Video Digitization of Aerial Photographs for Measurement of Wind Erosion Damage on Converted Rangeland

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ABSTRACT: This project developed a practical approach for measuring the area of wind erosion damage on rangeland converted to farmland. The selected study area consisted of 7,150 ha that was rangeland before 1954. A video graphics microcomputer system enhanced and digitized aerial photographs to measure the area of wind erosion or blowouts and the proportion of cotton cover crop on the selected farms. The result was that 23 percent of the total study area showed signs of wind erosion damage.

INTRODUCTION

MANY RANGELANDS have sandy soils that are prone to wind erosion (Fryrear, 1981). When range vegetation is removed, winds sift fine particles from the soils, leaving the land with limited nutrients and water holding capacity. Desertification results as blowouts and sand dunes form.

In the rangelands of west Texas these sandy soils are common, as is the practice of converting rangeland to farmland. Approximately 4,000 to 6,000 ha of rangeland have been converted each year in Gaines County (Sheridan, 1981). In years of adequate rainfall, poor soils can provide enough nutrients to support vegetation and Gaines County farms produce acceptable cotton crops (*Gossypium hirsutum*). However, years of low rainfall or drought can cause desertification of the land, rendering it unproductive (USDA, 1960; 1965). This wind erosion damage can ultimately cause abandonment, as was the case during droughts of the 1930s and 1950s (Fryrear, 1981; Gibbens *et al.*, 1983; Hunt, 1983).

Gaines County is one of many areas that has felt the effect of wind erosion on its converted rangeland. Sheridan (1981) reported that 31 out of 39 converted farms experienced extreme wind erosion with an annual soil loss in excess of 71 metric tons per ha per yr. This result was part of a project that evaluated ten U.S. counties (283 farms). The project concluded that Gaines County provided the worst example of desertification.

Obtaining quantitative damage statistics on rangeland converted to farmland is difficult. Such data are necessary in order to address the problem of wind erosion and to better manage soil resources (Tueller, 1980; Gifford and Whitehead, 1982).

The purpose of this study was to demonstrate one way of measuring wind erosion damage on rangeland converted to farmland. We conducted this study with materials and equipment commonly available to resource agencies so that they could ultimately use this method for management activities. Our approach used aerial photographs and microcomputers (Tueller, 1980). Previous rangeland studies using computer analysis of aerial photographs and satellite data have proven valuable to management agencies (Rohde *et al.*, 1979; Everitt *et al.*, 1981; Scarpace *et al.*, 1981; Carneggie *et al.*, 1982; McGraw and Tueller, 1983). Our quantitative approach also allowed us to measure areas of vegetative cover. By using video-to-digital analysis, we were able to estimate total farm area and verify accuracy by comparing our estimates with those of the U.S. Agricultural Stabilization and Conservation Service (ASCS).

MATERIALS AND METHODS

Twelve farms (7,150 ha) were selected from Gaines and Dawson Counties in west Texas (102° 15′ W longitude and 32° 45′ N latitude). Selected farms (a) had soils with great limitations for farming (SCS capability classes IVe-VIe), (b) were largely in rangeland cover before 1969, and (c) were converted to

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dryland cotton farms when the August 1981 photographs were taken (Plate 1). Farms were not selected randomly or systematically for several reasons, including (1) the difficulty of selecting lands meeting criteria "a" and "b" above, and (2) the abundance of other land covers such as oil fields, rangeland, and sorghum and wheat farms, which make selection difficult.

The majority of soils on the farms were of poor relative quality as compared to other soils in those counties and compared to soils in most U.S. agricultural areas. Literature (USDA, 1960; 1965) and field work indicated that the soils were predominately Brownsfield fine sands, a soil type very susceptible to wind erosion (Table 1). The Soil Survey recommended that these soils be managed in natural vegetative cover because of this limitation for farming.

Historical data were obtained from 1954 to 1983. Black-and-white photographs(5-15-54, 4-10-60, and 3-24-69) showed 100 percent of the study area was in rangeland cover prior to 1954. The ASCS provided 1:6,000 scale 35-mm color transparencies of pre-harvest crop conditions (August 1981, Plate 2) which were used to measure land cover on the study farms. Additional black-and-white photographs were acquired later in the year of the study (December 1981, 1:20,000) during mid- and post-harvest conditions. In July 1983, 1:600 to 1:1200 color and color infrared 35-mm photographs Plate 1) were taken with a small-format, large-scale photography system when the crop was in pre-harvest condition (McCarthy *et al.*, 1982; Lyon and Drobney, 1984).

The ASCS 35-mm color aerial photographs and a microcomputer system were used for measurement of land-cover area. The Measuronics video graphics microcomputer system was composed of two stand-mounted video cameras for input of data, and a video processing unit to mix and digitize the analog signals. Rectification of images and scale calculations were completed by registering magnified 35-mm transparencies onto a USGS map. Farm boundaries were located on a map, then projected on the monitor with the first video camera. The second video camera overlaid farm boundaries from transparencies onto the projected map. Both boundaries were matched, corrected by zoom and stretch-adjusted when necessary, so that there was no apparent distortion.

Video cameras displayed the analog images of the transparencies, which were digitized using a "binary frame grab" method. This method categorized every pixel within a range of grey levels representing a certain land-cover type. Once a correct range was selected, the video graphic overlays were digitized and stored in a raster or pixel format. Measurements were made by counting the pixels in the overlay and calculating area from the pixel-scale determined from maps and photos. Total farm area, area of blowouts, and the areas of two types of cot-

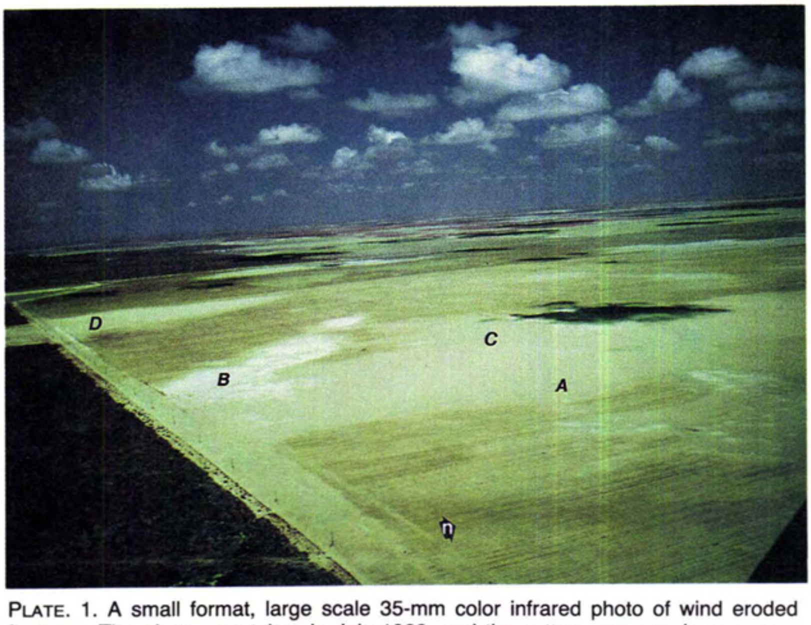

PLATE. 1. A small format, large scale 35-mm color infrared photo of wind eroded features. The photo was taken in July 1983, and the cotton crop was in very poor condition due to drought. Large blowouts are apparent as white toned areas in the field (A), as are areas with many caliche stones (B). Several features can be identified, including several large blowouts (C and D).

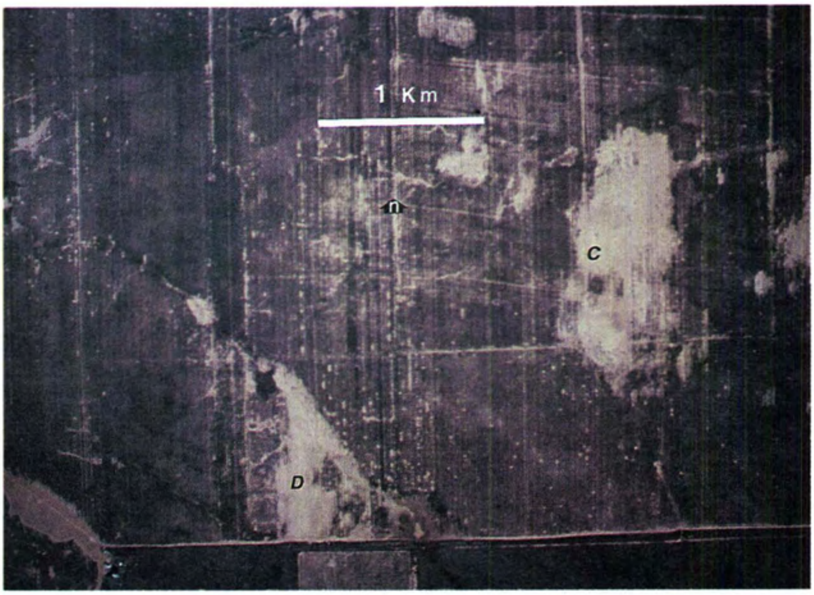

PLATE. 2. A 35-mm color photo of the same field as the previous example Plate 1. The cotton crop was green in August 1981, as the rainfall was adequate for crop needs. The location of individual blowouts was constant with respect to field boundaries (C and D), while the stony areas were less obvious under the canopy of cotton plants. The original scale was approximately 1:6000.

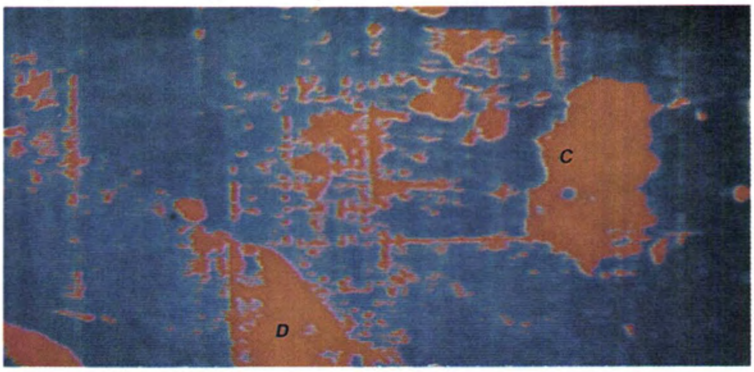

PLATE. 3. Video-digital image of the photo in Plate 2, showing the graphic overlays of different land cover types. Plate 3 shows bare areas or blowouts in red. The relative quantity of blowouts was 18 percent in this scene.

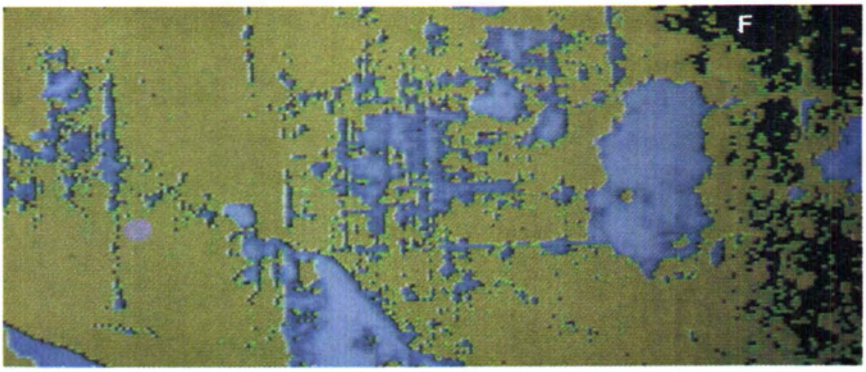

PLATE. 4. An overlay of the low relative cover of cotton class. The relative quantity of crop was 64 percent of the total area. The graphic overlay of the high relative cover areas of cotton is not shown, but that type is evident as dark toned areas (F) characteristic of a relatively high number of cotton leaves and high level of closure of the cotton canopy.

TABLE 1. SCS CAPABILITY CLASSIFICATIONS OF SOILS FOUND ON STUDY AREA FARMS. SCS CLASS IVE SOILS HAVE MODERATE-TO-SEVERE WIND EROSION LIMITATIONS, AND REQUIRE VERY CAREFUL MANAGEMENT (USDA, 1960; 1965). CLASS VIE SOILS HAVE SEVERE WIND EROSION LIMITATIONS AND ARE UNSUITABLE FOR CULTIVATION.

Soil Type	SCS Capability	SCS Erosion Hazard for wind	Percent farms with this soil	Average Depth of Sand in Surface Horizon
Brownsfield fine sand, thick surface	VIe	very high	100	0–60 cm
Brownsfield fine sand, thin surface	VIe	high	100	0–46 cm
Amarillo loamy fine sand	VIe	high	50	0–40 cm
Amarillo fine sandy loam	IVe	moderate	50	0–36 cm
Arvana fine sandy loam	IVe	moderate	40	0–20 cm

ton cover were measured from ASCS color transparencies using this system.

These area measurements were compared with farmland records of the ASCS. The ASCS had previously grouped the twelve farms studied into seven units to report the crop type, area, and yield for various agricultural programs (Tables 2 and 3, farm units A-G).

RESULTS AND DISCUSSION

Results of analyses of current year and historical aerial photographs provided specific, quantitative examples of damage caused by wind erosion. Analysis of historical aerial photographs from 1954 and 1960 revealed a very low number of blowouts on rangelands managed with natural vegetative cover. A few large blowouts were noted on farms adjacent to the study examples. These other farms were converted before 1954, were later abandoned by farmers, and by 1960 they were in a very eroded condition (USDA, 1960; 1965).

Wind erosion damage or presence of blowouts was quantified on study farms (7,150 ha) using video-to-digital analysis of color 35-mm aerial photographs from 1981. An average of 23 percent of the total farm area experienced wind erosion damage or blowouts (Table 2).These areas were bare of plants and covered by sands 0.3 m or more in depth (Plates 2, 3, and 4). Analysis of December 1981 and July 1983 photo sets showed that individual blowouts were permanent and not an artifact of a particular crop, farm practice, or weather condition. Blowouts were easily separated from cotton cover due to the absence of plants and their spectral signature (Plates 1 and 2). The blowout cover class had poor to no cotton foliage, even though the blowout or sandy areas were planted in 1981.

Two cotton-cover classes (high and low relative cover) were evident from field work and image enhancement of photos. These cotton-cover types were separated on the basis of numbers of plants in rows and by quantity of foliage. Determination of cover types were made by field inspection, including counts of leaves, bolls, and number of plants per row. The high cover class had plants in most rows of the field and good-to-excellent cover of foliage. The low cover class had groups of plants missing from rows and good-to-poor quantities of foliage. Measurement of the two cotton cover classes from 1981 aerial photographs indicated that 55 percent of fields were of the low cover class, and that the remaining 22 percent of farms were of the high cover class (Table 2).

Measurements of land cover and the area of blowouts can be valuable as parameters in models which predict wind erosion (Woodruff and Siddoway, 1965). Land-cover maps and knowledge of roughness characteristics of each cover class can be used to determine the potential of wind erosion over large areas.

This study allowed a verification of accuracy by comparison of video digitized estimates of total farm area to ASCS crop area records. The total area of farms was measured as 7,150 ha by the video-to-digital approach, and the ASCS total was 7,211 ha, or a difference of less than 1 percent (Table 3).

CONCLUSIONS

Farming sandy soils in these counties may produce acceptable cotton crops in years of adequate rain, as in 1981 when rainfall conditions were favorable for growing dryland cotton. The 1982–1984 drought, however, greatly increased damage to the soils in these and other Texas counties. A comparison of Plate 2 (August 1983) and Plate 1 (July 1981) shows the difference in green crop in one field. Estimates of 23 percent wind erosion damage found during 1981 are probably low compared to current conditions.

TABLE 2. ESTIMATES OF THE PROPORTION OF LAND AREA IN COTTON AND BLOWOUTS BY VIDEO DIGITIZATION AND IMAGE ANALYSIS. THE ASCS CROP REPORTING UNITS ARE LETTERED A-G. THE AVERAGE OF EACH CLASS IS WEIGHTED BY THE NUMBER OF HECTARES OF EACH FARM UNIT (A-G).

ASCS Farm Units	Relative Quantities of Land Cover Classes Cotton High	Low	Blowouts
A	0.33	0.50	0.17
B	0.23	0.53	0.24
C	0.10	0.70	0.20
D	0.24	0.37	0.39
E	0.23	0.44	0.33
F	0.22	0.53	0.25
G	0.16	0.62	0.22
Weighted Average	0.22	0.55	0.23

TABLE 3. COMPARISONS OF TOTAL LAND AREA ESTIMATES BY ASCS AND BY VIDEO-TO-DIGITAL ANALYSIS OF AERIAL PHOTOS OF EACH FARM AREA. THE FARM UNITS ARE ASCS CROP REPORTING UNITS (A-G).

Farm Unit	Image Analysis Totals (ha)	ASCS Totals (ha)	Difference in Totals (ha)	(%)
A	2,974	2,983	9	0.3
B	334	337	3	0.9
C	1,573	1,589	16	1.0
D	901	917	16	1.7
E	778	775	3	0.4
F	403	415	12	2.9
G	187	195	8	4.1
Total	7,150	7,211	67	0.9

The long-term management of these areas as farmland is tenuous. Blowouts and drought can cause the land to be unproductive and potentially result in abandonment. Wind erosion on lands converted from range to farmland is widespread. Because of the gradual and long-term nature of wind erosion, the impact of this problem may go unmeasured. The video-to-digital analysis approach used in this study can potentially allow quantitative evaluation of damage from aerial photographs and provide data for management activities.

REFERENCES

Carneggie, D., B. Schumpf, and D. Mouat, 1982. Rangeland applications. In *Manual of Remote Sensing*, R. Colwell, Ed., Second Edition, American Society of Photogrammetry, Falls Church, Va., pp. 2325–2384.

Everitt, J., A. Richardson, and C. Wiegand, 1981. Inventory of semi-arid rangelands in South Texas with Landsat data. *Proceedings of the Symposium on Machine Processing of Remotely Sensed Data*, Purdue Univ., West Lafayette, In., pp. 404–415.

Fryrear, D., 1981. Dust storms in the Southern Great Plains. *Trans. of the Amer. Soc. Agr. Eng.*, pp. 991–994.

Gibbens, R., J. Tromble, J. Hennessy, and M. Cardenas, 1983. Soil movement in mesquite dunelands and former grasslands of southern New Mexico from 1933 to 1980. *J. Rangeland Management* 36:145–148.

Gifford, G., and J. Whitehead, 1982. Soil erosion effects on productivity in rangeland environments; where is the research ?. *J. Rangeland Management* 35:801–802.

Hunt, C., 1983. Some land management problems in our Western U.S. arid lands. In *Origin and Evolution of Deserts*, S. Wells and D. Haragan, Eds., Univ. of New Mexico Press, Albuquerque, pp. 65–80.

Lyon, J., and R. Drobney, 1984. Lake level effects as measured from aerial photos. *ASCE J. Surveying Engineering* 110:103–111.

McCarthy, J., C. Olson, and J. Witter, 1982. Evaluation of spruce-fir forests using small-format photographs. *Photog. Eng. and Remote Sensing* 48:771–778.

McGraw, J., and P. Tueller, 1983. Landsat computer-aided analysis techniques for range vegetation mapping. *J. Rangeland Management* 36:627–631.

Rohde, W., W. Miller, K. Bonner, E. Hertz, and M. Engel, 1979. A stratified-cluster sampling procedure applied to wildland vegetation inventory using remote sensing. *Proceedings of the Thirteenth International Symposium on Remote Sensing of Environment*, Ann Arbor, Mi., pp. 167–179.

Scarpace, F., B. Quirk, R. Kieffer, and S. Wynn, 1981. Wetland mapping from digitized aerial photography. *Photog. Eng. and Remote Sensing* 47:829–838.

Sheridan, D., 1981. *Desertification of the United States*. Council on Environmental Quality, U.S. Government Printing Office, Washington, D.C., 142 p.

Tueller, P., 1980. Rangeland remote sensing interpretation problems. *Proceedings of the Remote Sensing for Natural Resources Conference*, College of Forestry, Wildlife and Range Science, Univ. of Idaho, Moscow, Idaho pp. 450–465.

U.S. Department of Agriculture, 1960. *Soil Survey for Dawson County, Texas*. Soil Conservation Service, Austin, Tx., 58 p.

U.S. Department of Agriculture, 1965. *Soil Survey for Gaines County, Texas*. Soil Conservation Service, Austin, Tx., 55 p.

Woodruff, N., and F. Siddoway, 1965. A wind erosion equation. *Soil Sci. Soc. Amer. Proc.*, pp. 602–608.

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