Accuracy Assessment of Landsat-Based Visual Change Detection Methods Applied to the Rural-Urban Fringe

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ABSTRACT: The accuracy of two visual change detection methods - comparison of classified images and interpretation of multidate composite images - is examined for Landsat MSS images of the Metropolitan Toronto rural-urban fringe for 6 July 1974, 12 July 1978, and 19 August 1981. The separate images comparison method produced higher levels of change detection accuracy than three different approaches to the multidate composite images method including (a) a simple, multidate composite image; (b) a supervised classification of change depicted in the simple, multidate, composite image; and (c) a principal component enhancement of the simple multidate composite image. Only the image comparison method and the multidate composite image method with principal component enhancement produced change-detection accuracies that approached or exceeded the 85 percent mapping accuracy criterion. Analysis of change detection accuracies and errors revealed that the two approaches together were able to identify most instances of rural-to-urban land conversion. The multidate composite image method presents an important limitation. It can detect rural-to-urban land conversion reliably only if conversion, depicted by active land development, is occurring at the moment of image capture. Because the two methods have some complementary strengths and weaknesses in detecting change on the rural-urban fringe, it may be advisable to employ them together to improve accuracy.

INTRODUCTION

SATELLITE REMOTE SENSING is a potentially powerful means of monitoring land-use change at high temporal resolution and lower costs than those associated with the use of traditional methods (Jensen *et al.*, 1983; Martin, 1986). However, there have been very few published assessments of change detection methods, employing detailed sampling and accuracy measurements, applied in the rural-urban fringe setting. Todd (1977), Gordon (1980), and Jensen (1981) provide examples. Land-use planners remain inadequately appraised of the potential of satellite imagery for monitoring land-use change in the rural-urban fringe.

This paper presents the findings of a study to assess the accuracy of two satellite remote sensing methods – comparison of classified images and interpretation of multidate, composite images – for visually detecting rural-to-urban land conversion in the rural-urban fringe of Metropolitan Toronto, Canada Between 1974 and 1981. Selected with the needs and capabilities of practicing planners in mind, the methods are comprehensible and draw upon the interpretation skills available to users of aerial photographs. Problems associated with the detection of remotely-sensed land-cover change are identified and suggestions for improvements are offered.

CHANGE DETECTION

Two basic methods for visually detecting land-cover change in satellite imagery are employed in this study. In the first approach, satellite images for different dates are compared. The method is appropriate with single-channel grey-tone images, multiple-channel color-composite images, or classified images. Image variation between dates signals the occurrence of land-cover change. Hereafter, this method is referred to as the image comparison method.

In the second approach images for different dates are overlayed to form a new composite image in which change is inferred from variations in grey tone or color hue. Hereafter, this is referred to as the multidate composite image method.

Enhancement procedures may be linked to either method of change detection. Enhancements most frequently employed for change detection include ratioing or differencing pixel digital values to suppress areas of no change and enhance the areas containing change (Todd, 1977; Friedman and Angelici, 1979; Howarth and Boasson, 1983), data compression methods (e.g., principal component) in which new channels emphasizing differences between images can be constructed (Williams and Borden, 1976; Byrne *et al.*, 1980; Richards, 1984; Duggin *et al.*, 1986), and spectral change vector analysis, a means of characterizing spectral change according to its variation in magnitude and direction over time (Malila, 1980). Change and non-change areas in composite images may be further enhanced by applying classification methods (Weissmiller *et al.*, 1977).

A very large number of change detection products can be produced from combinations of basic approaches and enhancement methods. Howarth and Boasson (1983) and Jensen (1986) have reported on and selectively evaluated some of these change detection products.

STUDY AREA

The study area is a relatively flat 8,266-hectare site comprising all of the City of Scarborough north of Highway 401 situated within the northeastern sector of Metropolitan Toronto, Canada and centered at lat. 43° 48'36"N, long. 79° 13'30"W. Because of its substantial stock of undeveloped land and its location within the Toronto Region, the study area has sustained continuous, intense urban development pressure. By 1986, most of the area, with the exception of an 800-hectare triangle in the extreme northeast corner, had been converted to urban uses. Conversion has occurred rapidly and, for the most part, in homogeneous tracts exceeding 20 hectares. These characteristics have made the area very useful as a test bed for a variety of different remote sensing methodologies focusing on change detection for urban planning purposes. Martin (1986) and Howarth *et al.* (1988) have documented other change detection studies.

DATA DESCRIPTION AND PREPROCESSING

Information for the study area was obtained from three Landsat digital tapes. The images were recorded on 6 July 1974 (Landsat 1), 12 July 1978 (Landsat 2), and 19 August 1981 (Land-

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sat 2). Quality of images was good to excellent with no cloud cover over the study area.

The 1974 Landsat image was geometrically corrected by resampling to the Universal Transverse Mercator Projection on 1:50,000-scale National Topographic Maps covering the study area. Images for 1978 and 1981 were resampled to the corrected 1974 image. A displacement error of less than one quarter of a pixel was recorded for the superimposed images.

Multidate composite images and their derived products may contain inaccuracies due to radiometric variations (Robinove, 1982; Teillet, 1986). Multidate composite imagery data employed in this study, derived from two Landsat sensors and captured at three different sun angles, were converted to reflectance values employing a standard radiometric correction of sun angle and sensor calibration.

Aerial photographs provided the principal means for checking and confirming the accuracy of information contained in the satellite images. Photographs were available for 19 April 1974, 12 July 1978, and 26–28 March 1981. the scale was 1:25,000 for the 1974 and 1981 photography and 1:10,000 for the 1978 photography.

Additional information on land conversion employed to augment aerial photographs included land subdivision records and maps from the City of Scarborough Planning Department and Canada Mortgage and Housing Corporation Land and Infrastructure Mapping Program maps and log books.

IMAGE CONSTRUCTION AND ACCURACY ASSESSMENT

Land-cover change in the study area for two periods between 1974 and 1981 was explored using the two basic methods. Employing the image comparison method, independently classified images for 1974, 1978, and 1981 were compared, pixel-to-pixel, to detect change. Three variations or treatments of the multidate composite image method were employed to detect change. These treatments were (a) the construction of a simple multidate composite image, (b) the application of supervised classification to the multidate composite image,and (c) the principal component enhancement of the simple multidate composite image. Each of the four approaches is described in greater detail below.

Spatial sampling for accuracy assessment was determined in a consistent manner for the four change detection approaches. First, a frame for spatial sampling was established. A 3 by 3 pixel sample block was selected by random generation of line and pixel coordinates in the study area image displayed on a CRT monitor. Then a 15 pixel grid was superimposed on the study area and aligned with the central pixel of the randomly selected 3 by 3 pixel block. An additional 150 central pixels for 3 by 3 pixel blocks were identified systematically at grid intersections within the study area boundaries. An identically positioned spatial sampling frame was employed for drawing a sample of 3 by 3 by 151 or 1359 pixels for each of three images in the first analysis and for one image in each of the remaining three analyses. This sampling method was chosen because it was simple to apply and, on the assumption that a mix of land-cover types was represented in any "cluster" of 151 pixel blocks, it satisfied the randomness criterion (Bryant and Russwurm, 1983).

In the first method of change detection, a supervised maximum likelihood classification of the study area was carried out separately for the 1974, 1978, and 1981 images. Five categories of land cover (residential, industrial/commercial, land development, agriculture, and woodland) were identified. A paired comparison of classified pixels in the 151 3 by 3 pixel sample blocks was carried out for the 1974 and 1978 classifications and for the 1978 and 1981 classifications in order to identify change or no change of land cover. Accuracy was determined by comparing each classified pixel located in the 3 by 3 sample pixel blocks with its equivalent location on aerial photographs and ancillary land conversion information.

From the paired comparison of the three supervised classifications, two 15-class land-cover matrices (Tables 1 and 2) were prepared containing eight classes of rural-to-urban land conversion and seven classes of no conversion. These change matrices provide the land-use planner with a detailed appreciation of land-use dynamics in an area undergoing urban development. The 15 classes of land cover then were aggregated and reorganized into two matrices (Table 3) containing six classes; three classes of rural-to-urban land conversion and three classes of no conversion.

In the first of the multidate composite treatments, three geometrically-corrected Band 5 images for 1974, 1978, and 1981 were loaded through the red, green, and blue color guns of the CRT monitor to produce a color-composite image. Band 5 of Landsat MSS was selected because it provided a visual discrimination of land-cover change between rural and urban land that was superior to that of the other three bands. From the visual comparison of this multidate composite image with the aerial photographs and ancillary land-cover information, it was determined that the pink hue represented the spectral response of the MSS to land undergoing urban development in 1974 but completed before 1978, the green hue represented urban development underway in 1978 but completed before 1981, and the blue hue represented change underway in 1981. Areas deemed to be urban (residential and industrial) in all three years were displayed as a medium grey tone. Areas recorded as rural (agriculture and woodland) for all three dates or rural at one date and urban at a subsequent date were displayed in complex patterns of dark grey, dark green, purple, and orange hues. Because of the visually confused change status of pixels representing transition between rural and urban land cover, the land development phase of the rural-to-urban land conversion process was singled out as the most reliable indicator of land conversion. Pixel change status in this multidate composite treatment was compared with change status for identical locations in the aerial photographs and ancillary land-cover information.

In the second of the multidate composite treatments, the color composite image of a multi-temporal data set was subjected to a supervised maximum likelihood classification utilizing three categories of change and three categories of no change. The three categories of change included land development under way in 1974 but completed before 1978, land development under way in 1978 but completed before 1981, and land development under way in 1981. The two categories of no change included urban and rural.

The important distinction to be made between this treatment and the initial multidate composite treatment relates to the role of judgment. In the first multidate composite image treatment, change is determined subjectively and directly by visually distinguishing color hues. In the classification approach, change is determined more objectively. A maximum likelihood classifier evaluates a preclassification pixel by comparing it to the spectral response pattern of an established change or no-change class. To assess accuracy, the classified pixels are compared with land cover at the same location on aerial photographs and ancillary land-cover change information.

For the third and final treatment, Bands 5 and 7 for the 1974, 1978, and 1981 images were concatenated as a single six-dimension data array. Considerable correlation was present among these six dimensions. Principal component analysis was employed to reduce the correlation or redundancy among these bands. Component 1 emphasized unchanged land cover, so it was excluded from subsequent examination. Components 2, 3, and 4 highlighted change and, when loaded through the red, green, and blue color guns of the video monitor, produced a

TABLE 1. DETAILED LAND-COVER CHANGE, IN PIXELS, IN THE SCARBOROUGH STUDY AREA, 1974-1978, EMPLOYING THE CLASSIFIED IMAGE COMPARISON METHOD.

Actual Land Cover	Interpreted Land Cover 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total Pixels
1	158					14					1		1			174
2	10	65				1					4		7			87
3			21					6			1					28
4	15			464	6	3				12	17			1		518
5	2				87											89
6						35										35
7							156									156
8						3		31								34
9						4		2	25							31
10				5		3				53	6		1	3		71
11				1		10				2	45					58
12						1				2	4	55	1			63
13	4												5			9
14														1		1
15														5		5
Tot. Pixels	189	65	21	470	93	74	156	39	25	69	78	55	15	10	0	1359

1 Residential
2 Industrial/Commercial
3 Land Development
4 Agriculture
5 Woods
6 Urban to Urban
7 Rural to Rural
8 Development to Residential
9 Devlopment to Industrial/Commercial
10 Agriculture to Residential
11 Agriculture to Industrial/Commercial
12 Agriculture to Development
13 Woods to Residential
14 Woods to Industrial/Commercial
15 Woods to Development

Overall Accuracy: 1201/1359* 100 = 88.4%
Confidence Interval = ±1.7 at the 95% level of probability

TABLE 2. DETAILED LAND-COVER CHANGE, IN PIXELS, IN THE SCARBOROUGH STUDY AREA, 1978-1981, EMPLOYING THE CLASSIFIED IMAGE COMPARISON METHOD.

Actual Land Cover	Interpreted Land Cover 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total Pixels
1	286					27				10						323
2	15	110				48				3						176
3			23					2		3						28
4	16	1		264		2				55		1				339
5					86		4						4			94
6						1										1
7							118									118
8						8		40								48
9	1					5		2	12							20
10						4				70	9					83
11		1		2						36	26					65
12						9					4	33				46
13													3			3
14													11			11
15															4	4
Tot. Pixels	318	112	23	266	86	104	122	44	12	177	39	34	18	0	4	1359

1 Residential
2 Industrial/Commercial
3 Land Development
4 Agriculture
5 Woods
6 Urban to Urban
7 Rural to Rural
8 Development to Residential
9 Development to Industrial/Commercial
10 Agriculture to Residential
11 Agriculture to Industrial/Commercial
12 Agriculture to Development
13 Woods to Residential
14 Woods to Industrial/Commercial
15 Woods to Development

Overall Accuracy: 1076/1359 * 100 = 79.2%
Confidence Interval = ±2.1 at the 95% level of probability

color-composite image analogous to the image produced by the first multidate treatment. However, the red, green, and blue colors depicting change exhibited richer hues and sharper definition along change boundaries. Aerial photographs and ancillary land-cover change information were again used to assess the accuracy of pixel change status.

ACCURACY ASSESSMENT: ANALYSIS

Tables 1 and 2 present a detailed appreciation of land-cover change in the study area during a six-year period of rapid urban development. Overall classification accuracy is 88.4 percent (± 1.7 at the 95 percent probability level) in the 1974–1978 period

TABLE 3. GENERALIZED LAND-COVER CHANGE, IN PIXELS, IN THE SCARBOROUGH STUDY AREA, 1974 - 1978, EMPLOYING THE CLASSIFIED IMAGE COMPARISON METHOD.

	1	2	3	4	5	6	Total Pixels	Errors of Omission
1 Urban	283				13		296	13
2 Development		21		6	1		28	7
3 Rural	20		713		30		763	50
4 Development to Urban	7			58			65	7
5 Rural to Urban	17		6		116		139	23
6 Rural to Development	1				12	55	68	13
Total Pixels	328	21	719	64	172	55	1359	
Errors of Commission	45	0	6	6	56	0		113

Overall Accuracy: 1246/1359 * 100 = 91.7%
Confidence Level = ± 1.4 at the 95% level of probability

TABLE 4. GENERALIZED LAND-COVER CHANGE, IN PIXELS, IN THE SCARBOROUGH STUDY AREA, 1978 - 1981, EMPLOYING THE CLASSIFIED IMAGE COMPARISON METHOD.

	1	2	3	4	5	6	Total Pixels	Errors of Omission
1 Urban	487				13		500	13
2 Development		23		2	3		28	5
3 Rural	19		429		59	1	508	79
4 Development to Urban	14			54			68	14
5 Rural to Urban	11		2		191		204	13
6 Rural to Development	9				4	38	51	13
Total Pixels	540	23	431	56	270	39	1359	
Errors of Commission	53	0	2	2	79	1		137

Overall Accuracy: 1222/1359 * 100 = 90.0%
Confidence Interval = ±1.4 at the 95% level of probability

TABLE 5. ACCURACY ASSESSMENT OF LAND DEVELOPMENT PIXELS DETECTED VISUALLY IN A MULTIDATE COMPOSITE IMAGE.

Identification of land Development	1974	1978	1981	Total 1974-1981
Total Correct	56	41	40	137
Errors of commission	4	13	6	23
Error of omission	37	45	39	121
Total Pixels	93	86	79	258
Percentage Correct	60.2	47.7	50.6	53.1*

* Overall Accuracy: 137/258 * 100 = 53.1%
Confidence Interval = ±6.1 at the 95% level of probability.

TABLE 6. ACCURACY ASSESSMENT OF LAND DEVELOPMENT PIXELS DETECTED VISUALLY IN A MULTIDATE COMPOSITE IMAGE ENHANCED BY SUPERVISED CLASSIFICATION OF CHANGE.

Identification of Land Development	1974	1978	1981	Total 1974-1981
Total Correct	64	60	57	181
Errors of commission	19	63	40	122
Errors of omission	29	26	22	77
Total Pixels	93	86	79	258
Percentage Correct	68.8	69.8	72.2	70.2*

* Overall Accuracy: 181/258* 100=70.2%
Confidence Interval = ±5.6 at the 95% level of probability.

and 79.2 percent (±2.1 at the 95 percent probability level) in the 1978-1981 period. Two types of change are identified: land cover converting from rural-to-urban and land cover changing within rural and urban categories. During a period when agricultural land and woods were experiencing an absolute decrease in area, there were changes in the relative proportions of these two land-cover types due to changing land market conditions. While some land-cover changes did occur between residential and industrial/commercial, much of it is spurious, reflecting the difficulty in dealing with mixed land-use sites and the limitations of aerial photographs in distinguishing between residential and commercial highrise districts. Considerable misclassification is associated with this change class. Because the emphasis of this study is on rural-to-urban land conversion, field investigation of this problem was not necessary.

In Tables 3 and 4, the original 15-class change matrices derived from the two supervised classifications are aggregated to six-class matrices in order to focus on land conversion status. The original land development class is retained in these Tables to facilitate subsequent comparison between this analysis and the analysis of the composite images. In general, the Tables demonstrate the progression of rural-to-urban land conversion in the study area, with approximately 29 percent of the area in urban land cover in 1974, 44 percent in 1978, and 63 percent in 1981. The rate of conversion increased from 3.7 percent per year during the first four-year period to 6.3 percent per year in the final three-year period.

With the aggregation of the 15 classes to six classes of conversion and no conversion, and the attendant loss of intraclass no-conversion error, overall accuracy of change detection reaches or exceeds 90 percent (± 1.4 at the 95 percent probability level) for the two time periods. A consistent pattern of important classification error persists in both time periods. Rural no-conversion pixels are erroneously assigned to urban no-conversion and rural-to-urban conversion classes. Development-to-urban and rural-to-urban conversion class pixels are erroneously assigned to the urban no-conversion class. Both these error groups result largely from a confusion between agricultural and residential land cover and are a common by-product of Landsat MSS multispectral analysis.

In Table 5, the accuracy assessment for the first application of the composite image approach is presented. Pixels in the sample designated by their color as undergoing land development were checked for accuracy against aerial photographs and other land-cover information. Recall that conversion in the composite image approach may be visually identified only if the land development stage of land conversion is present. If land conversion occurred between satellite overflights, it is not identified in this visual interpretation.

Correctly identified land development pixels ranged from 47.7 percent for 1978 to 60.2 percent in 1974. Overall accuracy was 53.1 percent (± 6.1 at the 95 percent probability level). Errors of omission for this one class of land cover in the study area exceeded errors of commission by a ratio of 5.3 to 1.

Results of the second application of the multidate composite image approach to change detection are presented in Table 6. The composite image displaying change as contrasting color hues was modified employing supervised classification. Pixels designated by their color to be undergoing land development were checked for accuracy against the master land-cover change matrix. The percentage of land development correctly identified ranged from 68.8 percent in 1974 to 72.2 percent in 1981. Overall accuracy between 1974 and 1981 was 70.2 percent (± 5.6 at the 95 percent probability level). Errors of commission for this one landcover class exceeded errors of omission by a ratio of 1.6 to 1.

Table 7 presents the results of the third application of the multidate composite image approach to change detection. This composite image was subjected to a principal component enhancement to increase temporally based color contrasts and to sharpen the visually determined boundaries between change and non-change areas. The percentage of land conversion correctly identified ranged from 68.8 percent in 1974 to 82.6 percent in 1978. Overall accuracy between 1974 and 1981 was 76.0 percent (± 5.2 at the 95 percent probability level). Errors of omission for this one class of land cover were greater than errors of commission by a ratio of approximately 4.5 to 1.

The spatial pattern of land conversion in the study area is displayed in Figure 1. Information on conversion is summarized by 3 by 3 pixel blocks for the entire seven year period in order to reduce the map's complexity and to produce a more legible product. Pixel blocks containing pixels undergoing conversion are identified, but the number and location of pixels experiencing conversion within those blocks is not indicated. Land conversion in the study area between 1974 and 1981 was concentrated in a west to east corridor through the middle of the study area. South of that corridor, the land was largely converted to urban uses prior to 1974. The several occurrences of conversion observed there were instances of residential and commercial infill. North of the corridor land remained in agriculture and woodland during the period of study.

Because the two methods, together, identified all but one pixel block containing land experiencing conversion, the errors of commission for one method are the correct detections by the other method. Thus, the spatial pattern of errors of omission is defined by the overall pattern of conversion. There is not a clearly defined pattern of spatial separability of errors of omission for the two methods. However, for 24-pixel blocks, the image comparison method alone correctly identified conversion. For six-pixel blocks, the composite image method alone correctly identified conversion. But three times out of five, both methods were in agreement in identifying conversion.

Pixel blocks containing errors of commission are distributed throughout the study area. The composite image method produced very few errors of commission. A large cluster of errors of commission, produced mostly by the image comparison method, extend in an arc across the northeast quarter of the study area. These errors resulted from an interpretation of agricultural to residential conversion where no conversion had occurred.

TABLE 7. ACCURACY ASSESSMENT OF LAND DEVELOPMENT PIXELS DETECTED VISUALLY IN A MULTIDATE COMPOSITE IMAGE WITH PRINCIPAL COMPONENT ENHANCEMENT.

Identification of Land Development	1974	1978	1981	Total 1974-1981
Total Correct	64	71	61	196
Errors of commission	0	11	3	14
Errors of omission	29	15	18	62
Total Pixels	93	86	79	258
Percentage Correct	68.8	82.6	77.2	76.0*

*Overall Accuracy: 196/258 * 100 = 76.0%
Confidence Interval = ±5.2 at the 95% level of probability.

DISCUSSION

An analysis of the four approaches to change detection indicates that only the comparison of classified images approach and the multidate composite method with principal component enhancement produced change-detection accuracies that approached or exceeded the 85 percent mapping accuracy criterion generally held as acceptable (Jensen, 1983). In the case of the image comparison method, change detection accuracies for specific categories of land-cover change (Tables 3 and 4) ranged from 75 percent to 97 percent. For the multidate composite method, accuracy was determined only for the land development class as a proxy for land conversion. In order to satisfy the needs of urban and regional planners concerned with monitoring rural-to-urban land conversion, change detection methods in satellite remote sensing must achieve higher levels of overall accuracy and must provide information on specific classes of land use/cover involved in conversion.

Improved levels of accuracy may be achieved in several ways. First, the analyst will benefit by having a close familiarity with the cultural and physical characteristics of the study area. For any given region, there will likely be optimal anniversary dates for change detection in which differences in reflectance caused by changing seasonal vegetation, soil moisture, and sun angle are minimized. Second, multidate images of the study area must be registered precisely to a cartographic grid. Displacement of superimposed images by one half pixel or greater will introduce unacceptable spurious change. Finally, the analyst must appreciate the strengths and weaknesses of all change detection methods available for application to a particular study area. Then, he must select methods that provide the highest change detection accuracies.

The multidate composite image method for visually detecting rural-to-urban land conversion, as employed in the second, third, and fourth treatments of this study, contains an important limitation. This approach is able to depict conversion only if the land development phase is present at one or more of the three dates in the composite, multidate image. If the land development phase occurs between image dates, then conversion will likely be overlooked because there will be no visually discernible color warning of its having occurred. For this reason, all estimates of conversion, employing the multidate composite image approach, are biased downwards. In this respect, and other factors being equal, the comparison of separate images for different dates will provide a more accurate estimate of actual land conversion. It will also provide conversion data for 15 classes of land cover and land-cover change with accuracy levels that equal or exceed accuracy levels obtained from multidate composite image analysis.

If multidate composite images are employed for land-cover change detection on the rural-urban fringe, it is advisable that an optimal period of time be identified between successive images in order to take advantage of the color warning provided by land development. On the Toronto rural-urban fringe, images should be available at four-month intervals to adequately capture rural-to-urban land conversion.

Improved approaches to general change detection have been discussed in the literature but there has been little effort, thus far, to carry out a systematic evaluation of these methods applied to rural-to-urban land conversion. However, several modifications of method hold promise. It was noted earlier that change detection, obtained by visually identified grey-tone and color-hue variations in multidate composite images, is somewhat subjective. Jensen (1983) has reported on two objective approaches to establishing a threshold (*T*) between radiance

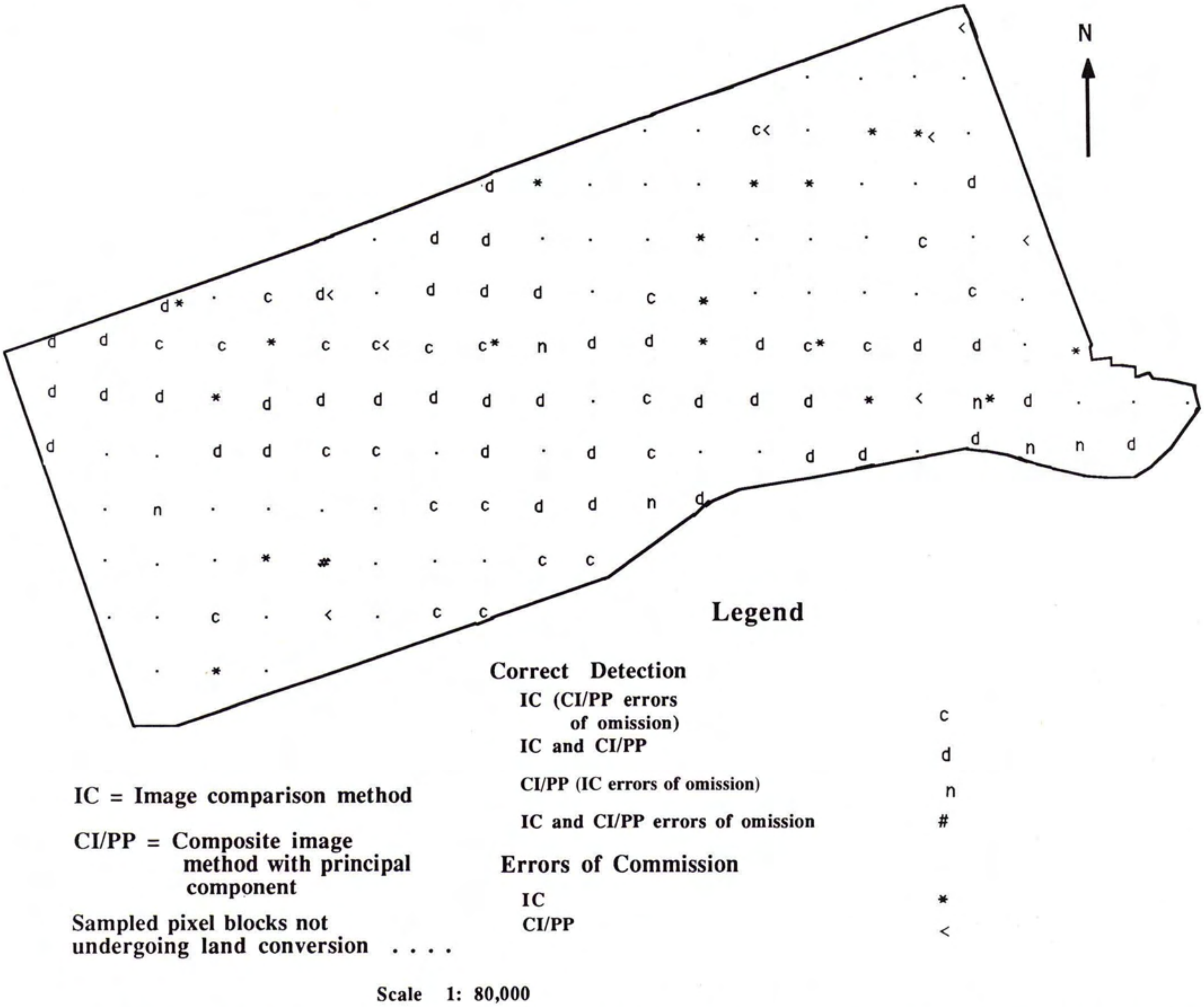

FIG. 1. Pixel block summaries of accuracy of two land conversion detection methods in the City of Scarborough, Ontario, Canada Study Area, 1974-1981.

change pixels and no-radiance change pixels. In the first method, T is estimated empirically by interactively adjusting the threshold until a balance between change and no-change is obtained. In the second approach, T is obtained statistically through use of an estimate of within-image variability incorporated into a univariate equation.

Preprocessing methods applied to image data prior to change-detection analysis should be examined. These include low and high frequency filtering, texture filtering, and summary brightness statistics. However, Jensen's (1981) reference to the variability of results in application of these methods suggests that success will likely result from combined approaches tailored to specific regions and localities.

If one image, employed in change detection, consistently produces a low level of correctly detected change, it may contain undetected radiometric and/or geometric distortions. Use of a substitute image for a different date may be indicated.

Improved levels of accuracy can be expected from refinements of classification procedures in the image comparison approach. Hybrid classification methods (Lillesand and Kiefer, 1987) may reduce the pixel heterogeneity problem frequently observed for urban areas (Milazzo and DeAngelis, 1984). Jensen (1981) has reported on a classifier employing multistage decision logic in which the analyst assigns pixels to classes on the basis of sequentially applied decision rules.

CONCLUSIONS

In this study, the accuracy of two visual change-detection methods, involving image comparison and three types of mutidate composite image analysis, were assessed. Only the first method, image comparison, and the third treatment of the second method, multidate composite-image analysis with principal component enhancement, produced minimally acceptable levels of accuracy with accuracy levels of approximately 90 percent for the first method and 76 percent for the latter method. However, analysis of accuracies and errors indicated that these methods had some complementary strengths and weaknesses. These findings suggest that a suitable strategy for improving the accuracy of remotely sensed change detection on the rural-urban fringe should consider the combined application of both methods to the task of change detection. Further research is required to determine the general applicability of these findings.

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42nd Photogrammetric Week
11-16 September
Stuttgart, Germany

The Institute of Photogrammetry of Stuttgart University and the Division of Photogrammetry of Carl Zeiss, Oberkochen are sponsoring the 42nd Photogrammetric Week in Stuttgart from Monday 11 September to Saturday 16 September. Lectures will emphasize:

Photogrammetric Data Acquisition for Spatial Information Systems
Digital Photogrammetry — Reality and Perspectives
Aerial Survey with GPS and Laser

The presentations will be in German and English. Experienced technical interpreters will simultaneously translate into English or German. Time will be allocated for discussions and demonstrations and explanations of practical examples will be held in the afternoons.

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