Paper A 16

REMOTE SENSING EXPERIMENT IN WEST AFRICA

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There are substantial needs of the Sahelien Zone to detail the state of regional agricultural resources in the face of a sixth year of serious drought conditions. While most of our work has been done in the Republic of Niger, the principles which have emerged from our analysis seem to be applicable to much of the Sahel. The discussion relates to quite specific rehabilitation and development initiations under consideration in Niger which are based in part upon direct analysis of ERTS imagery of the country, in part on field surveys and on discussions with Nigerian officials and technicians. Again, because the entire Sahelien Zone (including Niger) has large zones of similiar ecologic characteristics, modifications of the approaches suggested for Niger are applicable to the solution of rehabilitation of the desert, the savannah and the woodlands of West Africa in general.

Figure 1 defines the zonation of aridity in Africa under normal conditions, that is, those conditions found during the past fifty years or so. The three desertic regions are subcontinental in size and would normally be considered as classic cases of meteorologically defined deserts — that is, deserts formed as a result of the descent of cold dry air from the upper atmosphere, a part of the phenomena of global atmospheric circulation (Fig. 2). We have some reason to doubt that the Sahara is formed in such a manner, our doubts being based on archeological and ecological considerations. This is not just a passing comment. If the Sahara and the Sahel are so dry entirely because of meteorological phenomena, then the rehabilitation of the Sahel will be very difficult indeed.

On the other hand if there are cultural factors which have changed many microclimates through such means as the destruction of vegetation and if those cultural factors continue to play their role in climatic modification, then there is hope that these factors may be identified and changed to reverse the process of desert formation. The analysis of ERTS imagery of the Sahel and especially of Niger gives considerable hope that the process of desert formation can be reversed (Fig. 3). To reverse desert formation and to rehabilitate the desert and the Sahel, we are using the indications from satellite imagery to derive a set of operating principles upon which we are basing our recommendations to the Niger Government and our discussions of national development programs.

In field surveys in the Republic of Niger, we were able to substantiate the observations made in the Laboratory in Washington, D. C. In addition we had the opportunity to discuss the country's development goals with government officials and to develop a better understanding of social and economic impediments to presently envisioned development initiatives.

By February of this year there had developed a realization that short-falls in grain production in West Africa, the basic source of food for most West Africans, was due to a persistant drought. The accumulated effects of the drought since 1969 had evolved into an emergency situation. In March, six Sahelien countries declared themselves a disaster area and appealed to the United Nations for assistance in meeting the food requirements of their peoples. As part of the response to that appeal NASA began to acquire as much ERTS imagery as possible over the Sahel. To process and deliver useful information to the afflicted area, a Drought Analysis Laboratory was established at Goddard Space Flight Center, a cooperative effort of Goddard, The American University and Catholic University. It is from analysis of this imagery in conjunction with field studies and literature surveys that we have derived a concept of the regional dynamics of the Sahel.

In the 12-frame ERTS mosaic, including Niger, Upper Volta, and Mali, several of the major surface features of the Sahelien Zone are quite visible. Not only the Niger River itself, but the remnants of major Saharan drainage systems of Tertiary or Quaternary age are prominent features throughout the Central Sahel area (Fig. 4). From the large size of these ancient channels one can surmise that the intensity of rainfall during the earlier pluvial periods of formation was formidable, even in the Central Sahara. Since that early time the desert has formed; the Sahara and the Sahel both retain the marks of more humid times. The transition process to the present aridity is called desertification, a process which is going on today at an apparently faster and faster pace.

Our view is that the desertification process is linear, largely culturally induced and reversable. To a great extent the viewpoint is derived from analysis of ERTS imagery (Fig. 5). The banding of sand encroachment, and amount of vegetative cover are progressive north and south, as seen in this (Fig. 6) and other ERTS mosaics of the Sahel. A cyclic climatic variation should leave outliers or more mesic plant communities in favorably situated sites. Such outliers are not found in the Sahel. However, culturally induced equivalents are found, wherever cultural pressures on ecological systems are reduced or controlled in the Sahel. A rapid and positive change in plant cover is observed. A particularly interesting example is the Ekrafane Ranch, seen in the North-east corner of Figure 3 and in Figure 7.

The ranch is visible because of vegetative and soil changes occurring in the past five years, or the period since 1968 when this 110,000 hectare ranch was fenced and controlled access and grazing were introduced (Fig. 8). Aerial photography taken previous to 1968 shows no difference in general appearance between the present inside and outside of the ranch area. The ranch has five powered wells to supply man and cattle with water — but not for irrigation.

Outside the ranch in the Azouauk Valley, there are three powered wells installed at about the same time, with no control of access. Figure 9 shows the result of uncontrolled access to wells — hundreds of square kilometers of barren ground. This is in strong contrast to the effects of managed range in Ekrafane Ranch in an adjacent, actually less favored ecosystem. Figure 10 shows the border of the Ranch from the Air, and Figure 11 at the ground near the border fence.

The fencing and controlled grazing have resulted in greater seeding, seedling survival, and plant vigor and also in reduction of sand movement. These changes add up to a favorable change in both microclimate and carrying capacity. Indeed the changes represent a reversal of desert enchroachment, a demonstration of the feasibility of rehabilitation of the Sahel. The Ekrafane Ranch is not unique: it is large, only five years in production; the five years being the worst years of drought in this century. The ranch is productive, not simply reserved land taken out of production and there are other such areas — in Niger, in Upper Volta, in Mali and Senegal. These areas are also visible in the ERTS MSS images because of the rehabilitative effect of reducing or removing unmanaged cultural pressures on quite fragile ecosystems.

In this ERTS scene we see not only the Ekrafane Ranch, but also that there is opportunity for more ranching establishments in the same region — regions identified by seasonal assessment of the ERTS sequential images as more heavily vegetated grassland, and more favorably watered. On mosaicing of most of the interior zone of the Sahel west of Lake Chad, we find that similar opportunities are located across the Sahel. Ground observations in a significant portion of the Nigerien Sahel have substantiated the space observations (Fig. 12). These observations have been brought to the attention of the Niger government and are currently being formed into a set of recommendations for that government. Similar observations have been discussed with planners in the governments of Upper Volta and Mali as well.

In addition to the ranch observations just discussed, one can also see in Figure 7 the remnant drainage channels mentioned earlier. Particularly striking are the meanders in these channels, formed during the last stages of stream channel sedimentation. The soils in these meanders are heavy — mostly clays and silts — and unvegetated. The lack of vegetation may be due to the low rainfall in this particular area — less than 300 mm — and the higher water holding capacity of the soil. It is likely that these soils do not receive enough precipitation to hold water in excess of the wilting point. Where these soils are irrigated they are quite productive, with excellent crops of grains, produce and forage.

It was our impression, developed during image analysis, field survey and discussion with technical specialists, that the channels themselves are phreatic aquifers — that is, annually recharged near-surface water bearing systems (Fig. 13). In other papers we have discussed this pehnomenon and proposed that the conditions exist for rainfall to penetrate the sand cover of the watersheds, and then to run-off underlying impermeable laterites into the old stream channels. We have started mapping these heavy soils, using the ERTS Analysis System developed by J. S. Schubert at the Goddard Space Flight Center for computer MSS analysis with maximum geographic resolution. We are doing so to prepare ourselves and others for the possibility of recommending seriously that these soil and water resources be used for irrigated crop production to be conducted on a year-round basis. Because of a serious short-fall in grain production the Sahel this year, a short-fall greater by a factor of three than last year in Niger alone, these soil and water resources may have to be brought into production on an emergency basis. As they do not appear on conventional soil maps in general, the identification and location of these resources is being done as expeditiously as possible.

The ERTS mosaic is again of use in understanding the process of desertification as it occurs in zones of traditional sedentary cultivators where grains and other crops are grown (Fig. 14). The recognition of the problem comes through examination of the portion of the arable land that is acutally in cultivation, that which is in fallow, and that which is covered by perennial vegetation. In areas which can be used for cultivation — are free of disease, and have sufficient average rainfall to support rainfed agriculture — the proportion of land in cultivation is alarmingly high. In previous decades, the normal rotation was twenty or more years, providing sufficient time for some recovery of soil fertility. We have observed in the ERTS images and on the ground that two ominous trends have developed. One is the reduction of the rotational periods to three years or less — sometimes to zero; the other is the expansion of rainfed grain production into regions where rainfall is normally insufficient to make a crop. The expansion is accompanied by destruction of vegetative cover prior to cropping — a prime cause of ecological instability in the Sahel. In addition some of the areas of traditional cropping are now given over to cash cropping — cotton and peanut production on a commerical basis. While the decision to carry on cash cropping is an economic one, and probably necessary to obtain scarce foreign exchange funds, the decision nonetheless effectively reduces the land area available for stable production of basic food stuffs necessary to the support of the growing populations.

This particularly difficult problem of over-use of soil resources has led to the establishment of a vicious circle, i.e., over-use leads to losses in soil fertility and yield, which in turn requires less productive soils to be used to obtain an adequate harvest. How to break the cycle?

Among suggestions are the following:

1. creating multicrop rotation to replace the present monoculture

2. bringing livestock production into sedentary agriculture

3. to irrigate those alluvial soils located through ERTS image analysis (Fig. 15).

All these suggestions involve social changes which are largely unexamined. Such social changes can impose serious obstacles to development programs.

In closing, a few comments about the relationship of development in the Sahel to resource management in the United States. The Sahelien countries and the United States are in ecological and economic trouble. The Sahel, with its fewer people, less urbanization and technological infrastructure, is comprehensible. One can study the whole system. In the United States, however, we are confronted with segments of natural systems and an incomprehensible matrix of overlapping interests of land-use authorities, including private property, city planning, federal reserves, and commercial vs. environmental groups. As we begin to comprehend the Sahel through analysis of remote sensing imagery, we also learn to comprehend our problems here at home.

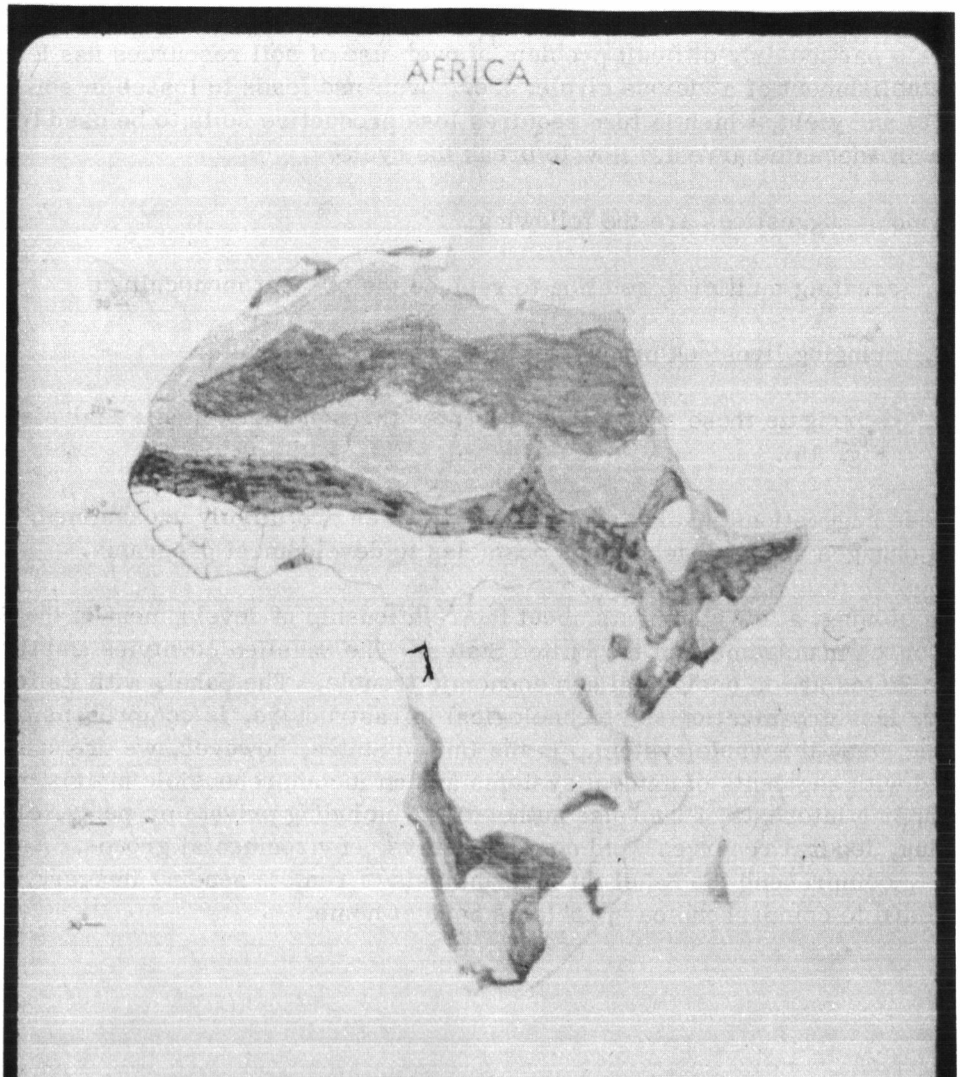

Figure 1.

Figure 2.

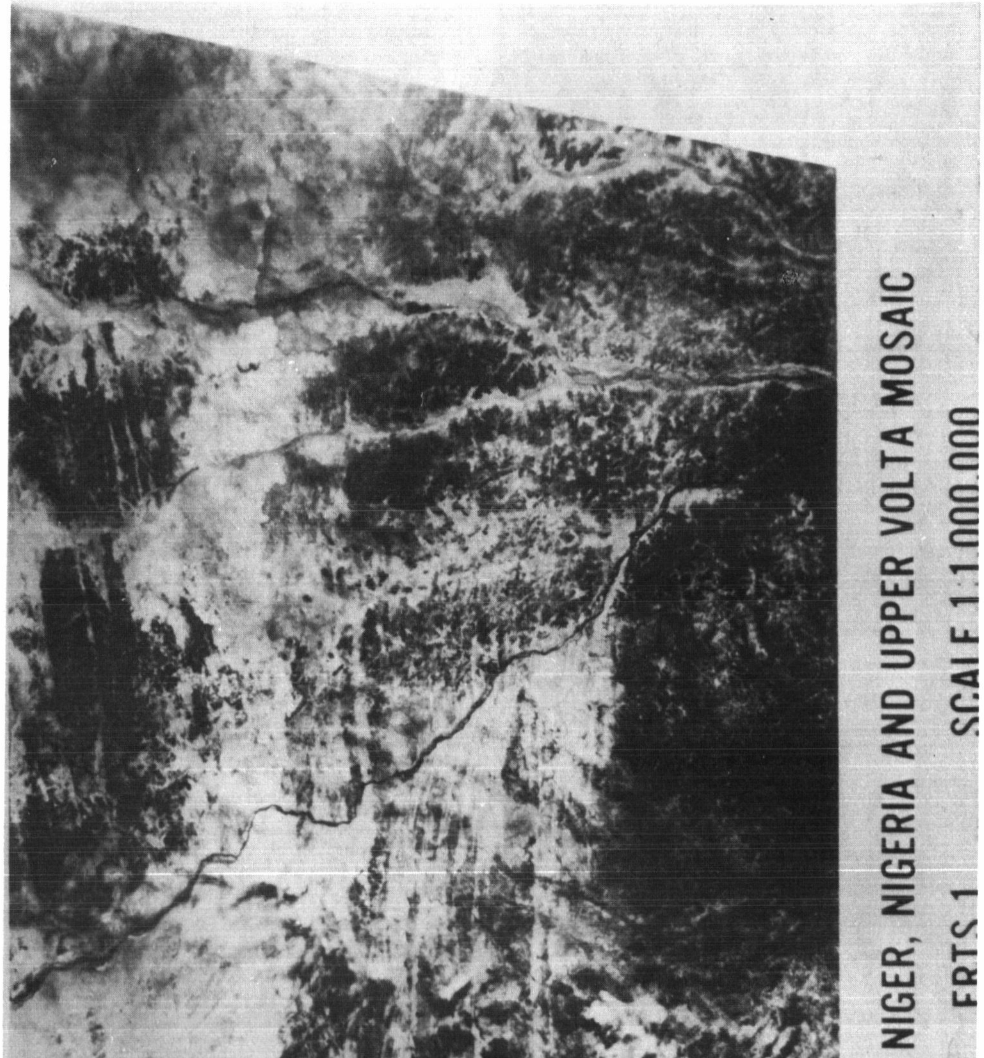
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Figure 3.


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Figure 4.


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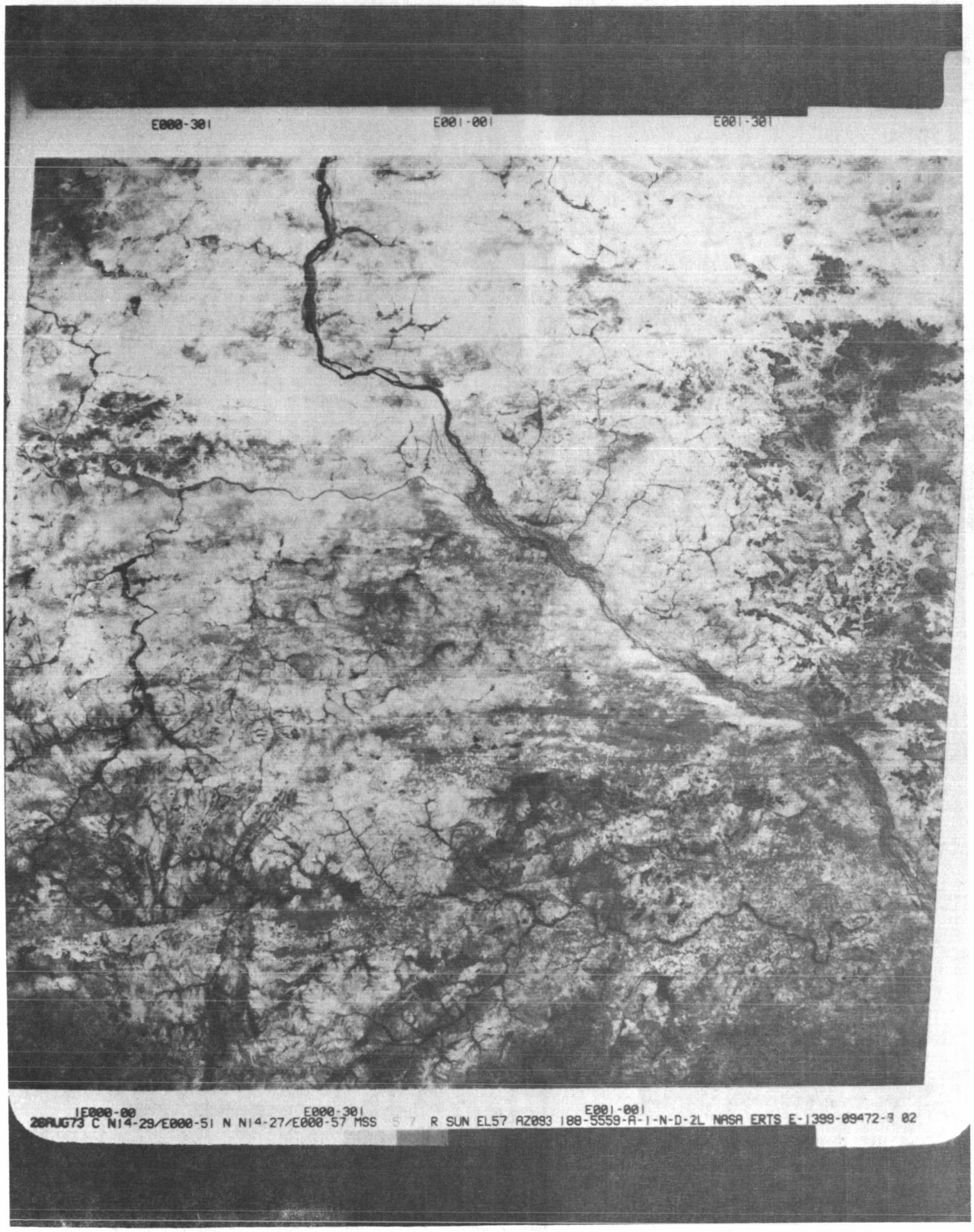
Figure 5.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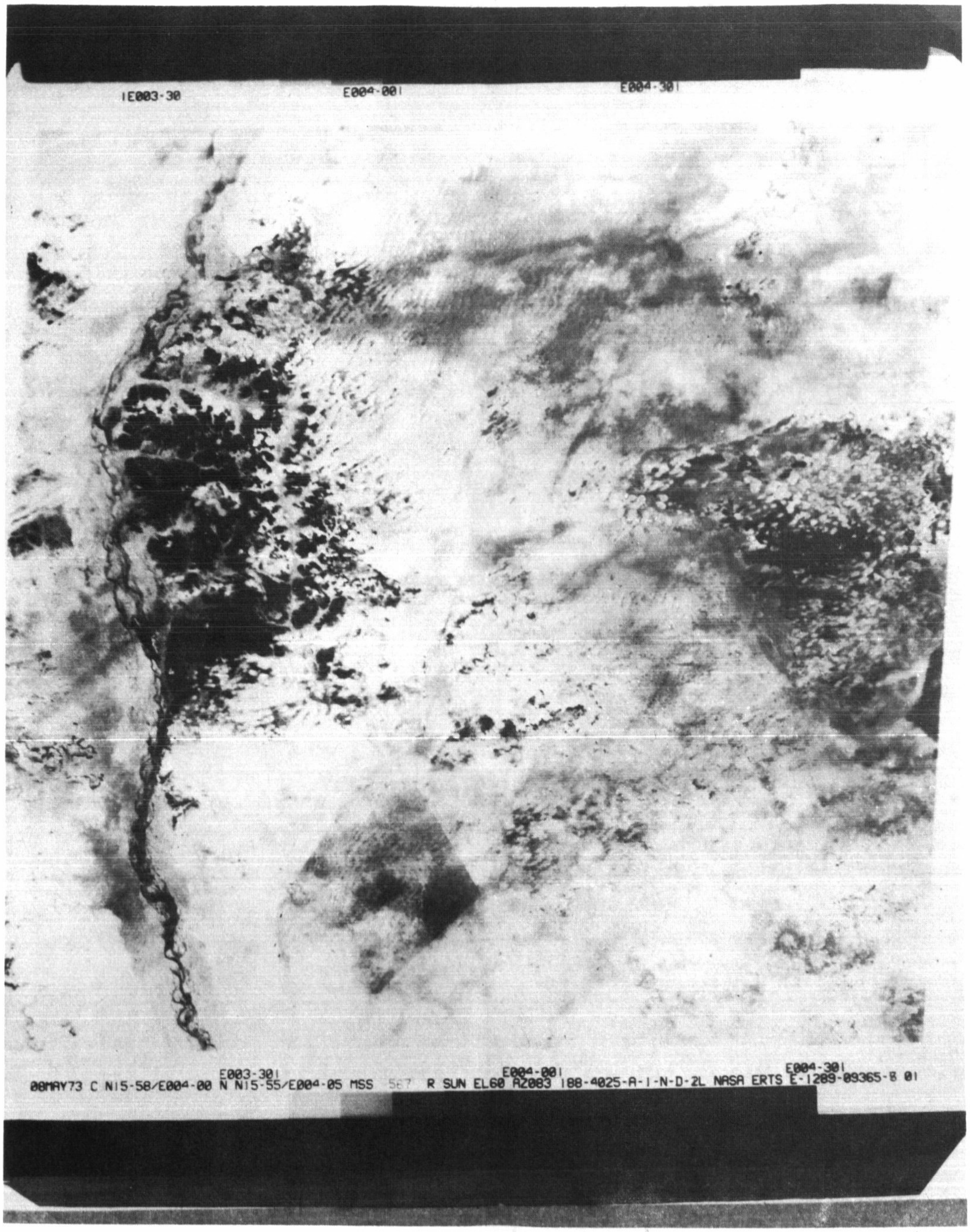
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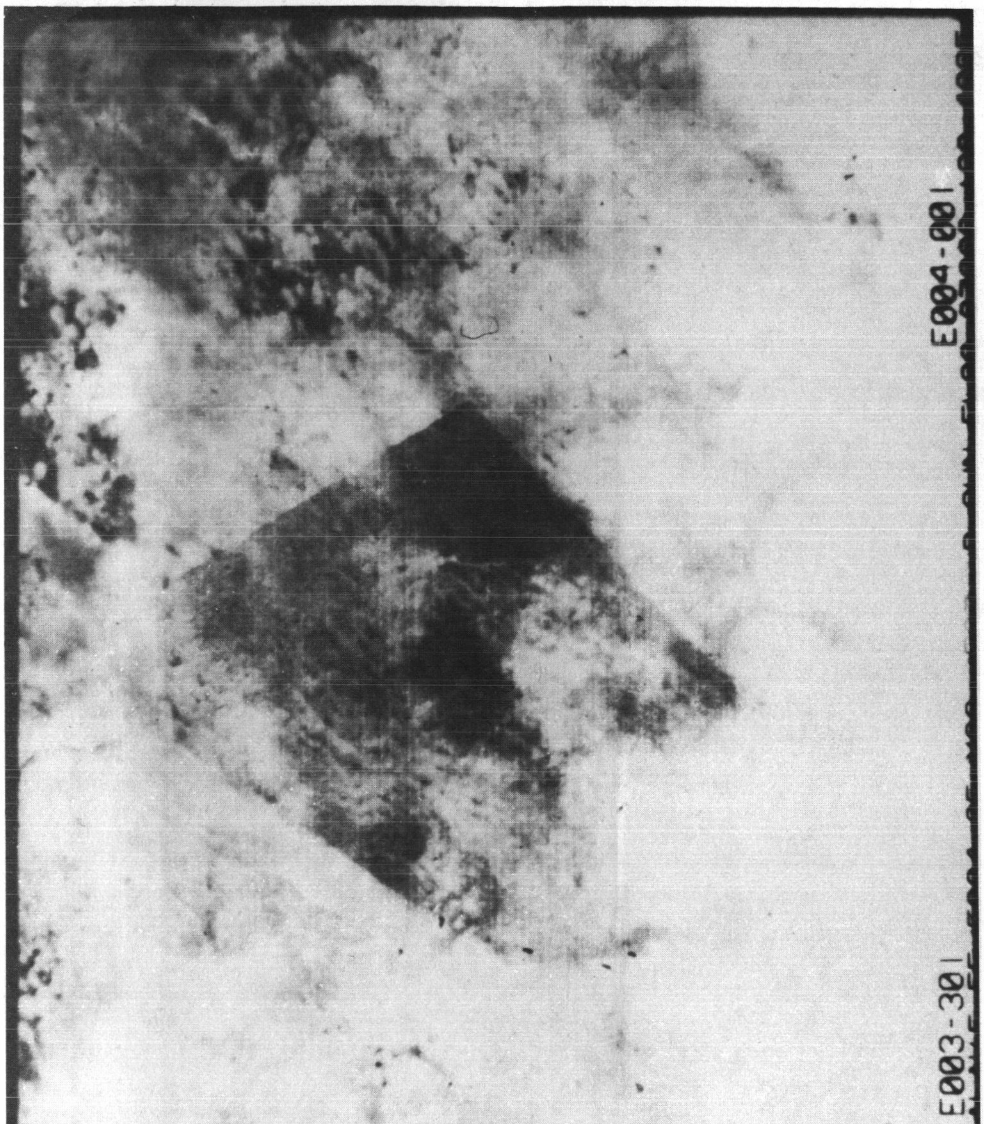
Figure 7.



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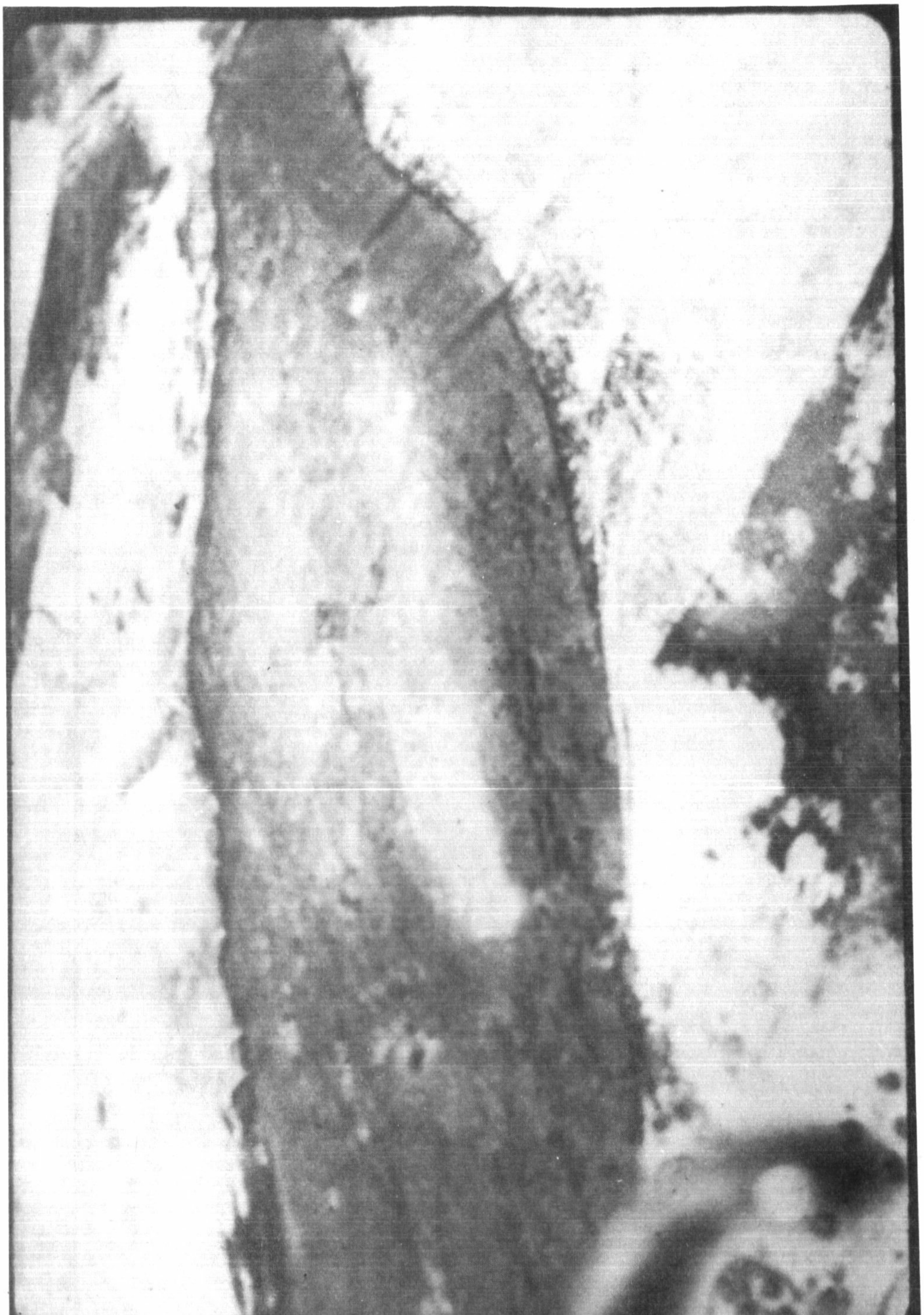
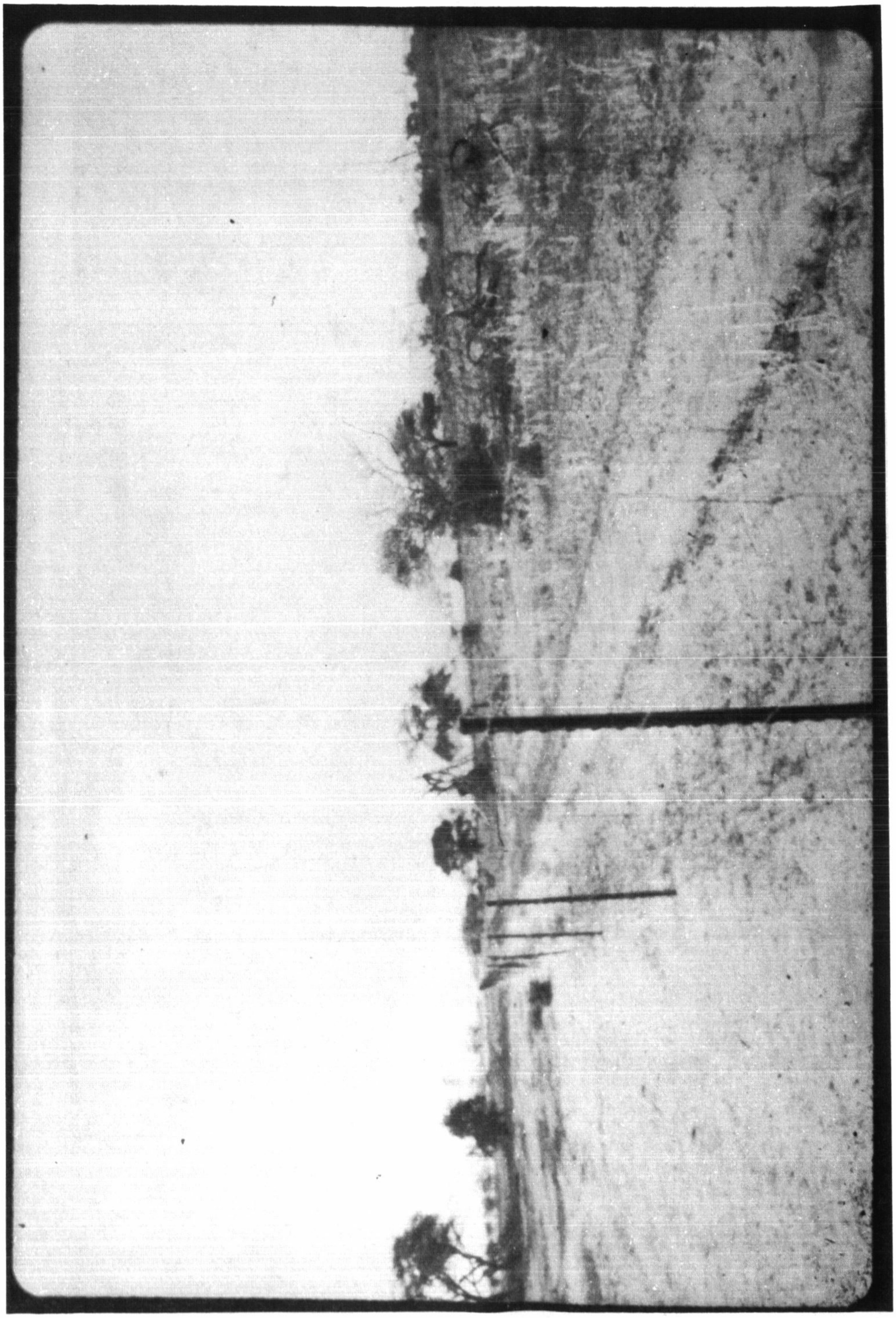


Figure 9.

Figure 10.



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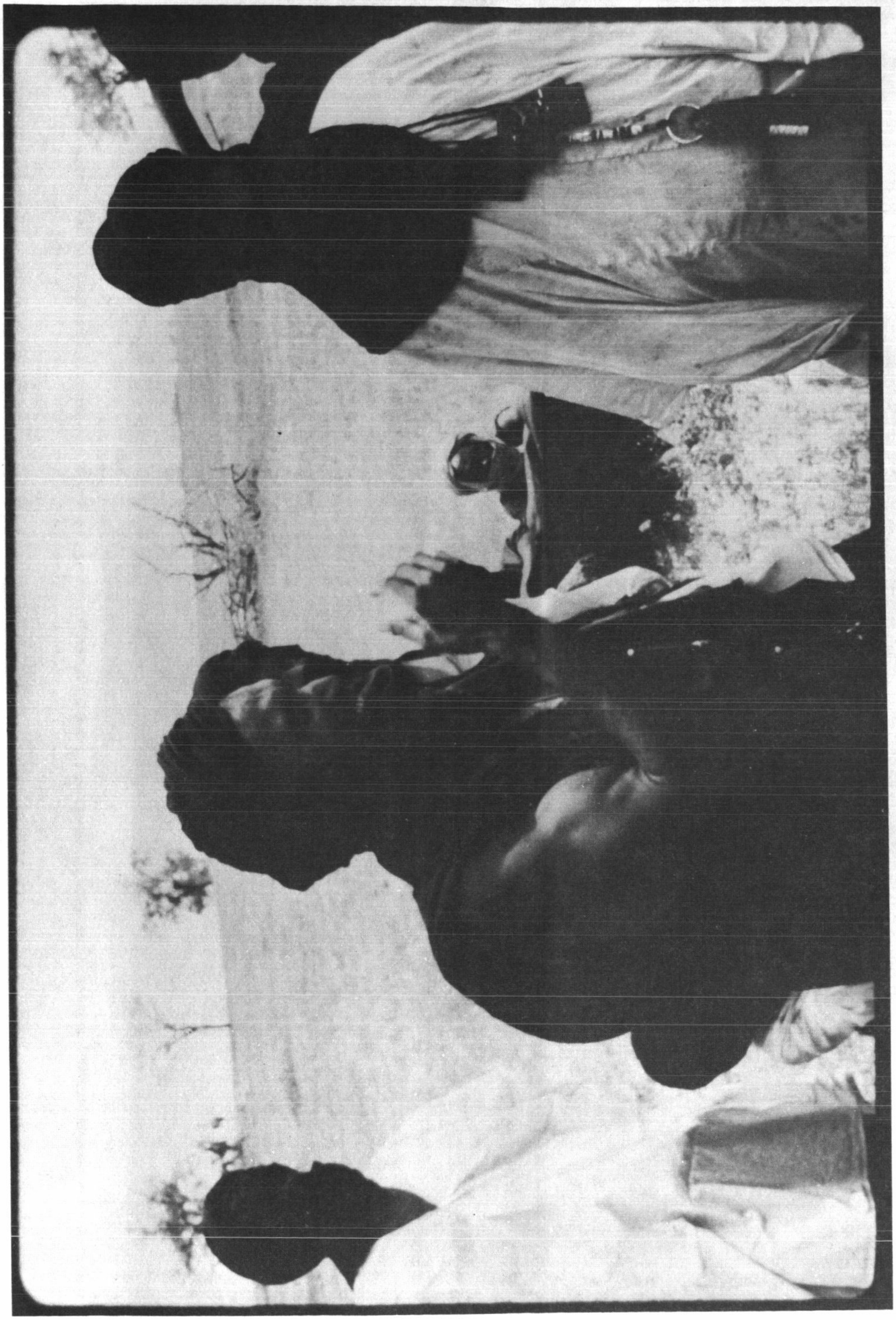

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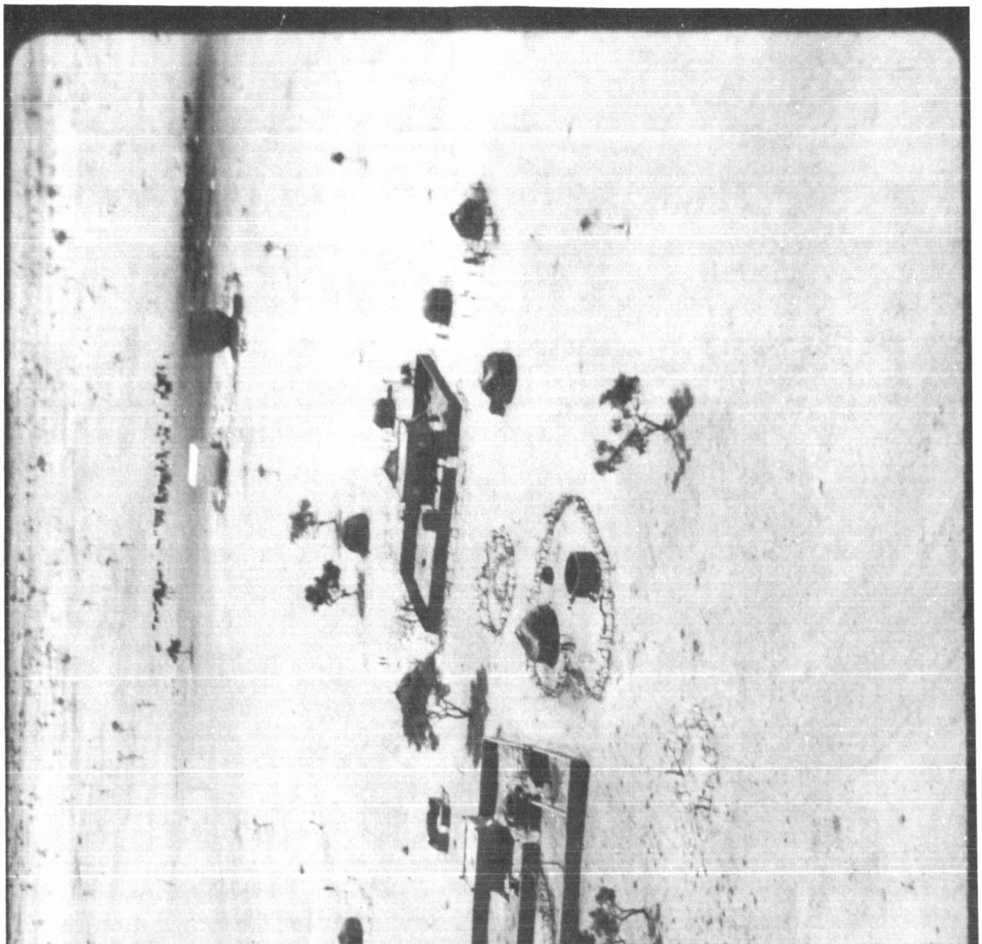

Figure 13.


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Figure 14.

OFFICE OF APPLICATIONS
ERTS ROLE FOR THE DROUGHT IN THE
SAHEL REGION OF AFRICA

CONCLUSIONS:

1. The Ekrafane Ranch demonstates the feasibility and usefulness of controlled grazing management in the Sahelian Zone. Benefits from improved practices are far more profound in terms of reversal of desertification than simply rationalized livestock production in the Zone. Improvement of water, soil and vegetation resources is quite apparent even after only five years of enclosure (cloture).

2. Large reserves of near-surface water, annually replenished, exist within the channels of the extensive ancient drainage systems identified in the ERTS-1 imagery. A very small part of this water is being used, by pumpage, for livestock and human water supplies-none for irrigation.

3. There are large areas of excellent soils in the channels, whose location is easily found through analysis of space imagery. The soils are useful for irrigated crop production with water supplied by pumpage.

4. Soil now used in traditional agriculture is badly eroded (sheet erosion), in many cases to the point of being uneconomic for further production. Most of the areas used in uncontrolled grazing are similarly afflicted by erosion — wind erosion in this case. While traditional agriculture has enabled Niger to export agricultural commodities in the past, its unmodified continuation in the region we examined can only lead to further deterioration of productivity and also to the deterioration of the agricultural resource base.

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