DUSTSTORMS FROM THE U.S. HIGH PLAINS IN LATE WINTER 1977-SEARCH FOR CAUSE AND IMPLICATIONS

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Views from artificial earth satellites show that the southwestern limit of severe dust storms in the U. S. during February and March 1977 coincided remarkably with the Texas-New Mexico border. Along parts of that border is a marked and abrupt change of agricultural practice, with rangeland usually predominant on the New Mexico side, and cropland, much apparently irrigated, predominant on the Texas side. Farming in Texas is encouraged by deeper soils, greater availability of subsurface water for irrigation and more liberal rules for its use, and various historical and cultural factors. The cropland is susceptible to wind erosion before spring crops are planted and irrigation water is applied, and where dry land farming is practiced, when the preceding months have been dry.

INTRODUCTION

Severe dust storms produced by sustained winds above 25 knots on the U. S. High Plains during late winter 1977 were associated with destructive erosion and transport of soil particles by the wind to areas further east. In central Oklahoma on February 23, 1977, the worst dust storm in more than 20 years produced 24-hr average values of total suspended particulate matter up to 5800 $\mu g/m^3$, more than 20 times the national and state primary ambient air standard for such matter (1). Local extrema were much larger. By authoritative estimate, seven million tons were deposited in Oklahoma during the storm of February 22-24, approximately 100 tons per square mile, or 300 pounds per acre (2). The path of dust is shown by photographs synthesized from satellite data to have been from the west and northwest. Figure 1 shows a sharp western limit to the wind-raised dust—this limit in Colorado corresponds to the western boundary of extensive cultivated lands in the eastern part of that state.

On March 2, Oklahoma had another severe storm with most of the dust originating in West Texas (Figure 2).

Note that in Figure 1, there are two well defined major dust swaths, separated by a nearly clear space about 150 km wide, while in Figure 2, there are several adjacent swaths covering much of the area which is clear in Figure 1. The difference in dust coverage appears to be related to differences in the wind fields — on February 23, winds of 30 to 40 knots were reported from the dust swaths, while in the clear area of the Texas Panhandle, wind speeds were reported in the 20-30 knot range. On March 2, the wind speed in the Panhandle area was generally higher. These general conditions are somewhat illustrated by the weather data plotted in Figures 3 and 4.

Both Figures 1 and 2 show that in Texas the western limit of dust nearly coincides with the border between Texas and New Mexico. Since the latter is a political division without a continuous corresponding geological division, it is difficult to understand at first glance why it is associated so clearly with a boundary of windraised dust.

Figures 1 and 2 have been selected from a series of time-lapse satellite photographs which show that the dust on both February 23 and March 2 rose from widely distributed sources in Texas, with the few sources in New Mexico mostly near the Texas border in the Clovis-Portales area. The distribution of dust sources and a basis for the several swaths in Figure 2 are suggested by Figures 5 and 6 (discussed below) wherein the pattern is very closely related to variety in use of the land. While the individual swaths could also be produced by local wind variations, it seems unlikely that such small-scale feature in the wind field would persist as observed in the series of satellite pictures.

The extensive area with many dust sources is generally at an altitude between 3,000 and 4,000 feet MSL (about 1000 m), has average annual rainfall between 12 and 20 inches (30 and 50 cm), and includes lands in both dry-land and irrigated cate-

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gories. During late winter some cultivated fields are bare, and some contain winter wheat planted the previous September or a stubble from the previous year's crop. Spring planting does not generally begin until April, and application of irrigation water, where available, is often correspondingly delayed. Late winter 1976-77 followed two years of mild to moderate drought along the Texas-New Mexico border area with which this paper is most concerned (3).

While many serious questions about our Nation's agricultural practices and policies are raised with the dust, we are largely confined here to consideration of the demarcation of agricultural practice along a particular segment of the Texas-New Mexico political boundary which shows up well in satellite photographs of both ground and dust. Elsewhere, the discontinuous distribution of the dust alone, as shown in Figures 1 and 2, is among our best evidence for different patterns of agricultural practice on opposite sides of the border.

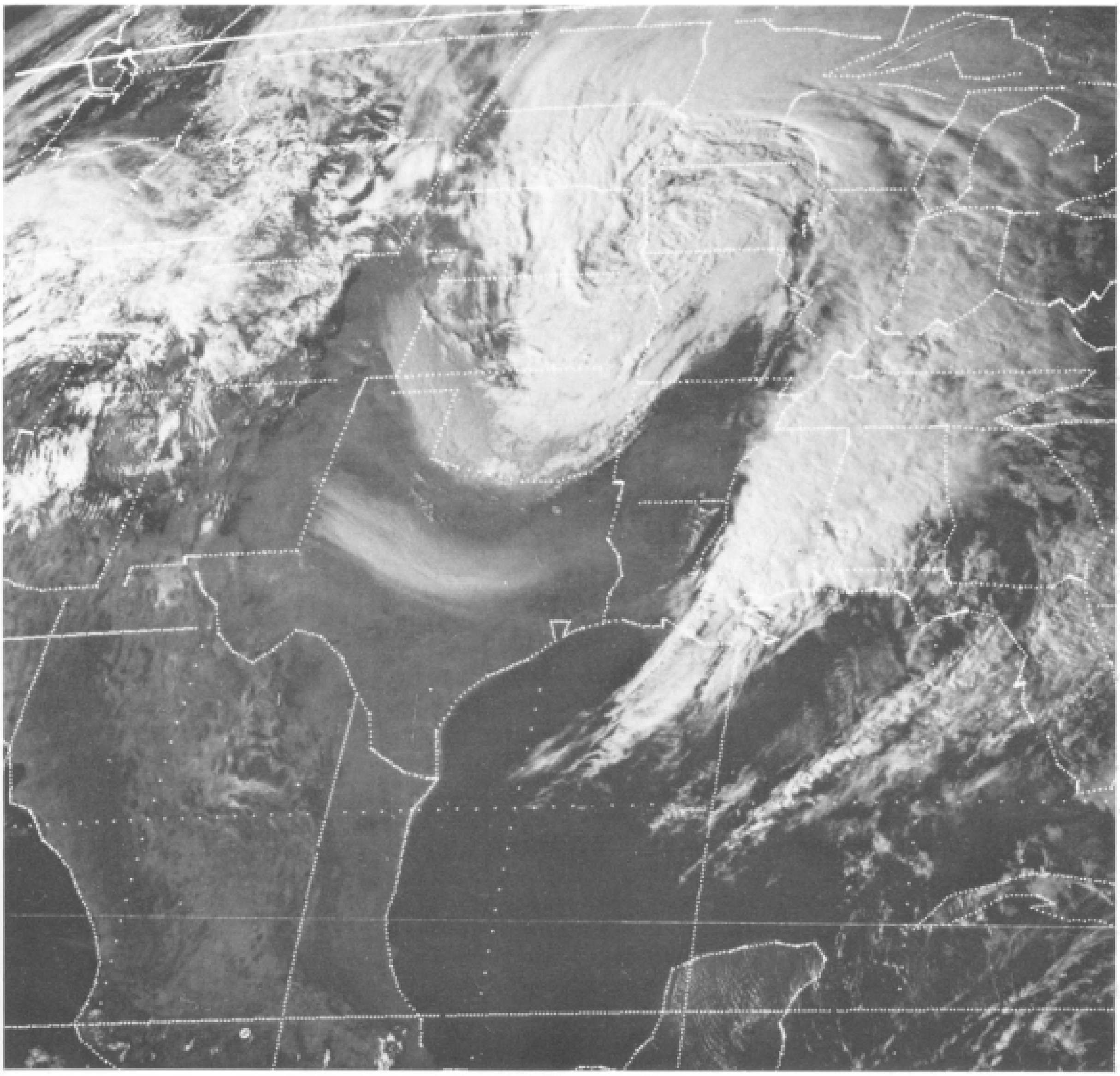

FIGURE 1. Photograph from GOES-1 geosynchronous satellite 2200 GMT (1600 CST) February 23, 1977, showing thick dust raised by strong west and northwest winds over eastern Colorado, western Kansas and Oklahoma, and west Texas. The dust boundary is nearly concident with the Texas-New Mexico boundary from Hobbs northward to the Clovis-Portales area where it laps into New Mexico about 10 miles. Bright areas are clouds, except for a few areas of snow-covered mountains.

APOLLO 9 - 1969

Our satellite photos raise anew a question pondered before in relation to photographs taken on March 12, 1969 from the Apollo 9 spacecraft. The photograph, which is shown in Figure 5, shows the Texas-New Mexico border along the 90 miles (145 km) between a point about 7 miles south of the intersection of U. S. Highway 82 with the border, northward to about 5 miles south of Farwell where U. S. Highway 84 intersects the border. Frank Rayner, in a monthly publication of the High Plains Underground Water Conservation District No. 1 (4), proposed that the difference in the types of groundwater basin management is the primary reason for the appearance of the Texas-New Mexico line on the Apollo photographs. But Reeves (5) took the different view: ". . . political philosophies of water management have played no part in land use practices between the two states." Reeves attributed the Apollo signature to a variety of factors: man-made physical features such as roads on the border, land use heritage, and greater

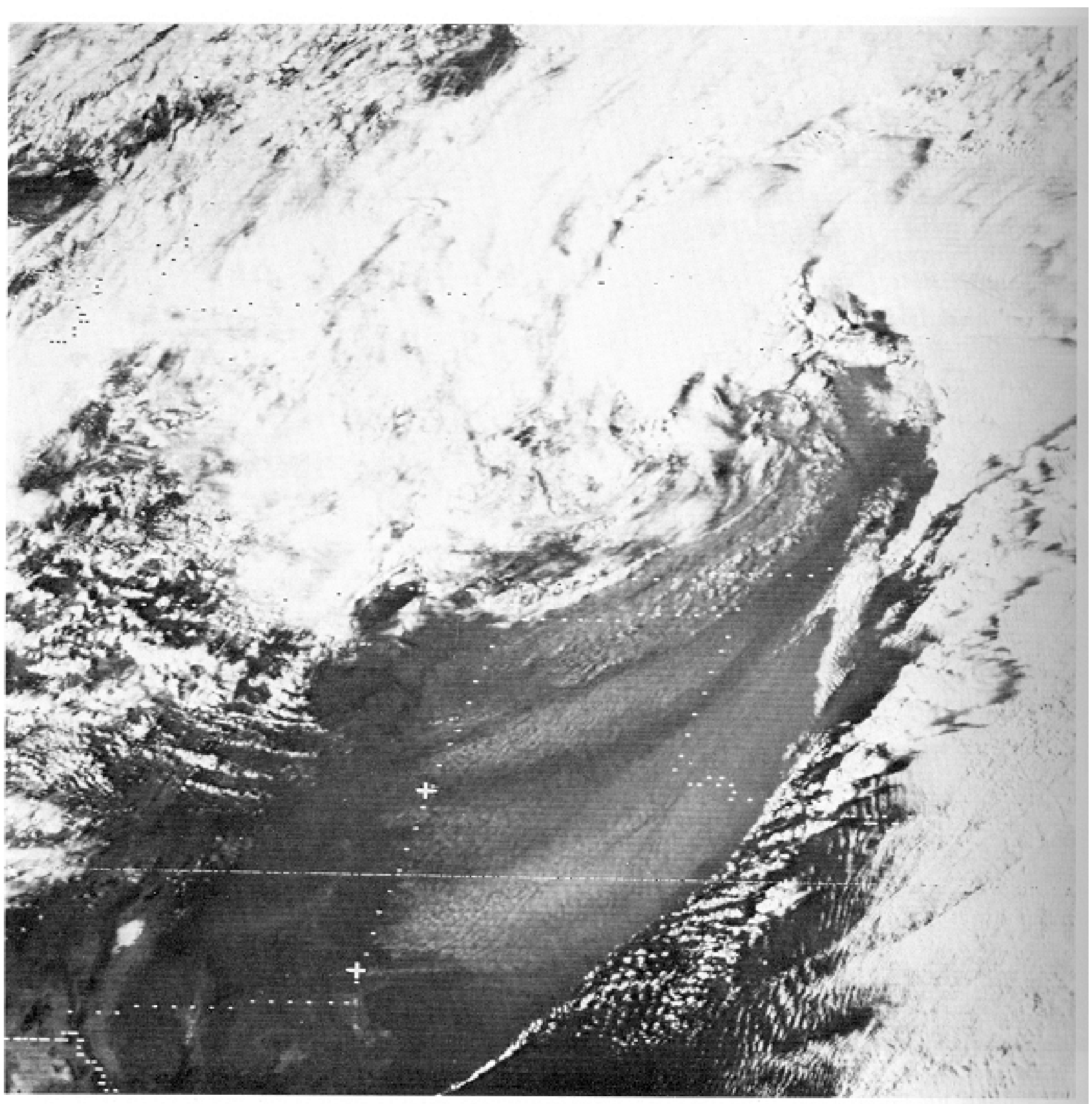

FIGURE 2. Photograph from GOES-1, 2230 GMT (1630 CST), March 2, 1977 showing heavy dust raised by strong southwest winds. Two heavy marks on the Texas-New Mexico border show approximate meridional extent of Figure 6, for judging land use at places where dust originates; white spot at lower left is White Sands, N. M.

presence and availability of tillable soils and water for irrigation in Texas.

1977 DATA

Certainly the satellite evidence is intriguing and we have investigated accordingly. The ERTS/LANDSAT log was consulted in order to identify more detailed views of the border area, and copies of 70-mm film positives of the entire border were prepared at the EROS Data Center, Sioux Falls, South Dakota, for October 16, 1976 and February 1 and 19, 1977. The photographs show the border area to have

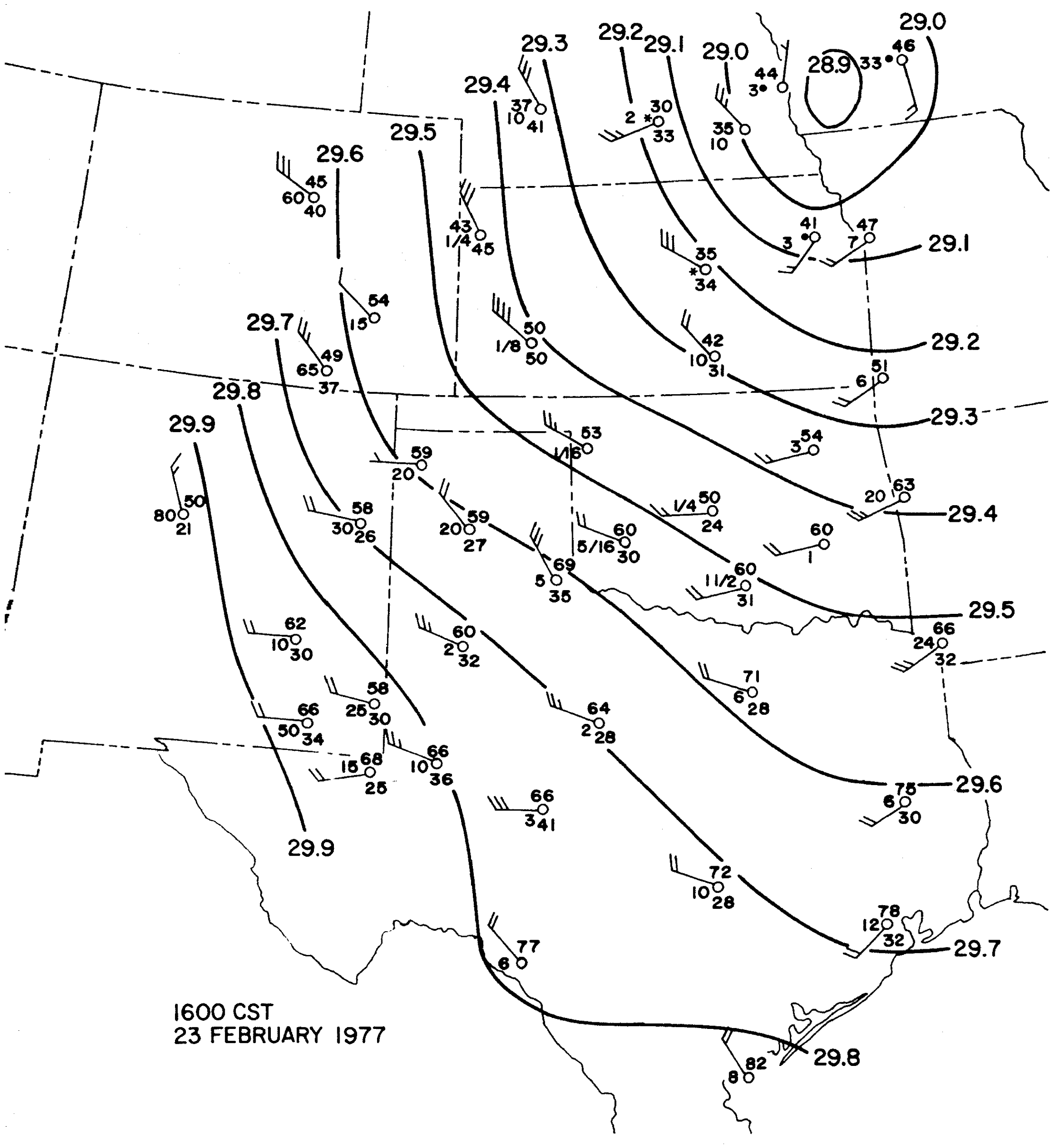

FIGURE 3. Abbreviated weather map prepared from airways reports on February 23, 1630 CST, 30 minutes after Figure 1. Station entries show wind direction and 10-minute average speed (a full barb represents 10 knots); temperature is at upper left of station circle; visibility in miles to left; peak gust, where given, appears below. Reduced visibility is associated with dust and haze except where rain (•) or snow (*) is indicated. Isobars are labeled with altimeter settings in inches of mercury.

presented a relatively unchanging view throughout this winter season. The border is indicated only by intermittent slight changes in shade in the photographs of its northern reach, clearly indicated in the south central section corresponding to the Apollo photograph, and practically not at all indicated along its extremity south of Hobbs, N. M. The south-central section is here indicated as Figure 6; many of its features have obvious counterparts in Figure 5.

Figure 6 shows the Texas-New Mexico border from (approximately) Texas Farm-to-Market Road 298 in the north to a point 23 miles south of the intersection near Hobbs, N.M., of U.S. Highway 62 with the border. This is a distance of about 120 miles (190 km). Between Hobbs and Bledsoe, the border is particularly well defined,

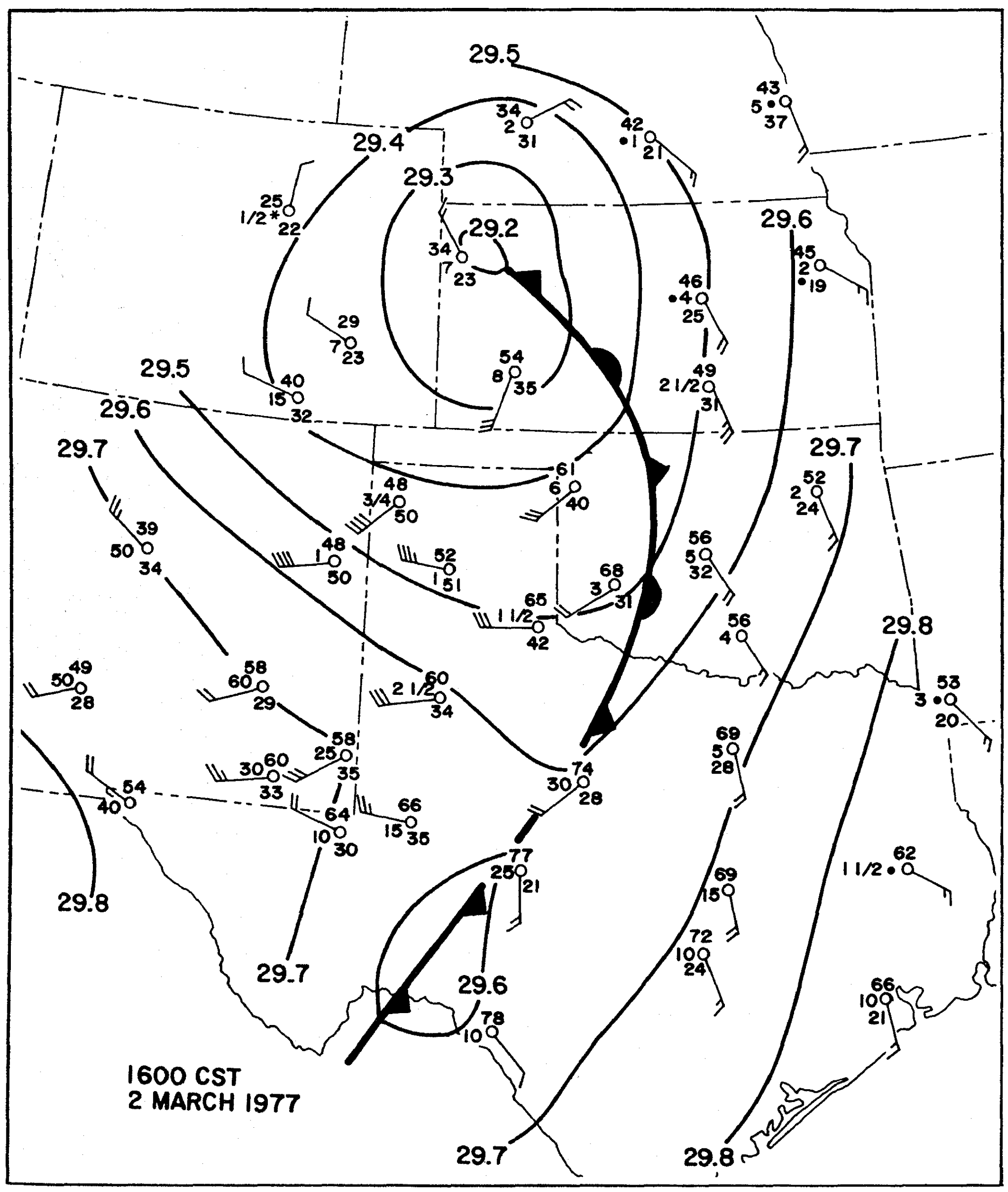

FIGURE 4. Weather map for March 2, 1600 CST. Entries are explained in the caption to Figure 3.

with cultivated lands (square or rectangular areas) many with center-pivot irrigation systems (circles inscribed in squares) much more in evidence on the Texas side. For the most part, there is a discontinuity in usage of the center pivot systems at the border, though a few can be counted spread out on the New Mexico side. It should be noted that the cultivated lands without evidence for center pivot systems may use another system for irrigation, or may represent dry land farms. The southern part of this stretch does not appear in the Apollo picture, Figure 5.

In the Clovis area, shown in the Apollo figure but about 30 miles north of the edge of the area in Figure 6, the center-pivot irrigation systems are shown by other LANDSAT photos now to straddle the border, which is correspondingly less clearly marked. It thus appears that where ground water is available in New Mexico, it may be applied to agriculture as it is in Texas and that this resource has been extensively

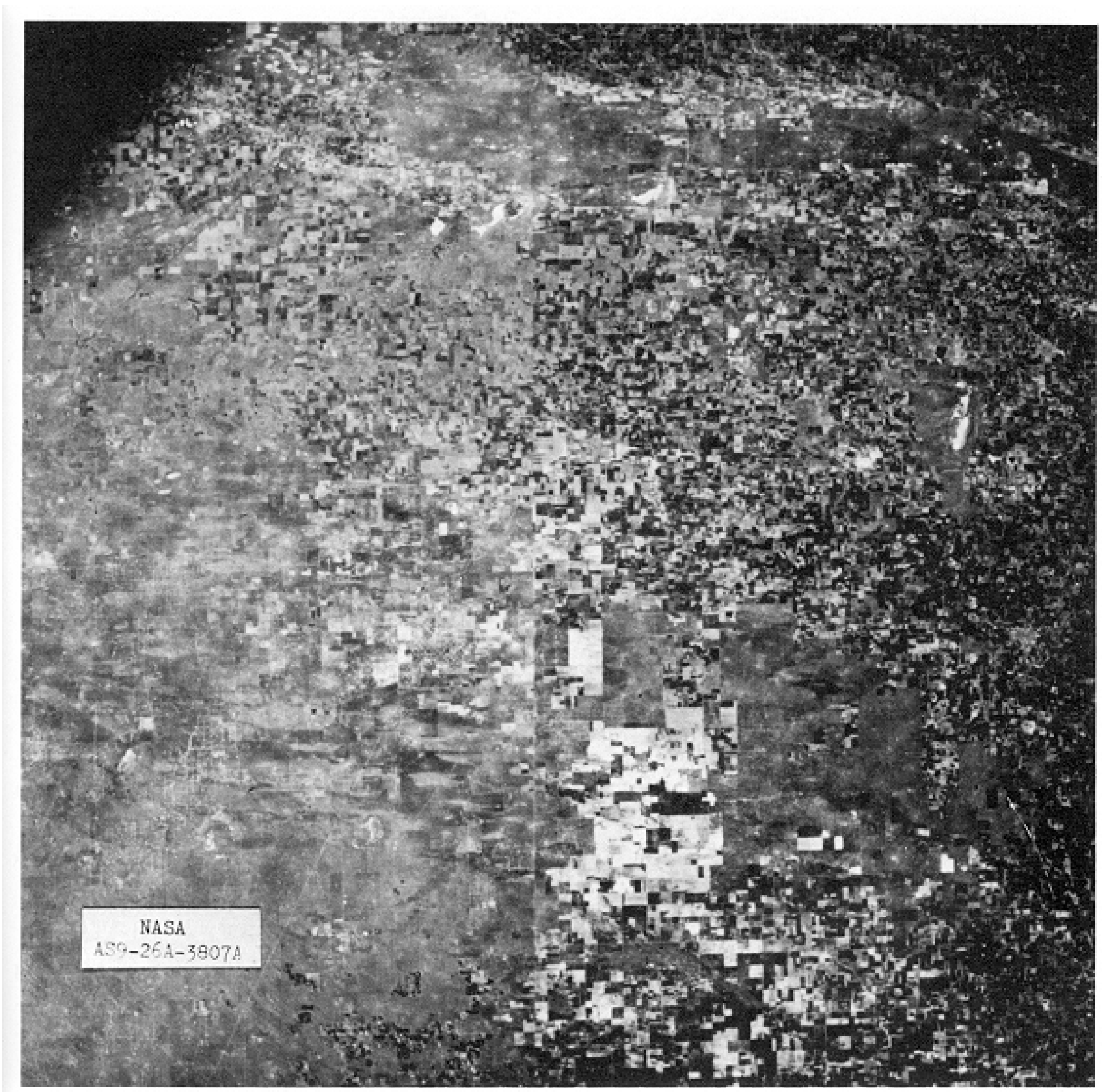

FIGURE 5. Photograph made with hand-held camera from Apollo 9, March 12, 1969. This shows approximately the northern half of the area marked in Figure 2 and shown in greater detail in Figure 6, and an additional area further north, including sand hills now extensively cultivated and irrigated in the Clovis-Portales area of New Mexico swath near the upper limit of the figure). The border delineation is accompanied by a distinct color change over much of its length.

developed in the Clovis area since Apollo. On the other hand, irrigation in Texas south of Bledsoe in Figure 6 stops sharply along the border, where the extreme lower left central portions of Reeves' aquifer map suggests that the water required for cropping is present.

Figure 7 is a section of Aandahl's soil map (6) which shows a basis in soil type for some of the delineation shown in Figure 6. In particular, type 156 has a boundary more or less contiguous with the Texas-New Mexico boundary and is shallower and more calcareous than either 160 or 167.

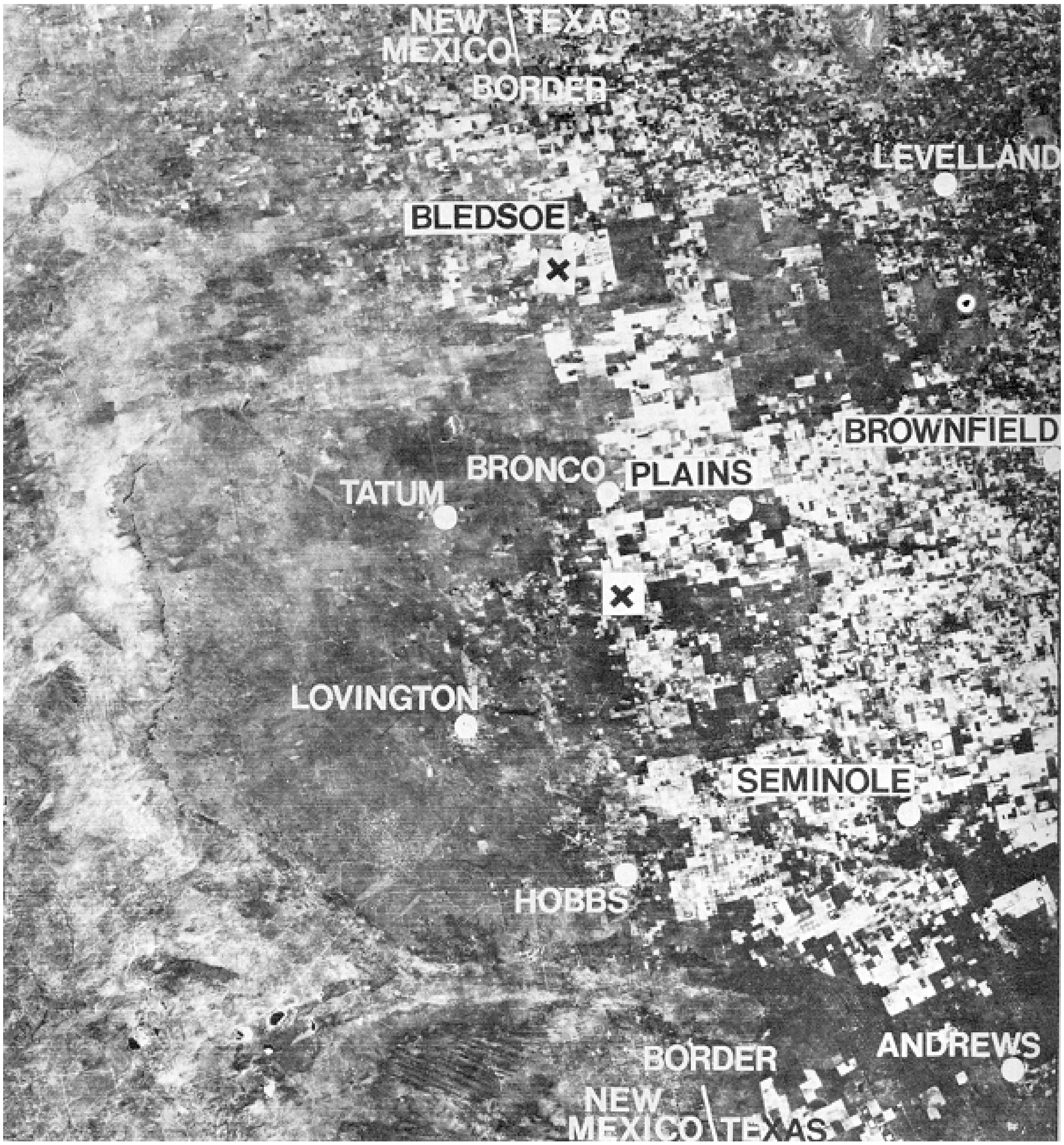

FIGURE 6. Photo constructed with data from the Earth Resources Technology Satellite, February 1, 1977, over a region whose extent south to north is indicated in Figure 2. Our ground survey was made in Texas and along the border between points marked X. Note rows of center-pivot irrigation system in Texas opposite Hobbs, N. M. and further north. Irrigation with water and nutrients greatly facilitates cropping in this semiarid region. Balance of cultivated land represents a mix of other irrigation systems and dry-land practices.

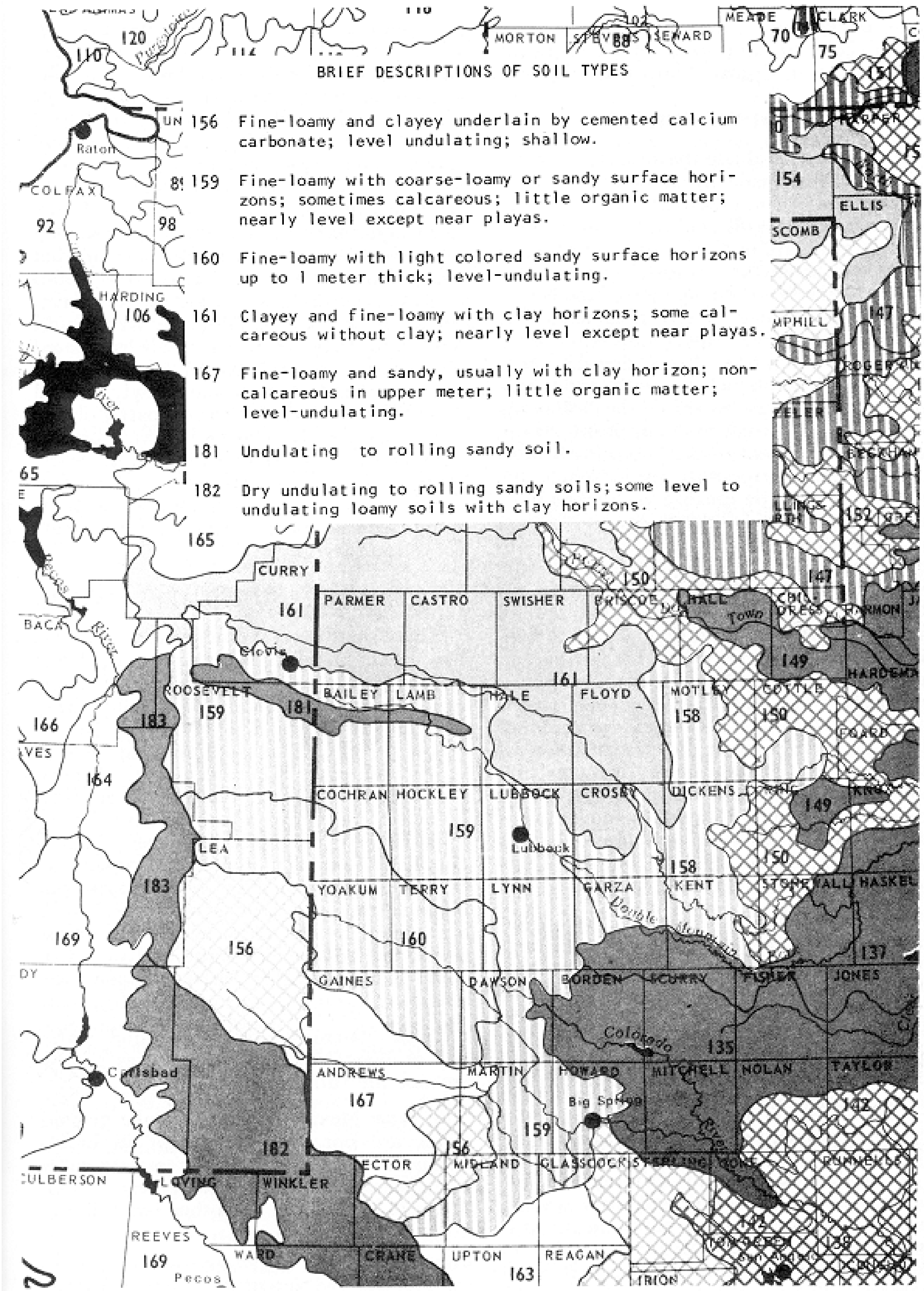

FIGURE 7. Portion of map prepared by A. R. Aandahl, showing soil types in the Texas-New Mexico boundary area.

The eastern boundary of type 156 extends from about 10 miles south of Hobbs northward to near Bronco, shown in Figure 6.

GROUND SURVEY

In order to evaluate the situation further, a survey was made by automobile on the border via Farm-to-Market Road 769, between Highways 82 and 125. The termini of this route are marked with X's in Figure 6. As seen from the highway on September 10, 1977, the New Mexico side of the border along this route is mostly rangeland with a cover of native vegetation, while most of the land on the Texas side has been cultivated. Conversations with local residents and others revealed the following factors as influential in determining abrupt change of land use at the Texas-New Mexico border: 1) opposing philosophies and traditions of cattle grazing vs "sodbusting", rooted in history of the States and culture of the people; 2) changes of soil composition and of ground water supply, usually with shallower soils and less water in the Ogallala formation on the New Mexico side; 3) different State regulations governing use of ground water for irrigation; ground water in New Mexico is public property while in Texas it belongs to the surface owner; 4) different patterns of land ownership, with the larger tracts of land in New Mexico more likely to provide an economic basis for cattle operations; some of the land is held by government entities and leased with various stipulations on its use; almost all land on the Texas side is privately held.

Since our study and survey is not comprehensive we do not venture even to rank our items in order of their importance; we believe, however, that the comprehensive study which should be made will show all of the mentioned factors to be significant, and probably others as well. In the following sections we elaborate slightly on traditions and water law.

TRADITIONS AND PHILOSOPHY

Attitudes are typically different on different sides of the border and there is some hostility between those adhering to different practices. New Mexicans tended to picture themselves as more concerned with conservation and in one interview even accused Texas farmers of deliberately letting the sandy surface of plowed land blow so that clays and finer materials beneath can be plowed. In the Bronco, Texas area, clay is said to lie beneath the sterile surface sands a variable depth often near 2 to 3 feet, barely reachable with heavy chisel plows. The clays contain some nutritive value for plants and their mixture with sand also provides a soil more tractable by farm equipment.* The ranching tradition seems stronger in New Mexico, so that even where soil and water conditions would probably permit cultivation of the land, for example near Hobbs, the fraction of land cultivated there is small compared with that across the border in Texas. On the other hand, there is some newly plowed New Mexico land, identified partly in relation to recently increased private ownership of land formerly held by the State. Plowing tends to be resented by those still ranching, but Texans plowing private lands supported the practice as necessary for their economic survival.

WATER LAW AND ITS APPLICATION

There has been a suggestion that the law concerning use of ground water has a role in producing duststorms which in origin respect state lines. Thus, it has been said that in Texas, the landowner has an absolute right to take unlimited quantities of ground water whereas in New Mexico one can take ground water for other than domestic uses only after the issuance of a permit by the State Engineer. Such a simplistic approach invites the conclusion that the top soil in New Mexico stays put on land that for reasons of water law is not turned by the plow, while just across the state line the Texas top soil on cultivated land leaves for Oklahoma and elsewhere.

These statements of the ground water law of New Mexico and of Texas simply are not the full truth.

In New Mexico, permits to take ground water are not required except in basins declared to have reasonably ascertainable boundaries by the State Engineer (N.M. Stats. 75-11-21). On the other hand, Texas

*We wonder about legal implications of damage to property and threats to health and safety downwind from dust sources, if traceable to knowing efforts at the sources.

statutes do provide for voluntary creation of underground water districts (Vern. Tex. Code Ann. Ch. 52, 1972). On the surface, these statements would seem to diminish the difference between Texas and New Mexico Law.

But these statements do not reflect the whole truth either. The area in New Mexico adjacent to our ground survey and shown in Figure 6 is the Lea County Underground Water Basin. The history of the establishment and administration of this basin by the New Mexico State Engineer is described in Mathers v. Texaco (77 N.M. 239, 421 P.2d 771, 1967).

In 1952, the State Engineer determined for each township the amount of water in its ground water basin, the amount that had been appropriated, and the amount which would be drawn from the stock or supply when the waters were fully appropriated. The Engineer used as "full appropriation" the amount of water that could be withdrawn from each township and still leave one-third in storage at the end of forty years.

In the cited case, prior appropriators in the basin were attacking a new permit issued to Texaco for a water flood secondary oil recovery program. It was admitted by the Engineer and Texaco that the permit in question, and every subsequent permit, would lower the water table in the wells of the prior appropriators, with an increase in pumping costs, and shortening of the time during which the prior appropriators could economically pump water from their wells.

It was the Engineer's thought that at the end of the forty-year period, the remaining one-third of the original supply could be economically withdrawn for domestic and perhaps other high-value uses, but not for irrigation.

The plan of administration was admittedly a controlled plan of mining. The Court approved it as a reasonable approach to the use of a nonreplenishing resource. Under the circumstances that the natural drainage of the basin about equalled the natural recharge, the only alternatives were mining or no use of the resource at all. It was at least implicit in the case that when the combined rate of withdrawals permitted by the Engineer equalled the rate that would exhaust two-thirds of the supply in the forty-year period, there would be no further permits issued.

This then is the plan under which the ground water underlying the area in New Mexico involved in this study is being administered.

How is the use of ground water being administered across the border from the Lea County Basin? First, there is no active underground water conservation district on the Texas side of the border in the area under examination. A publication of the High Plains Underground Water Conservation District No. 1 (7) indicates that occupying part of the Texas area in question is the inactive South Plains Underground Water Conservation District No. 4. No active district in the rest of the area is shown.

There is reason, however, to wonder about the efficacy of the water districts which may be created under the Texas statutes cited above. A study of water laws of each of the states published by the National Water Commission (8) makes absolutely no mention of the statutes permitting the creating of the districts.

Section 52.002 of the Texas Enabling Law confirms the ownership of the landowner in his underlying ground water. Section 52.052 authorizes the district to make and enforce rules to provide for conserving, preserving, protecting, recharging, and preventing waste. Section 52.114 authorizes the district to require permits for the drilling of wells. But Section 52.116 exempts wells producing 100,000 gallons of water (about 0.3 acre-foot) or less per day. The Rayner study, *supra*, indicates that under the spacing regulations of the High Plains District No. 1, four-inch wells (capacity to about an acre-foot per day) may be spaced every 200 yards (about one well per eight acres), and that eight inch wells pumping up to a 4 acre-feet per day (1000 gpm) may be located every 400 yards (about one well for each 33 acres). From its origination in 1951, through 1974, the district issued nearly 43,000 well permits, and received over 33,000 well completion reports.

It would seem that economic factors and water availability are the main real limitations on well drilling at present in the Texas Underground District No. 1, and that the real worth of the District is in the area of preventing waste. Beyond this, as the Rayner study concludes,

> "...the District has relied heavily upon the principle of its creed. *Dedicated to the principle that water conservation is best accomplished through Public Education."*

But again, note, the spread of intensive cultivation has been unhindered by the limited powers of a ground water district in our survey area in Texas which contributed substantially to the major 1977 duststorms.

While the cause and effect relationship suggested falls within the classic fallacy of "post hoc propter ergo hoc", the coincidence does suggest the propriety of further study.

CONCLUDING REMARKS

Satellite-eye views supported by a ground survey reconfirm the well-known connec-

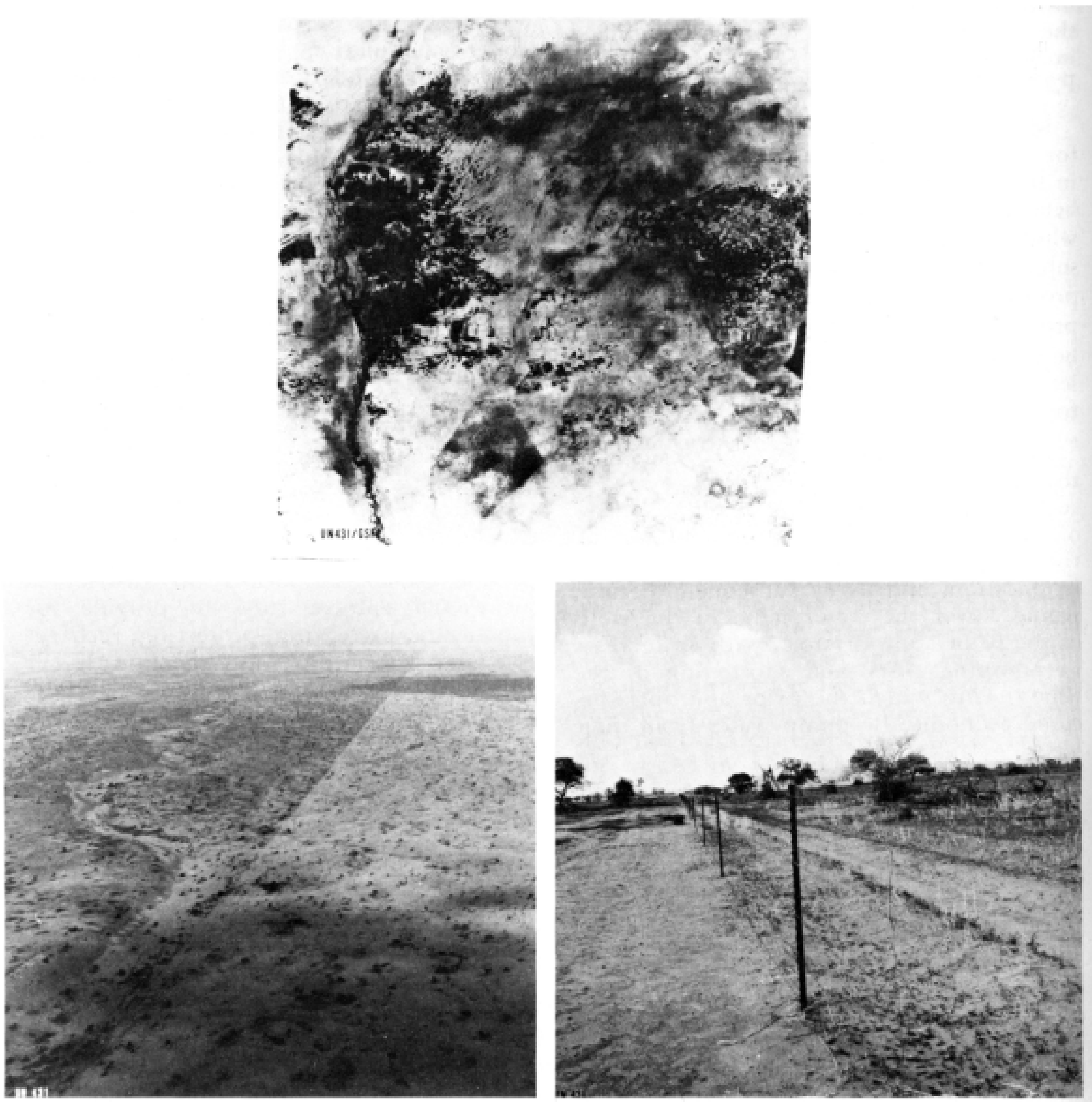

FIGURE 8. Top: Satellite view of partially cloud-covered African Sahel, showing a dark area with rectilinear boundaries in lower left. Lower left: An area that includes a section of the border of the dark region shown at left, as seen from an aircraft. The boundary between light and dark zones is a sturdy wire fence. Lower right: A portion of the fenceline as seen from the ground. The fence protects private land (Ekrafane Ranch) from overgrazing by cattle roaming the surrounding communal lands. (Lower photos by N. H. Macleod).

tion between dust storms and intensive cultivation of certain arid and semi-arid lands. Not so clear in our case is the role of irrigation, for there is insufficient detail in the data available to us to permit identification of the specific fields where dust originated. But we tentatively identify the dust sources with both irrigated and nonirrigated areas, some of the former contributing dust in the absence of actual application of water before the crop season starts.

In the geographical area discussed here, we are not surprised to identify multiple intertwined and interacting factors evidently influential in shaping agricultural practices. Elements already cited include features of soil type and the amount of accessible and suitable underground water, patterns of land ownership and use rooted in history and tradition, water law and agricultural technology. The list is incomplete even if we add federal policies and regulations dealing with price and availability of the energy required to apply irrigation water and to drive farm equipment, price supports for certain crops, and general conditions and regulations affecting cost and availability of transportation and farm labor. Although only a few of our elements are obviously discontinuous at the border, the impact of these few for discontinuous agricultural practice remains great in the presence of other interactive factors.

Thus, one aspect of our conclusions lies between those of Rayners and Reeves. Water law helps determine agricultural practice, is an important element in the Texas-New Mexico border delineation, and is a substantial factor in the raising of dust at certain seasons. But water laws also reflect geological and historical forces unique to the different States, forces which retain independent significance today. We are hard pressed to say what is primary and what is secondary, or what is cause and what is effect.

The spread of intensive agricultural practices, aided by technology under pressures of population, exploitative psychology, and economic desire and necessity, have degraded land in many parts of the world, often with enormous consequences (9). Extreme losses have occurred under a wide range of cultures and political regimes; a recent example from Africa, contrasting with the case discussed here, is illustrated by Figure 8. In the African Sahel, private ownership of a large tract has been identified with preservation of values in surroundings where the recent rule has been highly destructive competitive exploitation of communal lands (10). On the other hand, in the Texas-New Mexico situation, intensive machine-aided agriculture has involved a maximization of (short term) profits from privately held lands. The primary issue is thus not how the land is held, but how the land is used.

Our Texas-New Mexico evidence is at once discomfiting and encouraging — the former because it shows abuse in an area of some affluence, the latter because it shows that practices can be influenced by political and social conditions and should be responsive therefore to thoughtful efforts at adjustment.

The condition discussed here should be viewed as just one element in an immensely varied agricultural landscape. Closely related problems have been discussed recently by Pimentel, *et al*. (11) and Carter (12), among many others. The High Plains area has a special importance because of the imminent depletion of much of the ground water now available for irrigation. If irrigation is to be maintained or extended, massive energy-intensive water transfer projects will be required; the alternative is return to dry farming or ranching over much of the High Plains area.

A much larger study effort, including careful site-specific investigations, should be undertaken better to establish facts and to help plan, develop, and apply policies that are fair, effective, and wholesome in agriculture, public works, economics, and law.

ACKNOWLEDGMENTS

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REFERENCES

1. J. GALLION, J. Okla. State Med. Assoc. 70 (5): 194 (May 1977).
2. J. H. STIEGLER, correspondence from Oklahoma State University, Stillwater, Oklahoma, 1977.

3. TEXAS WATER DEVELOPMENT BOARD, *Index of Drought Severity 1931-1976,* High Plains, prepared by Weather Modification and Technology Division, Austin, Texas (bar graphs and map), 1977.
4. F. A. RAYNER, The Cross Section Newsletter, High Plains Underground Water Conservation District No. 1, 16 (10): 1 and 3 (1970).
5. C. C. REEVES, Photogram. Eng. 15: 461-465 (1974).
6. A. R. AANDAHL, *Soils of the Great Plains,* (Map), P.O. Box 81242, Lincoln, Nebraska, 1972.
7. F. A. RAYNER, *Report*, High Plains Underground Water Conservation District No. 1, 18 pp. plus Appendix, 1975.
8. NATIONAL WATER COMMISSION, Report to the President and Congress, p. 826, 1973.
9. V. G. CARTER and T. DALE, *Topsoil and Civilization*, University of Oklahoma Press, Norman, Oklahoma, 1955, p. 292.
10. M. GLANTZ, J. Intern. Law Policy 6: 527-540 (1976).
11. D. PIMENTEL, E. C. TERHUNE, R. DYSON-HUDSON, S. ROCHEREAU, R. SAMIS, E. A. SMITH, D. DENMAN, D. REIFSCHNEIDER, and M. SHEPARD, Science 194: 149-155 (1976).
12. L. CARTER, Science 196: 409-411 (1977).