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CENTER PIVOT IRRIGATION IN FINNEY COUNTY, KANSAS: AN ERTS-1 INTERPRETATION PROCEDURE

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ABSTRACT

ERTS-1 images were used to map the distribution of center pivot sprinkler irrigation systems in Finney County, Kansas. This recently developed irrigation system is rapidly increasing in importance throughout the Great Plains of North America. In Finney County, 83 new systems were installed between June 1971 and September 1972. By the latter date 327 systems were in operation irrigating 40,527 acres. Conventional statistics are not available for this irrigation system but ERTS-1 imagery may be effectively used to provide data on the distribution of the system. This paper describes a procedure which may be used to obtain these data.

INTRODUCTION

Center pivot sprinkler irrigation is a recent innovation in the repertoire of agricultural practices in the Great Plains of North America. The system has already been recognized as creating a unique pattern on aerial photographs (1). Preliminary analysis of ERTS-1 imagery of southwestern Kansas indicated that the same unique pattern is readily interpretable from multispectral images procured at orbital altitudes. Since the diffusion of this innovation is known to be extremely dynamic, mapping of the system was undertaken on a test basis in Finney County, Kansas. Finney County was selected because of the importance of center pivot irrigation in this area and the availability of conventional imagery and surface observations.

Center pivot irrigation is a relatively simple and efficient water application procedure (Figure 1). The system operates in the following manner. Water is delivered through a pipe in the center of the field. A horizontal pipe suspended from steel towers is connected to the central pipe. Sprinklers are then attached at intervals along the horizontal pipe and the volume of each sprinkler individually set so that all parts of the field receive an equal application of water. The steel towers are equipped with wheels

Figure 1. Center pivot sprinkler system in operation, southern Finney County, Kansas, 6 October 1972. Forage corn had been harvested from this field and winter wheat, being grown for winter grazing, had just emerged. This field is on undulating loamy fine sand.

and are mechanically propelled around the central "pivot" pipe. Liquid fertilizer is applied by mixing with the water passing through the central pipe. The system therefore irrigates a circle in an agricultural region where fields are normally rectilinear. The term system, as it is being used here, refers to a pivot sprinkler irrigated field and not to the irrigation equipment itself. One equipment unit is often used in two adjacent fields and transported by tractor between those fields by turning the wheels parallel to the horizontal pipe.

Four sizes of systems are currently being used in Finney County (Table 1). Ninety-five per cent of all systems have the 1320-foot pipe. This system creates a circle with a diameter of one-half mile.

LOCATION AND USE

Sprinkler irrigation is especially effective on sloping or undulating terrain and porous soils. The horizontal pipes of center pivot systems are quite flexible and operate even over sand dunes with 10 feet or more vertical relief within the field. Since water is applied directly to all parts of the field, high permeability rates do not adversely affect water distribution. In contrast, flood irrigation requires level land (natural or man-made) and sufficiently slow permeability to permit water to flow the length of the field.

In Finney County, 71.4 per cent of all center pivot systems are located on undulating and sandy soils, an increase of 4.2 per cent from 1971 (Table 2). In the past year 57 systems have been installed on soils not considered suitable for any type of cultivation in 1965 (2).

Corn is the crop most extensively produced under center pivot irrigation in Finney County (Table 3). Wheat, grain sorghum, and pasture are also important crops in this land use system. Double cropping is also being practiced to a limited extent. After the forage corn crop is harvested, wheat is planted for winter pasture. In the Spring, the wheat is cultivated to enrich the soil and the field is again planted to corn.

INTERPRETATION OF ERTS-1 IMAGES

Shape was the sole criterion used in mapping center pivot fields (Figure 2). Tone was not useful because it varied from white to black, depending on the state of the vegetation in the field. The size of the system was determined by the apparent diameter

TABLE 1.

SIZE OF CENTER PIVOT IRRIGATION SYSTEMS
INSTALLED IN FINNEY COUNTY, KANSAS

Qualitative Size	Length of Horizontal Pipe (feet/meters)	Area Irrigated (Acres)	Area of Corners not Irrigated (Acres)	Apparent Diameter of Circular Field on 9.5 inch ERTS-1 Image (in/mm)
Large	1650/500	196	54	0.039/1.0
Normal	1320/400	126	34	0.031/0.8
Small	990/300	71	19	0.024/0.6
Very Small	660/200	31	9	0.016/0.4

TABLE 2.

DISTRIBUTION OF CENTER PIVOT SYSTEMS BY SOIL TYPE, 1972. SOIL TYPES ARE GENERALIZED FROM (2).

Soil Type	Slope	Percent of Previously Installed Center Pivots	Percent of New Center Pivots	Percent of All Center Pivots
Loamy fine sand	Undulating	28.3	51.8	34.3
Loam and fine sandy loam	Undulating	31.2	17.6	27.7
Loam and silt loam	0-1%	23.1	12.9	20.5
Fine sand	Undulating	7.7	14.1	9.3
Saline soils	0-3%	4.4	2.4	3.9
Silt loam	1-5%	4.0	1.2	3.3
Clay soils	0-1%	1.2	0.0	0.9

TABLE 3.

USE OF CENTER PIVOT IRRIGATED FIELDS, FINNEY COUNTY, KANSAS. BASED ON FIELD DATA COLLECTED 6 AND 7 OCTOBER 1972, FOR A SAMPLE OF 117 CENTER PIVOT FIELDS.

Crop	Number of Fields
Corn	57
Wheat	26
Grain Sorghum	13
Corn and Wheat, double cropped	7
Pasture	6
Volunteer Wheat	4
Alfalfa	3
Forage Sorghum	1

Figure 2. ERTS-1 image of southern Finney County, Kansas. The distinctly circular fields are center pivot irrigated. Notice the particular concentration of such fields in the northwestern part of the image. These fields are located in a grassy sand dune area which has been newly opened to cultivation by the advent of this irrigation system. Dark tones on this positive are associated with corn and grain sorghum and light tones with nearly bare ground. This enlargement of part of an MSS-5 image has an approximate scale of 1:330,000. The image (1061-16570-5) was obtained 22 September 1972.

of the circle on the image (Table 1). Actual length of the pipe and area irrigated were measured from the 1971 aerial photographs. The ERTS-1 system corrected red light band images (MSS-5) for three dates (29 July and 21 and 22 September 1972) were used. These images had the greatest agricultural scene contrast and sharpest boundary definition of any acquired bands. Approximately 97 per cent of all circular fields identified were detectable on each MSS-5 image examined. However, each image contributed fields which were not detectable on the other two coverage dates. Infrared images (MSS-7) were supplementally employed in locating reference landmarks in the image. The images were examined under variable (7X to 30X) magnification. As circular fields were identified, their location was recorded on a base map containing the reference landmarks. One of us compiled the map and the other checked the work.

Two interpretation strategies were employed. First, a map was prepared without any prior knowledge of the location of center pivot fields. Second, a map was prepared with knowledge of the location of such fields in 1971. This knowledge had been derived from conventional aerial photographs. Comparisons of change were made with reference to that map which showed 248 pivot sprinkler systems irrigating 30,583 acres. The first ERTS-1 map (Figure 3) shows 270 pivot sprinkler fields with 34,065 acres under irrigation. The net increase of 22 fields and 2772 acres conceals 61 center pivot systems which were present in 1971 but which were not identified on the ERTS image. Of these, 10 were in the small and very small categories. Field checks in October 1972 established that four of the normal-sized fields had not been used in 1972. Therefore, the actual underestimation was 47 fields, or 19.7 per cent, in the primary size class. By referring to the data collected by a field party on 6 and 7 October 1972, some of the causes for non-identification can be listed as: (1) square field cropping with the sprinkler irrigating the center of the field, (2) irrigated pastures, (3) large weeds in the non-irrigated corners, (4) more than one crop being grown within the irrigated area, (5) overlapping areas of sprinklers, and (6) lack of awareness of the existence of the smaller sized systems. Examination of images of several dates should eliminate most occurrences of the first three problems since the center of the field will be darker than corners if it has been recently irrigated. With increasing experience, the interpreter will be able to reduce errors caused by the last three problems. Although it is possible that some of the newly identified circular fields are not center pivot irrigated, the field party did not find any misidentifications while checking about 60 per cent of these newly identified fields. Therefore, we conclude that, while a small error of overestimation may exist, it is substantially smaller than the established error of underestimation.

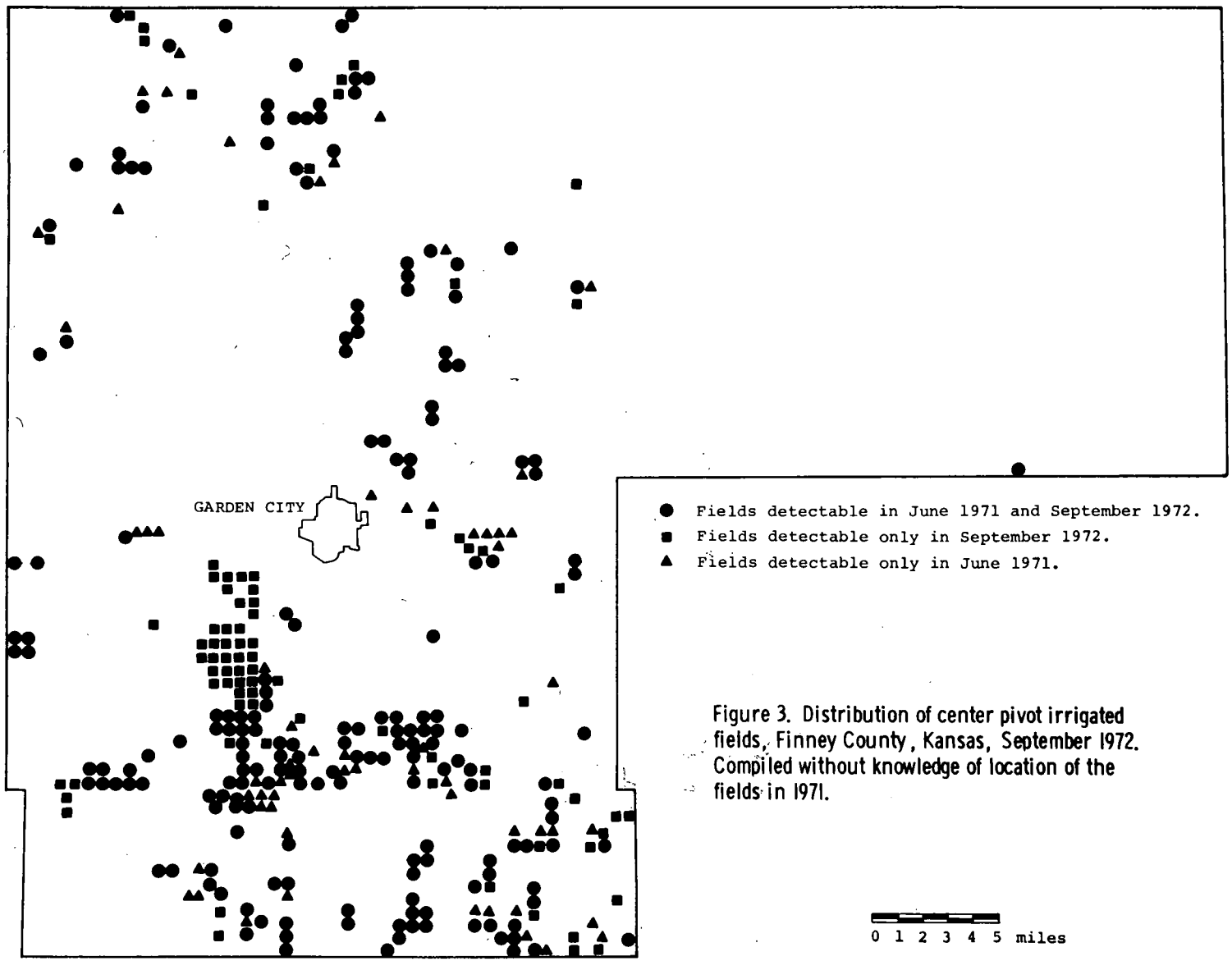

Figure 3. Distribution of center pivot irrigated fields, Finney County, Kansas, September 1972. Compiled without knowledge of location of the fields in 1971.

The second map (Figure 4) was plotted on a base map showing the 1971 locations of fields. The map shows a total of 331 center pivot fields with 41,031 acres under irrigation. This map includes all large, small, and very small fields that were present in 1971. Of the normal-sized fields present in 1971, fourteen were not detected on the ERTS images. Of these, four were not in use and the other ten were being cropped as square fields but irrigated as circular fields. Therefore, 327 center pivot fields with 40,527 acres under irrigation were operational in Finney County in September 1972. This represents an absolute increase of not less than 83 center pivots installed between June 1971 and September 1972. The underestimation term on new systems is the error term associated with detection without prior knowledge. Therefore, the number of new normal-sized systems may be as high as 103. The fact that some underestimation of new systems does occur was verified by the field party, which mapped one new system that has not been detected on the ERTS images.

CONCLUSIONS

Center pivot irrigation is a rapidly expanding innovation in the Great Plains. ERTS-1 imagery may be effectively used to monitor the location and expansion of this system. The results of this analysis differ sharply from a recent study of center pivots conducted by traditional data collection methods, specifically data collected by letter from county agents (3). In that study, the estimate for Finney County was 200 systems, compared to 327 systems interpreted from ERTS-1 imagery. Accurate statistics on the use of center pivot irrigation are not available through conventional channels because most of the crop production on these fields is not subject to government regulation. Analysis of ERTS-1 images can provide timely and accurate statistics on the use of this irrigation system.

IMAGERY REFERENCES

Date	Agency	Mission Number	Frame Number	Scale	Quality
9/22/72	NASA	ERTS-1	1061-16570-5	1:3,300,000	Good
9/22/72	NASA	ERTS-1	1061-16564-5	1:3,300,000	Good
9/21/72	NASA	ERTS-1	1060-16512-5	1:1,000,000	Good, partial haze cover
7/29/72	NASA	ERTS-1	1006-16511-5	1:1,000,000	Good, partial cloud cover
7/7/71	USDA	CDA-2MM	1-9, 16-26	1:64,000	Good
6/24/71	USDA	CDA-1MM	9-180, 199-209	1:64,000	Good

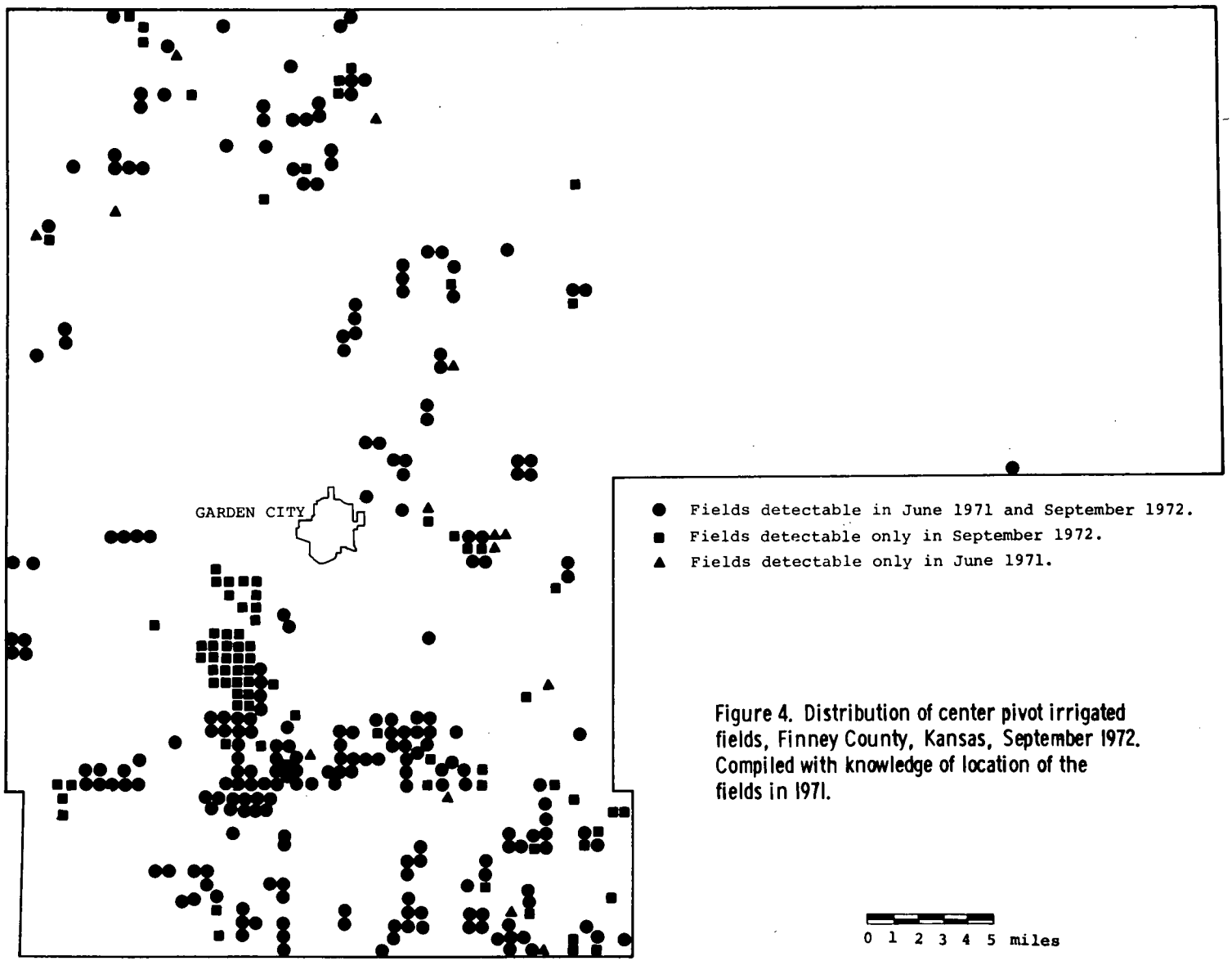

Figure 4. Distribution of center pivot irrigated fields, Finney County, Kansas, September 1972. Compiled with knowledge of location of the fields in 1971.

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(1) Photogrammetric Engineering 34(4), cover photograph. 1968.

(2) U.S.D.A. Soil Conservation Service. Soil Survey, Finney County, Kansas. Series 1961, no. 30. 1965.

(3) Chapman, Frank. 1972. Center Pivot Irrigation Systems, Paper read before Great Plains/Rocky Mountain Division, Association of American Geographers, Annual Meeting.

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