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Paper L 17

INVESTIGATIONS OF AN URBAN AREA AND ITS LOCALE USING ERTS-1 DATA SUPPORTED BY U-"PHOTOGRAPHY"

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ABSTRACT

An urban area in central Pennsylvania and the surrounding locality were investigated separately at first by photointerpretation of ERTS-1 imagery and by computer processing of MSS tapes. Each of these independent approachs had shortcomings. Next the photointerpretation and processing were coordinated. The results of the cooperative effort of photointerpreters and computer processing analysts were much improved over independent efforts. It was found that single frames of U-2 photography could be projected onto printer output maps with little recognizable distortion in areas 10 to 25 cm square. In this way targets could be identified for use as training areas for computer processed signature identification. In addition, at any stage of category mapping, the level of success in correct classification could be assessed by this method. The results of the classification of the study area are discussed.

The state of the art of producing thematic land use maps by digital processing and analysis of multispectral scan data from ERTS-1 by the Office for Remote Sensing of Earth Resources at The Pennsylvania State University as of March 1, 1973, is the concern of this report. The geographic area of the study is a portion of East Pennsboro, Hampdon, and Lower Allen townships in Cumberland County just across the Susquehanna River from Harrisburg, Pennsylvania. The area is especially well suited for the study because it exhibits many terrain and cultural features most readily recognizable on ERTS imaging systems. The area is rapidly developing with a variety of targets including

the Susquehanna River, Conodoguinet Creek, rail marshalling
yards, urban and suburban areas, industrial developments,
agricultural regions, forest, as well as a newly developed
system of interstate highways. Such targets, properly
identified, provide fixed points of reference between which
items of lesser definition can be investigated and mapped.
The rapid growth in the area provides an opportunity for
evaluating the temporal dimension offered by ERTS data.
Initial work at Penn State exposed the limitations of
machine processing alone as well as the restrictions of
visual photointerpretation alone from ERTS scenes. Hence,
this paper emphasizes the development of a system combining
the strengths of each method.

The maps shown in Figures 2, 3, and 4 were produced
on a CalComp Drum Plotter.[1] MSS bulk ERTS-1 data tapes
were processed on an IBM system 370/165 using a Remote
Job Entry terminal. The programs used are described in a
paper by Borden (1972). Supporting ground truth used for
verification came from the 7-1/2 minute quadrangle map
(1:24,000 scale) of Harrisburg-West prepared by the U. S.
Geological Survey from aerial photographs taken in 1961 and
field checked in 1963. Culture as of 1961 required supple-
mental data that was provided by infrared photography taken
from U-2 aircraft on July 26, 1972. The photos are of 70 mm
format with a scale of 1:445,000. As character maps were
produced by the high-speed printer, they were verified for
accuracy by projecting the U-2 photographic transparency onto
the map using a 3-1/4" x 4-1/4" Model D American Optical
Company slide projector. Scale distortions of the computer-
generated, character map prevented proper registration of
the projected photo over the entire area of the map. This
required a distribution of positively identified targets
throughout the area so that adjacent portions of the scene
could be sequentially brought into proper registration.

Figures 2, 3, and 4 were produced from ERTS image
number 1080-15185 of October 11, 1972. As bulk MSS tapes
were received from NASA, they were subset to produce work-
ing tapes for selected portions of the image with guidance
for the scan line and element numbers provided by an Ozalid
print from any channel of the ERTS positive transparency.
Two preliminary maps are produced for review of definable

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[1] These maps were presented in this form for the
convenience of publication. The normal form of map presen-
tation is a character map prepared on the high-speed printer.

boundaries. One shows variation in overall reflectance of the scene that is similar to gray scale maps in other systems. The second map is prepared to identify local areas of spectral uniformity. In some scenes the location of clouds and their shadows are noted to avoid misinterpretation as ground features. When these preliminary steps are completed, one is ready to proceed as indicated in the flow chart in Figure 1.

First level mapping is started by choosing training areas from the two preliminary maps. Select the most easily recognized targets from spectrally homogeneous areas with positive widely separated geographic locations. The Susquehanna River is an excellent example of such a target. Clusters of characters of lesser areal extent on the spectrally uniform map are next persued. Mean vectors are computed for the training areas using the four channels to establish spectral signatures. The euclidean distance of separation for pairs of mean vectors are computed and printed out as shown in Table 1 (to be referred later). As the character maps are produced, they are verified as described above by projecting the U-2 photos on the map. The maps may be produced in separate categories for ease of checking. Figure 2 shows such a map. Note first the easily recognized category of river in the upper right with the meandering creek entering from the left. This map shows the categories of open fields, forest, and golf course in addition to water. Areas verified by U-2 photo correlation are outlined with heavy lines. This process leads to the definition of lesser areas now geographically fixed and interpreted on the U-2 photograph. The number and variety of targets is expanded both with respect to type and extent of geographic separation. This is a cyclic operation, as indicated in the flow diagram, that continues until the mapper feels he is ready to advance to the next stage.

Second level mapping exploits a computer program using cluster analysis developed by Turner (1972). This program works where uniform training areas cannot be found because of spectral nonhomogeneity or small area. Figure 3 was greatly benefited by this technique. The signatures for some suburb, old suburb, confusion suburb, and industrial and for all parking lots and concrete were thus developed. This map was also verified by correlation with U-2 photographic projection and the targets successfully defined so marked. The category "confused suburb" comes about because of its lack of positive separation from agricultural fields. When one considers the mixed character of a suburb consisting of roofs, lawns, trees and shrubs, and streets, it is easy to see how some of these combinations might fortuitously

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compare to a mix of small fields or long, narrow fields
related to contour stripping. Reference to Table 1 shows
that the signatures for a category of "confused suburb"
(the = symbol) and that for a field (the - symbol) does
not have a wide separation. This separation is the euclidean
distance of separation of the vectors representing the
particular target.

Categories are separated for mapping on the basis of
some minimum distance. When this distance is too small,
confusion may result. For example, the distance between
the "confused suburb" signature and the field signature is
relatively small, 1.1, thus confusion between these cate-
gories could be anticipated. In contrast, the separability
of river water (the W symbol) from every other category is
quite large implying no problem in classifying river water
correctly. If a mixture of characters is printed in an
area, it may be desirable to keep the separate signatures,
but lump the area. On the other hand, the signatures may
be blended to produce one character, for example, in the
two industrial signatures (the + symbols) that are quite
separate, 17.7, but that occur together in a mixture for
many industrial areas. These separate signatures must be
preserved, but would be assigned the same mapping symbol.
Judgment should be used here. More work is still required
on the category called highways. It comes up well in
areas of high subject-to-background contrast, but is weak
in urban and suburban areas. Perhaps the mapper will have
to produce highway networks by the judicious connection of
scattered symbols. This is not a satisfactory procedure.
Other spectrally nonhomogeneous targets definable by
cluster analysis that are difficult but worthy of great
effort are quarries and small streams. Note again the
cyclic procedure through level two.

The third and final level of mapping is now approached.
It may be that too many categories have been defined and the
resulting map output is too refined or too confusing to
the reader. Stray symbols can be suppressed. A careful
review of the map objectives should serve as a guide to the
final number of categories to be mapped. When a limiting
goal is established, then the final cycle can be cut off.
It should be noted that the mapping program includes a
percent of the area mapped for each category. This makes
it easy to express the area of each category when the total
area bounded is known. Figure 4 is the final presentation.
This is a combination of the first two. However, in order
to make the map readable, the forest area was subdued so the
blank areas are forest and unclassified. The hope of

Table 1. Distances of separation for categories.

		1 W	2 =	3 -	4 +	5 +
1	W	0.0	31.8	31.5	14.2	31.4
2	=	31.8	0.0	1.1	18.3	14.2
3	-	31.5	1.1	0.0	18.0	13.8
4	+	14.2	18.3	18.0	0.0	17.7
5	+	31.4	14.2	13.8	17.7	0.0

diminishing the unclassified group may rest on the merging of data from two scenes for different seasons of the year.

Conclusions that can be reached from the work on these maps are as follows: The categories of water, forest, high density suburbs, old suburbs, industrial, parking lots and concrete are reasonably well defined. The categories of agricultural fields, highway, and low density suburbs need more study. Some items highly desirable in land use mapping may not be obtained because of size or low subject-to-background contrast. The temporal aspect of the data has not yet had sufficient opportunity to be exploited. The combined efforts of interpretation of ERTS images, aircraft underflight photographs, and computer-generated, character maps has the potential to generate land use maps of high quality.

LITERATURE CITED

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Turner, B. J. 1972. Cluster Analysis of Multispectral Scanner Remote Sensor Data. In Remote Sensing of Earth Resources, Vol. I. Edited by F. Shahrokhi. The University of Tennessee, Space Institute, Tullahoma, Tennessee. pp. 538-549.

ACKNOWLEDGEMENT

FIRST LEVEL MAPPING

SELECT TRAINING AREAS (TA's) BASED ON COMPUTER PROCESSING

COMPUTE SIGNATURES FOR TA's CLASSIFY AND MAP

COMPARE MAPPING UNITS WITHIN TA's WITH PROJECTED U-2 PHOTOGRAPH

DEFINE TA's WHENEVER NECESSARY ON BASIS ON U-2 CORRELATION

EXTEND THE NUMBER AND VARIETY OF TARGETS WITH GUIDANCE FROM U-2 IMAGES

SECOND LEVEL MAPPING

EXTEND CORRELATION OF U-2 PHOTOS WITH CLASSIFICATIONS OUTSIDE TA's

USE CLUSTER ANALYSIS TO DEFINE ITEMS NOT SUBJECT TO DEFINITION BY TA's

WORK TO OBTAIN SIGNATURES IN PREVIOUSLY UNCLASSIFIED AREAS

THIRD LEVEL MAPPING

REVIEW CATEGORIES - CONSIDER COMBINING AREAS

IF REQUIRED CATEGORIES ARE NOT YET DEFINED - BROADEN SPECTRUM

CONTINUE REVIEW AND COMBINATION TO MATCH U-2 CLASSES

Figure 1
Mapping activity flow chart.

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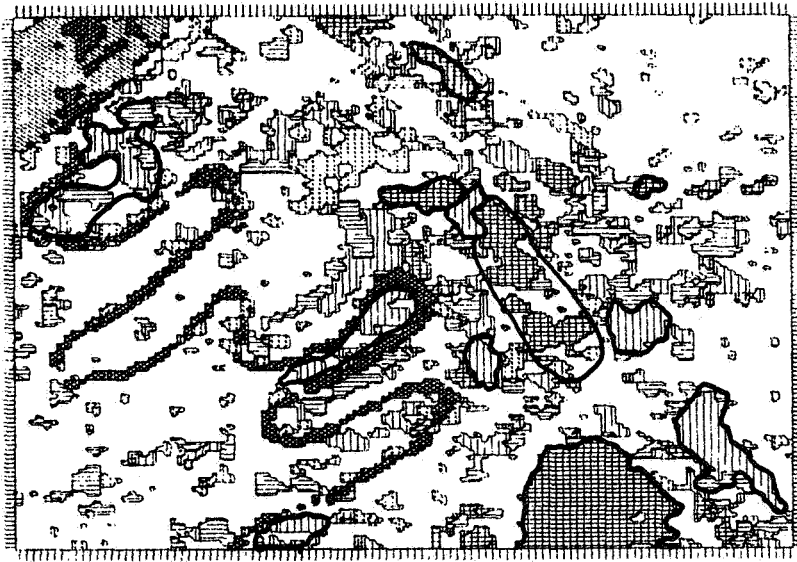
Figure 3

Classification map of
suburb and industry.

Creek
River
Forest
Fields
Golf course

Creek
River
Suburb
Old suburb
Suburb
confusion
Industry
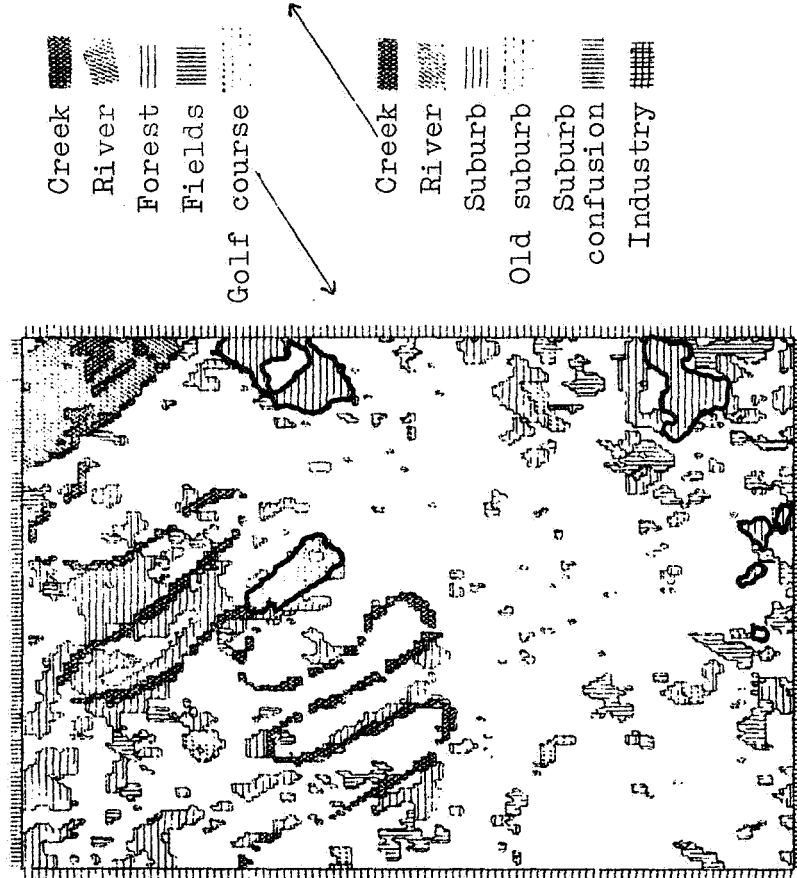
Figure 2

Classification map of
agriculture and forest.

Creek	▦
River	▨
Suburb	☰
Old suburb	▓

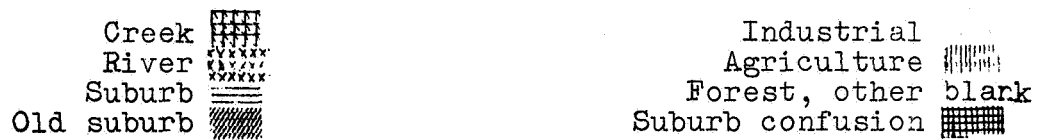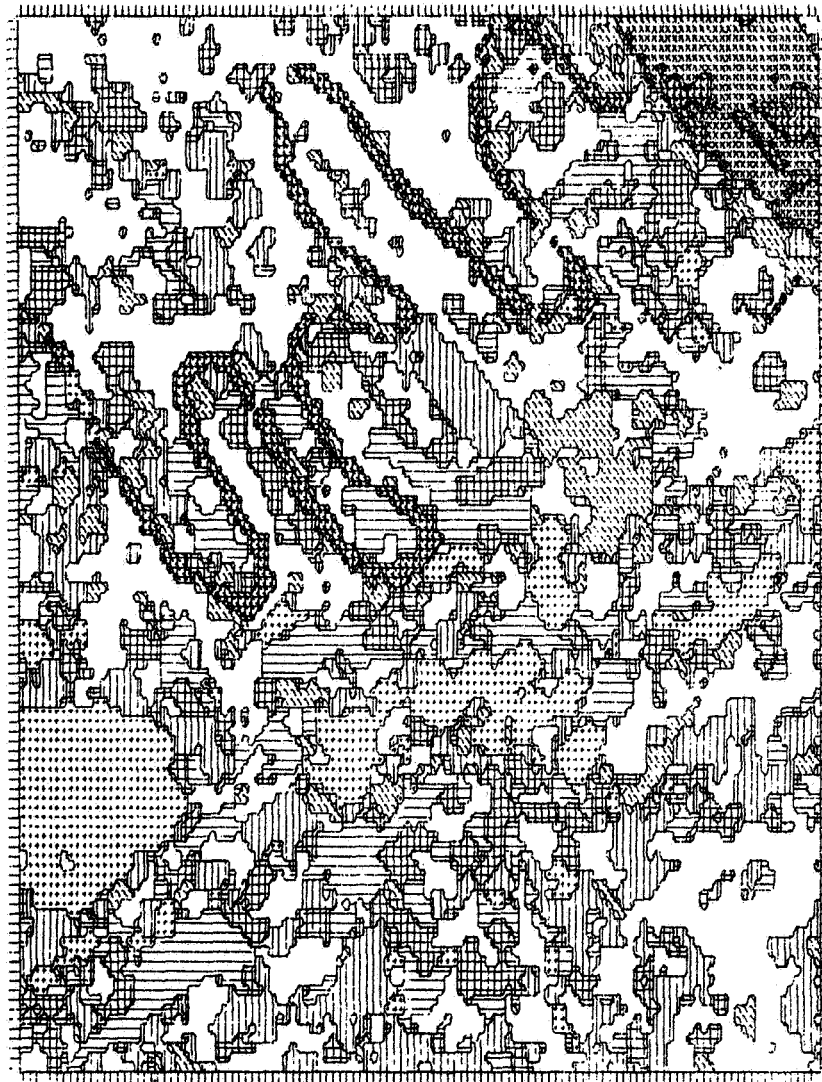|	
Industrial	
Agriculture	▥
Forest, other	blank
Suburb confusion	▦

Figure 4.   Classification map of all categories.