INTERACTIVE MULTI-SPECTRAL ANALYSIS OF MORE THAN ONE SONRAI VILLAGE IN NIGER, WEST AFRICA L-20

By Priscilla Reining, American Association for the Advancement of Science, Washington, DC, and Dwight Egbert, General Electric Company, Beltsville, Maryland

ABSTRACT

Use of LANDSAT data for identifying and measuring small scale compact human settlements (villages) for demographic and anthropological studies is considerably enhanced with the use of an interactive system. Because village components are not uniformly distributed within any one village, they apparently are multimodal, spectrally. Therefore, the functions of location and enumeration need to be kept separate, at this stage. Measurement of a known village is compared with CCT response.

INTRODUCTION

LANDSAT data, as independent sources of information, are potentially important for analyzing human settlements especially in rural tropical areas where rapid population growth is postulated. The potential of using LANDSAT-1 data in conjunction with other data derived from intensive micro studies has been examined in a number of previous papers (Reining 1973, 1974a, 1974b and 1975a). A primary concern in these papers has been the integration of multiple data sources (orbital imagery, aerial photographs, ground level photographs and anthropological field data) derived from specific, circumscribed test sites. However, extrapolation to the precise context, for which single test sites are examples, has always been a goal. In this paper the results and methodology employed in taking the next step toward this goal are described.

More than one facet of anthropological micro studies can be explored, but elemental first steps are discerning and measuring the small scale, compact human settlements called villages. Not all villages are compact, but approximately half of all village types everywhere, and Sonrai villages in particular, are of this type (Murdock 1957, 1967). Location and extent of villages can be used for demographic enumeration when it can be combined with genealogical censusing. Such censusing can also provide migration rates, as well as fertility and mortality rates and age and sex structure. Censusing and extent of village thus provide an accurate estimate of population density. For villages of a known type and designation, the population density estimate can be used as a "multiplier".

Others are working with LANDSAT for demographic purposes (Ellefsen, Gaydos and Wray 1974, Baldwin 1974, Hsu 1973, Durland 1974, 1975, Lingren 1975, Foresti and de Mendonça 1974) but few are working with tropical rural settlements. We concur with the finding of the Baldwin workshop that field data (ground truth) are relevant if the utility of LANDSAT data for demographic purposes is to be evaluated adequately.

METHODS

In work with LANDSAT data, the unit of measurement equals the unit of observation, or pixel. Therefore, a capability of training on a single pixel is of elemental significance for village identification.

The data sources used in this study are: LANDSAT-1 scene No.1345-09480, 3 July 1973, and No.1272-09433, 21 April 1973, Institute Geographique National 1/50,000 map Gotheye 4c, field data from a Sonrai village, data from a low altitude flight 13 July 1973 over this area, Perille's Analyse de la Situacion Demographique au Niger, 1973, and an interactive multispectral analysis system. Correlation of these data sources makes positive the identification of named Sonrai villages in Landsat CCT data displayed on a color monitor.

Initial work, beyond simple identification, indicates that known Sonrai villages are multimodal in spectral characteristics, suggesting that (1) village components (e.g. houses, compound floors, varying types of roofing, trees, open pathways, tethering places and market places) are not so evenly distributed in every village as to present a uniform, and unimodal, brightness level and (2) until additional work is done the locator function needs to be distinguished from the enumerating or measuring function.

The specific methodology employed follows. As a preliminary to multispectral training and classification with the system, a detailed visual examination of several Sonrai village sites was made. Utilizing the "zoom" magnification Feature of the system, small sections of the image surrounding villages were enlarged and displayed on the color CRT monitor. The LANDSAT-1 CCT digital data stored in the system's refresh memory were used to create the magnified sections, thus maintaining maximum resolution. An 8X magnification was found to be optimum for close examination of the villages.

In the test site area villages range in size from approximately 100 LANDSAT picture elements (pixels) to as few as 3 or 4 pixels. A few single compound settlements were exhibited by only 1 or 2 pixels, while several villages fell in the 20 to 30 pixel size range. For a preliminary study, a small section of the LANDSAT-1 scene was entered into the system at a slightly magnified scale of 2X. At this scale the color monitor image covered 15 x 15 kilometres at approximately 1:50,000. Small areas were then magnified to 8X for selecting training areas. Training on a single pixel appears to be optimal for village components. In operation, a specified training area is delineated on the image under analysis through the use of an adjustable electronic cursor which is both displayed on the monitor and scanned by the hardware for size and position coordinates. The multi-spectral brightness data within the training area are automatically measured, and their limits are used to define a four dimensional parallelepiped in spectral space. Then the entire image is scanned pixel by pixel and compared to the parallelepiped limits. All pixels which lie within the bounds defined by the training data are flagged or alarmed and displayed on the monitor as a color map. This can be done in approximately 5 seconds, and allows iteration. Only places corresponding to identified residential areas (villages) were flagged or alarmed by the initial training data. The residential range is from single pixels to more than one hundred pixels. The single pixels are composed of single quartier, or one compound-cluster villages or settlement areas.

If after a few iterations of the basic training and classification procedure the results are unsatisfactory, other procedures are employed. One of the more valuable complementary procedures is histogram analysis. Each time the system performs a parallelepiped training it calculates and stores complete histogram data for each of the four spectral channels. The operator can call these data to be displayed on the graphics terminal and alter any of the parallelepiped limits as defined on the histograms. Again in real time (1/30 second) he can see the results of any changes he might make, and if necessary, can proceed to other techniques. Of the available options, multiple parallelepiped analysis and cluster analysis were performed. Once the desired classification resluts have been achieved, they are then stored on one of the eight binary channels to form a thematic map which can be displayed on the original image data base.

ANALYSIS

The analysis is based on 8 hours of work with the interactive multi-spectral analysis system.

Extent of Village

A Sonrai village, Koulbagou-Haoussa, was studied in June and July of 1973. A partial reproduction of a 1:50,000 map showing the village appears in Figure 1, a 1972 aerial photograph of the village appears in Figure 2, and a ground photo taken inside the village appears in Figure 3. A black and white photograph of the system monitor, of MSS 6 only, is shown in Figure 4. The response of the village is seen in 6 pixels (8X training window) also shown in Figure 4. In Figure 5, MSS 7 of the same portion of the scene is shown with some differences among the pixels. The LANDSAT CCT response indicates that the village area is 6 pixels or 27,018 square metres.

Two estimates of the area of the village have been derived from an aerial photograph. A chain used to measure between points readily identifiable in the photograph suggests that the photo is at a scale of 1:6,800. Making that assumption a planimetric measurement of the photo yielded an area estimate of 33,750 square metres while a direct count using a grid provided an estimate of 32,960 square metres. The difficulties inherent in making a simple direct conversion of number of pixels to obtain an area measurement have been examined by Chafaris (1975) among others. It seems quite clear that additional work will need to be done for demographic studies, but Sonrai villages provide a useful range in size, from 1 or 2 to 100 plus pixels and the problem of border pixels under conditions of high contrast should be examined.

Location of Villages

Thirteen out of fourteen named villages occurring on the Gotheye map are flagged following training on one village as may be seen by comparing Figure 2 and Figure 6. All other alarms or flags are smaller (unnamed) settlements corresponding to settlements on the Gotheye sheet, or, in three instances, to likely settlement locations. In short, considerable certainty exists that everything identified is a settlement. However, it is not certain that every settlement is identified -- there may be "underreporting" or response. The classification shown in Figure 6 consists of white spots on a black and white reproduction of a color composite. The horizontal lines are due to data dropouts in MSS 4, which was not used in the classification.

Subsequent Analysis

In general, for subsequent analysis previously derived, spectral signatures or parallelepiped limits can be used by recalling them from storage or re-entering them. Thus, the entire analytical procedure for the new data base does not need to be repeated. But, evaluations can be made as to the accuracy of the new results and additional changes made if needed.

In the two areas studied in this investigation, an attempt was made to transfer the signature. However, it was found that direct transfer was not possible, although the spectral signatures in both cases were similar. This is not unexpected, since the LANDSAT data are from different seasons. In one case, three rather than four channels were used.

A second area, immediately upstream of that shown in the earlier figures, is shown in Figures 7-10. Figure 7 is a background shot of the monitor at a 2X magnification displaying an area approximately 15 km x 15 km. Figure 8 shows an initial classification based on training on the village of Ziguida (see Figure 1). After detailed work with the 2X scene and comparison of the results with maps, a large area was entered into the system at 1X magnification. This scene (Figure 9) covers 30 km x 30 km and contained approximately 190,000 pixels. Three different spectral signatures developed on the 2X test site were applied to the larger area and 561 pixels were identified as being villages. Evaluation of the results is still in progress, although qualitatively they appear to be very good. Figure 10 shows the composite classification of the area. In the area shown in Figure 10, three settlement patterns can be seen: (1) discrete, compact and relatively large villages located on the banks of the Niger River, and on islands in the river; (2) ribbon settlements along minor tributaries; (3) very small, one-compound-cluster village settlements. The last may correspond to rainy season compounds. The greatest source of potential error in demographic enumeration is here, since rainy season compound inhabitants have village houses as well.

Population Growth Rate

The projected population growth rate of 2.83% per year demands a 47% increase in population between 1957, when the IGN aerial coverage was flown, and 1973, when the LANDSAT data used here were acquired. A desirable next step in the investigation is comparison of more recent LANDSAT coverage with the 1973 data for possible or probable (given the projected growth rate) changes in the extent or number of villages.

CONCLUSIONS

1. Small scale human settlements can be identified optically on a color monitor of an interactive multi-spectral analysis system. Such settlements range in size from 1-2 pixels to more than 100 pixels. A significant number show a response to classification procedures.

2. Adequate mapping for the entire area inhabited by Sonrai is not available (Niger, 1972), therefore village location could be estimated by the methodology employed here.

3. Further work with compact villages in the size range of Sonrai villages is thought to be justified to determine the demographic capabilities of this technique.

4. At this stage separation between identification and measurement of villages is an appropriate strategy.

ACKNOWLEDGMENTS

Field data used in this paper were acquired in the course of work conducted under the auspices of contract # AID/CM/afr-C-73-21. LANDSAT CCTS # 1272-09433 and 1345-09480 were made available for this research by Goddard Space Flight Center. Access to the GE Image 100 system was a courtesy of General Electric and Goddard Space Flight Center.

REFERENCES

Baldwin, C. Stephen, 1974, Satellite Data Workshop, May 10, 1974. Paper. The Population Council.

Chafaris, George J., 1975, Area Computation from ERTS data via Image 100. General Electric Paper, 9 January 1975.

Durland, Robert E., 1974, Potential Uses of ERTS Satellite Imagery for Population Studies and Census Activities. Paper presented at the World Population Conference, Bucharest, Rumania.

Durland, Robert E., 1975, Applications of Remote Sensing in Population Estimation in Bolivia and Kenya. Paper presented at the Population Association of America meetings, April 1975.

Ellefsen, Richard, et. al., 1974, Computer Aided Mapping of Land Use Using ERTS Multispectral Scanner Data. Paper presented at First Pan American Congress on Photogrammetry, Photo interpretation, and Geodesy, Mexico City, Mexico, July 1974.

Foresti, E. and De Mendonça, F., 1974, Demographic Inference Using ERTS Images. Seminar on Space Applications of Direct Interest to Developing Countries. COSPAR Brazilian Space Research Institute, Sao Jose dos Campos, p. 239-256.

Hsu, Shin-yi, 1973, Population Estimation from ERTS Imagery: Methodology and Evaluation. Proceedings of the American Society of Photogrammetry. 39:no. 3.

Lindgren, David, 1975, Possible Applications of ERTS Technology for Population Policy Research in the United States, with Special Reference to Metropolitan Planning. Paper Population Association of America Meetings, Seattle, April 1975.

Murdock, George P., 1957, World Ethnographic Sample. American Anthropologist 59:664-687.

Murdock, George P., 1967, Ethnographic Atlas: A Summary. Ethnology 6:no 2. April.

Niger Publication Carte Au 1:50,000, Situation au 31 Decembre 1972.

Reining, Priscilla, 1973, Utilization of ERTS-1 Imagery in Cultivation and Settlement Site Identification and Carrying Capacity Estimates in Upper Volta and Niger. National Technical Information Service, Springfield, Virginia E 74 10813.

Reining, Priscilla, 1974a, Human Settlement Patterns in Relation to Resources of Less Developed Countries. Proceedings of Seminar on Space Applications of Direct Interest to Developing Countries. COSPAR: Brazilian Space Research Institute, Sao Jose dos Campos.

Reining, Priscilla, 1974b, Earth Resources Technology Satellite 1 Data and Anthropology. Paper presented at the American Anthropological Association Meetings, Mexico City, Mexico, D.F. November 1974.

Reining, Priscilla, 1975a, The Demographic Potential of ERTS-1 Data. Paper presented at the American Association for the Advancement of Science meetings, New York City, January 1975.

Figure 1. Portion of a 1:50,000 scale topographic map along the Niger River near the villages of Koulbagou-Haoussa and Ziguida. Map reduced to approximately 1:28,000.

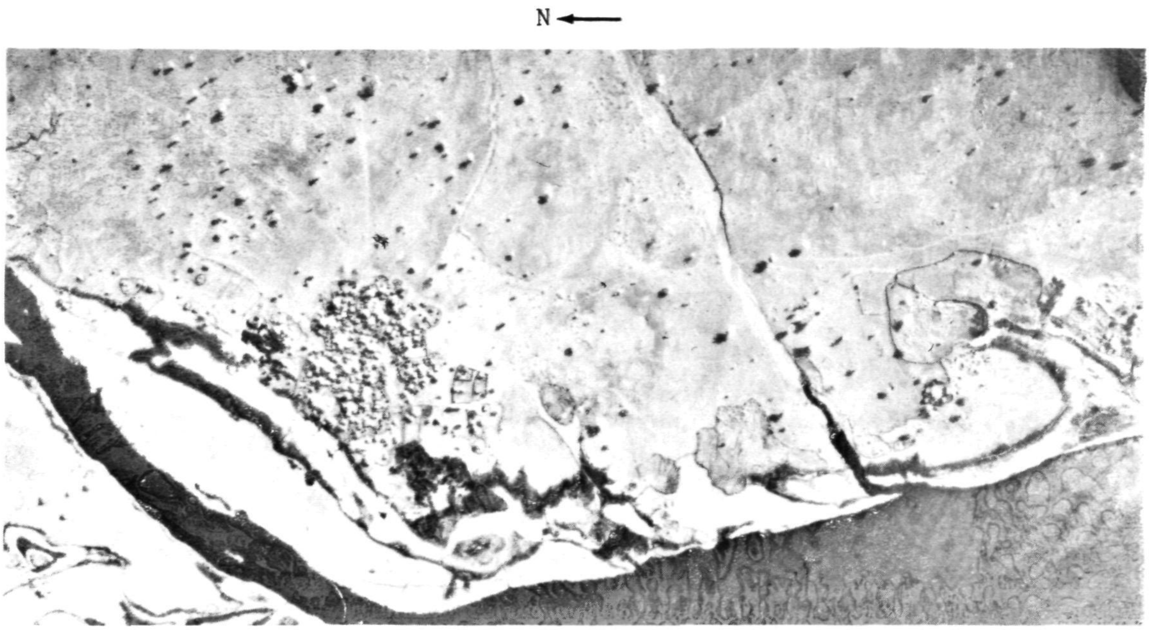

Figure 2. Aerial photograph showing the village of Koulbagou-Haoussa. Photo covers 750 by 1750 meters (scale = 1:10,000).

Figure 3. Ground photograph of the village of Koulbagou-Haoussa.

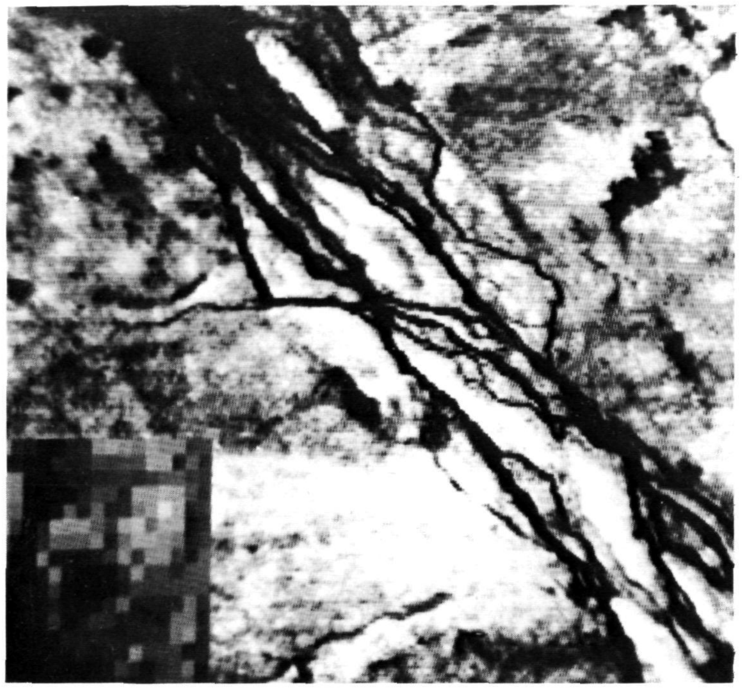

Figure 4. Television monitor display of a 15 x 15 km portion of MSS band 6 ID No. 1272-09433. 8X "window" (lower left) is centered on the village of Koulbagou-Haoussa.

Figure 5. Television monitor display of MSS band 7 for the same scene shown in Figure 4.

Figure 6. Classification results (white) superimposed on black and white rendition of color composite television display for same scene shown in Figure 4.

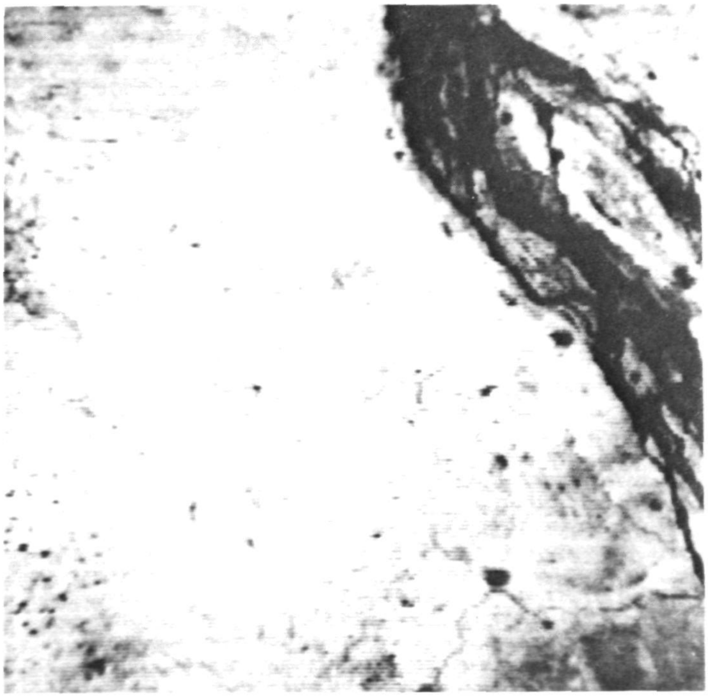

Figure 7. Black and white rendition of color television display for a 15 x 15 km area surrounding Ziguida (Scene ID No. 1345-09480).

Figure 8. Results of classification (white) for scene shown in Figure 7. Training area (Ziguida) is shown in the 8X window (center left).

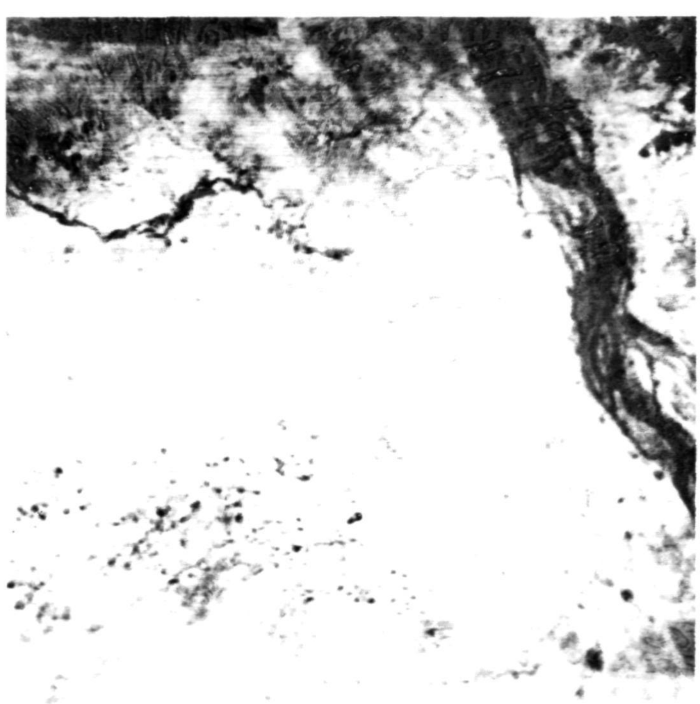

Figure 9. Black and white rendition of a color monitor display of a 30 x 30 km portion of scene ID No. 1345-09489 along the Niger River, near the village of Ziguida.

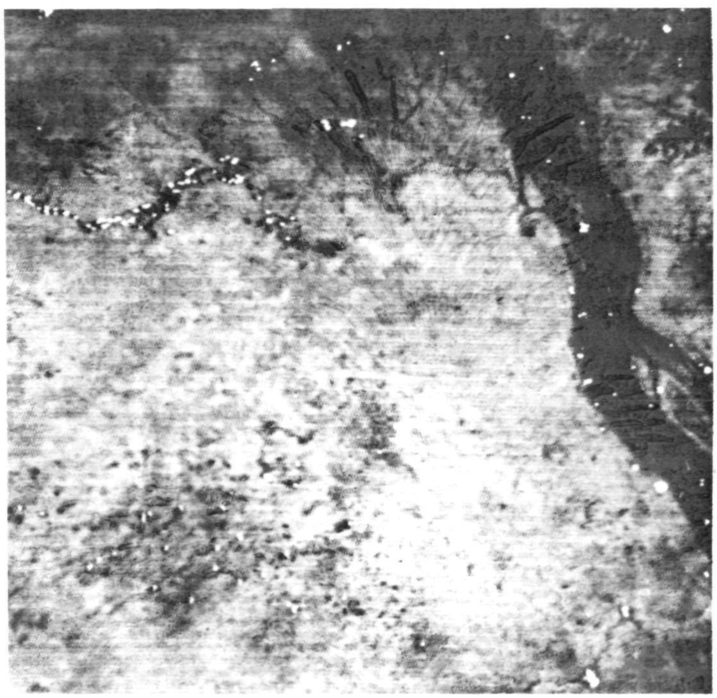

Figure 10. Classification results (white) for scene shown in Figure 9. These results are for the same spectral signature (from training on Ziguida) as in Figure 8.