PREPARATION OF URBAN LAND USE INVENTORIES BY MACHINE-PROCESSING OF ERTS MSS DATA

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ABSTRACT

Spectral classes of urban phenomena identified from Earth Resources Technology Satellite (ERTS) multispectral scanner data in Milwaukee included "Suburban", "Inner City", "Industry", "Grassy" (open area), "Road", "Wooded Suburb", "Water", "Cloud", and "Shadow". The Milwaukee spectral class statistics were used to classify the Chicago area, within the same ERTS frame, and similar results were achieved. In another ERTS frame, Marion County (Indianapolis) data were classified into similar classes. The Marion County ERTS study was supported by a land use classification of an area near downtown Indianapolis that utilized 12-band MSS data collected by aircraft from 3000 feet. The results of the ERTS analyses suggest that satellite data will be a useful tool for the urban planner for monitoring urban land use.

1. GENERAL DISCUSSION

The Milwaukee County Subframe

Land use information systems are becoming increasingly important to investigators interested in large urban complexes. On August 9, 1972 ERTS passed over a large area in the Midwest, including portions of northern Illinois and southern Wisconsin. The Milwaukee County subframe was chosen to assess the utility of ERTS data for urban land use studies.

Four bands (4,5,6,7) of ERTS multispectral, digitized data were analyzed by computer programs developed at the Laboratory for Applications of Remote Sensing (LARS)[1]. Initially, the data were examined on a digital imaging display (e.g. Fig. 1-A, Fig. 1-B). Significant amounts of information may be learned by studying gray scale band images but their primary purpose was for orientation. The major effort was directed toward obtaining a land use classification of the county from analysis of the four bands of ERTS MSS data.

The nonsupervised clustering algorithm ($NSCLAS) was used to disect the data into the most spectrally separable classes, using all four bands of data. Statistics were calculated for the clusters delimited, using a maximum likelihood classifier ($CLASS), and the results displayed by a line printer with different alphanumeric symbols for each class ($DISPLAY).

[1] T. L. Phillips, (Editor), LARSYS Users Manual, (West Lafayette, Indiana, Laboratory for Applications of Remote Sensing, Purdue University, 1973).

Most of the classes of ground cover types delineated by $NSCLAS were not adequately representative of the land use in the county. Thus, it was necessary to train the computer manually to recognize many earth surface features. Only one class chosen by $NSCLAS, representing grassy, open areas, was retained. Its field coordinate cards were combined with those chosen manually for other classes. As before, the $STAT, $CLASS, and $DISPLAY programs were used to classify the study area. Finally, the $PHOTO program was used to display and photograph the classification results from the digital display. Table 1 lists the spectral reflectance of the classes and the gray levels used for display.

In the classification results (Fig. 1-C) the white area in the central part of the study area, which contains Milwaukee's Central Business District, has a very high reflectance in the visible bands. The principal component of this class is concrete while rooftops are secondary features. This class, termed "Road", occurs also as Interstate highways and sandy beaches along Lake Michigan.

The first ring outward from the Central Business District, appearing black, is termed "Inner City". A majority of the homes in this area are the bungalow or "two-flat" type of structure, housing two or more families, and were usually built prior to 1940. Rooftops and roads are the primary constituents of this class while green vegetation is a secondary component.

The class "Industry" (dark gray) was identified only where the larger areas of heavy industry predominate. Two very large industrial regions were identified, which together form an L-shaped region located just south of the Central Business District. One region is in the Menomonee River Valley and the other in the Kinnickinnick River Valley. Rooftops are the primary, and roads are the secondary components of this class.

The ring north, west, and south of the "Inner City" is an area of complex land uses. The three primary cover types in this area are "Suburban", "Grass", and "Wooded Suburb". Most of this ring is classified as suburban (shown as white) and includes the outer areas of the City of Milwaukee, northern Wauwatosa, West Allis, and other suburbs within Milwaukee County. "Suburb" consists primarily of single-family, middle-income residences built after World War II which are characterized by a complex mixture of roads, rooftops, and green vegetation. The areas of the class "Wooded Suburb" (very light gray) are southern Wauwatosa, Fox Point, Whitefish Bay, and Shorewood which comprise the older upper income sectors of Milwaukee County. Green vegetation is the primary component of this class. Finally, the class "Grass" (very dark gray) manifests itself in this ring in the parks, golf courses, and cemeteries. Most of the outer areas of the county were classified as "Grass". A problem in the classification of this area was the misclassification of newer, upper-income areas as "Grass".

Five classes of water were identified within the study area, four of which are located almost exclusively in Lake Michigan. There is a regu-

lar succession of water classes eastward (Fig. 1-C), suggesting that the various classes of water are indicators of depth. However, reference to U.S. Geological Survey topographic quadrangles shows only slight association between the spectral classes of water and depth of water.

The fifth class of water ("Water 4") occurs in small water bodies and in the Milwaukee River. This class also appears in Milwaukee Harbor (inside the breakwater) and to the south along the coast. Factors influencing the spectral differences in water may be color, turbidity, and clarity.

Several small cumulus clouds were identified within the study area; these are located in the southern part of Milwaukee County and are displayed as white (level 16). The cloud shadows are displayed as black (level 1).

Chicago Subframe

Analysis of the Chicago subframe was undertaken to determine if the spectrally separable classes which were used to classify urban land use successfully in one metropolitan area could produce satisfactory results in another metropolitan area, within the same ERTS frame.

Images representing spectral data of Chicago from bands 5 (Fig. 2-A) and 7 (Fig. 2-B) were produced, using the same histograms generated for use in the Milwaukee area. The Chicago spectral data were analyzed by applying the $CLASS through $PHOTO sequence of computer programs, using the same $STAT deck of computer cards as used in the Milwaukee study. Chicago classification results were similar to those of Milwaukee (Fig. 2-C). The same gray levels were used for both urban classifications.

The first major ring of land use outward from the Central Business District was classified as "Inner City". This area includes most of the city of Chicago, Cicero, Berwyn, and Blue Island. Larger parks, cemeteries and large industrial areas were identified within this ring.

The next ring outward includes large areas of the classes "Suburb" and "Wooded Suburb". The larger areas of "Suburb" are found in the municipalities of Oak Lawn, Hodgkins, Norridge, Harwood Heights, and Morton Grove. Four major regions of the class "Wooded Suburb" appeared: (1) the Glencoe, Wilmette, Evanston area along Lake Michigan; (2) the suburban agglomeration south of O'Hare Airport including Oak Park, Elmhurst, Lombard, and Wheaton; (3) the suburban agglomeration to the south of the second, including Hinsdale and Downers Grove; and (4) an area in Chicago bounded by the Dan Ryan Woods on the north, 119th Street on the south, Beverly Street and Vincennes on the east, and Western Avenue on the west.

The classes "Cloud" and "Shadow" were identified in the northwestern part of the Chicago area, north of O'Hare Airport.

A problem in the Chicago classification arose in the central, older part of the urbanized area, most of which was classified as "Inner City". Too many data points within this area were classified as "Industry"

suggesting that yet another type of residential area exists in Chicago, which is not found in Milwaukee. It is speculated that such residential areas are largely void of vegetation and consist mainly of rooftops and roads.

Marion County (Indianapolis) Subframe

In another ERTS frame (pass of Sept. 30, 1972), similar spectral classes were obtained for the Indianapolis area, using the same procedures of analysis developed for the Milwaukee area. Initially, the nonsupervised ($NSCLAS) method of classification was implemented followed by the manual, or, supervised approach. Classification results are presented in Figure 3-A, and Table 2 lists the mean reflectance of classes and the gray levels used in the figure.

Whereas a class for heavy industry was obtained in the Milwaukee area, a general class of heavy industry/commerce was developed (shown as medium gray) for Indianapolis. This class includes the Central Business District. As in Milwaukee, the class "Suburban" was developed for Indianapolis. Areas in this class are located on the eastern and western flanks of Interstate 465.

In the Milwaukee study, a class "Wooded Suburb" was obtained, but a more general class "Wooded" was used in Indianapolis. Areas around the city's reservoirs and certain upper income areas near Meridian Hills and to the east were classified as "Wooded". Only one class of "Water" was developed which was represented by the primary water bodies of Geist and Eagle Creek Reservoirs. Several small cumulus clouds and their shadows were identified within the county.

A problem in the classification arose in some locations between "Suburb" and "Inner City". Areas in these classes were misclassified frequently as "Grassy" (open) or "Wooded". Apparently, the distinction between the "Suburban" and "Inner City" is not as well defined as in Milwaukee.

Supporting the Indianapolis ERTS study was an analysis of 12-band multispectral scanner data collected by aircraft from 2000 ft. over a portion of the West Fork White River near downtown Indianapolis. The same procedure of analysis was used as in Milwaukee, Chicago, and Marion County except that only four of the twelve bands (#2, .46-.49μm; #6, .55-.60μm; #10, 1.0-1.4μm; #12, 9.3-11.7μm) were used to classify the study area. Table 3 lists the mean reflectance and gray levels used in the three photos of the classification. Fig. 3-B shows the general classes of earth surface features. The classes, from darkest to lightest, are "Water", "Bare Soil", "Road", "Fine Grass", "Coarse Grass", "Trees", and "Rooftops". Fig. 3-C shows the variations in cultural features. All natural features are displayed by one gray-tone, while the two classes of "Road" and three of "Rooftop" are given varying graytones. Fig. 3-D shows the variation in natural features. All cultural features are one graytone, while "Trees", two classes of "Coarse Grass", and two classes of "Fine Grass" vary in graytone.

CONCLUSIONS

Machine processing of ERTS MSS data in urban areas has produced spectral classes which may be of value to the urban planner. Looking toward the future, timely processing of such data could result in quick updating of land use inventories. The Chicago results indicate that a careful analysis of one urban area can provide valuable information for other urban areas, with no a priori knowledge. It is not unreasonable to forecast the development of statistics, taking into account seasonal variations, which may be used to classify automatically many urban areas.

RELATIVE MEAN REFLECTANCE AND GRAY LEVELS USED FOR DISPLAY OF SPECTRAL CLASSES

Table 1. Milwaukee (ERTS)

	Bd. 4	Bd. 5	Bd. 6	Bd. 7	Level[1]
Water 1	35.20	21.41	9.94	1.49	5
Water 2	24.23	10.37	5.40	0.69	3
Water 3	19.71	9.42	5.86	1.10	1
Water 4	21.47	13.85	12.65	3.34	1
Water 5	46.83	46.50	23.83	2.83	14
Grass 1	27.01	19.88	53.16	31.35	6
Grass 2	24.03	16.25	44.18	26.59	6
Road	47.42	48.26	46.84	20.16	16
Wood Sub.	24.94	18.66	40.24	22.91	10
Inner City	30.16	25.97	34.59	16.53	1
Suburban	39.17	37.09	53.12	26.99	16
Industry	25.98	21.77	21.30	8.50	8
Cloud	71.55	69.50	89.07	44.38	16
Shadow	17.70	9.45	16.15	6.75	1

Table 2. Indianapolis (ERTS)

	Bd. 4	Bd. 5	Bd. 6	Bd. 7	Level[1]
Commerce	34.28	30.70	28.17	11.88	8
Inner City	24.01	17.04	26.18	14.09	1
Suburban	31.87	25.82	41.07	22.51	16
Grassy	23.65	17.33	34.69	20.36	5
Wooded	19.79	12.01	32.95	21.10	11
Water	22.64	13.73	8.24	1.37	1
Cloud	82.41	78.88	85.08	41.17	16
Shadow	16.49	8.46	9.46	3.31	1

Table 3. Indianapolis (2000 Feet)

	Bd. 2	Bd. 6	Bd. 10	Bd. 12	GC[2]	CC[3]	NC[4]
Rooftop 1	130.04	145.81	88.40	199.23	16	16	3
Rooftop 2	86.28	98.27	70.33	221.53	16	13	3
Rooftop 3	47.34	44.75	37.63	248.43	16	10	3
Road 1	158.67	201.79	120.61	122.80	6	6	3
Road 2	90.59	102.96	71.39	152.58	6	8	3
Fine Grass 1	50.30	72.20	150.58	132.11	8	4	9
Fine Grass 2	44.82	60.98	146.43	124.81	8	4	11
Coarse Grass 1	51.49	68.73	108.56	134.96	10	4	13
Coarse Grass 2	44.74	57.87	105.80	128.21	10	4	16
Trees	38.69	48.27	105.28	88.49	12	4	7
Bare Soil	86.93	106.52	80.57	153.01	4	4	5
Water	43.11	53.00	27.11	84.73	1	1	1
Shadow	37.82	35.70	39.24	73.98	1	1	1

[1]Gray levels used in land use classification.
[2]Gray levels used in classification: general classes.
[3]Gray levels used in classification: cultural features.
[4]Gray levels used in classification: natural features.

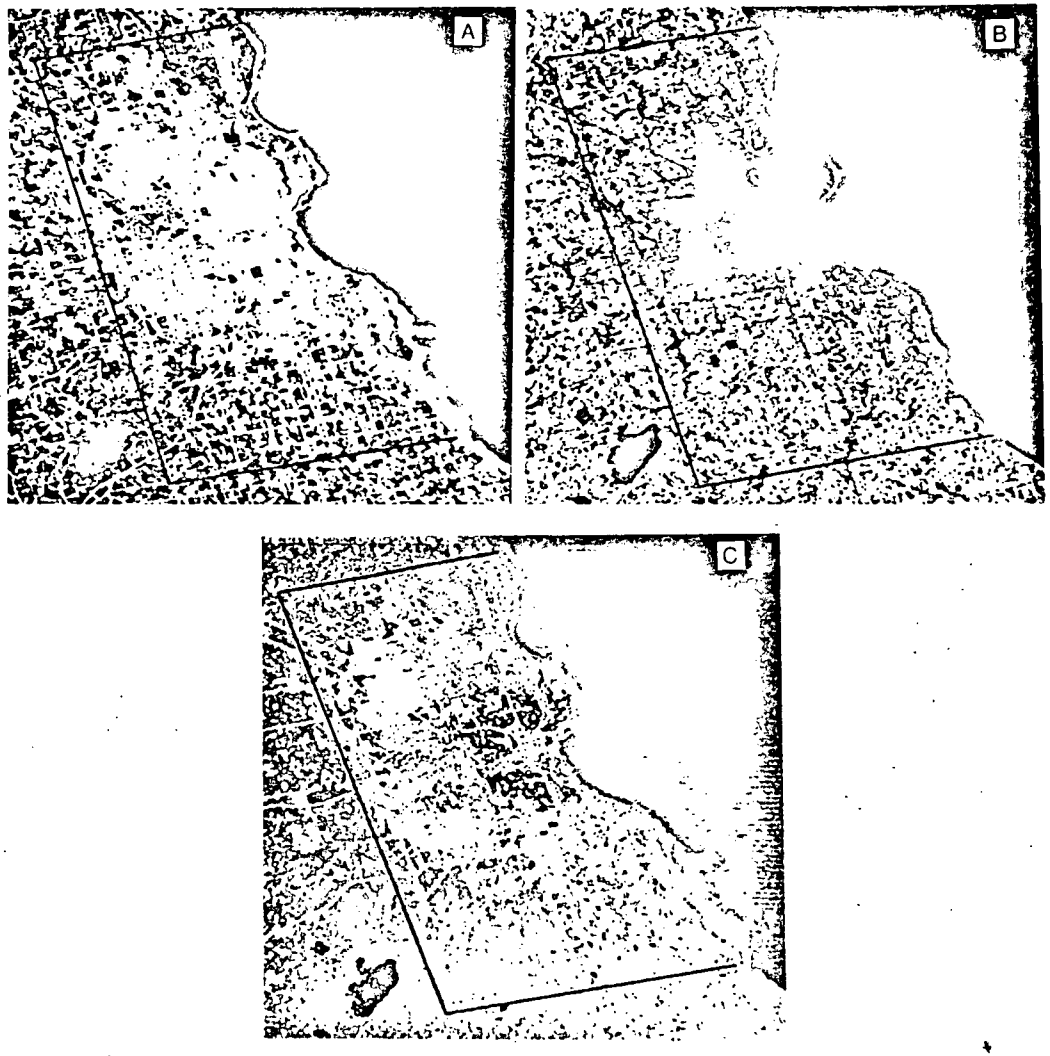

Figure 1. Photos of images from digital display. (A) is from the visible portion of the spectrum (band 5, 0.6 to 0.7 μm); (B) is from the infrared (band 7, 0.8 to 1.1 μm). (C) is a land use classification. Black line is boundary of Milwaukee County.

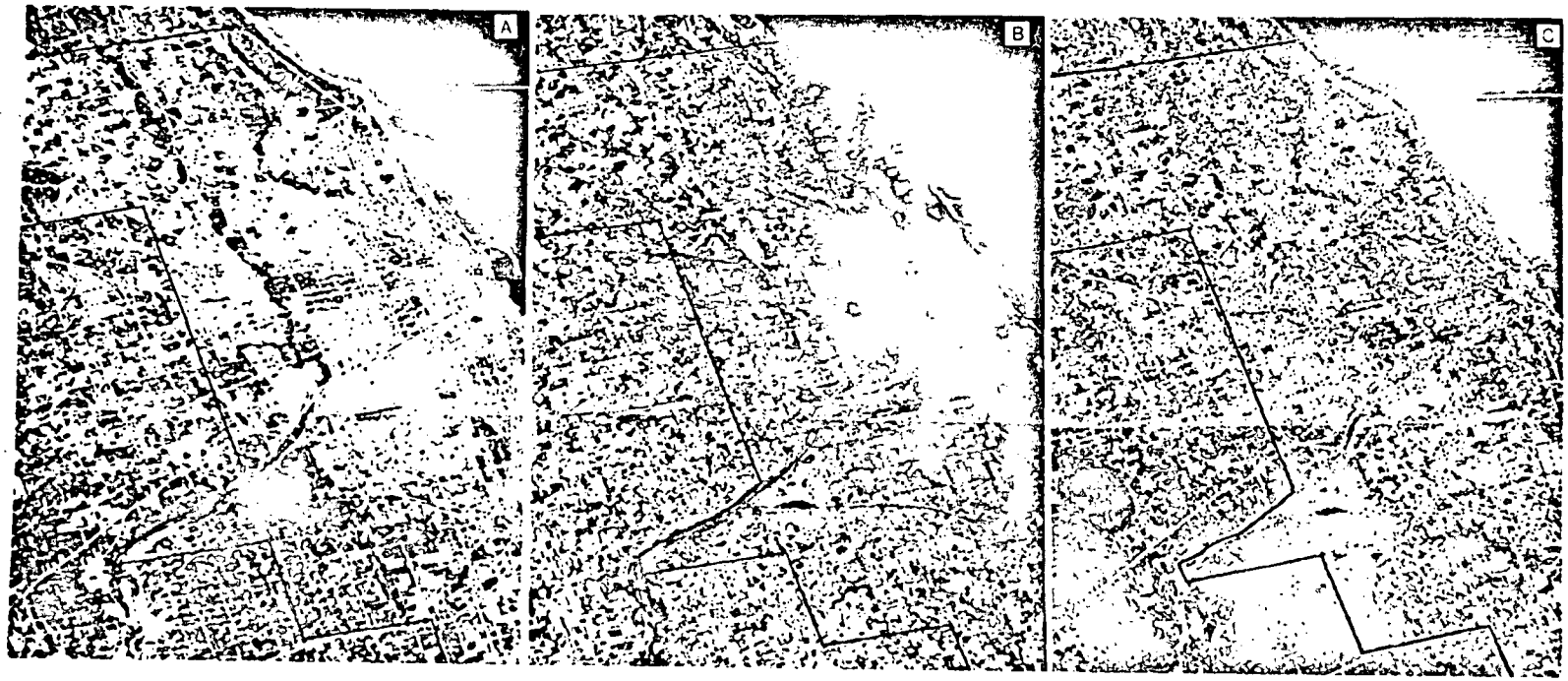

Figure 2. Photos of images from digital display. (A) is from the visible portion of the spectrum (band 5, 0.6 to 0.7 μm); (B) is from the infrared (band 7, 0.8 to 1.1 μm). (C) is a land use classification. Black line is boundary of Cook County.

Figure 3. Photos of images from digital display. (A) is a land use classification of Marion County/Indianapolis (black line is county boundary). (B), (C), and (D) are various portrayals of a single land use classification of 2000 feet MSS data near downtown Indianapolis. (B) shows variations in general classes of surface features; (C) the variation in cultural features; (D) the variation in natural features.

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