in the numbered locations (10, 16, 17, 21). See table 1 for explanation.

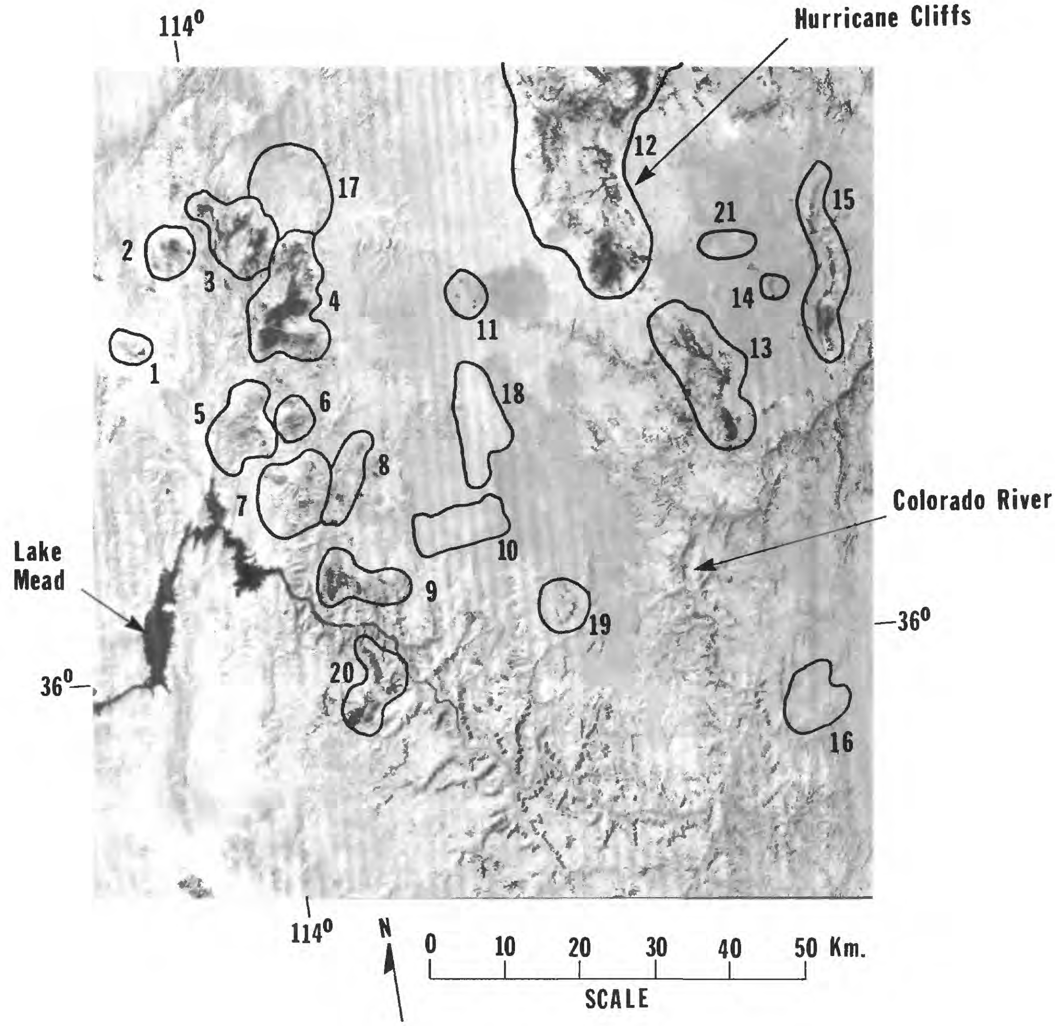

Figure 7.—Areas where albedo decreased by more than three percentage points from 1977 to 1980 are shown in black in the numbered locations (1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 18, 19, 20). See table 1 for explanation.

TABLE 1. Sites of Major Albedo Change and their Explanations.

Site No.	Location and description	Albedo Change 77 to 79	Albedo Change 79 to 80	Albedo Change 77 to 80	Reason for Change
1	Middle Spring grazing allotment south of tip of Virgin Mts.	Decrease	None	Decrease	An area of red sandstone. No discernible reason for change was seen in 1981 but it may be due to the flush of annual vegetation.
2	Mosby-Nay grazing allotment.	Decrease	None	Decrease	Revegetation of an old burned area.
3	Southwest end of Mud Mountain	Decrease	None	Decrease	Flush of annual vegetation in canyon bottoms. Some burned areas.
4	Southeast end of Mud Mountain Black Knolls	Decrease	Decrease	Decrease	Flush of annual vegetation in canyon bottoms. Some burned areas.
5	Tassi Bench	Decrease	None	Decrease	Flush of annual vegetation.
6	Tassi Bench	Decrease	None	Decrease	Flush of annual vegetation.
7	Lower Grand Wash Cliffs	Decrease	Decrease	Decrease	Burned in 1980.
8	Bench between upper and lower Grand Wash Cliffs.	Decrease	Decrease	Decrease	Revegetation of pre-1977 burn (mine fire).
9	Sanup Plateau (LMNRA)	Decrease	None	Decrease	Revegetation of pre-1977 burn.
10	Pinyon-Juniper Chaining area	Decrease	Increase Decrease	Increase	Chained areas and vegetation regrowth.
11	Poverty Mountain	Increase Decrease	None	Increase Decrease	Some changes in small stock ponds; some clouds and cloud shadows.
12	Lower Hurricane Valley	Decrease	Increase Decrease	Decrease	Flush of annual vegetation.
13	Whitmore Canyon	Decrease	Increase	Decrease	Flush of annual vegetation.
14	Arkansas Ranch	None	Decrease	Decrease	Plowed farm fields.
15	Toweep Valley	Decrease	Decrease	Decrease	Vegetation growth.
16	Hualapai Indian Reservation	Increase	None	Increase	Old burn and revegetation.
17	Mud Mountain	Decrease	Increase	Increase	Burned in 1979.
18	Wildcat-Big Sage brook flat	Increase	Decrease	Decrease	Flush of annual vegetation.
19	Home Ranch	None	Decrease	Decrease	Possibly flush and annual vegetation.
20	Lake Mead area	None	None	Decrease	Vegetation increase in very open area. May be an old fire scar.
21	Trumbull treatment areas.	Increase	None	Increase	Reduction in vegetation growth.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1982—361-614/327