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Earth Resources Technology Satellite-1 (ERTS-1) Data and Anthropology: use of these data in carrying capacity estimates for sites in Upper Volta and Niger.

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Abstract

Repetitively derived multi (spectral) band imagery from ERTS-1, launched in July 1972, is now available for many parts of the earth's land surface and represents major new data sources for anthropological work in habitat, land use and settlement patterns. A completed first step test of ERTS-1 data is available in carrying capacity estimates for Mossi, Hausa and Sonrai sites derived from (1) field work, (2) aerial photography and (3) ERTS-1. Data can test more than one carrying capacity formula.

When a new source of data first becomes available and few anthropologists (Reining, 1972, 1973a,b, 1974a, Fanale, 1974, Cook and Stringer, 1974) have used it, work is exploratory and broad generalizations are tempting. Earth Resources Technology Satellite (ERTS), providing major, new, independent data sources, may be as important for anthropology as the camera and tape recorder in "sensing" data and the computer in analyzing it, but it takes the informed to convert these data into information. The combination of coverage, making it possible to view regions in mosaics of images comprehending several hundred thousand square miles (kilometers) with resolution fine enough to discern individual villages, is a forest-and-trees view never publicly available heretofore for scientific work. Odum's expressed need for "functional studies of large units of landscape" (1969) held back, in his opinion, by conservatism of academics and funding institutions, may find in now available data the realization and stimulus needed for such studies.

As an example we have a 12-scene color composite mosaic of the central West African Sahel in which major and very minor features can both be seen. For working purposes a 55-scene mosaic of the Sahel at a scale of 1:1,000,000 can be laid out on a 3' by 9' work table and comprehends approximately 500,000 square miles of distortion free coverage in which a number of micro environments can readily be discerned! In these mosaics a 300 m. cultural feature, a village or a field can be seen if in contrast with its immediate surroundings.

A laundry list of possible ERTS use for anthropology is not the aim of this paper, but at least two areas, close to anthropological interests - settlement pattern studies in the context of agrarian ecology and demographic studies - are not as well represented in the anthropological literature as they could be (Netting, 1974, Baker, 1972). Chief among the reasons for this, in my opinion, are some very real methodological obstacles - the problems of quantification and extrapolation. This opinion is shared, I believe, by Bennett (1973) and Netting (1974). The strengths of anthropology have always been in intensive field studies and a substantial weakness of anthropology especially vis-a-vis other disciplines has been the difficulties of extrapolating those findings to a wider, larger context with security that these findings from the principle study area apply. Careful enumeration of household and family memberships, cropping areas, labor parties and intricate recording of interrelationships among thses overlapping groups abound in field studies; techniques of aggregation are left to the economist, the agricultural economist, the demographer, the sociologist. Unlike the anthropologist, professional members of these other disciplines usually do not derive their own data but have a sophisticated methodology for analyzing data derived by others. Orbital imagery is a potential means of bridging the methodological gap between the anthropologists with their field studies and the demographer and agriculturalist with their techniques.

Secondly, and importantly, use of ERTS data products can enable anthropologists to develop their own techniques for extrapolation from the particular and specific to the perceptible physical domain of one culture's anthropogenic effects, it's impact on nature. When one can directly assay the "universe", as well as sample it, it's a whole new ball game; simulation studies can now be tested with the empirical.

Retrospective location of sites of ethnological and archeological studies should be possible for most already completed field work because 146,000 images or scenes of data have been derived since the satellite was launched in 1972.

So far disciplines in the earth sciences are much more active in exploring and exploiting these new data products and some of this is briefly summarized in the NASA handout which accompanies this paper. The breakdown used in application studies is mineral, land resources, environment, land use, water resources, mapping and charting, marine resources/oceanography/agriculture/forestry/range resources. Such results suggest that the portion of the discipline of anthropology involved in human adaptation to and human impact on environment be reviewed for methodologies for incorporation of these data in the solution of anthropological problems, thus joining some members of the disciplines of geology, geomorphology, geography, hydrology, meteorology and agronomy who are already doing so.

Although an active public affairs office makes knowledge about the satellite readily available and known to many, a resume of the status of the spacecraft and of the application studies program is given here as essential background information.

Earth Resources Technology Satellite (ERTS) is the first satellite of its kind in that all of its data are put into the public domain. Data from previous satellites of this resolution capability have been classified, and earlier data banks so created continue to be classified. For many actual or potential users the development of application procedures depends upon continuity of coverage. Hence, the importance of an unclassified satellite data program is the first point I would like to stress. For example, although we have coverage from 1972 and 1973 in the Sahel, there is no coverage of the 1974 cropping season in that area because the tape recorder on board the spacecraft is no longer functioning. Thus, we cannot compare the difference between the 1973 rainy season deficit with the near normal 1974 rainy season. However a very substantial reservoir of data is available at modest cost to all comers of any nationality through the EROS data facility. A data request sheet is appended.

The ERTS project is under NASA jurisdiction and has been funded at approximately $200,000,000 for the first two satellites, which are lettered prior to launch, then numbered when they become operational after launch. ERTS-1 was launched in July 1972, for an expected lifetime of one year. However, it is still producing data for direct transmittal to receiving stations, three of which are in the United States, with one in Canada and one in Brazil. Direct transmission takes place during daytime passes when the sensors are on. Coverage from other parts of the earth which was taken during daytime passes is stored on a tape recorder and then "dumped" during nighttime passes over the receiving stations. A basic limitation on data acquisition has always been tape recorder capacity. This limitation is most effectively solved by the creation of new receiving stations, one of which is planned for Italy. Discussions include possible stations in Kenya and Upper Volta or Zaire. A contract has been signed with Iran.

The original funding for ERTS included costs for the two spacecrafts, their instrumentation, support staff, the development of the NASA Data Processing Facility (NDPF) at Goddard to handle the data, as well as for application studies. Approximately $34,000,000 was available for these studies which were to be subcontracts. Representatives of the potential user community, divided among university, private corporations and government agencies, were invited to pre-launch conferences at Goddard, preliminary to preparation of application study proposals for potential funding. As a result, NASA received some 800 proposals, and approved some 350 Prinicpal Investigators; 210 investigations were funded, and 100 foreign investigations were chosen for ERTS-1, allocating approximately $28,000,000 out of the original budget. A basic feature of the contracts is that all investigations be reported in the public domain through the National Technical Information Service, Springfield, VA. NTIS publishes weekly abstracts of reports received; thus not only the data, but also the analyses of them, are available in the public domain. ERTS-1 investigators have reported results in two major conferences held under NASA auspices, in March and December 1973. Results are available in NASA publications.

Journals, such as Photogrammetric Engineering, regularly publish articles such as "Agricultural Inventory Techniques with Orbital and High Altitude Imagery", and "Digital Mapping and Digital Image Processing", (40, no. 11:1282-1293, 1295-1302).

Each scene is imaged by the ERTS spacecraft four times because the functioning instrument, the multispectral scanner (MSS), has four sensors for different parts of the visible and near infrared portions of the electromagnetic spectrum. They are:

MSS 4	0.5 - 0.6 um,	green-yellow
MSS 5	0.6 - 0.7 um,	orange-red
MSS 6	0.7 - 0.8 um,	red-infrared
MSS 7	0.8 - 1.1 um,	(near) infrared

Virtually all of the land surface of the globe has been imaged except the People's Republic of China. The aim has been to get at least one cloud free scene of the earth's land surface.

ERTS-B proposals for applications numbered 669. Many people who were principle investigators for ERTS-1 reapplied with developed projects for the satellite which is to be launched in mid-January 1975. Of these, only 54 U.S. investigations and 45 foreign have been funded due to drastic cutbacks in allocation by OMB. In contrast with the funding level of ERTS-1, funding for ERTS-B is at $5,900,000. Government agencies such as USGS, and AID will directly fund demonstration projects for ERTS-B. The academic part of the user community is least well funded under current policy. However, this is for U.S. investigators. NASA will be supplying data to as many foreign investigators as domestic users.

The scenes are taken at 9:30 am local time and the orbit tract follows an oblique path trending west to accommodate the time change as the earth rotates beneath the satellite in any one orbit. Some compromises were necessary to accommodate different users. The 9:30 time was selected to give a maximum balance between light and shadow and is especially good for geomorphologists, geologists, etc. Agriculturalists would have preferred 12:00 noon for maximum light on fields. Possibly the 12:00 time would have been preferable for demographic purposes as well. Resolution is 10 meters for some linear elements to 80 meters for most features.

ERTS-1 data comes in two modes - imagery (like photographs), and computer compatible tapes, which print out in alphanumerics (letters and symbols). Imagery at scales of 1:1,000,000 are excellent for synoptic coverage. CCTS at 1:20,000 have better resolution, but take a very large room to lay out one scene. However, once a feature is identified, the computer can count all other areas with the same reflectance characteristics. Also there is a big difference in expense. One scene of imagery in all four bands can be bought for $12.00 and analyzed directly or converted into color transparencies by anyone anywhere. Working with the tapes takes computer time, programmers, etc.; the budget quickly moves into thousands of dollars.

The retrospective availability of ERTS data needs to be qualified with the observation that funded application studies received priority in data acquisition; however, additionally with continuation of the spacecraft sensors and equipment, further coverage has been acquired. With the launch of ERTS-B in January a new set of priorities will be established. A list of U.S. and foreign investigators is not yet available but can be obtained later in 1975 by writing to the Office of International Affairs, NASA (Washington, D.C. 20546); the test site location of these studies will be a direct indication of new data availability.

Any anthropologist preparing a new field study could incorporate existing ERTS data in preliminary selection of community location or as an archeologist could use established signatures for known sites to locate new ones (Cook and Stringer, 1974). Adventitious use can be made of still to be acquired ERTS-2 imagery.

Much of the discussion so far relates to institutional funding from NASA, but extra-NASA funding should now be explored. Such demand will strengthen continuation of the program. The demographic potential in using ERTS-1 data products is being explored in another paper, scheduled for the AAAS meetings in 1975. The potential of using ERTS-1 data in studies in agrarian ecology has already been tested in work largely restricted to carrying capacity formula.

The concept of carrying capacity typifies the relationship between population and resources in a defined geographic area, being cropped by members of a specific society following a known cultural tradition. One problem with carrying capacity formula is that they do not incorporate marketing system/migration factors in them but assume an essentially or largely closed system. However for rural areas, with no mechanized means of transport, one has to make some basic assumptions about cultivation and propinquity of cultivators, as Bender also notes (1971).

More than one carrying capacity estimate can be made: (1) the actual land use equation at any one time, (2) the potential land use or carrying capacity, at a given level of technology, (3) the optimum land use in terms of meeting a defined standard of nutrition for man and beast with conservation of soil and vegetation and water resources, and (4) augmented carrying capacity under changing technology leading to intensification of cultivating regimes.

The carrying capacity formula specifically tested in 1973 with field studies augmented by analysis of 1:1,000,000 color transparency composites was that proposed by Allan in 1965; one signal advantage of the Allan approach is his use of soil type as the basic factor upon which differential carrying capacity for the entire domain of a given group of people is built. Soil type differences are quite readily discerned in the orbital imagery, and the changes in seasonal appearance of different soil types as they bear characteristic vegetation is also quite marked as this sequence shows (16-6). The dates are: 18 September 1972, 22 April 1973, 03 July 1973, 26 August 1973, 13 September 1973, and 1 October 1973.

These form a "data base" of some considerable future use as well as present utility, even though we unfortunately do not have the 1974 cropping season coverage. However, Allan's formula, although presumably testing potential carrying capacity since it allows for the fallowing cycle, in fact uses present population as an indication. "For a single Vegetation-Soil type, the area of land required per head of population may be expressed by the formula 100 L.U. X C/P when LU is the Land-Use Factor (duration of cultivation and period of subsequent rest required for res- toration for each unit of land), C is the Cultivation Factor (assumed to be approximately an acre) and P the Cultivable Percentage (the amount of land which already has indication of being arable) for the type" (1965:89). Once the required number of acres per head are known by use of this formula and the total number of acres (hectares) known for each soil type the total carrying capacity can be calculated. There is, however, one problem. If the Cultivation Factor is calculated rather than assumed as the average acreage (hectarage) under cultivation per head of population at any one time it may be (as indeed it was) that the area in cultivation is less than one acre or one half a hectare per person at any one time. If that is the case the area required is lowered and the carrying capacity consequently inflated. Instead of Critical Population Density as the potential carrying capacity one may be measuring an already over extended cultivation schema still being "carried". If, however, one does take one acre or the slightly larger half hectare as a reasonable average for land in crop per person per season and work from there while retaining the very useful distinctions about soil and vegetation type differences being differentially utilized for a single cultivation regime, Allan's work is extremely useful.

In addition, Allan's use of aerial photographs to complement field work also recommended itself because the usual course followed in analyzing this orbital imagery is to use a multi-stage approach of (1) field work, (2) aerial photographs and (3) imagery/CCTS. When hand held ground level camera photographs are taken they are closest to what is called "ground truth" by NASA. I prefer the term field work and subsume under it, as Allan also does, soil surveys and samples, measurement of field (garden) areas, household/family size, and crops and cropping techniques. Moreover, ideally, aerial photography flights are coordinated with the orbital coverage, and with field work so that the multi-stage analysis will be based on truly comparable data. In the 1973 field work among Hausa, Sonrai and Mossi (with a day's trip only to a Wolof village in Senegal), April 1973 dry season imagery was used for June-July work corresponding that year to end of the dry season and beginning of a late and finally deficient rainy season. Rainy season ERTS coverage became available later. Aerial photo- graphs were only exceptionally available at a useful scale (1:15,000) in Niger and this latter constraint was an important one in selection of field sites. Aerial photos were enlarged to a 1:10,000 scale - the minimum useful for mapping of quatier and compounds and houses for determining house location.

ERTS imagery was enlarged to a scale of 1:50,000 for direct mapping of fields in known village domains and for which field work results were also available. The carrying capacity estimate for Sonrai is 30 people per square km of riverain terrain, for Hausa is 13 persons per square km of valley, or dallol, bottom land, and for Mossi is 28 persons per square km under conditions of seriously overworked soils. The details may be found in Reining (1973: 12-14).

No Computer Compatible Tapes are yet available for analysis of village and cultivation sites in which field work has been done. It is quite generally agreed that the resolution of the CCTS is far better than the imagery; the unit of observation is the unit of measurement, one picture element (pixel).

An important additional finding from examination of the imagery in this area is that some fields failed to regenerate vegetation in the 1973 rainy season and may be evidence of formerly arable land which is now wasteland. Given future coverage, precisely these fields should be consistently monitored in repetitive coverage for their capacity to or failure to regenerate vegetation. Such monitoring could and should be done in a period longer than a single seasonal cycle and points up the advantage of using the imagery to meet Bennett's strictures about deficiencies in "standard ethnological approaches to cultural ecology has been the tendency to confine research to short time periods, thus failing to observe man-environment relations over the (often) relatively long cyclical change patterns, anthropologists are being encouraged to extend their research across years instead of months." Although not explicitly refering to ERTS, Bennett goes on to say, "The same need for more rigorous demonstration is pushing anthropologists into technical contexts of analysis which require them either to obtain specialized training or to work in tandem with technical specialists. With the larger bodies of data acquired by such methods, research on extensive agriculture is coming to have impressive implications for ecological, demographic and social-organizational theories." (1973:44-5).

Conclusions:

1. Actual availability of orbital imagery from ERTS-1 in the time, place, and sequence desired by an individual anthropological researcher cannot in any way be guaranteed, but the ca. 150,000 scenes derived in its functioning period make adventitious use of these data a potential for many.

2. Scientific use of these data for problems posed by the theoretical concerns of this or other disciplines is in its infancy. An unknown number of scenes have actually been analyzed/interpreted but the total may not be more than 10 per cent. Type of analysis rather than quantity is of concern here.

3. The compromise between synoptic coverage and resolution resulted in a product which can be adapted to augment other conventional data sources. If budget permits purchase and with the CCTS, the product is that much better for detailed work.

4. Agrarian ecology, or cultural ecology and demographic or population anthropology are almost certainly in for a flourishing period of work if this data source is combined with existing sources and techniques.

5. Anthropologists have most frequently been concerned with more or less closed systems - taking this to mean an identifiable culture/society with a known domain even though some intractable problems have been explored by Moerman and others (CA:196). To the extent that discrete domains can be physically defined or are self-defining by their impact on the environment their study is enhanced by including repetitive orbital data with other data.

[1] ERTS-1 imagery used in this paper is supplied through the Drought Analysis Laboratory under the jurisdiction of American University and Catholic University of America, GSFC I.D. UN431 (SR 368), Contract # NAS 5-21970. The imagery is specified.

Study Date	ID #	Country Location	DAL Orbit and Frame #
20 April 1973	1271-09365*	Mali and Niger	Track 14 Frame 5
20 April 1973	1271-09372*	Niger	Track 14 Frame 6
07 February 1973	1199 09373	Niger and Nigeria	Track 14 Frame 7
20 April 1973	1271-09374*	Niger and Nigeria	Track 14 Frame 7
13 June 1973	1325-09371	Niger and Nigeria	Track 14 Frame 7
21 April 1973	1272-09430*	Mali and Niger	Track 15 Frame 5
21 April 1973	1272-09430*	Mali and Niger	Track 15 Frame 6
7 August 1973	1380-09415	Mali and Niger	Track 15 Frame 6
21 April 1973	1272-09433*	Niger and Upper Volta	Track 15 Frame 7
20 July 1973	1363-09423	Niger and Upper Volta	Track 15 Frame 7
22 April 1973	1273-09482*	Mali and Niger	Track 16 Frame 5
22 April 1973	1273-09485*	Niger and Upper Volta	Track 16 Frame 6
3 July 1973	1345-09480	Niger and Upper Volta	Track 16 Frame 6
26 August 1973	1399-09472	Mali and Niger	Track 16 Frame 6
13 September 1973	1417-09470	Mali and Niger	Track 16 Frame 6
22 April 1973	1273-09491*	Niger and Upper Volta	Track 16 Frame 7
23 April 1973	1274-09541*	Mali and Upper Volta	Track 17 Frame 5
23 April 1973	1274-09543*	Upper Volta	Track 17 Frame 6
7 October 1972	1076-09540	Upper Volta	Track 17 Frame 7
25 October 1972	1094-09542	Upper Volta	Track 17 Frame 7
12 November 1972	1112-09544	Upper Volta	Track 17 Frame 7
23 January 1973	1184-09542	Upper Volta	Track 17 Frame 7
23 April 1973	1274-09550*	Upper Volta	Track 17 Frame 7
4 July 1973	1346-09541	Upper Volta	Track 17 Frame 7
23 April 1973	1274-09552	Upper Volta	Track 17 Frame 8

* Constituent in Mosaic.

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