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UTILIZATION OF LANDSAT MULTISPECTRAL DATA IN GEOBOTANICAL INVESTIGATIONS: THE LOCATION OF IRONSTONE GRAVEL IN THE SAM HOUSTON NATIONAL FOREST

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NATIONAL SPACE TECHNOLOGY LABORATORIES

UTILIZATION OF LANDSAT MULTISPECTRAL DATA IN GEOBOTANICAL INVESTIGATIONS: THE LOCATION OF IRONSTONE GRAVEL IN THE SAM HOUSTON NATIONAL FOREST

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by

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This study was a cooperative effort between NASA and the U.S. Forest Service. The concept of using remote sensing for location of gravel was suggested to the author by Dr. William Lucas who was then with the Forest Service at their Jackson, MS office. As a result of our initial discussions, the Sam Houston National Forest was chosen as a pilot study area for our first efforts during FY81 in remote sensing of non-renewable resources. During the course of this program, Dr. Lucas has offered many useful suggestions and has participated with the author in some of the field work. Mr. Joe Clayton, USFS, of the Jackson, MS office, has been most helpful and has offered constructive suggestions to this program. Additionally, Mr. Gerald Key, District Ranger, Sam Houston National Forest, Cleveland, TX and Mr. Schweitzer, USFS, Lufkin, TX supplied valuable data on recent gravel pits and areas which are to be mined in the near future.

Personnel from Lockheed Corporation worked with the author in data processing and final product preparation. Data processing was accomplished primarily with the participation of Mr. Frank Ransom and photo products were produced through the photo lab headed by Mr. Moon Mullins.

The help of all who participated in this project is greatly appreciated.

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UTILIZATION OF LANDSAT MULTISPECTRAL DATA IN GEOBOTANICAL INVESTIGATIONS: THE LOCATION OF IRONSTONE GRAVEL IN THE SAM HOUSTON NATIONAL FOREST

I. INTRODUCTION

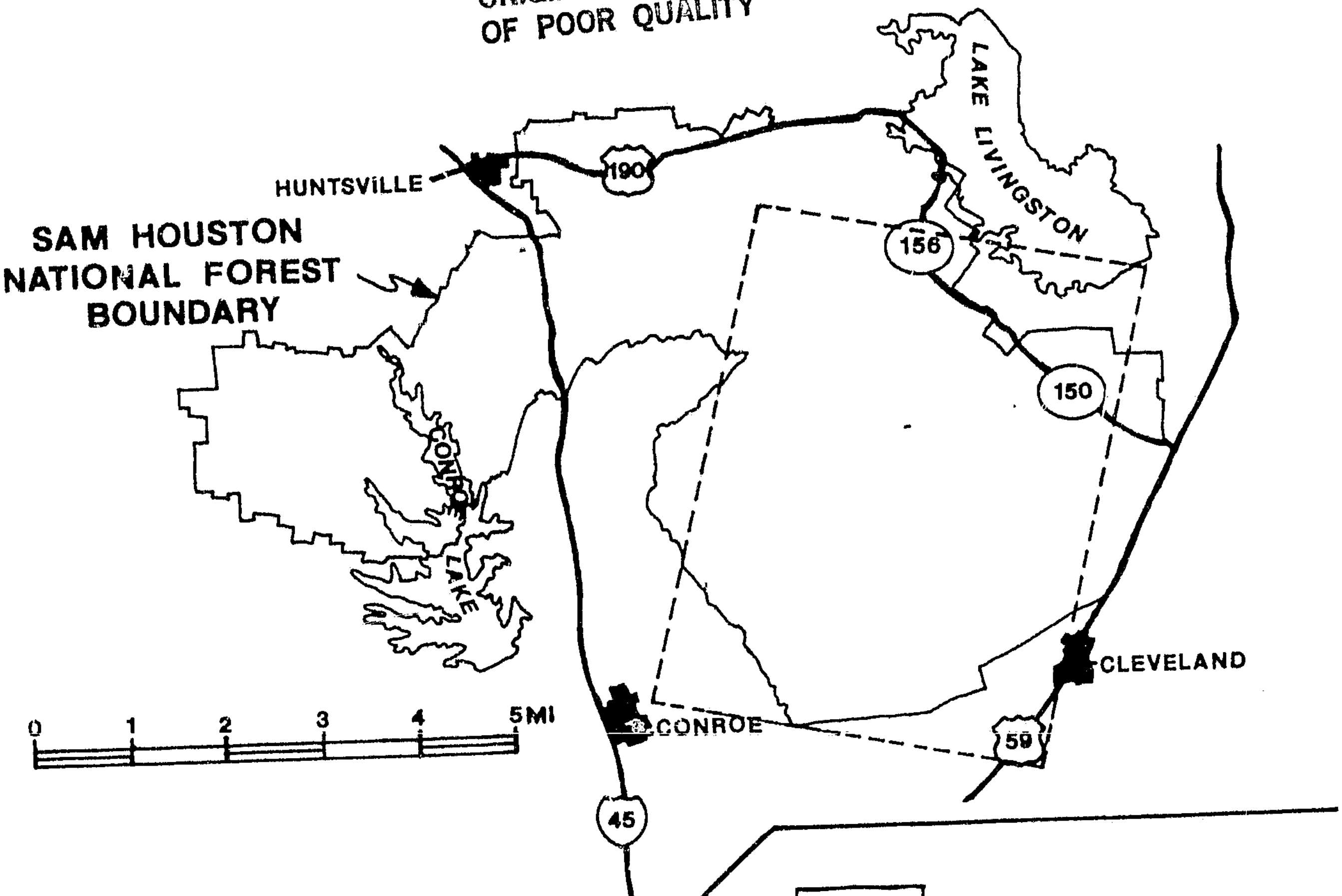
A. Objective

The overall objective of the geobotanical research program is to develop and evaluate practical techniques for deriving geobotanical information from remotely sensed data acquired by air and space borne systems. This report details the results using Landsat MSS data acquired for a test site in the Sam Houston National Forest near Cleveland, Texas where gravel deposits exist in sufficient quantity that economical extraction would be feasible. The research was conducted cooperatively with the U.S. Forest Service from the Jackson, MS office.

B. Description of the Study Area

The Sam Houston National Forest is located in east Texas, at the western most extension of the pine belt of the forested Gulf coastal plain, and is almost directly north of Houston. The portion of the Sam Houston National Forest used in this study is bounded by the cities of Huntsville, Livingston, Cleveland, and Conroe, Texas (Figure 1). This area is within the rolling hills and prairie of the Gulf Coastal Plain physiographic province. The Gulf Coastal Plain is a wide mildly undulating plain bordering the Gulf of Mexico. It owes its gentle features to the presence of relatively soft, non-resistant rocks alternating with more resistant strata, a gulfward dip of beds, low elevation above sea level, a luxuriant diversified vegetation and mild climatic conditions.

The Sam Houston National Forest is composed of geological formations that are young in age as measured by geological time. Its surface formations were deposited in the Pleistocene and Holocene epochs of the past few



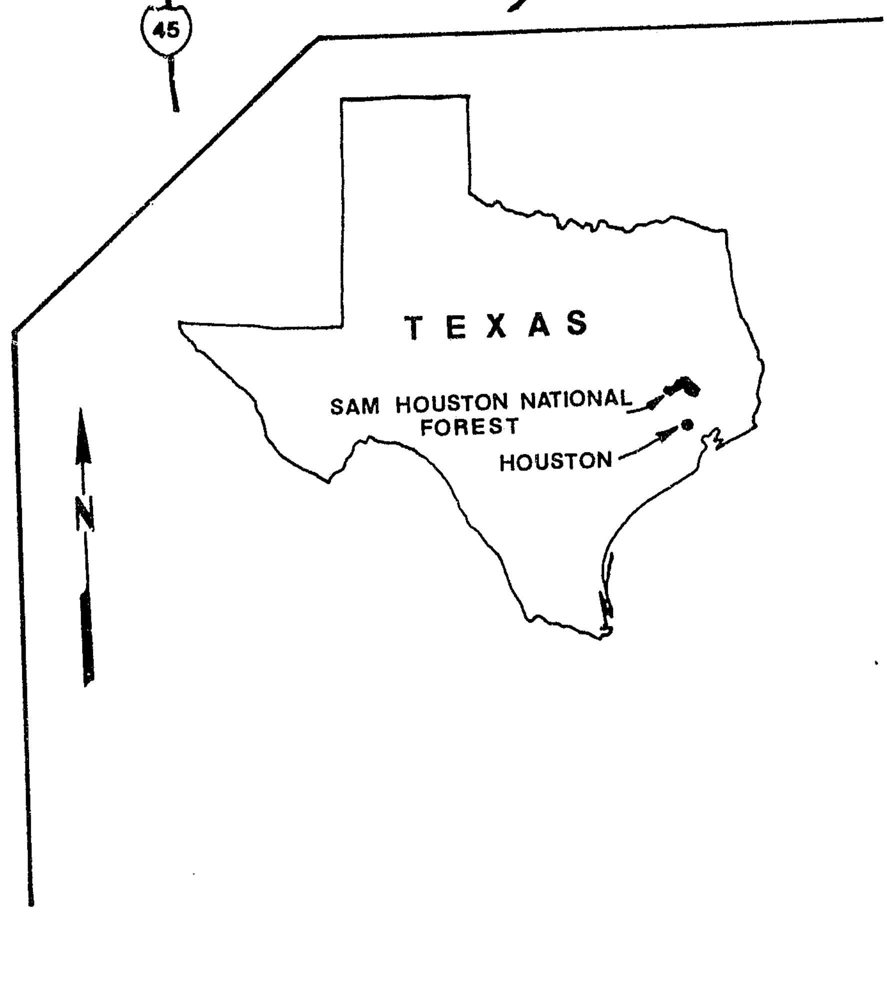


Figure 1. STUDY SITE
LOCATION

million years. During the Pleistocene epoch there were four major glaciated stages. These glaciers did not reach the southern United States, but their influence on sea level and climate were responsible for the land forms of Southeast Texas. As these ice masses grew or melted with changes of climate, sea level fell or rose accordingly.

The geological formations of the Sam Houston National Forest were deposited by streams as alluvial plains and deltas in the high seas of the warm interglacial periods. Each warmer period was followed by lowered sea level (glacial build-up on land to the north) and erosion of these previously deposited plains. The northern ends of these layers of deposition are exposed as narrow, irregular bands paralleling the Gulf of Mexico. These formations from north and south (oldest to youngest) are: Fleming, Willis, Bentley, Montgomery and Beaumont. The Fleming formation is Miocene in age. Some geologists believe that Pliocene deposits were completely eroded away before the Pleistocene period of deposition began while others include the Willis Formation in the Pliocene epoch.

Increasing weight of sediments, occurring during the deposition of these deltas, caused gradual subsidence of the entire Gulf of Mexico, slanting the layers gulfward and causing the northern ends of the Willis formation to rise, tilt and wrinkle, producing the somewhat hilly topography of the study area. The geology of this area is similar to that in the Big Thicket area and has been described in some detail by Watson (1979).

These strata which underlie the Gulf Coastal Plain and dip seaward at angles slightly steeper than the preserved land surface cause the more resistant strata to break the gentle slope of the land with low landward-facing escarpments or cuestas.

The study area is located just south of the Kisatchie escarpment. This escarpment is supported mostly by indurated quartzitic rocks of the Jackson Group and the Catahoula formation.

Thin deposits of ironstone gravel are widespread in the southeastern portion of the Sam Houston National Forest. These residual ironstone pebbles have been widely used as a source of roadbase and aggregate material. The current demand is high with the value of the gravel in place being approximately \$1.75 per cubic yard (\$2.29 per cubic meter). The value at some locations may be greater than \$3000.00 per acre (\$7,410.00 per hectare).

The Willis Formation is the source of the ironstone gravels in the study area. The formation consists mostly of clay, silt, sand and some petrified wood. Over much of the area the sediments are deeply weathered and lateric.

Most of the uplands are covered with pine while the riverbottoms are primarily forested with hardwood. The major plant communities encountered are nearly identical to those of the Big Thicket National Preserve, about fifty miles distant to the east. These communities have been described in detail by Watson (1979), Harcombe and Marx (1981) and Cibula and Nyquist (1981). The major difference encountered is that on the more xeric upland sites, longleaf pine, as found in the Thicket, is replaced by shortleaf.

II. METHODOLOGY

A. Data Acquisition

1. Landsat frames chosen for study:

Landsat satellites have been collecting data over the earth's surface since 1972. The satellites are in near polar, circular, sun-synchronous orbits with an altitude above the earth's surface of approximately 920 km (570 miles), and have a nominal 9:30 am crossing of the equator during the descending mode. They circle the earth every 103 minutes (14 times a day) with each successive pass displaced to the west approximately 26° of longitude due to the earth's rotation. The multispectral scanner (MSS), the primary sensor aboard Landsat, provides a continuous image of a strip of the earth's surface 185 km (115 statute miles) wide. On the fifteenth pass, occurring 24 hours after the first pass, the coverage is shifted to the west an amount that provides a sidelap with the previous day coverage of 14% at the equator to 100% at the poles. After 18 days, orbit 252 (on the 19th day) retraces that of the first orbit providing repetitive coverage (NASA, 1976).

Data analyzed in this study were obtained from the MSS. The MSS measures radiance in the following wave length bands: 0.5-6μm, 0.6-0.7μm, 0.7-0.8μm, and 0.8-1.1μm. Values obtained in each of these bands for each ground resolution element (pixel) form a multispectral data set which was the basis for analysis. The four radiance values for each pixel form a "data vector" which is associated with that element. Use of a digital computer permits each data vector to be assigned to a class which contains vectors of similar character, hence a classification.

The analog signals produced by each of the four MSS detectors are digitized and formatted into a 15 megabit data stream for transmission to an Earth receiving station. After being received by the NASA Image Processing Facility (IPF), the MSS data are transformed into segmented imagery with an overlap between "frames" (frame size 185 km x 185 km). The framed data are also produced onto 9 track 800 or 1600-bpi computer compatible tapes (CCT's). These are the tapes which are available from the USGS EROS Data Center, Sioux Falls, South Dakota and which were used in this study.

Four Landsat frames were ultimately chosen. The summer frame, 26 June 1974, was chosen after analysis of weather records for Coldsprings, TX indicated that a drought was in effect at the time of this Landsat pass. It was desirable to have one frame of data to possibly represent a water stress condition. This concept was based on the premise that the presence of gravel close to the surface of the soil would have a marked effect on the availability of water for the vegetation which was present on these sites. The frames used in this study were:

26 June 1974, Frame 1703-16173 - Representative of early summer data just after leaf maturation. In addition, this frame was acquired after there had been an extended period of drought, so some vegetation might have been under water stress.

13 Feb. 1977, Frame 20753-15585 - Representative of winter data without snow. This data permitted evergreen understory vegetation to be sensed, as all deciduous overstory was leafless at that time.

8 April 1977, Frame 20807-15562 - Chosen to give a mid spring set of data at a time when nearly all vegetation had leafed out.

25 Sept. 1979, Frame 21707-16084 - This data was useful for identifying all new gravel pits which originated between 1974 and 1979.

2. Field Studies

After the Landsat frames described above were spectrally classified (discussed in RESULTS section), selected areas representing those spectral classes which were thought to have a relationship to gravel deposits were chosen from the Landsat data and transferred to USGS 1:24,000 topographic maps for field use.

In gathering and recording the field data relating to vegetation cover, a modified Braun-Blanquet (1944) technique was employed. This technique is discussed in more detail by Cibula and Nyquist (1981). In addition, core samples were taken at some sites to determine the presence and extent of gravel. For this sampling, a bucket sand sampler was used.

These sites were visited by ground field teams. The canopy analysis employed permitted the stratification of forest sites, usually into four distinct canopy levels. This is shown schematically in Figure 2. An example of a completed ground truth form also with soil profile is shown in Figure 3.

After completion of this form, a photograph was taken of most sites using Kodacolor film. Later, after processing, the print(s) which corresponded to each site were mounted with the respective ground data sheet. The original data sheets are archived with the U.S. Forest Service.

This ground truth, along with other data on recent borings and mines supplied by the Forest Service formed the basis for naming the spectral classes.

B. Data Processing

Final processing and manipulation was accomplished with the Earth Resources Laboratory Applications Software (ELAS).

ELAS is divided into two major components, (a) the operating subsystem and (b) the application modules. The operating subsystem is written in FORTRAN as are the application modules; application modules rely on the operating subsystem for machine-dependent functions. The ELAS subsystem requires an interactive display system. In use with this project, ELAS operated on an Interdata (Perkin-Elmer) 8/32 computer with a Comtal series 8000 image display system. The various overlays used in this project are described elsewhere (Cibula 1981).

Each frame was spectrally classified by SRCH which is an automated procedure for acquiring spectrally homogenous training fields from multivariate data by passing a 3 x 3 window through the data. There are several variables incorporated into this overlay. These variables statistically define the homogeneity of the selected training fields. In practice, small portions of each Landsat frame representative of data acquired over the

Figure 2. Illustrates the division of canopy layers as encountered in a typical forested site in the Sam Houston National Forest. The upper canopy is represented as being the first layer. The second layer includes those trees which represent either less tall representatives of the upper canopy or successional elements which are not fully mature. The third canopy most often represents the shrub layer where their height does not exceed 20' but may include saplings of the first two layers. The fourth layer represents usually, any grass or forbs, bare soil, rocks and leaf debris. This layer may also include very small saplings of the higher canopy layers.

Sample I. D. 100 On Map: ____________

Location, N ____________ E. ____________

Taken By: W. Cibula Date: 28 July, 1981

Ground Truth Photo: Roll # C Exposure # 21 & 22

Species	Layer 1	Layer 2	Layer 3	Layer 4
PITA	80			
QUFA	5-10			
ILOV			70	
grasses				5
mixed needles/leaves				95

Species	Layer 1	Layer 2	Layer 3	Layer 4

Estimated average height of upper story ______ If plantation, spacing __X__, dir. ______

Comments:
(If necessary, continue on reverse side)

Soil profile:

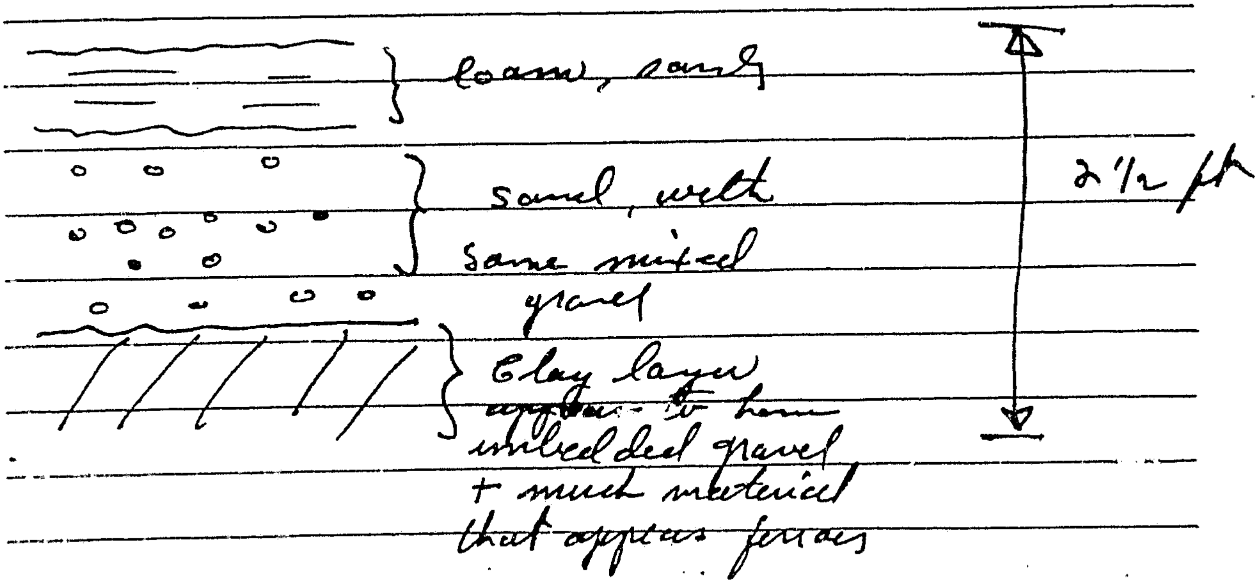


FIGURE 3

Sam Houston National Forest, were processed and then examined. The final settings used were those which raised the SRCH classes just above the noise threshold inherent in Landsat data, e.g., the sixth line banding aspect. Ground truth data as well as other modules of ELAS were used to develop the final surface feature classifications.

Once a satisfactory classification had been achieved for each frame, each was designated to a single channel in a georeferenced data base. Construction of such a data base permits efficient comparison of each classification within the limits imposed by the registration accuracy.

III. RESULTS

A. Discussion of Classifications and Rationale for Final Choice

All data after surface feature classification were screened by both Forest Service and NASA personnel. The spring data set (Frame 20807-15562) appears to have yielded an excellent separation of the major plant ecosystems of this area. The efficacy of spring vegetation has been noted earlier. The winter data set (Frame 20753-15585) appears to give a good separation of the major lithology of this area (personal communication, Dr. William Lucas) because the leafless overstory permits a more direct observation of the geology in deciduous areas. The data set separates out some elements of evergreen understory which was not detected in the other three data sets.

The fall data set (Frame 21707-16084) did not appear to contain as much useful data as the other sets. This is consistent with earlier studies near this area. However, since this is the most recent Landsat pass, this frame was very useful as recent gravel pits were classified. These pits did not exist at the time of the earlier Landsat passes.

Of all the frames classified, the June 1974 data was the most intriguing. Prior to the acquisition of this Landsat frame, there had been a prolonged drought. In the final classification, one spectral class, depicted as deep magenta (see Figures 4 and 5), appeared to correlate with existing gravel pits also classified in this data set.

Field studies demonstrated that there were three classes relating to upland pine, but only the magenta class shown in figures 4 and 5 correlated with the existing mines.

Analysis of weather records for Coldsprings, TX, 10 miles distance from our test area, indicated that there was a drought which preceded and persisted through the acquisition of this Landsat frame. It was for this reason that the initial decision was made to acquire this data. On this basis, we postulated that the upland pine class, depicted as magenta, represents pine which was under severe water stress at this time. The correlation between the stress and presence of near surface gravel is not difficult to rationalize. The sand/gravel soils present where known deposits exist have much less field capacity for water than would the more clay/loam soils that can also be found in the study area.

Field observations made using a bucket soil sampler demonstrated the presence of gravel in all cases where the sampling was accomplished in sites chosen within the magenta class whereas other classes sampled for soil profile did not have any gravel. There were variations in depth of deposit of the ironstone gravel and some sites probably did not contain sufficient gravel for economical mining.

When classified using SRCH, the most obvious feature of the 1979 Landsat classification was the existence of new gravel pits in areas which were vegetated in the 1974 classification.

FIGURE 4

ORIGINAL PAGE
COLOR PHOTOGRAPH

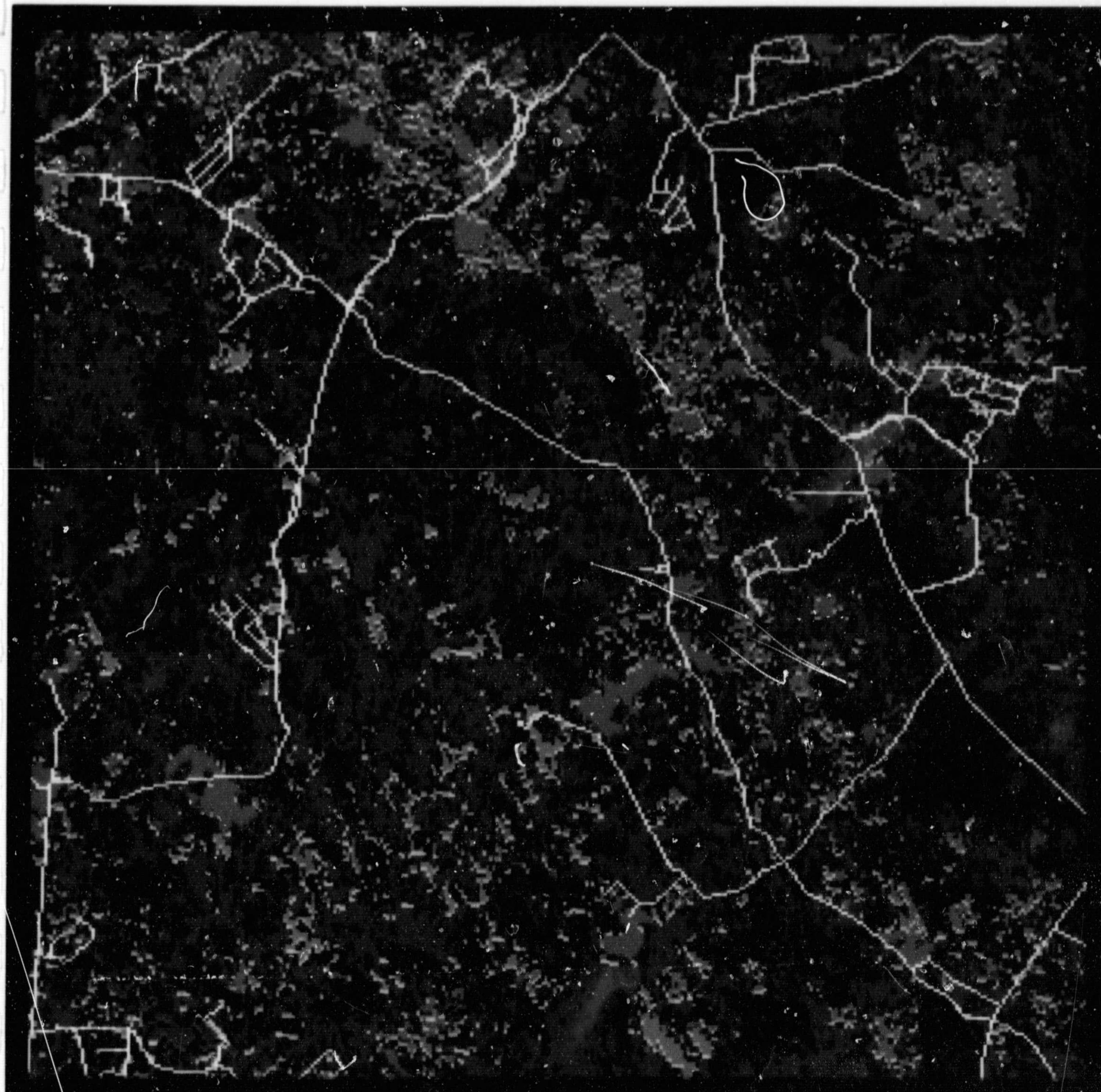


FIGURE 5

When this data was placed in a data base and compared with the 1974 classification, the new gravel pits delineated in the 1979 data show a 1:1 correlation with the areas that had been classified as stressed upland pine in the 1974 data. This is shown in Figures 5 and 6. Figure 5 is an expanded portion of Figure 4 of an area near Maynard, TX, where the stressed upland pine is shown as magenta. Compare this figure with Figure 6 which represents the 1979 data. In this classification, all weather roads are represented by white, water by dark blue, gravel pits, which existed at the time the 1974 data was acquired, are shown as yellow, while gravel pits which came into existence between 1974 and 1979 are shown as red. Cleared areas which are not gravel pits are depicted in green while all other classes are shown as cyan.

Comparison of these two classifications show that all new gravel pits occur within the stressed pine class from the 1974 data. Furthermore, data supplied to us by the Forest Service which map several projected gravel pit sites show these to be also in the stressed pine class of the 1974 data. It is worthwhile to note that these areas are near the eastern side of the study area, about 10 miles from the area depicted in Figure 5 and 6.

Those results strongly suggest that the areas of stressed pine separated in the 1974 data depict the areas where more detailed analysis for gravel should be accomplished.

All the analysis of this data occurred in the coastal portion of the Willis formation (QWC) as it has been within this portion of this formation that the Forest Service has concentrated its mining efforts. This classification shows stressed pine to the north in this formation in the landward portion (QWL) but there is no information available on the presence of ironstone gravel here.

ORIGINAL PAGE
COLOR PHOTOGRAPH

FIGURE 6

B. Products

Color coded classifications have been developed and placed in a data base. Examples of the classification from the 1974 data are shown in Figures 4, 5, and 7. These products represent color prints on Kodak RC 74 color print paper. The color negatives used to prepare these prints were exposed in the Optronix Colorwrite 4300 using Kodak 8x10 Kodacolor negative film as the exposing material. During processing, these negatives were given extended development to yield negatives of proper density.

Similar color negatives representing an area of one 7-1/2 minute (1:24,000) Quad sheet were prepared and enlarged to scale on 20" x 30" color print paper. One set was retained at ERL, while another set was delivered to the Forest Service. An example of the Bear Creek quad sheet is shown in Figure 7 (not to scale). The tic marks in the corners represent the corners of this particular quad sheet.

C. Conclusions and Recommendations

A correlation has been shown between a single spectral class and the presence of ironstone gravel. Field data indicates that this class relates to upland pine which was probably under water stress as the result of a prolonged drought which was in progress at the time of data acquisition. It is suggested that the subsurface gravel produces a soil which has less field capacity for water retention, causing, as a result, early appearance of water stress in the surface vegetation over these soils.

In all areas within the QWC formation where this class has occurred, gravel has been located where borings were made. To the north, within the QWL formation, this class also occurs, but there is little knowledge of whether or not these soils contain gravel.

ORIGINAL PAGE
COLOR PHOTOGRAPH

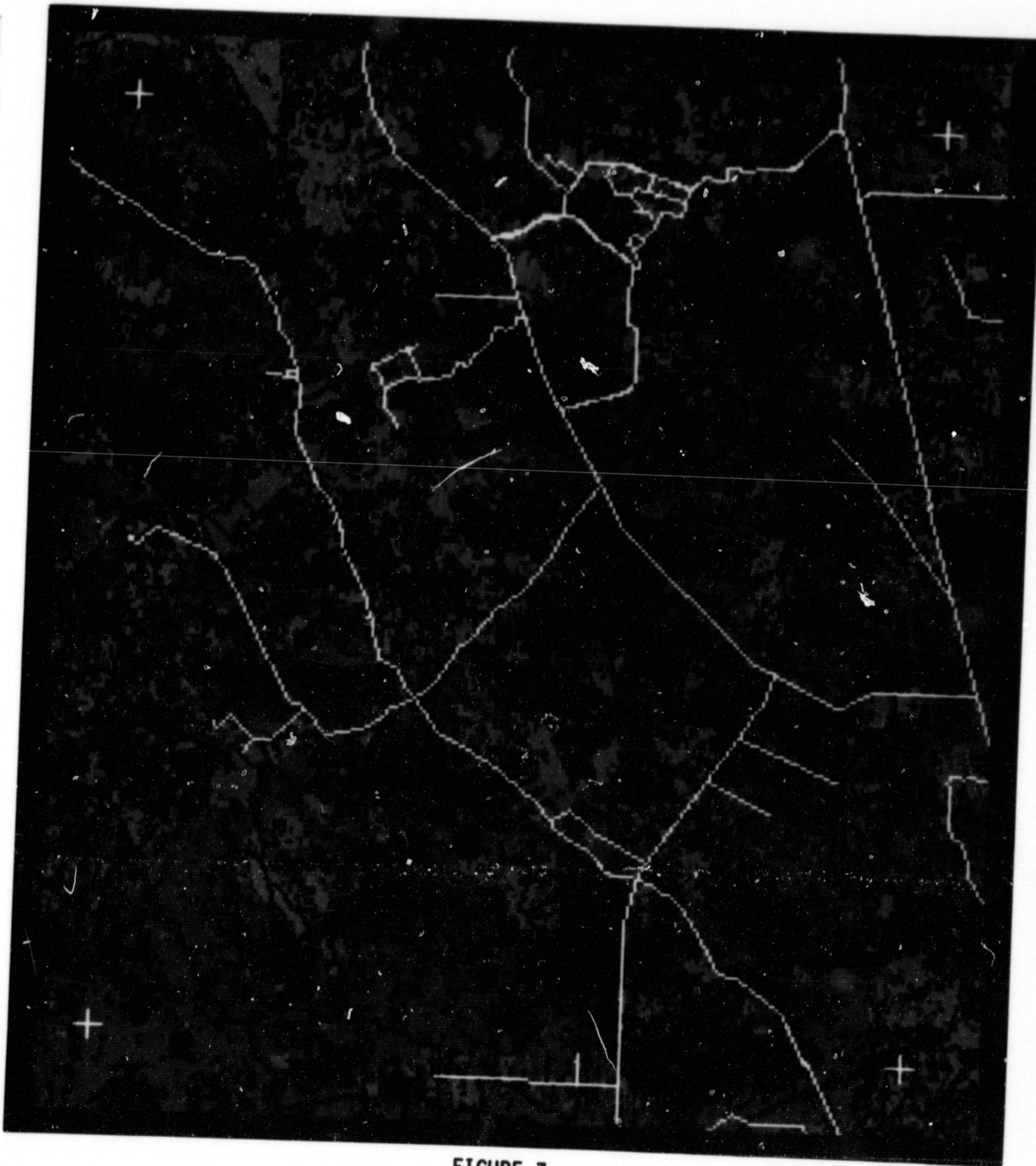


FIGURE 7

The positive results suggest that this study should continue as a low profile effort. The following are suggested:

During the coming year, the USFS will conduct an independent series of borings throughout the study area, and these borings can be correlated with the Landsat classification, which now resides in a geographically referenced data base. Apparent stressed vegetation in other parts of the Sam Houston National Forest should also be investigated for deposits of ironstone gravel. In addition, it is recommended that at some future date, the study area be used to investigate the Mid-IR bands of the Thematic Mapper as an even better indicator of vegetation stress.

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