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SPOTTING ONEONTA: A COMPARISON OF SPOT 1 AND LANDSAT 1 IN DETECTING LAND COVER PATTERNS IN A SMALL URBAN AREA

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SPOT 1 was launched on 21 February 1986 approximately fourteen years after Landsat 1 was placed into orbit. The first high quality, nearly cloud free Landsat image covering Oneonta, New York was obtained on 12 October 1972; whereas, the first similar SPOT image was acquired on 9 September 1986. Both images were taken shortly after the two satellite systems were put into operation; this was a critical time because the quality and acceptance of each system's products were just beginning to be tested. Most urban studies based on satellite imagery have been limited to the identification of a few, general land cover patterns in large metropolitan areas, a condition which mainly relates to the large size of the picture element (pixel) associated with the Landsat (MSS) multispectral scanner. This author's detailed search of the remote sensing literature listed in *Geographical Abstracts* shows that little research has been done on small urban areas using satellite imagery.

The purpose of this study is twofold. First, it provides a review of the important factors that must be considered when selecting Landsat and SPOT images for relatively large-scale study areas, particularly of images taken when the two satellite systems were first put into operation. Second, the study compares land cover detection capabilities of Landsat and SPOT imagery with respect to a small urban area, namely Oneonta, New York. Based on the SPOT 1 MSS pixel resolution size of 20 m, which is much smaller than the Landsat pixel, the SPOT image should produce better results.

DATA ACQUISITION

Image acquisition is a difficult process and the quality of an image can play an important role in determining the outcome of a study; thus, it is essential for the reader to understand the circumstances under which the images used in this study were purchased. Before acquiring them, cloud cover conditions, data quality levels, and scene coverage had to be considered. The Oneonta region, centered in the hilly plateau area directly northwest of the Catskill Mountains, receives a great amount of cloud cover throughout the year; this fact makes it difficult to find a cloud free image.

In the 1970s, with the advent of the Landsat series, Visitor Assistance Centers were established to enable individuals to view microfilm or microfiche copies of the photographic prints of images and ascertain the degree, type, and location of the cloud cover. Although most of these Centers are no longer in operation, those that are provide a valuable service to researchers seeking acceptable images. Printouts were provided for this study listing available images for the Oneonta area along with the percentage of cloud cover for each image. If an image was identified as having zero percent coverage, one could feel certain that no clouds existed. If a percentage rating other than zero was indicated, one was not sure about the location and degree of coverage without viewing a photographic print of the image.

With SPOT imagery one has no means of viewing an image without first purchasing a photographic print at a relatively high price. Selection of an image can be quite expensive, since it might be necessary to acquire several prints before finding one of acceptable quality. Although not an established procedure, the customer service division of SPOT, Incorporated will perform a cursory examination of microfiche copies of a limited number of photographic prints for a potential buyer of an image's digital data set. Generally the SPOT representative who views the copies has little knowledge about the study area or potential application of an image and can provide only some vague comments pertaining to the cloud situation. The printout generated by a computer search, referred to as a catalog query, provides some information about cloud cover; a rating value based on the amount of cloud cover is recorded for each quadrant of an image. A rating of zero represents anything between 0 and 10 percent; thus, one cannot be certain if the image is cloud free. Obviously identifying cloud conditions by quadrant helps in dealing with the location of clouds on an image, but the system would be much better if a rating level existed for 0 percentage.

In the 1970s the Landsat MSS imagery consisted of four spectral bands, three of which had potential data ranges of 0 to 127. The fourth band had a potential range of 0 to 63. SPOT has three multispectral bands and one broad panchromatic band. The two SPOT sensing systems are handled independently of each other and images generated from them are sold as separate items. The SPOT image used in this study is multispectral and each of its three bands possesses a potential range of 0 to 255. The data quality level for each Landsat band is rated as either poor, average, and excellent. The SPOT system does not rate each band, but provides a quality level for the data.

The Landsat imaging device operates an oscillating scanner which scams amd records six lines of pixel data with each sweep of the scanner. Four spectral bands, each with its own detector, are recorded for each scan line. Stripes occur on an image when the detectors are not synchronous. To rectify this situation the data have to de-striped, a process which is based on a statistical "smoothing" operation. The Landsat data set used in this study was de-striped.

SPOT avoids problem of striping by using a "push-broom" approach to record data. However, many of SPOT's images are taken from an off-nadir view which introduces other types of data quality problems. In nadir position the pixel resolution for the multispectral data is 20 m but in off-nadir it can vary from 20 m to 27.2 m. (The resolution size varies with the incidence angle from ground nadir.) In acquiring a SPOT image one can request one of four data processing levels. Under Level 1A the off-nadir condition is not rectified and each multispectral line has 3,000 pixels; whereas, with Level 1B the image is geometrically corrected to reduce distortion and the number of corrected 20 m elements per line can range from 3,200 to 4,240. No additional process charge exists between Levels 1A and 1B. The image covering Oneonta was slightly off-nadir with an incidence angle of -3.9 degrees and processed at Level 1B. The negative angle indicates a west-looking recording and results in the recording of more reflectance from east-facing slopes.

A Landsat MSS image covers an area of approximately 185 km x 185 km (115 mi. x 115 mi.); whereas, SPOT image coverage is 60 km x 60 km (37.3 mi. x 37.3 mi.) at a vertical viewing angle or 60 km x 80 km (37.3 mi. x 49.7 mi.) at the maximum angle of 27 degrees. The computer printouts generated by both satellite systems provide latitude and longitude readings to assist in delimiting an image. However, these readings are difficult to use since images are not oriented towards true north. In addition, a user with a study area situated on the edge of an image finds it hard to determine how much of the area falls inside an image. The latter problem is more apparent with a SPOT image which covers a smaller area and has a smaller pixel. SPOT Incorporated will create a new image from portions of adjacent north-south images, but it is unable to perform this operation for overlapping east-west images. The SPOT image employed in this study was created by merging the southern half and northern half of adjacent north-south images. This merging process was necessary, since the study area was situated at the edge of the two images and its location could not be pinpointed based on the known latitude and longitude readings.

Oneonta is also situated near the edge of Landsat scenes but the size of these scenes makes it easier to determine the location of places. In addition, a Landsat digital data set was always accompanied by a photographic print which could be used to pinpoint areas within the data. No such print was provided with the SPOT data set which makes looking for a particular site in a 3,000 x 3,000 matrix comparable to trying to find a needle in a haystack. Fortunately, Oneonta could be placed near the center of the combined image.

Weighing these different factors was important in choosing the Landsat and SPOT images for this study. Computer printouts listing thirty or forty images of the study area were reviewed initially, but the time of year, cloud cover, quality level ratings and edge locations left only one or two useable images from which to choose. The Landsat photographic print and digital data set that was selected cost originally $5 and $200, respectively. The SPOT data set was $1,700. A SPOT print would have cost an additional $155, but none was available. At $1,700 or more a university researcher is going to be very careful in selecting a SPOT data set.

IMAGE PROCESSING PROCEDURES

Oneonta, the study area, is a community of approximately 20,000 people with an economy based mainly on two colleges which together enroll about 7,000 students. Historically the city was a major railroad center. A partially used railroad yard with its accompanying shops remains the predominant land use feature within the city. Oneonta extends in a general east-west direction along the valley of the

Susquehanna River. The railroad lines, Interstate 88, and New York State Route 7 correspond to this pattern. With few exceptions the residential areas are old and contain many large trees which partially block the view of houses from overhead. The city has a downtown commercial area and outside ribbon development, including several shopping centers. In many respects Oneonta's general land use patterns are typical of numerous small cities throughout the northeastern United States.

Due to Oneonta's elongated settlement pattern the SPOT data set developed for this study was 500 elements by 320 scan lines in size or 160,000 pixels. The Landsat data set covered the same area, but it included 180 elements by 81 lines or 14,580 pixels. The obvious difference in the size between the two data sets relates to the much larger Landsat pixel which is 79 m x 56 m in comparison to SPOT's 20 m x 20 m pixel. All three SPOT spectral bands as well as all four Landsat bands were used in the study. Although slightly narrower, the two SPOT visible bands approximate the two Landsat visible bands. The single SPOT near infrared band covers .79 to .89 microns of the electromagnetic spectrum, whereas the two Landsat bands of .7 to .8 and .8 to 1.1 microns provide a much greater near infrared capacity. As previously stated the potential data range for each of the three SPOT bands is 256, and Landsat has a range of 128 for the first three bands and 64 for the fourth band. The recorded dynamic range of each band for the two data sets was considerably less than the potential. The dynamic ranges as a percentage of the potential ranges for the three SPOT bands were 24.6, 26.5, and 48.8. The same values for the four Landsat bands were 15.7, 18.1, 29.9, and 46.0 percent. The greatest dynamic range and therefore statistical separability for both data sets was in the near infrared bands. In statistical space, only one of three SPOT bands had a sufficient range of values to help discriminate between pixels, whereas Landsat had two discriminating bands. Nevertheless, greater separability actually existed in the SPOT data set because in absolute terms the potential ranges for the SPOT bands are much greater than Landsat's.

To reduce the level of human bias in analyzing the two data sets, an unsupervised technique known as *Search* was employed to produce the needed spectral classes. *Search* was developed by NASA's Earth Resources Laboratory. The same method for establishing the input parameter values for *Search* was employed with both data sets. Spectral class statistics generated by *Search* were used with the maximum likelihood classifier to create the two classified data sets. The classified pixels in each set were then associated with different land cover conditions to produce land cover images. These spectral class-land cover associations were accomplished by using an image processing work station with a high resolution color monitor. Low-level aerial photography taken in April 1973 was used to help determine land cover on the October 1972 classified Landsat data set. Aerial photos taken in September 1987 by students in the Geography Department's air photo missions course were used to identify land cover in the September 1986 SPOT data set. Eighty-five spectral classes were obtained from the SPOT data set and sixty classes from the Landsat data set.

SPOT CLASSIFICATION

Six land cover classes were derived from SPOT's eighty-five spectral classes (Table 1, p. 105). These classes were identified as Forests and Wooded Areas, Brush and Yard Areas, Cropland and Grass Areas, Commercial-Industrial Zones, Residential Areas, and Water and Wetlands. Under the Forests and Wooded Areas class, forests represented large, uninterrupted tracts of mature trees associated mainly with high elevations where there is less settlement. Wooded areas are small tree-covered sections of land found more often at lower elevations and intermixed with other land cover patterns. Nineteen spectral classes were consolidated to form this single land cover class. Portions of the forested areas could have been further subdivided but to do so would move this study away from its main focus on urban land cover patterns.

Brush areas of the Brush and Yard class generally contain a mixture of trees, bushes, and grasses. This class includes mostly farm land which has been either abandoned or used to obtain an occasional hay crop. Brush areas are classified throughout the city; they are generally associated with land deemed undesirable for development. Yards of the Brush and Yard class corresponds to the city's residential areas, because they contain a mixture of trees, bushes, and grasses. It was impossible to discriminate their reflectance values from those associated with brush lands.

The SPOT Cropland class is either land used for hay or corn; the former is scattered throughout the fringe of the urban area, but it is found mainly in the valley bottom. Grass Areas class is scattered throughout the city and it includes several athletic playing fields and one large golf course. Twenty-two spectral classes were used to form this land cover class, but it was not possible to separate cropland and grass areas.

Commercial-Industrial Zones classified from SPOT data include mainly the Central Business District, shopping centers, commercial ribbon development, the railroad yard, two small industrial parks, college buildings, and Interstate 88. Each of these features has surfaces predominantly associated with high reflectance values. Three small clouds are recorded in the SPOT data as areas of high values or "bright" surface areas. The clouds could not be discriminated from the Commercial-Industrial activities; thus, this class is misrepresented in several areas. It was also impossible to separate the commercial from the industrial activities; a similar condition has occurred in many studies of larger urban areas using Landsat MSS data. The SPOT data also incorrectly indicated two small patches of water in the middle of the Central Business District; this is another pattern frequently noted in studies of larger urban areas.

The SPOT Residential Areas class does not appear as solid patterns but more as pepper patterns intermixed with areas classified as brush and yard. The final SPOT land cover class is Water and Wetlands. The Susquehanna River is reasonably well-defined, although sections of the river are misclassified under the Commercial-Industrial Zones class. At the time of the satellite's overflight the river was low and many of the rocky and sandy areas lining it were producing bright surfaces. In addition, pixel areas associated with the shadows of small clouds produced false water areas.

Table 1 shows the number of spectral classes used in classifying each land cover type and the total number and percentage of pixels associated with each class. In addition, the table presents the total number of pixels classified at the third standard deviation threshold level for each land cover and the percentage of threshold pixels to the total number of pixels for each land class. The table clearly illustrates the high accuracy levels of the first three land cover classes compared to those of the last three, two of which are urban. The Water and Wetlands class has a large number of pixels associated with the cloud shadows; thus, its considerable variance in reflectance is probably due to the combining of shadow with other land covers. The shadows of clouds may also have reduced the number of pixels classified as Commercial-Industrial. However, the urban classes still possess considerable variance and are not well-defined.

Table 1: Spot Classification Summary Data

	No. Spectral Classes	Pixel Count Per Class	Percentage of Total Count	Threshold Pixels	Threshold Percentages
(1) Forests and Wooded Areas	19	79,637	49.77	65,237	81.92
(2) Brush and Yard Areas	24	40,350	25.22	29,100	72.19
(3) Cropland and Grass Areas	22	15,842	9.90	10,265	64.80
(4) Commercial-Industrial	9	9,025	5.60	478	5.29
(5) Residential Areas	7	13,188	8.20	2,701	20.48
(6) Water and Wetlands	4	1,958	1.20	201	10,26
Totals	85	160,000	99.89	107,982	67.49

LANDSAT CLASSIFICATION

Only three general land cover classes were identified based on the sixty Landsat spectral classes that were generated (Table 2). These classes were given the following titles: Forests and Wooded Areas, Brush and Crop Areas, and Urban and Built-up Areas (Table 2). The Forests and Wooded Area class is similar in definition to the same class associated with the SPOT image. Some mature brush land areas are included under this class, which might account for the approximately five percent difference in land cover between this class and the corresponding SPOT class (cf. Table 1). The threshold accuracy level dropped over forty percent, 81.92 for SPOT to 40.70 for Landsat. This dramatic contrast is no doubt the result of the differences in the pixel resolution size between the two images. The Brush and Crop class includes large areas with sparse vegetation cover. This class corresponds generally with areas depicted in two SPOT classes - Brush/Yard and Cropland/Grass. The accuracy results for this class is low, but it is still the higher than the SPOT classes. The Urban and Built-up class represents a consolidation of the two urban classes in the SPOT classification. In 1972 Interstate 88 was being built through the Oneonta area resulting in a considerable amount of disturbed land which created high reflectances similar to those found throughout the Urban and Built-up Area class. The threshold level is quite low, which indicates a considerable variance in the reflectance values for the urban landscape. No water class was identified because the surface water-to-pixel area ratio in the scene is small.

Table 2: Landsat Classification Summary Data

	No. Spectral Classes	Pixel Count Per Class	Percentage of Total Count	Threshold Pixels	Threshold Percentages
(1) Forests and Wooded Areas	37	7,967	54.64	3,243	40.70
(2) Brush and Crop Areas	15	3,528	24.19	2,178	61.73
(3) Urban and Built-up Areas	8	3,085	21.15	727	23.56
Totals	60	14,580	99.98	6,148	42.16

FINAL COMMENTS

With respect to Oneonta, a small city, the SPOT data set produced results comparable to those obtained from previous studies using Landsat MSS data sets for large urban areas. Most Landsat MSS studies of large urban areas have produced a single commercial and/or industrial class, one or two residential classes (depending upon vegetation patterns), several vegetation classes, and a water class. Basically these classes are very similar to those generated by SPOT for Oneonta. The lack of two residential classes might be because the city has extensive old residential areas with large tree coverage and few new residential areas with large amounts of open space. The SPOT threshold accuracy levels are low for the urban classes and high for the vegetation classes. These results are similar to those found for large urban areas based on Landsat MSS. SPOT's very poor accuracy level for water was a surprise, and it is hard to explain since water is generally accurate at the 95 percent confidence level.[1] Although the threshold accuracy procedure provides an easy and comprehensive means for testing the accuracy levels of classes, it does not test for spatial accuracy.[2] From field observation the spatial patterns appear to be more accurate than the threshold test would suggest.

SPOT produced better overall results than Landsat. The main reason for the better results is probably due to pixel size. For every Landsat pixel, SPOT had 11.6 pixels. *Search* with its 9-pixel window could find a SPOT training field within an area smaller than one Landsat pixel. Finally, despite SPOT's accuracy, better data acquisition procedures for small users must be developed.

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[1]P.R. Baumann, *Evaluation of Three Techniques for Classifying Urban Land Cover Patterns Using Landsat MSS Data* (NSTL Station, MS: NASA Earth Resources Laboratory, 1979); P.R. Baumann, "Comparative Study Between Regular Landsat Data Sets and a Merged Landsat Data Set for an Urban Area," *Proceedings of the Middle States Division of the Association of American Geographers* 15 (1981): 1-8.

[2]P.R. Baumann, "Urban Land Cover Detection Employing a Winter Landsat MSS Data Set," *Proceedings of the Middle States Division of the Association of American Geographers* 20 (1987): 38-46.