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Paper A 1

IDENTIFICATION OF WINTER WHEAT FROM ERTS-1 IMAGERY

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ABSTRACT: Continuing interpretation of the test area in Finney County, Kansas, has revealed that winter wheat can be successfully identified. This successful identification is based on human recognition of tonal signatures on MSS images. Several different but highly successful interpretation strategies have been employed. These strategies involve the use of both spectral and temporal inputs. Good results have been obtained from a single MSS-5 image acquired at a critical time in the crop cycle (planting). On a test sample of 54,612 acres (22,101 hectares), 89 percent of the acreage was correctly classified as wheat or non-wheat and the estimated wheat acreage (19,516 acres, 7.898 ha.) was 99 percent of the actual acreage of wheat in the sample area.

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Continuing interpretation of ERTS-1 MSS images of Finney County, Kansas, has established that hard red winter wheat may be successfully distinguished from all other crops and cropping conditions by a simple human interpretation technique. This technique was initially developed for irrigated wheat, but has proven applicable to non-irrigated wheat as well. On a test sample of 54,612 acres (22,101 hectares) for which surface observations were available, 89 percent of the acreage was correctly classified as wheat or non-wheat. The error terms conformed to the Central Limit Theorem. The estimate of wheat in this test was 19,516 acres (7,898 ha.), 99 percent of the actual amount of wheat (19,674 A., 7,962 ha.) in the sample. This estimate was based on a single band/time-frame image, MSS-5, acquired September 21 and September 22, 1972. The estimate is therefore based on imagery acquired during the planting period.

The sample analyzed for this report represents 6.5 percent of the land area of Finney County and includes all environmental and agricultural types in the county except for the intensive irrigation area in the northwestern part of the county, where wheat is not a significant component of the landscape. Finney County (Figure 1) was originally selected as a test area because of the magnitude and diversity of agriculture in the county. Most of the 1308 square mile (3,388 sq. km.) area is typical of the large field agricultural system of the winter wheat belt of the Great Plains. However, large areas of rangeland exist in the county and extensive and intensive irrigation is widely practiced. The single most important crop in the county is wheat. In 1971, Finney County ranked third among Kansas counties with wheat production of 6,921,000 bushels (188,326 metric tons). In the same year, the county was among the ten most productive counties in Kansas for sorghum for grain, corn for grain, corn for silage, alfalfa hay, and sugar beets while ranking seventh in number of cattle on farms (Kansas State Board of Agriculture, 1972).

Five sample areas were selected in Finney County in such a way that the areas are readily located on ERTS-1 imagery and all environmental and agricultural types in the county have been included. Surface observations of crop type and condition have been obtained for each field in these test areas. Environmental parameters, principally soil type and topography, have been obtained from the standard soil survey map (USDA, Soil Conservation Service, 1965) and available topographic maps.

Four of the five sample areas were used in this analysis (Figure 1). The fifth sample is located in the small field irrigated area of northwestern Finney County and contains a limited amount of wheat. Samples 1 and 2 represent the part of the county with sandy soils. Most of this area is composed of large irrigated fields. Samples 3A and 3B represent the area with nearly level loamy soils. Most of this area is composed of large non-irrigated fields. Sample 4A represents the area of rolling lands with mostly loamy soils. All cultivation in this area is large-field dryland. Sample 4B represents the area of nearly level clayey soils. Most of this area is large-field dryland cultivation.

To obtain ERTS-1 data for analysis of these samples, a simple human image interpretation technique was employed. The gray scale tablet along the bottom of the image was divided into five steps which the three interpreters, Williams, Coiner and Barker, agreed were distinct and detectable in the image context (Figure 2). A map showing field boundaries and field numbers for each sample area had been previously prepared. The interpreter recorded the apparent tone of each field as perceived by comparison to gray scale tablet. All interpretations were replicated, by all three interpreters in most instances. However, Williams performed the data analysis. To avoid possible bias, after he began the analysis for a given sample area, he took no further image data for that area.

The initial wheat detection experiment was designed on a multi-image basis (Williams, et al, 1973). Tonal data had been taken from four images for sample areas 1 and 2. These images were MSS-5 acquired August 16, September 21, and December 2, and MSS-7 acquired December 2. A decision matrix (scattergram) was constructed for the data from sample area 1 and a wheat/non-wheat boundary was drawn through the decision matrix. This boundary resulted in 93 percent separation of wheat fields from non-wheat fields. Due to partially offsetting errors, the estimated number of wheat fields (47) was 98 percent of the actual number. When this decision boundary was applied to the data from sample area 2, 86 percent of the fields were correctly classified and the estimated number of wheat fields (14) equaled the actual number. However, the method (1) did not appear applicable to the data from Sample Area 4, (2) was cumbersome, and (3) seemed unsuitable for application to large areas. Further analysis of the decision matrix revealed that the MSS-7 image had not contributed to the successful discrimination of any field.

This fact led to the concept of monitoring temporal change as a method of identification. The MSS-5 image acquired December 21, 1972, was added to the data set at this time. Although this method of observing tonal change through time also successfully discriminated wheat, the method was plagued by the same shortcomings as the other multi-image approach.

While the temporal change analysis was in progress, further study of the original decision matrix revealed that most of the wheat/non-wheat separation had been due to a single image, MSS-5 acquired September 21, 1972. Part of the county was cloud covered on that date. However, all cloud covered sample areas were clear on September 22. The cloud free coverage for each test area was used for the interpretation.

The hypothesis under which any binary discrimination is achieved is that the two conditions are more or less distinct in the data space (Figure 3). In the case under consideration, the hypothesis is that wheat fields have lighter tones than non-wheat fields. This conclusion may be confirmed by inspection of the graphs in Figure 3. However, the significant degree of overlap in tone level 3 is obvious. This overlap constitutes a serious error if the tone is assigend to either wheat or non-wheat.

Inspection of the data subdivided according to environmental area (Figure 4) reveals that this serious overlap does not exist in the individual areas. Instead, most fields assigned to tone level 3 are wheat in sample areas 1, 2, and 4B, while most fields assigned to tone level 3 are non-wheat in sample areas 3 and 4A. That is, error is spatially distributed as a function of the spatial distribution of environmental variables.

Based on these spatial results, the following optimum rule for wheat indentification in Finney County, Kansas, was devised: on MSS-5 imagery acquired during the wheat planting period in 1972, all fields with light and medium tones (tone levels 1, 2, and 3) on sandy soils and nearly level clays are wheat and all fields with light tones on nearly level to rolling loamy soils are wheat.

This rule was initially developed for and applied to all fields 80 acres (32 ha.) or larger, because these fields were consistently detectable as discrete entities in the image. The four sample areas contained 377 fields 80 acres or greater in size. These 377 fields contained 54,612 acres (22,101 ha.), for an average size of 145 acres (59 ha.). The accuracies (Table 1) of classification and estimation of wheat were identical for both number of fields and acreage. Eighty-nine percent of all fields and acreages were correctly classified as wheat or non-wheat. The estimated number and acreage of wheat fields was 99 percent of the actual number and acreage. Use of a single classification rule for all sample areas results in slightly decreased accuracy of classification and serious errors in the estimation of wheat acreage. For example, if only fields having tones 1 and 2 are assigned to wheat, the accuracy of the classification is 86 percent but wheat acreage is underestimated by 26 percent. On the other hand, if all fields having tones 1, 2 and 3 are assigned to wheat, the classification accuracy drops to 82 percent and wheat acreage is overestimated by 35 percent.

Fields smaller than 80 acres had been omitted from the initial analysis because (1) they were often hard to separate from adjacent fields, and (2) most of the resolution cells contain boundaries and are, therefore, averages of often disparate tones. However, tones were also assigned for smaller fields in areas 1, 2, and 3A. These areas contained 202 large and 78 small fields. The large fields contained 23,896 acres (9,670 ha.). This acreage was classified with 91 percent accuracy and the wheat acreage estimate was 100 percent correct. The 78 small fields contained only 2,925 acres (1184 ha.). Only 74 percent of this acreage was correctly classified and wheat acreage was overestimated by 13 percent. But when this modest acreage was added to that of the large fields, the resulting acreage classification was still 89 percent accurate and the overestimation of wheat acreage was 2 percent.

Although temporal data were not required for the identification of winter wheat, these data may serve two important roles. The estimates of wheat acreage presented here are estimates of acreage planted and are, therefore, significantly larger than the acreage harvested. In the fall of 1970, 192,000 acres (77,702 ha.) were seeded in Finney County. In June 1971, 189,000 acres (76,488 ha.) were harvested. Although this difference was small, the amount of wheat destroyed is quite variable from year to year and must be removed from the original acreage estimate. Furthermore, temporal data may provide information on the state of the crop. For example, tones of wheat fields are highly variable on MSS-5 images acquired in December. This variability is an indication of the degree of fall growth, which varies greatly from one field to another. This tonal variability makes identification of wheat very difficult, but, if a field has already been identified as wheat, the variability provides useful data on the state of the crop in that field.

The results presented here demonstrate that a simple method for winter wheat identification may be developed given an adequate prior knowledge of local environment and crop cycle. The method appears to be applicable to other crops if suitable distinct crop cycle events may be defined. Knowledge of the local environment is critical if the interpretation is to be successfully conducted. Components of the local environment data set can be taken directly from the ERTS-1 imagery (Williams and Coiner, 1973) but other components are best developed at the local level. Furthermore, surface observations for a small number of fields from each environmental area would be a necessity. The necessity for (1) surface observation, (2) knowledge of the local environment, (3) knowledge of local crop cycles, and (4) the modest amount of equipment and training required to perform these interpretations make this method suitable for implementation at the local (county) level.

REFERENCES:

ERTS-1 Imagery

DATE	FRAME NUMBER	SCALE	QUALITY
8-16-72	1024-16511-5	1:1,000,000	Excellent
9-21-72	1060-16512-5	1:1,000,000	Good, partial haze cover
9-22-72	1061-16564-5	1:3,300,000	Good
9-22-72	1061-16570-5	1:3,300,000	Good
12-2-72	1132-16514-5	1:1,000,000	Good
12-2-72	1132-16514-7	1:1,000,000	Good
12-21-72	1151-16572-5	1:1,000,000	Good
12-21-72	1151-16575-5	1:1,000,000	Good

Reports:

Kansas State Board of Agriculture. 1972. Farm Facts, 1971-1972. Topeka, Kansas: Kansas State Printer.

U.S.D.A., Soil Conservation Service. 1965. Soil Survey, Finney County, Kansas. Washington: Government Printing Office.

Williams, Donald L., and Jerry C. Coiner. 1973. Land Use Map, Finney County, Kansas. Center for Research, Inc. CRINC - DIIR 2264-3.

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TABLE 1: Contigency table for discrimination of wheat from non-wheat fields ≥ 80 acres, all test areas, Finney County, Kansas, September 21, 22, 1972.

Rule: Field is wheat (areas 1, 2, 4B) if tone is ≤ 3
Field is wheat (areas 3, 4A) if tone is ≤ 2

	Number of fields assigned		Acres assigned	
	wheat	non-wheat	wheat	non-wheat
Actual wheat	140	22	16,710	2,964
Actual non-wheat	20	195	2,806	32,132

Total = 377 fields
Accuracy of Assignment = 89%
Accuracy of estimation wheat = 99%

Total = 54,612 acres
Accuracy of Assignment = 89%
Accuracy of estimation of wheat acreage = 99%

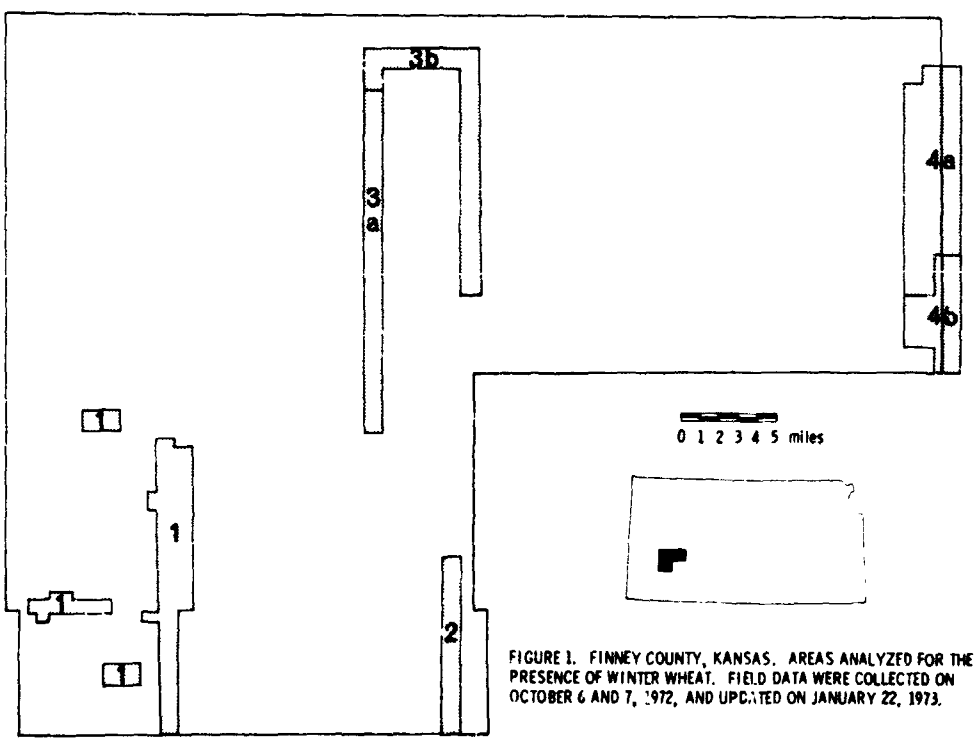

FIGURE 1. FINNEY COUNTY, KANSAS. AREAS ANALYZED FOR THE PRESENCE OF WINTER WHEAT. FIELD DATA WERE COLLECTED ON OCTOBER 6 AND 7, 1972, AND UPDATED ON JANUARY 22, 1973.

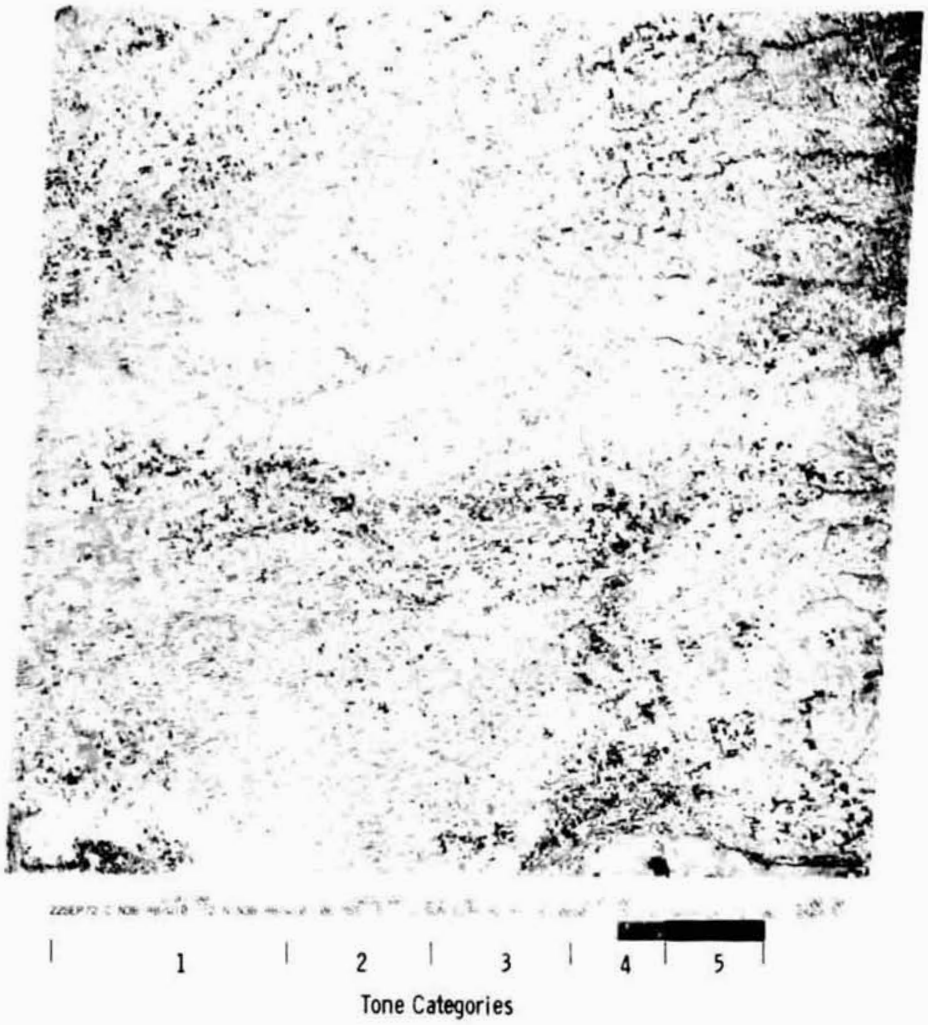

Figure 2. ERTS-1 MSS-5 image acquired September 22, 1972. Part of Finney County, Kansas, is in the southeast corner of this image.

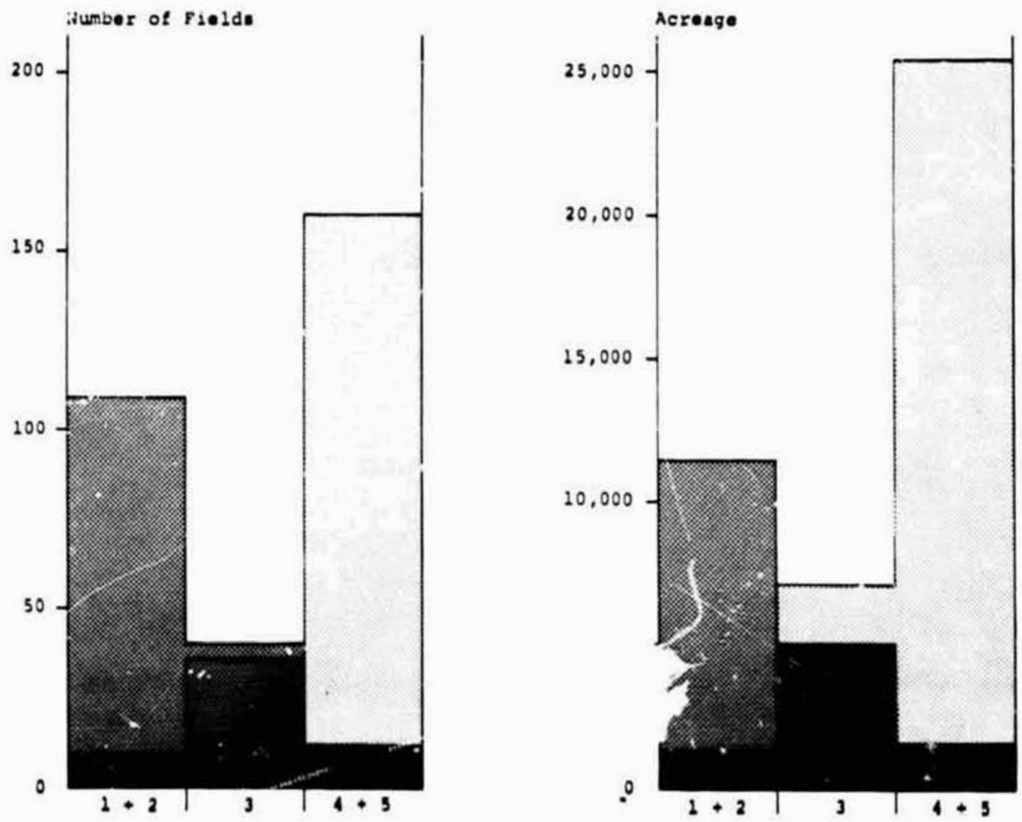

Figure 3. Frequency with which MSS-5 image tones were associated with wheat and non-wheat field conditions in Finney County, Kansas, September 21 and 22, 1972.

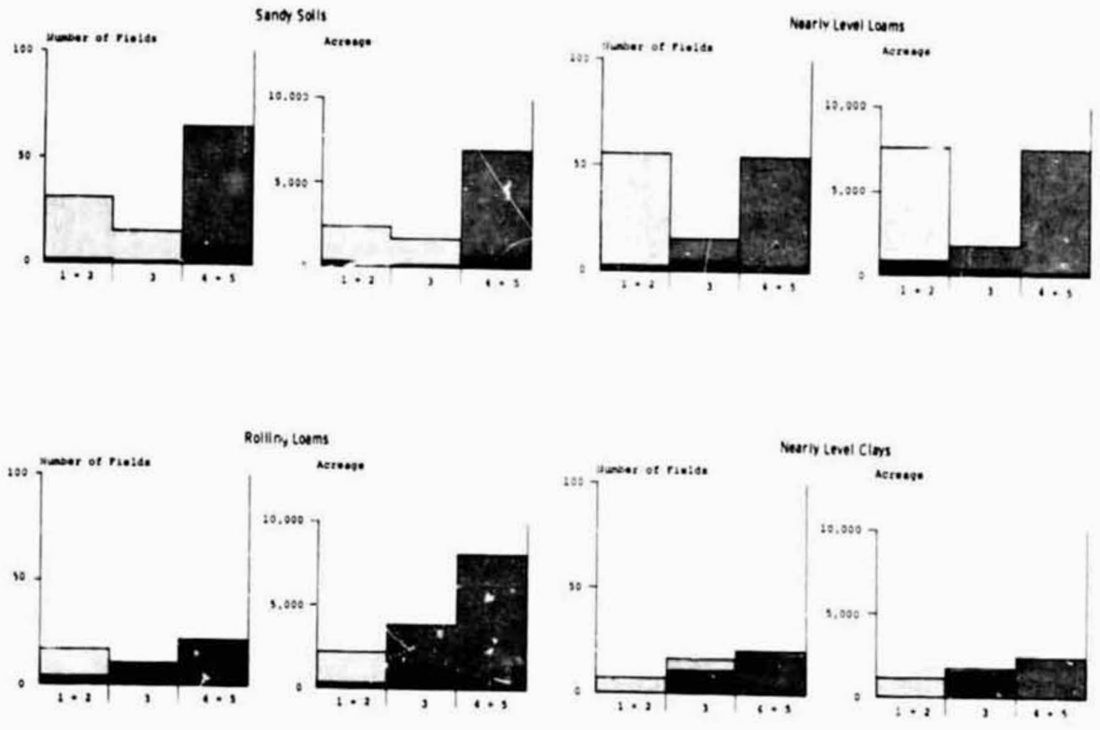

Figure 4. Frequency with which MSS-5 image tones were associated with wheat and non-wheat field conditions in Finney County, Kansas, September 21 and 22, 1972, as a function of soil and landform types.