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HOUSTON AREA MULTICROP INSPECTION TRIPS

E. W. Dunham

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16. Abstract

The phenology and signatures of small grains were studied vigorously during the Large Area Crop Inventory Experiment and Transition Year projects. However, many of the new crops that will be of interest during the Agriculture and Resources Inventory Through Aerospace Remote Sensing program (such as corn, cotton, soybeans, sorghum, sunflowers, and rice) have not been adequately studied. The purpose of this task was to obtain insight into the phenology of these crops and their observed signatures on Landsat imagery. This was accomplished by photographing the various crops in segments 275 and 276 located in Wharton County, Texas, and comparing those photographs with Landsat imagery of the same dates. These comparisons have given insight into the reason why a particular crop growth stage appeared as a definite signature on Landsat and how the percentage of ground cover of various crops affected the signatures on Landsat imagery. Because of cloud cover during several Landsat overpasses, numerous crop growth stages could not be directly compared.

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HOUSTON AREA MULTICROP INSPECTION TRIPS

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This report describes Multicrop classification technology activities of the Foreign Commodity Production Forecasting project of the AgRISTARS program.

PREPARED BY

E. W. Dunham

APPROVED BY

F. W. Solomon, Supervisor
Systems Verification Section

B. L. Carroll, Manager
Commodity Forecasting Department

LOCKHEED ENGINEERING AND MANAGEMENT SERVICES COMPANY, INC.

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For

Earth Observations Division

Space and Life Sciences Directorate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

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PREFACE

Documented in this report and in 12 volumes of photographic data are the results of the Houston Area Multicrop Inspection Trips conducted during the 1979 crop year on sample segments 275 and 276 in Wharton County, Texas. The crops studied were: corn, cotton, rice, sorghum, and soybeans.

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1. INTRODUCTION

A major task within the Large Area Crop Inventory Experiment (LACIE) and the current Agriculture and Resources Inventory Through Aerospace Remote Sensing (AgRISTARS) program has been to conduct research into the relationships between crop phenology and Landsat multispectral signatures. Continued attention has been given to investigating this issue, and detailed ground observations have been collected from within two AgRISTARS multicrop test sites in Wharton County, Texas.

The collection and analysis of these data support the development of AgRISTARS classification procedures primarily. Specific assistance to this effort has included providing information concerning a multicrop environment. The Wharton County data collection task was designed to provide information which could be analyzed in conjunction with Landsat data and then incorporated into the development of labeling decision logic. To meet this goal, 20 data collection field trips were conducted during 1979, whereby detailed observations regarding crop phenology were documented.

1.1 SCOPE

The multicrop ground-data collection task was confined to the two test sites (segments 275 and 276) in Wharton County, Texas. The close proximity of the test sites to the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (NASA/JSC) provided the opportunity for cost-effectiveness in collecting a portion of the data required for multicrop classification procedures development.

1.2 OBJECTIVES

The general objective of this study was to collect ground-level observations of specific crops in a multicrop environment.

Specific objectives were:

- To document the phenological growth stages in the forms of photographic albums and a logbook and make the data available for classification procedures development.
- To document crop phenology in terms of plant height, ground cover, management practices, etc.
- To obtain vertical photographs of the crops of interest during their various phenological stages so that ground cover could be determined.
- To obtain radiometer readings to support accuracy assessment efforts to determine the effect of haze intensity on the spectral data of the Landsat imagery.
- To study the relationships between the various phenological growth stages for the crops of interest and the coincident Landsat data, in order more fully to understand multitemporal signatures.

2. STUDY AREA

2.1 LOCATION

Wharton County, Texas, is located about 160.93 kilometers (100 miles) west-southwest of NASA/JSC (fig. 1). It was easily accessible for the studies that needed to be accomplished during the daylight hours and contained a wide variety of crops. Because of their accessibility, sample segments 275 and 276 (fig. 2) were chosen for a ground-level inventory within the AgRISTARS Program.

2.2 TOPOGRAPHY

The land area covered by segments 275 and 276 is fairly level to gently sloping. Consequently, the runoff from rainfall in the area moves across the land very slowly. This sluggish drainage is one of the chief concerns of the farmers in Wharton County. They realize that standing water in the fields can prove disasterous to their crops. With more than 96 percent of the land in the county sloping less than one percent, a network of ditches has been constructed in the farm areas, and the alignment of row crops has been carefully laid out to help eliminate water accumulation in the lower areas.

2.3 WEATHER

The climate for the area of segments 275 and 276 is conducive to agricultural crop growth. The area is subject to a humid, subtropical climate, which is characterized by warm to hot summers and mild winters. The growing season, or the average number of days between the last freeze in the spring and the first freeze in the fall, is 266 days. This is approximately the first week in March through the end of November. The annual average rainfall for the area is about 114.30 centimeters (45 inches). The year of this study, 1979, was an exceptionally wet year with more than 167.64 centimeters (66 inches) of rainfall on the county area (tables 1 and 2). This unusually large amount of rainfall proved disastrous for many of the farmers in terms of their crop yields because they could not get into their fields to harvest at the necessary time.

TABLE 1.- MONTHLY RAINFALL IN EAST BERNARD, WHARTON COUNTY, TEXAS, DURING 1979

Month	Rainfall, cm (in.)
January	20.32 (8.0)
February	10.92 (4.3)
March	7.11 (2.8)
April	20.57 (8.1)
May	12.19 (4.8)
June	7.11 (2.8)
July	16.51 (6.5)
August	10.54 (4.2)
September	43.18 (17.0)
October	4.83 (1.9)
November	5.33 (2.1)
December	11.18 (4.4)
Total	169.80 (66.9)

TABLE 2.- ANNUAL RAINFALL IN EAST BERNARD, WHARTON COUNTY, TEXAS FROM 1973 to 1979

Year	Rainfall, cm (in.)
1973	210.31 (82.8)
1974	157.48 (62.0)
1975	109.47 (43.1)
1976	144.02 (56.7)
1977	101.85 (40.1)
1978	121.67 (47.9)
1979	169.80 (66.85)

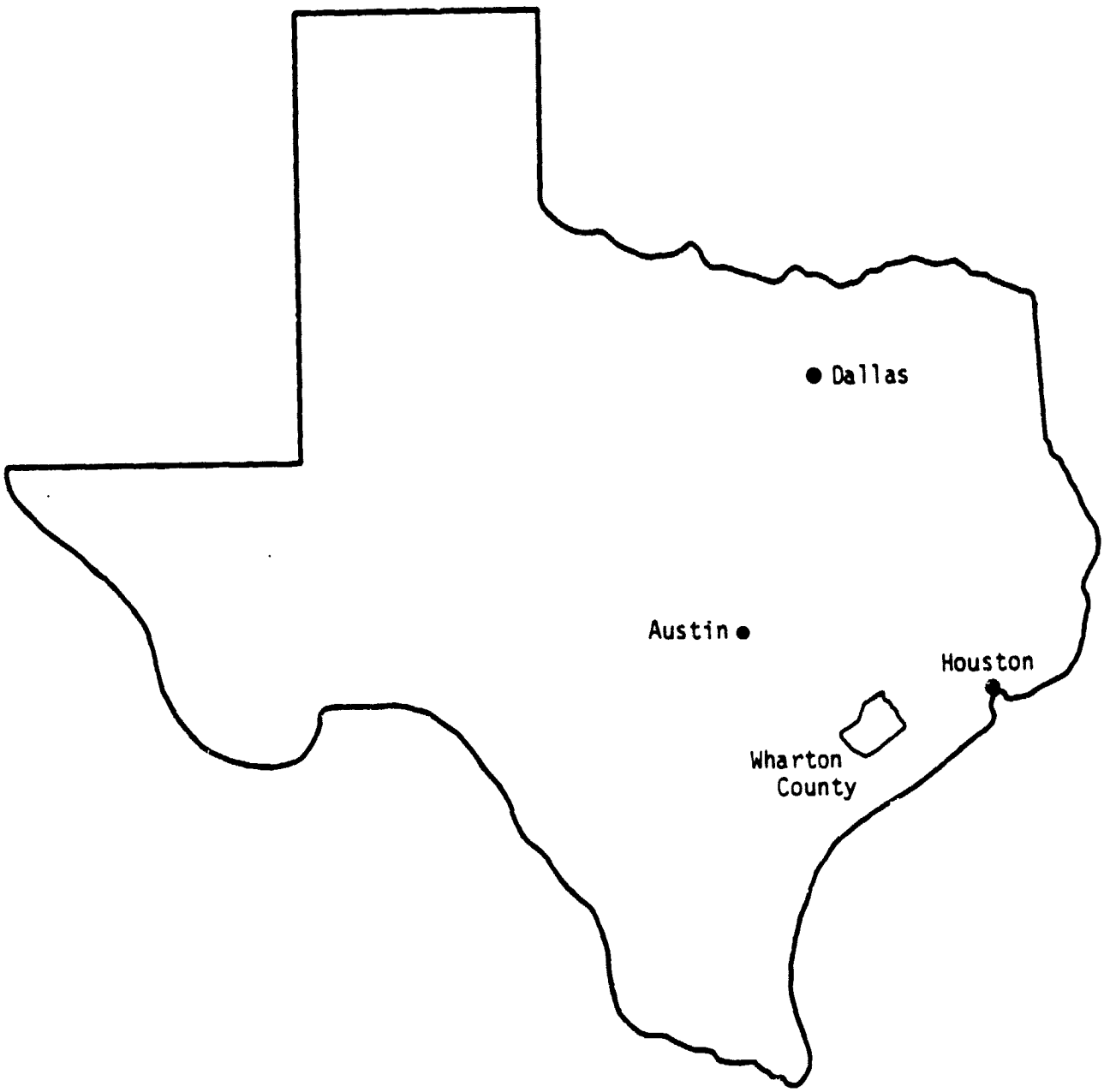

Figure 1.— Location of Wharton County, Texas

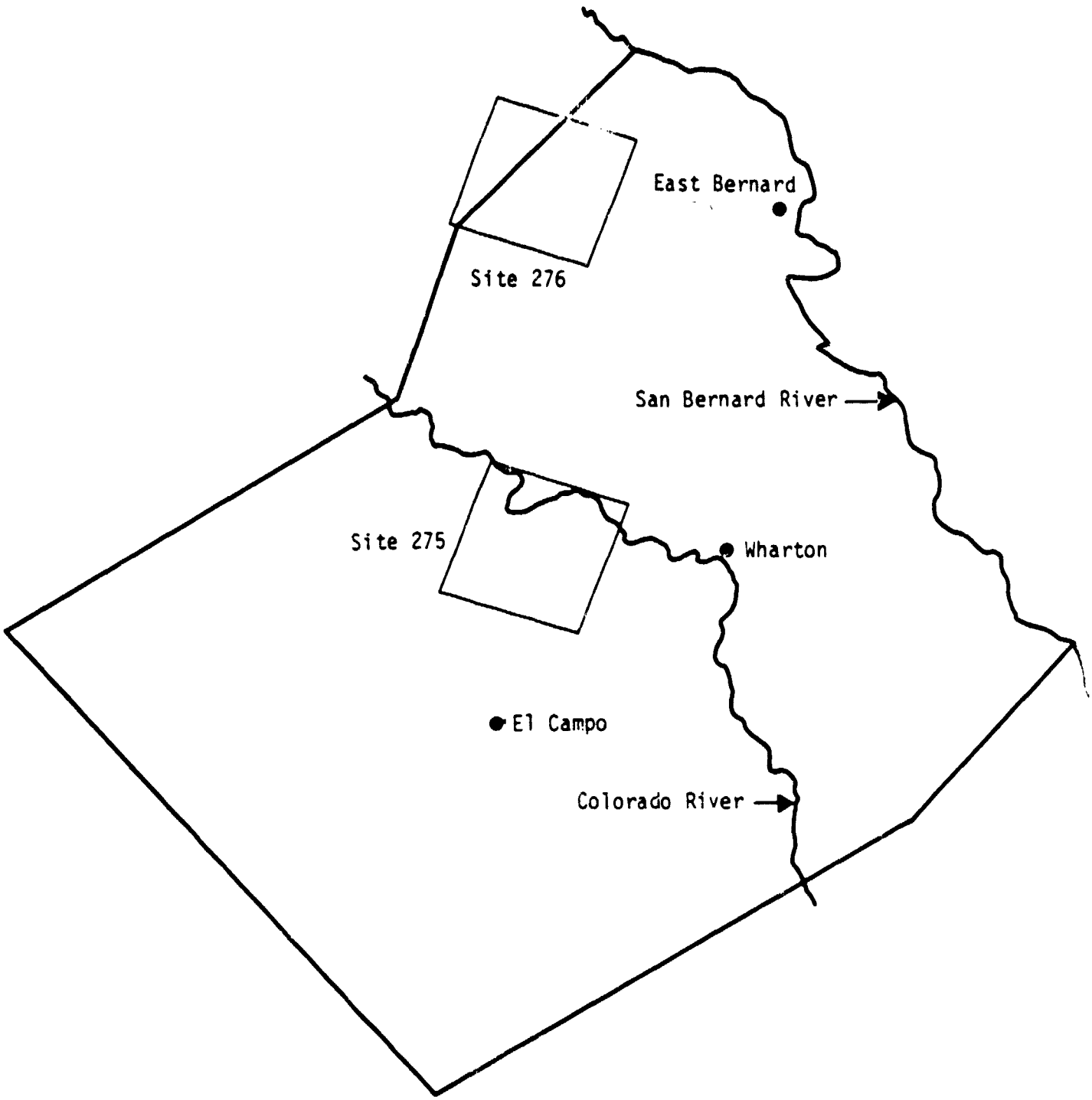

Figure 2.— Location of segments 275 and 276 in Wharton County.

2.4 SOILS

Segments 275 and 276 combine to have several soil association groups as seen on the soils map of Wharton County (fig. 3). All of the soils in the area are poorly drained. This condition contributes to the cropping practices used by the Wharton County farmers.

SOIL ASSOCIATIONS

Edna-Bernard association: Poorly drained and somewhat poorly drained soils that have a surface layer of fine sandy loam and clay loam and lower layers that are dominantly clay; on uplands.

Crowley association: Somewhat poorly drained soils that have a surface layer of fine sandy loam and lower layers of clay and sandy clay; on uplands.

Lake Charles association: Somewhat poorly drained soils that have a surface layer and lower layers of clay; on uplands.

Miller-Norwood association: Moderately well drained and well drained soils that have a surface layer and lower layers of clay and silt loam; on bottom lands.

Edna-Crowley association: Poorly drained and somewhat poorly drained soils that have a surface layer of fine sandy loam and lower layers of clay and sandy clay; on uplands.

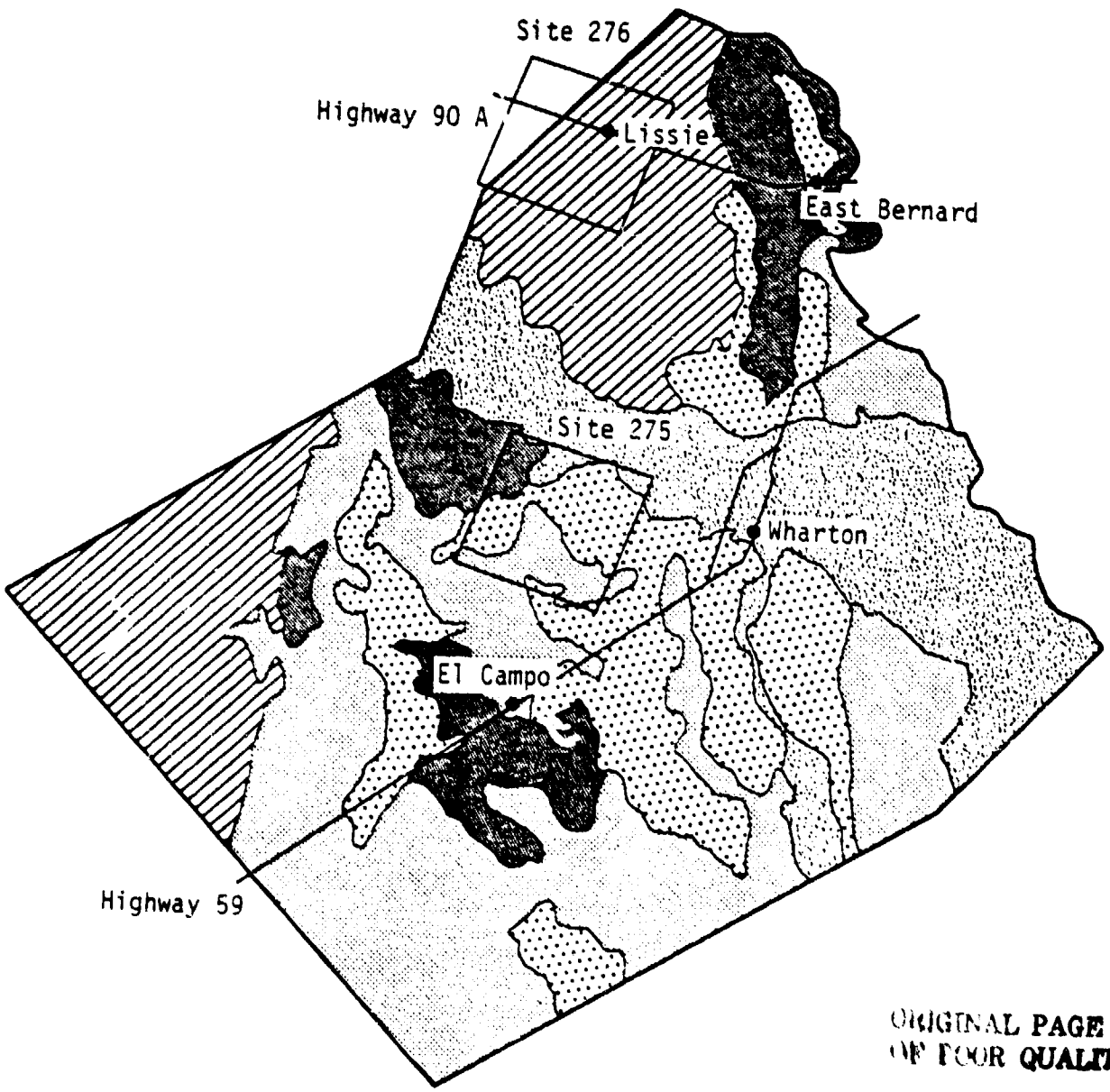

Figure 3.— Wharton County soils map.

3. PROCEDURES

Twenty field trips to segments 275 and 276 were conducted. Except for two trips, these field trips coincided with an overpass by either Landsat 2 or 3. Field trip No. 1, on March 9, 1979, was used as an exploratory trip to contact the U.S. Department of Agriculture, Soil Conservation Service (USDA/SCS) executive and allow him to familiarize us with the area so the appropriate fields could be selected. Field trip No. 6 was conducted on Friday, June 8, prior to the weekend overpass of Landsat-2 (appendix A).

On each field trip, photographic data were taken of each field. These data included:

a. Color field photograph - Using color Ektachrome film (ASA 200), this photograph was taken from the same location in the same direction for each field on every trip.

b. Color infrared photograph (CIR) - Using CIR Ektachrome film, this photograph was taken from the same location in the same direction for each field on every trip, providing there was vegetation in the field.

c. Overhead field shot - This photograph was taken at an altitude of 3 meters (10 feet), shooting straight down. It was taken at every field that had crop vegetation, on every trip, to help determine the percentage of ground cover.

The photographic data collected during the trips were documented and organized into separate volumes, along with Polaroid photographs taken of the Landsat imagery received for segments 275 and 276. These photographic data have been assembled into 12, the contents of which are listed in appendix B.

In addition, the following crop-related data were collected on each trip to better enhance the relationship between the field photographs and Landsat imagery.

a. Cropping practices

    1. Planting methods - aerial, drill, or rows

    2. Width of rows (when used)

    3. Cultivation activities

    4. Harvesting practices

b. Plant information

    1. Crop growth stage

    2. Plant height

    3. Crop condition

    4. Ground cover percentage

This information was recorded in a logbook along with additional comments pertaining to overall field conditions, weather, cloud cover, etc.

On each field trip that was cloud-free, radiometer readings were recorded according to NASA and USDA procedures, and these recordings were given to the field measurement group (NASA) for analysis. The analysis of these data is the subject of the overall JSC AgRISTARS Field Measurements Program and will be incorporated in its operational plans and associated reporting schedules.

4. OBSERVATIONS

Twelve volumes of photographic documentation accompany this report. References are made, in this section, to the comparison of Landsat imagery and color photographs of the crops of interest. The Polaroid photography of the Landsat imagery can be found in volume XII, and the color photography can be found in volumes I and II.

Studying various crop stages and comparing each stage with its respective signature on Landsat imagery were major objectives of this study. In general, the growth progression of the individual crops that were studied during the observations were similar in that they were planted and harvested at about the same times. Deviation from the normal planting date and alternate cropping practices were noticed, also and will be discussed in detail to illustrate the effects from crop calendar shifts such as this. Knowing the unique growth patterns of individual crops and their planting and harvest dates is important to the identification of these crops using Landsat data.

During the summer months when most agricultural crops in Wharton County are experiencing their most active growth period, weather patterns are being influenced by sea-to-land breezes, which cause early morning cloudiness. This morning cloudiness interferred with the generation of usable Landsat sample segment images. From June 10 through September 7, no Landsat images were received; and, consequently, many crop stages were not observed on the imagery.

The observed crops include corn, cotton, rice, sorghum, and soybeans; each crop will be discussed separately. To illustrate these comparisons, appendix C contains a table which includes plant height, crop stage, percentage of ground cover, appearance of the crop in the photograph, and its Landsat appearance on each observation made in Wharton County. Comments on each field are also included.

4.1 CORN

Four corn fields were observed on sample segment 275. Three of these fields - 1, 4, and 7 - displayed the expected growth pattern in that they were planted near the end of March and harvested by the end of August (appendix E). Field 10 deviated from this in that it was not planted until the end of May and was harvested in mid-September. All the fields displayed the same general characteristics expected of bare soil in the beginning of March. Field 10 had a white appearance on Landsat imagery, which is indicative of an idle, bare soil signature with no vegetation. Fields 1, 4, and 7 also displayed a bare soil appearance but were dark green on Landsat imagery, which is indicative of field preparation for a spring crop. The photographs taken of these fields on March 9 confirm these observations and can be observed in the accompanying log book, where the photographs of the fields taken on the first observation are located.

The next Landsat image acquired was of May 13, 1979. An observation was not made on this date, but comparisons can be made with the photographs on observation 5, May 22. The signature for field 10 on Landsat imagery was still white, indicating no field work had taken place. Field 10, on May 22, indicated that, since May 13, the field had been prepared and planted with corn. Fields 1, 4, and 7 displayed a dull red appearance on the Landsat image for May 13, which is indicative of vegetation on the field. The photographs for May 22 prove this, for the corn is about 91 centimeters (36 inches) high with a 60- to 70-percent ground cover.

The next Landsat image received was for June 10, and field 10 still had a bare soil appearance of light green. The photograph taken on June 8 for field 10 shows that corn was just emerging. The emerged corn was about 5-percent of the ground cover, and no vegetative response could be expected on the Landsat imagery. Fields 1, 4, and 7 had a dark red appearance on the Landsat image, indicative of complete or near-complete ground cover. The ground level photographs verify this, showing that these fields were all in the tasselling stage and indeed had 100-percent ground cover.

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The next Landsat image received was for September 7, and field 10, on this date, displayed a light green signature. This is indicative of a ripe corn crop with no chlorophyll in the plant. The photograph of field 10 proves that the corn was ripe, had no chlorophyll in the plant, and was ready for harvest. Fields 1, 4, and 7 displayed a white to light green signature on the Landsat imagery, which is indicative of a harvested field. The photographs for these fields show that the fields had been harvested and only corn stubble and bare soil were left to produce the signatures seen on the Landsat imagery.

On September 26, the date of the next Landsat image, field 10 showed a light pink signature. This is indicative of regrowth in the field in the form of grasses. The photograph of field 10 for September 25 shows that there was a large amount of grass covering the field. Field 1, 4, and 7 continued to display a harvest signature on Landsat (white), and the photographs for those fields verify this. Even though grass can be seen on these fields in the photograph, there was insufficient ground cover to produce a Landsat imagery signature. Hypothetically, in doing an interpretation for corn or any crop on this segment, field 10 have been incorrectly, identified, inasmuch as the only vegetative response that ever showed was the regrowth of grass (September 26 Landsat image).

4.2 SORGHUM

Three sorghum fields were observed on segment 275 - fields 3, 8, and 12. Sorghum is generally planted between March 10 and April 10 and harvested between July 15 and August 15 in Wharton County (appendix E). Fields 3 and 8 followed this expected sequence but field 12 deviated from this norm drastically. Field 3 is a narrow strip field and does not produce a Landsat vegetation signature. The integrated signature resulting from the narrow field and the adjacent nonvegetative (fallow) field produced a nonvegetative signature.

The first Landsat image received was for March 3. On this date, fields 8 and 12 had a signature of dark green to dull green, indicative of plowed fields or some kind of field preparation. The photographs taken on March 9 show that

fields 8 and 12 had recently been tilled, giving these fields a dark brown color; this substantiated the interpretation of the signatures seen on the Landsat image.

The next Landsat image received was for May 13. It indicated that there was some vegetative growth on field 8 because a dull red signature is seen on the imagery. The signature for field 12 on the Landsat imagery is a dull green, which is indicative of bare soil or not enough vegetation to give a response. The photographs taken of field 8 on May 22 show that there was a 50-percent ground cover of sorghum, which would cause the dull red signature on the Landsat imagery. The photograph for field 12 shows recent tilling had taken place and that it was now ready for planting.

The next Landsat image was for June 10. On this date, field 8 showed a red appearance, indicative of 100-percent ground cover and healthy vegetation. Field 12 showed a dark green signature on the Landsat image, which means no vegetation or not enough vegetation for a vegetative response. The photographs taken on observation 6, June 8, verify that field 8 did have 100-percent ground cover and the sorghum was in the headed stage. The photograph for field 12 shows a 25-percent ground cover of sorghum, but the minor amount of vegetation in the field was insufficient to initiate a response on the Landsat imagery.

The Landsat image received for September 7 showed that there were no vegetative responses on any of the three sorghum fields, and all fields displayed a dull green signature, indicative of bare soil. The photographs of these fields on September 7 verified that they had been harvested, and stubble and bare soil were all that could be seen on these fields.

The last Landsat image received was for September 26. Field 8 showed a combination of mottled dull red and dark green signatures, indicating a small amount of vegetation on the field. Field 12 still showed a dark green signature exemplifying a dark bare soil. The photographs of these fields on September 25 verified these conclusions.

Field 8 had a large amount of sorghum regrowth and grasses, which explains the mottled red signature seen on the imagery. Field 12 had some regrowth, but not enough to show up on the Landsat imagery.

A review of the signatures for field 12 shows that a vegetative response was never indicated on the Landsat imagery. If ground observations had not been made in Wharton County, it would not have been known through Landsat data analysis that sorghum was planted in this field. Field 12 was planted 2 months later than expected, and there was no Landsat imagery from June 10 to September 7. This accounts for the lack of a vegetative response on the Landsat images.

4.3 COTTON

Five cotton fields were observed on segment 275 - fields 2, 5, 6, 9, and 11. Historically, cotton is planted in Wharton County during April and harvested between August 15 and October 15 (appendix E). All of the cotton fields observed were consistent with these typical planting and harvest dates.

The Landsat image for March 3 had signatures of dull green to dark green for all five cotton fields, which indicates a bare soil or possible ground preparation activity in the fields. Temporal photographs for these fields verified that there was field preparation on all of the cotton fields.

The next Landsat image was for May 13, and all fields still had a bare soil signature. The photographs taken on observation 5, May 22, all showed that cotton had recently emerged and was 10 to 15 centimeters (4 to 6 inches) tall with less than a 5-percent ground cover; so no vegetative response was expected on the Landsat imagery.

The Landsat image for June 10 showed a couple of different signatures for the cotton fields. Fields 5, 6, 9, and 11 all showed a bare soil signature of dark green, while field 2 had a white signature, indicative of a dry, bare soil. However, photographs taken on June 8 for observation 6 all showed that cotton was present in the fields and ranged from 18 to 41 centimeters (7 to

16 inches) tall. The percentage of ground cover for field 5 was only 5 percent, so no vegetative response was expected on the Landsat image. The percentage of ground cover on field 2 was observed to be 30 percent and was thought to have enough ground cover to show up on Landsat imagery; however, this was not the case. The other fields of cotton had 20- to 25-percent ground cover, and no vegetative response was seen or expected on the Landsat imagery.

The next Landsat image was for September 7, and all the cotton fields except field 2 showed varying signs of vegetative response in the form of different examples of red signatures. Field 5 showed a dull red signature, indicative of vegetation that is maturing and losing its chlorophyll or of a cotton field that is not very healthy. Field 11 displayed a bright red signature which is indicative of very healthy vegetation. The signature for field 6 displayed a pink to red response, which was also indicative of a healthy cotton crop. Field 2 displayed a blue-green response, indicative of no vegetation on the field.

The photographs taken on observation 14, September 7, verified that fields 11 and 6 had a good cotton crop which was in the full boll stage. Field 5 was also in the full boll stage, but it did not appear to be as healthy as fields 11 and 6. Field 5 was in the defoliation stage, giving the field a brownish signature on the photograph. Field 2 was also in the defoliation stage, but a good deal of green vegetation was still present.

The various signatures for the cotton fields observed on the Landsat image for September 26 indicated that the cotton was in varying growth stages. Field 2 displayed a white signature, indicating harvest had taken place; whereas field 11 showed a dull red signature, which is expected of cotton after it has been defoliated. Fields 5, 6, and 9 all displayed a dull green and mottled red signature, implying the cotton field probably had been defoliated and could be ready for harvest.

The photographs taken on observation 15, September 25, verified that field 2 had been harvested and that fields 5, 6, and 9 had been defoliated and were ready for harvest. Field 11 still showed a gond deal of vegetation but had been recently defoliated and could be expected to be harvested in a week or two.

A heavy rain occurred between observations 14 and 15, and the cotton crop was considered to be very seriously damaged on fields 5, 6, and 9. This could explain the difference in signatures for fields 5, 6, and 9 when compared to field 12. The reddish signature, indicating vegetation, is very noticeable on the Landsat image for field 12, while it is barely detectable for field 5, 6, and 9. The heavy rains completely covered the fields and their crops and actually stripped the cotton and vegetation from the plants, as evidenced by the accumulation of cotton at the ends of the rows where the water eventually drained off.

4.4 SOYBEANS

There were two soybean fields observed during the study period. Field 15 was located in segment 275, and field 24 was in segment 276. Soybeans are usually planted between May 1 and June 15 and harvested by October 15 (appendix E). Fields 15 and 24 both followed these usual planting and harvest dates.

The Landsat image for March 3 showed that field 15 had a dull light green signature, typical of bare soil or an unprepared field. Field 24 had a reddish signature indicating that vegetation was on the field. The photographs of these fields showed that field 24 did indeed have small winter grasses growing, which explains the reddish signature on Landsat. A photograph for field 15 was not available.

The next Landsat image received was for May 13, and it showed that both fields had a light green signature typical of bare soil. The photograph of field 15 for observation 5 on May 22 verified that there still was no vegetation in the field and that soybeans had just been planted. There was no photograph for field 24 on this date.

The signature on the Landsat image for June 10 was light green to white on both fields, indicating that neither field had vegetation. The photographs of these fields showed that soybeans had emerged and were 10 centimeters (4 inches) tall on field 24. On field 15, the soybeans were 25 centimeters (10 inches) tall with about a 15-percent ground cover. It can also be noticed, by observing both fields, that field 15 was planted in rows while field 24 was planted with a drill. The reason for the difference in planting was probably due to the individual preference of the farmer. The yields should be about the same on each field.

The September 7 Landsat image showed that field 24 had a bright red signature. This is indicative of a good healthy crop. The signature for field 15 was also bright red, but the north and west edges of the field showed a dull red signature, apparently indicating a less than healthy crop. The photograph for field 24 verifies a healthy soybean crop 107 centimeters (42 inches) tall in the full seed stage, with a 100-percent ground cover. Field 15 also was in the full seed stage and the crop was 97 centimeters (38 inches) tall. The dull red signature seen on Landsat was caused by an army worm infestation in which the leaves were almost completely eaten by the worms.

The Landsat image for September 26 showed that the signature for field 24 was a dull, pinkish brown, which would mean that the soybean crop was in senescence. The signature for field 15 had more brown on the edges but was still bright in the center of the field. The photograph taken on observation 15, September 25, showed that field 24 was indeed dying back and that the soybeans were reaching maturity. Field 15 showed that the army worm infestation had worsened, causing even less vegetation to be visible. The center of the field had not been affected by the army worms. Both soybean fields were harvested between October 4 and October 23, and it was concluded that the yields from field 15 were considerably less than field 24 because of the army worm problem.

4.5 RICE

Seven rice fields were observed during the Wharton County observations. Two fields (13 and 14) were in segment 275 and five fields (16, 17, 18, 22, and 23) were in segment 276. Historically, rice is planted between March 15 and April 30 and is harvested the first time between July 15 and August 1 and the second time in October (appendix E). All of the rice fields observed closely followed these usual planting and harvest dates.

The Landsat image for March 3 indicated a bare soil signature of light green for fields 13, 16, 17, 18, 22, and 23, while the signature for field 14 showed a red response, indicating vegetation on the field. The photographs of observation 1, March 9, verified that bare soil was the reason for the Landsat signatures for fields 13, 16, 17, 18, 22, and 23. Field 14 had recently been tilled, so the vegetation observed on the Landsat image was no longer in the field; the field was bare soil.

The next Landsat image received was for May 13. Fields 13, 14, 16, 17, and 18 had signatures of white to light green, indicating bare soil or an insufficient amount of ground cover to give a vegetative response. Fields 22 and 23 exhibited a signature of very light pink, which is indicative of a recently emerged crop.

The photographs for fields 13, 14, 16, 17, and 18, taken on May 22, observation 5, show the rice in these fields was 15 to 25 centimeters (6 to 10 inches) tall and ground cover was sufficient to cause a vegetative response expected on the imagery. Unfortunately, no Landsat imagery was received to verify this field observation. Photography for fields 22 and 23 showed rice to be 25 to 30 centimeters (10 to 12 inches) high with about 90-percent ground cover. This explains why Landsat imagery on May 13 showed the light pink signature, meaning the rice was up and had better than 50-percent ground cover.

The next Landsat image was for June 10. It showed that fields 13, 14, 16, 17, 22, and 23 all had a red signature, indicating a 100-percent ground cover and a healthy crop. Field 18 displayed a mottled pink and brown signature,

indicating that the field had somewhat less than a healthy crop. The photographs for fields 13, 14, 16, 17, 22, and 23 had 100-percent ground cover. The rice was between the jointing and heading stage and was 46 to 66 centimeters (18 to 26 inches) tall. The photograph of field 18 showed rice to be 25 to 36 centimeters (10 to 14 inches) tall with a 40-percent ground cover at the jointing stage.

The first crop of rice was harvested between July 25 and September 1, as the photographs indicate on observations 12, 13, and 14.

On the Landsat image for September 7, fields 13, 14, 16, 17, and 22 all had the same signature of a dark brownish green. Field 23 showed more of a brown signature, meaning a higher percentage of ground cover for the second crop of rice while the signature for field 18 was a blue-green, which indicates very little vegetation in the field.

The photographs of these rice fields taken on observation 14, September 7, explained the signatures seen on Landsat imagery. Fields 13, 14, 16, 17, and 22 appeared to have a healthy rice crop. Closer inspection showed that rice stubble, bare soil, and water appeared to dominate the ground cover of the rice, which would cause the brownish green signature seen on Landsat.

Field 23 had more ground cover than the other fields, causing the reddish brown signature seen on the imagery. Field 18 had more bare soil, water, and stubble than it had rice, causing the blue-green signature seen on the Landsat imagery. The Landsat image for September 26 displayed a brownish red signature for fields 13 and 14, which is typical of a fairly healthy second crop of rice. Fields 16, 17, 18, 22, and 23 all showed a mottled gray, brown, and green signature, signifying that the rice crop was starting to turn and mature.

The photographs of fields 13 and 14 showed a healthy second crop of rice, but obviously not as good as the first rice crop. The photographs for fields 16, 17, 18, 22, and 23 showed signs of the senescent stage, which explains why the

healthy vegetation signature was not seen on the Landsat imagery. The second harvest of these rice fields took place near the end of October, as shown on the photographs of these fields on observations 17, 18, 19, and 20.

The second crop of rice is usually considered pure profit for the farmers, for the first crop usually pays for the expenses of seed, planting, fertilization, insecticides, and harvest. The second crop of rice usually yields about 4356 kilograms per hectare (810 pounds per acre) as compared to 29 405 kilograms per hectare (5400 pounds per acre) for the first rice crop.

5. CONFUSION CROPS

Confusion crops are two or more crops that reflect the same Landsat signature on two or more acquisitions; however, spectral confusion can also occur when insufficient acquisitions prevent the discrimination of two crops which have different growth calendars. An example of the latter was observed with corn and sorghum on segment 275. On the Landsat image for March 3, all the fields of corn and sorghum exhibited a bare soil signature of dark green. The May 13 Landsat image showed that fields 1, 4, and 7 of corn had a brownish red signature, and the sorghum fields 3 and 8 also exhibited a brownish red signature. The June 10 Landsat image revealed that corn fields 1, 4, and 7 and sorghum fields 3 and 8 all had the same signature of rusty red. There is currently no way to distinguish between these two crops.

On the September 7 Landsat image, the corn fields 1, 4, and 7 and sorghum fields 3 and 8 had been harvested. Although they do reveal different signatures after harvest, it would be very inconclusive to determine that their postharvest signature would be the deciding factor that separates these two crops. All of the other crops observed in the two segments had a unique signature pattern that was not confused with any other crop.

6. PRODUCTS

Several photograph and slide albums were built as a result of the ground-level photographs taken during each observation trip. The photograph albums consist of the following: the overhead field shot for all the observations, showing if there was vegetation in the field; the color infrared field shot for all the observations, in which there were crops in the field; and the color field shot taken of the field on each observation. There is also a slide album containing the same information as in the photograph album.

Also included in the logbook are the individual field recordings, including plant height, percentage of ground cover, crop stage, and other pertinent comments about the crop on each observation. Also, a section is devoted to observation comments for information that may not be directly related to any one field; i.e., weather, surrounding activities, etc.

A Landsat album is also included, in which a Polaroid photograph was made of each Landsat acquisition received over the sites. These Polaroid photographs have the individual fields outlined, labeled, and numbered, so they can be followed as the crops go through the growth cycle.

The radiometer recordings, which monitored the haze for spectral data at the time of the Landsat overpass, were still in study at the time of writing this report.

7. CONCLUSIONS AND RECOMMENDATIONS

The comparison of the phenological growth stages with the Landsat imagery provided some useful information regarding multicrop Landsat signatures. Only five Landsat acquisitions were received for each of the segments, but each provided the opportunity to study the field preparation stages and some of the early and late phenological growth stages of the crops. Due to cloud cover and/or technical problems, several other phenological stages were unobservable on the Landsat imagery.

The photographic documentation of these phenological stages was successfully carried out with the formation of the accompanying photograph and slide albums.

Vertical ground-level photographs were successfully collected and can now provide the enumerators with a standard for identifying ground cover percentages. The complete set of ground photographs consists of ground cover percentages ranging continuously from 0 to 100 percent.

Corn and sorghum were indistinguishable on the Landsat imagery. It is not known if they could be identified better with the imagery during the more critical phenological growth stages of these crops. Further study and more Landsat imagery would help find these answers.

It was known that crop damage due to insects or weather could be seen on Landsat imagery. The extent of this damage and at what stage it could be seen on the imagery was not known. The army worm infestation on field 15 and the flooding damage on the cotton helped reflect on this problem.

After examination (during daylight hours) of the sample segments that are within driving distance of JSC, it was determined that segments 275 and 276 are the best candidates for further study because the Wharton County segments have the best crop diversity. Although the acquisition history was considered poor for segments 275 and 276, the other segments that were within the bounds

of the study area had even poorer acquisition histories for this past crop year. This year had an abnormally high rainfall in comparison to previous years; and, because of this, many Landsat acquisitions may not have been received.

The photograph and slide albums are a complete history of each crop's phenological growth stage. These albums can be used to demonstrate to analysts what the individual crop stages look like in the field and as training vehicles for newly hired personnel to show them what various crops stages look like in the field and on Landsat imagery. To do this more completely, more Landsat imagery is required to cover the crop growth stages that were missed this past crop year. Consequently, another program similar to this year's is recommended in hopes of gaining access to these missing crop growth stages.

8. REFERENCES

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2. Analyst Interpretation Keys: United States and Canadian Great Plains Regional Keys. JSC-12556, NASA/JSC (Houston), May 1977.

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APPENDIX A

OBSERVATION AND LANDSAT DATES

APPENDIX A
OBSERVATION AND LANDSAT DATES

This table lists the Wharton County, Texas observation dates with their corresponding Landsat overpass dates and specifies which Landsat (2 or 3) was in use.

TABLE A-1.- OBSERVATION DATES AND
COINCIDENTAL LANDSAT OVERPASS DATES

Observation	Observation date	Landsat	Landsat image date
1	March 9, 1979	3[a]	March 3, 1979
2	March 30, 1979	2	March 30, 1979
3	April 16, 1979	2	March 16, 1979
4	May 4, 1979	2	May 4, 1979
5	May 22, 1979	2	May 22, 1979
6	June 8, 1979	2[a]	June 9, 1979
7	June 18, 1979	3	June 18, 1979
8	June 27, 1979	2	June 27, 1979
9	July 6, 1979	3	July 6, 1979
10	July 16, 1979	2	July 16, 1979
11	July 25, 1979	3	July 25, 1979
12	August 2, 1979	2	August 2, 1979
13	August 20, 1979	2	August 20, 1979
14	September 7, 1979	2	September 7, 1979
15	September 25, 1979	2	September 25, 1979
16	October 4, 1979	3	October 4, 1979
17	October 23, 1979	3	October 23, 1979
18	October 31, 1979	2	October 31, 1979
19	November 9, 1979	3	November 9, 1979
20	November 19, 1979	2	November 19, 1979

[a]Observation date did not coincide with a Landsat overpass date.

APPENDIX B

INDEX FOR THE ACCOMPANYING VOLUMES OF PHOTOGRAPHIC MATERIAL

APPENDIX B

INDEX FOR THE ACCOMPANYING VOLUMES OF PHOTOGRAPHIC MATERIAL

This table lists the contents of the volumes of photographic material which was collected during the Wharton County, Texas, field observations.

TABLE B-1.- CONTENTS OF PHOTOGRAPHIC VOLUMES

Volume	Contents
I	Color field photographs, segment 275
II	Color field photographs, segment 276
III	Color infrared field photographs, segment 275
IV	Color infrared field photographs, segment 276
V	Ground cover photographs, segments 275 and 276
VI	Color field slides, segment 275
VII	Color field slides, segment 276
VIII	Color infrared field slides, segment 275
IX	Color infrared field slides, segment 276
X	Ground cover slides, segment 275
XI	Ground cover slides, segment 276
XII	Polaroids of the Landsat images, segments 275 and 276

APPENDIX C

SUMMARY OF CROP OBSERVATIONS

APPENDIX C

SUMMARY OF CROP OBSERVATIONS

Table C-1 specifies the crop growth stage, height, percentage of ground cover, and appearance of photographic and Landsat acquisition data for each observation.

TABLE C-1.- COMPREHENSIVE OBSERVATIONS OF THE STUDY FIELDS IN WHARTON COUNTY, TEXAS, IN 1979

(a) Corn

Observation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Observation Date		3-9	3-30	4-16	5-4	5-22	6-8	6-18	6-27	7-6	7-16	7-25	8-2	8-20	9-7	9-25	10-4	10-23	10-31	11-9	11-19	1979 Crop Year
Crop and Field #	Descriptor	Observations																				Comments
Corn 1	Crop Stage*	0	1.5	1.7	2.5	2.5	3.7	3.8	3.9	3.9	4.5	5.1	5.5	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Excellent looking crop with high yields expected.
	Plant Height (")	0	2	4	24	30-36	78	100	100	100	100	100	100	90	0	0	0	0	0	0	0	
	% Ground Cover	0	0	5	30-40	60-70	99	99	99	100	100	90-95	50	50	0	0	0	0	0	0	0	
	Photo Appearance	Lt Bn	Lt Bn	Bn	NA	Gn	Gn	Gn	Gn	Gn	Yl-Gn	Lt Gn	Bn	Bn	Gn	Bk Bn	Bk Bn	Bk Bn	Lt Bn	Lt Bn	Bk Bn	
	Landsat Appearance	Gy-Gn	NA	NA	NA	NA	Bk Rd	NA	NA	NA	NA	NA	NA	NA	Lt Gn	Wt	NA	NA	NA	NA	NA	
Corn 4	Crop Stage*	0	1.0	1.7	2.5	2.5	3.7	3.8	3.9	4.0	5.0	5.0	5.5	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Good looking crop with moderately high yields expected.
	Plant Height (")	0	0	5	18	30-36	80	86	88	88	88	88	88	88	0	0	0	0	0	0	0	
	% Ground Cover	0	0	5	35-40	70-80	95-99	99	100	100	100	100	80	50	0	0	0	0	0	0	0	
	Photo Appearance	Bk Bn	NA	Bn	NA	Gn	Gn	Gn	Gn	Gn	Yl-Gn	Lt Gn	Lt Bn	Bn	Bn	Bn	Bn	Bk Bn	Bn	Bk Bn	Bk Bn	
	Landsat Appearance	Gy-Bn	NA	NA	NA	NA	Bk Rd	NA	NA	NA	NA	NA	NA	NA	Lt Gn	Wt-Gy	NA	NA	NA	NA	NA	
Corn 7	Crop Stage*	0	1.0	1.7	2.0	2.5	3.4	3.7	3.8	4.0	4.4	4.8	5.5	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Excellent looking crop with probable high yields.
	Plant Height (")	0	0	5	12	30-36	82	86-88	90	90	90	90	90	75	0	0	0	0	0	0	0	
	% Ground Cover	0	0	5	40	80	95	99	100	100	100	100	80	75	0	0	0	0	0	0	0	
	Photo Appearances	Bk Bn	NA	Bn	NA	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Lt Bn	Bn	Bn	Lt Bn	Lt Bn	Bk Bn	Bk Bn	Bk Bn	Bk Bn	
	Landsat Appearance	Bk Gy	NA	NA	NA	NA	Bk Rd	NA	NA	NA	NA	NA	NA	NA	Wt-Yl	Wt-Gy	NA	NA	NA	NA	NA	
Corn 10	Crop Stage*	0	0	0	0	0	1.7	2.0	2.5	3.0	3.4	3.7	4.0	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	Field planted 2 months later than expected. Would not have been interpreted as corn on Landsat imagery.
	Plant Height (")	0	0	0	0	0	8-10	10	25	50	90	92	97	90	90	0	0	0	0	0	0	
	% Ground Cover	0	0	0	0	0	5	10	50	70	75	90	95	90	40	0	0	0	0	0	0	
	Photo Appearance	Lt Bn	NA	Bn	NA	Bk Gy	Bk Gy	Bn	Bn-Gy	Gn	Gn	Gn	Gn	Lt Bn	Bn	Lt Gn	Lt Gn	Bk Bn	Bn	Bk Bn	Bn	
	Landsat Appearance	Wt	NA	NA	NA	NA	Wt-Gy	NA	NA	NA	NA	NA	NA	NA	Rd-Gn	Pk	NA	NA	NA	NA	NA	

*Crop stages are described in appendix B.

Codes describing photo appearance and Landsat appearance:

Bn = Brown, Bk = Dark, Gy = Gray, Pk = Pink, Wt = White
Bl = Blue, Gd = Gold, Lt = Light, Rd = Red, Yl = Yellow
Br = Bright, Gn = Green, NA = Not available, Tn = Tan

TABLE C-1.- Continued.

(b) Cotton

Observation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1979 Crop Year
Observation Date		3-9	3-30	4-16	5-4	5-22	6-8	6-18	6-27	7-6	7-16	7-25	8-2	8-20	9-7	9-25	10-4	10-23	10-31	11-9	11-19	
Crop and Field #	Descriptor	Observations																				Comments
Cotton 2	Crop Stage*	0	0	2.2	2.4	2.6	3.0	4.0	4.2	5.0	5.0	5.5	5.8	5.8	6.5	7.0	7.0	7.5	7.5	7.5	7.5	Followed expected planting
	Plant Height (")	0	0	1	2	4-6	16-17	24	25	36	40	48	48	48	48	0	0	0	0	0	0	and harvest dates.
	% Ground Cover	0	0	0	5-10	10	30	50	80	90	99	100	100	100	100	0	0	0	0	0	0	Excellent looking crop.
	Photo Appearance	Lt Bn	Bn	Bn	NA	Dk Bn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Bn	Bn	Bn	Bn	Bn	Bn	High yields expected.
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Wt	NA	NA	NA	NA	NA	NA	NA	Bl-Gn	Wt	NA	NA	NA	NA	NA	
Cotton 5	Crop Stage*	0	0	0	1.5	1.5	2.5	2.80	3.5-4.0	4.5-5.0	5.0	5.0	5.2	5.3	6.0-6.5	6.5	6.5	7.0	7.5	7.5	7.5	Followed expected planting
	Plant Height (")	0	0	0	2	3-4	6-7	8-9	10-12	14-16	31	34	40	40	40	40	0-40	0	0	0	0	and harvest dates.
	% Ground Cover	0	0	0	<5	<5	5	10	20	40	57	60	75	90	90	90	0-90	0	0	0	0	Real slow in growing.
	Photo Appearance	Dk Bn	NA	Dk Bn	NA	Bn-Gy	Bn-Gn	Bn-Gn	Gn-Bn	Gn	Gn	Gn	Gn	Gn	Bn	Bn	Bn	Bn Bn	Bn Bn	Bn Bn	Bn Bn	Low yields expected.
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Dk Gn	NA	NA	NA	NA	NA	NA	NA	Dk Rd	Gn	NA	NA	NA	NA	NA	Field flooded by heavy rains.
Cotton 6	Crop Stage*	0	0	1.0	1.5	2.6	3.0	3.3	4.0	5.0	5.0	5.0	5.2	5.3	6.0	[illegible]	7.0	7.5	7.5	7.5	7.5	Followed expected planting
	Plant Height (")	0	0	0	2	6	16-18	22-24	25	27	32	40	40	40	40	40	0	0	0	0	0	and harvest dates.
	% Ground Cover	0	0	0	<5	5	30	40	50	60	80	90	100	100	100	100	0	0	0	0	0	Fair to good crop yields
	Photo Appearance	Dk Bn	NA	Bn	NA	Bn	Bn-Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Bn Bn	Bn Bn	Bn Bn	Bn Bn	Bn Bn	expected.
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Dk Gn	NA	NA	NA	NA	NA	NA	NA	Pk-Rd	Gn	NA	NA	NA	NA	NA	
Cotton 9	Crop Stage*	0	0	1.0	1.5	2.6	3.0	3.3	4.0	5.0	5.1	5.2	5.3	5.4	6.5	6.5	7.0	7.5	7.5	7.5	7.5	Followed expected planting
	Plant Height (")	0	0	0	2.5	6	10-12	22-24	25-27	32	35	38	40	38	38	38	0	0	0	0	0	and harvest dates.
	% Ground Cover	0	0	0	<5	5	25	40	50	50	80	85	90	90	90	Gn	Bn Bn	Bn Bn	Bn Bn	Bn Bn	Bn Bn	Poor crop yields expected
	Photo Appearance	Bn-Gy	Gy	Bn	NA	Gy-Bn	Bn-Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Dk Rd	Bl-Rd	NA	NA	NA	NA	NA	due to flooding caused by
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Gn-Rd	NA	NA	NA	NA	NA	NA	NA								heavy rains.
Cotton 11	Crop Stage*	0	0	1.0	1.5	2.6	2.8	3.2	4.0	5.0	5.1	5.2	5.5	5.7	5.8	6.5	6.5	7.0	7.5	7.5	7.5	Followed expected planting
	Plant Height (")	0	0	0	2	4.6	10-12	20-22	25	36	42	46	52	57	57	57	57	0	0	0	0	and harvest dates.
	% Ground Cover	0	0	0	5	7	20	40	50	60	75	95-100	100	100	100	100	100	0	0	0	0	Excellent looking crop.
	Photo Appearance	Gy-Bn	Gy	Bn	NA	Gy-Bn	Bn-Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn-Bn	Bn-Gn	Bn	Gy-Bn	Bn Bn	Bn Bn	High yields expected.
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Dk Gn	NA	NA	NA	NA	NA	NA	NA	Bl Rd	Dk Rd	NA	NA	NA	NA	NA	

*Crop stages are described in appendix B.

Codes describing photo appearance and landsat appearance:

Bn = Brown Bt = Dark Gy = Gray Pk = Pink Wt = White
Bl = Blue Go = Gold Lt = Light Rd = Red Yl = Yellow
Br = Bright Gn = Green NA = Not available Tn = Tan

TABLE C-1.- Continued.

(c) Rice

Observation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Observation Date		3-9	3-30	4-16	5-4	5-22	6-8	6-18	6-27	7-6	7-16	7-25	8-2	8-20	9-7	9-25	10-4	10-23	10-31	11-9	11-19	1979 Crop Year
Crop and Field #	Descriptor	Observations																				Comments
Rice 13	Crop Stage*	0	0	1.0	2.1	2.1	3.0	3.5	3.6	4.0	4.2	4.9	5.0	7.0	3.0	4.0	4.0	4.2	5.0	6.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	0	2	6-8	22	24	28	40	42	42	42	42	10	18	24-30	30	30	30	18	
	% Ground Cover	0	0	0	10	90	100	100	100	100	100	100	100	100	50	70	70	70	70	70	60	First and second crops looked good.
	Photo Appearance	Gy-Bn	Bt Gy	Gn	NA	Lt Gn	Gn	Gn	Gn	Gn	Gn	Gn	Wt-Gd	Lt Bn	Gn	Gn	Gn	Gn	Gn	Gn	Lt Bn	
	Landsat Appearance	Bl-Gn	NA	NA	NA	NA	Bt Rd	NA	NA	NA	NA	NA	NA	NA	Bt Gn	Bn-Rd	NA	NA	NA	NA	NA	
Rice 14	Crop Stage*	0	0	1.0	2.1	2.1	3.0	3.4	3.5	4.0	4.5	5.0	5.2	7.0	3.0	4.0	4.0	4.9	5.5	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	0	2	6.0	20-22	22-24	30	30	42	42	42	12	18-22	24-30	24-30	30-36	30-36	12	12	
	% Ground Cover	0	0	0	20	90	100	100	100	100	100	100	100	30	70	70	70	70	70	60	60	First and second crops looked good.
	Photo Appearance	Gy	Gy	Bn	NA	Gn	Gn	Gn	Gn	Gn	Gn	Lt Gd	Lt Gd	Lt Bn	Gn	Gn	Gn	Gn	Lt Gd	Lt Gn	Lt Bn	
	Landsat Appearance	Rd	NA	NA	NA	NA	Bt Rd	NA	NA	NA	NA	NA	NA	NA	Bt Gn	Bn Rd	NA	NA	NA	Bt	NA	
Rice 16	Crop Stage*	0	0	1.0	1.5	2.5	3.0	3.3	3.5	4.0	4.2	5.0	6.0	7.0	4.0	4.0	4.0	5.3	7.0	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	0	0	8-10	18	22	24	30	42	42	42	15	24	30	30	30	18	18	18	
	% Ground Cover	0	0	0	0	45-50	60-70	100	100	100	100	100	100	60	70	70	70	70	60	60	60	First and second crops looked good.
	Photo Appearance	Gy	Gy	Bn	NA	Lt Gn	Gn	Gn	Gn	Gn	Gn	Gn	Lt Gd	Gn-Bn	Gn	Gn	Gn	Lt Gd	Bn-Gd	Lt Bn	Lt Bn	
	Landsat Appearance	Lt Gn	NA	NA	NA	NA	Rd	NA	NA	NA	NA	NA	NA	NA	Bt Bn	Bn-Gn	NA	NA	NA	NA	NA	
Rice 17	Crop Stage*	0	1.5	1.0	2.0	2.5	3.0	3.3	3.4	4.0	4.2	4.9	5.5	6.0	3.0	3.9	4.0	5.3	6.0	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	0	4	8-10	18	22	24	30	42	42	42	42	12	24	30-36	30-36	30-36	12	12	
	% Ground Cover	0	0	0	0	40-50	100	100	100	100	100	100	100	100	30	60	70	70	70	60	60	First and second crops looked good.
	Photo Appearance	Gy	Lt Bn	Bn	Lt Gn	Gn	G.	Gn	Gn	Gn	Gn	Gn	Lt Gd	Bn-Gn	Gn	Gn	Gn	Lt Gd	Gd	Lt Bn	Bn	
	Landsat Appearance	Lt Gn	NA	NA	NA	NA	Rd	NA	NA	NA	NA	NA	NA	NA	Gn-Rd	Gn-Rd	NA	NA	NA	NA	NA	
Rice 18	Crop Stage*	0	0	1.0	1.5	2.1	3.0	3.2	3.3	3.5	4.0	4.5	5.0	6.0	3.0	3.9	4.0	6.0	6.0	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	0	[illegible]	6	10-14	20	21	24	28	29	32	32	18	24	30	30	32	12	12	
	% Ground Cover	0	0	0	[illegible]	20-30	40	70	80	100	100	100	100	100	50	60	60	60	60	40	40	Poor looking crop - weedy - low yields expected.
	Photo Appearance	Gy	Gy	Bn	NA	NA	Gn	Gn	Gn	Gn	Gn	Gn	Lt Gd	Lt Gd	Gn	Gn	Gn	Gd	Lt Gd	Gy-Gn	Bn	
	Landsat Appearance	Lt Gn	NA	Bn	NA	NA	Pk-Rd	NA	NA	NA	NA	NA	NA	NA	Bt Gn	Lt Gn	NA	NA	NA	NA	NA	
Rice 22	Crop Stage*	0	0	2.1	2.3	3.0	3.5	3.7	4.0	4.0	5.0	6.0	7.0	2.3	3.7	4.0	4.5	7.0	7.0	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	4	8	10-12	22	24	28	38	38	42	12	12	30	36	36	16	18	18	18	
	% Ground Cover	0	0	15	30	80-90	100	100	100	100	100	100	50	60	70	70	70	60	60	60	60	Excellent looking crop.
	Photo Appearance	Gy	Gy	Lt Gn	Gn	NA	Gn	Gn	Gn	Gn	Lt Yl	Lt Gd	Lt Bn	Gn	Gn	Gn	Gd-Gn	Lt Bn	Lt Gy	Gy-Bn	Lt Tn	High yields expected.
	Landsat Appearance	Bt Gn	NA	NA	NA	NA	Rd	NA	NA	NA	NA	NA	NA	NA	Lt Gn	Bt Gn	NA	NA	NA	NA	NA	
Rice 23	Crop Stage*	0	1.0	1.2	2.1	3.0	3.5	3.7	4.0	4.0	5.0	6.0	7.0	2.3	4.0	4.1	4.5	7.0	7.0	7.0	7.0	Followed expected planting and harvest dates.
	Plant Height (")	0	0	4	7	10-12	26	28	29	40	41	41	12	12	30	34	36	12-18	18	18	18	
	% Ground Cover	0	0	10	30	70-90	100	100	100	100	100	100	50	60	80	80	80	60	60	60	60	Excellent looking crop.
	Photo Appearance	Gy	Bn	Gn-Bn	Gn	NA	Gn	Gn	Gn	Gn	Lt Gd	Tn	Bn	Gn	Gn	Gn	Gd-Gn	Lt Bn	Lt Bn	Lt Bn	Lt Tn	High yields expected.
	Landsat Appearance	Gn	NA	NA	NA	NA	Rd	NA	NA	NA	NA	NA	NA	NA	Bt Rd	Gn-Rd	NA	NA	NA	NA	NA	

*Crop stages are described in appendix D.

Codes describing photo appearance and Landsat appearance:

Bn = Brown Bk = Dark Gy = Gray Pk = Pink Wt = White
Bl = Blue Gd = Gold Lt = Light Rd = Red Yl = Yellow
Bt = Bright Gn = Green NA = Not available Tn = Tan

TABLE C-1.- Continued.

(d) Sorghum

Observation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Observation Date		3-9	3-30	4-16	5-4	5-22	6-8	6-18	6-27	7-6	7-16	7-25	8-2	8-20	9-7	9-25	10-4	10-23	10-31	11-9	11-19	1979 Crop Year
Crop and Field #	Descriptor	Observations																				Comments
Sorghum 3	Crop Stage*	0	1.0	1.7	2.5	2.5	2.7	3.5	3.6	4.2	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Excellent crop in appearance - high yields expected.
	Plant Height (")	0	0	3	12	18	36	42-48	50	50	50	50	0	0	0	0	0	0	0	0	0	
	% Ground Cover	0	0	5	10-15	50	95	99	100	100	100	95-100	0	0	5	80	80	0	0	0	0	
	Photo Appearance	Dk Bn	NA	Bn	NA	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Lt Bn	Bn	Bn	Gn	Gn	Dk Bn	Dk Bn	Bn	Bn	
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Dk Rd	NA	NA	NA	NA	NA	NA	NA	Dk Gn	Dk Gn	NA	NA	NA	NA	NA	
Sorghum 8	Crop Stage*	0	1.0	1.8	2.5	2.5	3.2	3.5	3.9	4.5	4.6	5.5	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Excellent crop in appearance - high yields expected.
	Plant Height (")	0	0	3	12-18	24	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	
	% Ground Cover	0	0	0	30-40	90	95-99	99	100	100	100	95-100	100	0	5	70	30	0	0	0	0	
	Photo Appearance	Gy-Bn	NA	Dk-Gy	NA	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Bn	Gy-Bn	Gn	Bn	Dk Bn	Bn-Gy	Bn-Gy	Bn	
	Landsat Appearance	Dk Bn	NA	NA	NA	NA	Dk Rd	NA	NA	NA	NA	NA	NA	NA	Dk Gn	Bn-Rd	NA	NA	NA	NA	NA	
Sorghum 12	Crop Stage*	0	0	0	0	0	1.7	2.4	2.8	3.0	3.5	3.8	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	Crop planted 2 months later than expected. Would not have been interpreted as sorghum on Landsat imagery. Lower yields expected.
	Plant Height (")	0	0	0	0	0	15-17	24	35	42	47	47	48	52	0	0	0	0	0	0	0	
	% Ground Cover	0	0	0	0	0	20	40	90	99	99	100	100	100	0	0	0	0	0	0	0	
	Photo Appearance	Bn-Gy	Dk Gy	Dk Bn	NA	Dk Gy	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Bn	Bn-Gn	Bn-Gn	Dk Bn	Dk Bn	Dk Tn	Dk Bn	
	Landsat Appearance	Dk Gn	NA	NA	NA	NA	Dk Gn	NA	NA	NA	NA	NA	NA	NA	Dk Gn	Dk Gn	NA	NA	NA	NA	NA	

*Crop stages are described in appendix D.

Codes describing photo appearance and Landsat appearance:

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Bt = Bright Gn = Green NA = Not available Tn = Tan

TABLE C-1.- Concluded.

(e) Soybeans

Observation		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Observation Date		3-9	3-30	4-16	5-4	5-22	6-8	6-18	6-27	7-6	7-16	7-25	8-2	8-20	9-7	9-25	10-4	10-23	10-31	11-9	11-19	1979 Crop Year
Crop and Field #	Descriptor	Observations																				Comments
Soybeans 15	Crop Stage*	0	0	0	0	0	2.0	2.2	2.3	2.5	2.7	2.8	2.8	3.0	4.0	4.0	5.0	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Planted in rows. Army worms devastated outside perimeter of field. Low yields expected.
	Plant Height (")	0	0	0	0	0	10	16-18	25	32	40	40	42	42	42	42	42	0	0	0	0	
	% Ground Cover	0	0	0	0	0	15	30	50	70	90	100	100	100	100	100	100	0	0	0	0	
	Photo Appearance	NA	NA	NA	NA	Gy-Bn	Gy-Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn-Bn	Gn-Bn	Gn-Bn	Bn	
	Landsat Appearance	Lt Gn	NA	NA	NA	NA	Gn-Bl	NA	NA	NA	NA	NA	NA	NA	Rd	Rd-Bn	NA	NA	NA	NA	NA	
Soybeans 24	Crop Stage*	0	0	0	0	0	1.7	1.9	2.0	2.1	2.4	2.7	2.7	3.0	4.0	4.5	4.5	6.0	6.0	6.0	6.0	Followed expected planting and harvest dates. Good crop and moderate yields expected. Planted with drill.
	Plant Height (")	0	0	0	0	0	4	7	11	12	20	33	38	38	38	36	36	0	0	0	0	
	% Ground Cover	0	0	0	0	0	<5	10	25	70	100	100	100	100	100	100	100	0	0	0	0	
	Photo Appearance	Lt Gn	Gy-Bn	NA	NA	Gy-Bn	Gn-Gy	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Gn	Lt Bn	Lt Bn	Lt Bn	Lt Bn	
	Landsat Appearance	Rd	NA	NA	NA	NA	Wt	NA	NA	NA	NA	NA	NA	NA	Bt Rd	Dk Rd	NA	NA	NA	NA	NA	

*Crop stages are described in appendix B.

Codes describing photo appearance and Landsat appearance:

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Bl = Blue Gd = Gold Lt = Light Rd = Red Yl = Yellow
Bt = Bright Gn = Green NA = Not available Tn = Tan

APPENDIX D

CROP GROWTH STAGES

APPENDIX D

CROP GROWTH STAGES

The following table defines the stages of growth for each of the crops observed in Wharton County, Texas during the 1979 study.

TABLE D-1.- GROWTH STAGES

Crop	Growth stage	
	Code	Description
Corn	1.0	Planting
	1.5	Emerged
	2.0	Leaf development, 8 leaves
	2.5	6 weeks, 12 leaves
	3.0	Tasseling, 8 weeks, 16 leaves
	3.2	9 weeks, 18 leaves
	3.4	Silk, 9 to 10 weeks, pollen shedding
	3.7	Seed development
	3.8	Dough stage
	4.0	Beginning to dent
	4.2	Denting
	4.5	Full dent
	5.0	Physiological maturity
	5.5	Dry mature
	6.0	Postharvest
Cotton	1.0	Planting
	2.0	Emergence
	2.2	2 leaves
	2.4	4 leaves
	2.6	6 leaves
	2.8	8 leaves
	2.10	10 leaves
	2.12	12 leaves

TABLE D-1.- Continued

Crop	Growth stage	
	Code	Description
Cotton (cont.)	3.0	First square on plant (budding)
	4.0	Blooming
	5.0	First full ball
	6.0	Fully open ball (lent dry)
	6.5	Defoliation
	7.0	Postharvest
	7.5	Stalks cut/plowed under
Rice	1.0	Planting
	2.0	Emergence
	2.1	Early emergence
	2.5	Tillering
	3.0	Jointing
	4.0	Heading
	5.0	Turning
	6.0	Mature/ripe
	7.0	Harvest
Sorghum	1.0	Planting
	2.0	Greening, 5 leaves
	2.5	7 to 10 leaves
	2.6	Flag leaf visible
	2.8	Full grown
	3.0	Half bloom
	3.5	Headed
	4.0	Soft dough
	4.5	Hard dough
	5.0	Mature/ripe
	6.0	Postharvest

TABLE D-1.- Concluded

Crop	Growth stage	
	Code	Description
Soybeans	1.0	Planting
	1.7	Second node emergence
	1.9	Third node
	2.0	Fourth node
	2.5	Beginning to bloom
	2.7	Full bloom
	3.0	Podding
	3.5	Full pod development
	4.0	Full seed
	4.5	Beginning maturity
	5.0	Mature/ripe

APPENDIX E

HISTORIC PLANTING AND HARVEST DATES

APPENDIX E

HISTORIC PLANTING AND HARVEST DATES
FOR CROPS IN WHARTON COUNTY, TEXAS

This table specifies the expected planting and harvest dates, based on historical data, for the observed crops in Wharton County, Texas.

TABLE E-1.- PLANTING AND HARVEST DATES

Crop	Expected dates for —	
	Planting	Harvesting
Corn	February 22 to March 21	August 15 to September 7
Cotton	April 1 to May 1	August 10 to October 15
Rice	March 15 to April 30	July 15 to August 1 and October 1 to November 1
Sorghum	March 10 to April 10	July 15 to August 15
Soybeans	May 1 to June 15	October 15

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