Paper L 14

CONCEPTS OF INTEGRATED SATELLITE SURVEYS

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ABSTRACT

FAO initially contracted with NASA to carry out investigations in three countries; but now as the result of rapidly increasing interest, ERTS imagery has been/is being used in 7 additional projects related to agriculture, forestry, land-use, soils, land forms and hydrology. Initially the ERTS frames were simply used to provide a synoptic view of a large area of a developing country as a basis to regional surveys. From this, interest has extended to using reconstituted false colour imagery and latterly, in co-operation with Purdue University, the use of computer generated false colour mosaics and computer generated large scale maps. As many developing countries are inadequately mapped and frequently rely on outdated maps, the ERTS imagery is considered to provide a very wide spectrum of valuable data. Thematic maps can be readily prepared at a scale of 1:250,000 using standard NASA imagery. These provide coverage of areas not previously mapped and provide supplementary information and enable existing maps to be up-dated. There is also increasing evidence that ERTS imagery is useful for temporal studies and for providing a new dimension in integrated surveys.

Looking towards the future, ERTS imagery or equivalent imagery is seen as providing developing countries with relatively inexpensive information as a basis to regional surveys, management surveys and local and regional planning activities.

As we are well aware, there has been a technological revolution in recent years in the methods of aerial survey. This revolution has been accompanied by publications on integrated surveys of land-use and natural resources using aerial photographs (e.g. Christian, 1958; Becket & Webster, 1962; Brink et al., 1966; Hardy, 1970; Howard, 1970, 1971); but these do not take into account the role of and the impact of satellite imagery on integrated surveys. In fact, the potential contribution of satellite imagery to integrated surveys in developing countries is only beginning to be appreciated. In the past, national inventories of rural resources have seldom been undertaken using complete coverage by aerial imagery, although national inventories of land-use and natural resources are in general recognized as a prime requisite to effective national rural planning and rural management. As indicative of the expanding role of satellite imagery, the Food and Agriculture Organization of the United Nations (FAO) initially contracted with NASA to carry out three investigations using Earth Resources Technological Satellite (ERTS) imagery (Sudan, Colombia, Philippines); but the Organization is now extending the use of its satellite imagery to seven additional countries.

SOME BASIC CONSIDERATIONS

When attempting to interpret ERTS imagery for integrated surveys, we should bear in mind the following pertinent facts:

1. ERTS-1 imagery is confined to four contiguous bands (bands 4-7) of reflected solar energy in the visible and near infra-red spectra.

2. Although band 4 (0.5/0.6 microns) covers the peak of spectral reflectivity of vegetation in the visible spectrum (i.e. c. 0.54 microns), its value may be lost by the somewhat similar reflective characteristics of the other surfaces (cf. spectral curves 1 & 2 with 3 - Figure 1). An exception, lies in its penetrative quality of ocean surfaces by solar energy of this waveband. High density phytoplankton, associated with high density fish populations, may contrast well against the surrounding ocean in band 4, due to the higher reflectivity of phyto-plankton. Similarly band 4 may reveal near in-shore features not to be observed in the other bands.

3. Band 5 (0.6/0.7 microns) covers the spectral range of maximum chlorophyll absorptivity by plants at about 0.655 microns (cf. curves 1, 2 - Figure 1). As most other natural surfaces, water excepted, have a much lower spectral absorptivity, and hence higher spectral reflectivity, this band provides good contrast between vegetal surfaces and exposed dry soil and sand. When there exists a high correlation between vegetal cover and soil type or sub-soil water, then this band is of value to soil surveyors and hydrologists.

4. Bands 6 (0.7/0.8 microns) extends from the far-red of the visible spectrum into the near infra-red and includes the spectral range in which the shoulder of the plant spectral reflectivity curve is sensitive to disease, severe drought and mineral changes. Investigators have variously put the commencement of the near infra-red band, as between 0.70 microns and 0.78 microns (cf. Howard 1970); but most commonly it is accepted as beginning between 0.72 to 0.75 microns. The writer accepts a value of 0.75 microns, since this is beyond the shoulder of the curve for healthy plant foilage. As water surfaces and moist surfaces are highly absorptive in the infra-red, these are usually readily distringuishable in this band (cf. Figure 1), provided their characteristic reflectivity is not masked by vegetation.

5. Band 7 (0.81/1.1 microns) is entirely in the near infra-red, but includes two hydroroxyl absorbing bands (0.95, 1.1 microns). Improved penetration of alto-stratus clouds can be observed on some imagery in band 7.

6. Due to the altitude of the satellite (i.e. 920 km, 560 miles), ERTS imagery provides a perspective of the Earth approaching a plan view, which can often be used directly for small-scale planimetric mapping with relatively few ground control points.

7. As a single ERTS frame covers a ground area of about 26,000 km^2, it offers advantages associated with a synoptic view and favours deductive reasoning rather than inductive reasoning. Recognition of the latter is important, since much of our present-day approach to research depends on well tried methods developed for working from the particular to the general (i.e. by inductive reasoning).

8. As the electromagnetic data recorded in a single signal by the tape of the ERTS optical mechanical scanner covers an area of approximately 65 m x 70 m, this is often considered to be the minimal resolving power of the imagery. However, objects with a size smaller than this may be identified sometimes by interpreting the mixed signal of the data cell. For several reasons, a resolution of about 70 m will usually not be obtained when working from 1:1,000,000 ERTS black-and-white prints or transparencies. Using this type of imagery, it is frequently difficult to identify features related to landform, soils, vegetation and crops with a ground area less than about 0.5 sq. km.

9. As ERTS-1 has an 18-day cycle, it enables time-dependent information (e.g. seasonal flooding) to be studied. However, clouds may be a limiting factor to frequent time dependent studies. As shown by Table A, which summarizes ERTS data (<30% cloud cover) for one-year for Africa, South America and Southern Asia, cloud can be an important limiting factor to studies, particularly in South America.

Table A

ERTS-1 Imagery - % of Frames with <30% Cloud: 1972/73

Continental Area	Frames % Satisfactory for Spatial Studies	Frames % Satisfactory for time-dependent Studies
South America	50	38
Africa	85	63
Southern Asia	93	88

TYPE OF ERTS IMAGERY

As follows, FAO's investigations are indicative of the increasing range of ERTS imagery formats, etc. from which to chose for integrated surveys. These are:

a. 70 mm black-and-white transparencies in the four spectral bands at a scale of 1:3,369,000.

b. 18 cm x 18 cm, net image area, black-and-white transparencies in the four spectral bands at sclae of 1:1,000,000. This format is also referred to as 9"/9-1/2".

c. as b. but black-and-white prints in the four spectral bands at scale of 1:1,000,000 and 1:500,000.

d. multi-spectral imagery (reconstituted colour) at 1:1,000,000, 1:290,000 and 1:70,000/1:100,000 using additive viewing techniques.

e. multi-spectral colour mosaics formed from an assembly of computer-compatible video-tape displays at 1:158,000 or from multi-spectral imagery.

f. computer print-outs at 1:25,000.

18 cm transparencies and black-and-white prints have been found suitable for a range of field activities, where the final mapping scale does not exceed about 1:200,000. There is increasing evidence that with adequate ground checking, a range of discipline oriented thematic maps can be prepared at 1:250,000. These will be useful to national planning and to regional and reconnaissance surveys. However, the information to be obtained from the imagery is seldom useful in local surveys and local management planning. For these latter purposes, maps usually require to be at scale of about 1:50,000 or larger. In the past, conventional aerial photography has often been taken at scales between 1:30,000 and 1:60,000 without recognizing the fact that smaller scales would be as satisfactory, since the final map scale will be 1:250,000. Under these circumstances, ERTS black-and-white imagery in 2 bands may suffice, particularly if the imagery is enlarged 2-4 times for field use. It may require emphasizing that, as many developing countries are remote from experienced aerial survey companies, aerial photography is expensive and often exceeds a $100,000 per mission.

Seventy millimeter chips, unless used in conjunction with a slide projector or with an additive viewer in a multi-spectral study, has the limitation of working at a much reduced scale (i.e. 1:3,369,000). Chips are therefore only used in additive colour viewing or occasionally by copying them on to a 35 mm format for slide studies in black-and-white using a standard 35 mm projector and a viewing screen. There is little doubt that multi-spectral colour imagery at about 1:1,000,000 is quicker and less tedious to interpret than black-and-white imagery at the same scale. Although, what is obvious from multi-spectral colour imagery can also be observed often by back-checking to 35 mm slides, data has been observed from multi-spectral imagery, which even with back-checking was not adequately detected from black-and-white material.

A colour mosaic assembled from video-tape displays by Purdue University is now being used in a desk-study in Rome. It seems to be intermediate in value between the ERTS prints and computer compatible tape print-outs; but also requires a critical appraisal with multi-spectral colour imagery at 1:70,000 to 1: 100,000. Print-outs at 1:25,000 provides information, which is not observable from imagery at 1:1,000,000 or enlargements thereof.

ANALYSIS OF SELECTED ILLUSTRATIONS

For integrated surveys related to land-use and natural resources, small-scale ERTS imagery (i.e. 1:1,000,000) is useful for (a) preparing small-scale thematic maps (e.g. :250,000) of areas as yet not covered by planimetric maps (b) planning reconnaissance and pre-investment surveys in areas not adequately covered by existing maps (c) planning conventional aerial photography (including contract preparation) of selected areas of development, so as to ensure that the area will be fully covered at the most suitable scale and in the best film-filter combination (d) amending existing small-scale maps to eliminate planimetric errors (e) amending existing maps, so as to include details previously omitted (f) up-dating land-use information contained on existing maps (e.g. new forest boundaries in areas of recent settlement and agricultural development) (g) two to four times enlargements of black-and-white imagery to serve as photo-mosaics. In addition, using an additive viewer, a colour inter-negative is obtained and from this a two to four times colour enlargement is prepared, which may then be used as substitute for a colour photo-mosaic from aerial photographs.

Three examples from Africa, indicative of the type of information obtained from the ERTS imagery are as follows. A comparison of ERTS imagery and existing maps of Morocco have shown that it is practicable to prepare quite detailed thematic geological maps from the imagery as many structural features are clearly defined (e.g. major and minor faults to north-east of Agadir). Also, the existing maps may be amended to correct planimetric errors in water-course alignments and additional information enables the length of water-courses to be extended. The synoptic view of the arid coast of Morocco provided information on the former coast lines in this region.

A reconstituted multi-spectral additive colour image of Awash Valley, Ethiopia, and prepared by Huntings Aerial Surveys Ltd. (London), has been found useful in providing a better understanding of the hydrology of the area. The colour imagery also assisted in the geomorphic and groundwater (thematic) mapping of the region (Currey, 1973). Several unknown sources of freshwater were discovered. If the imagery had been available prior to the aerial photography at 1:40,000 of the commercially irrigated cotton growing areas, the flight-plan would have been amended to advantage of the follow-up survey. In the vicinity of the irrigated cotton crops, induced and natural vegetation was identified and delineated on the imagery and Papyrus swamp was clearly recognizable along the edge of the major lake.

Imagery of the Sudan (El Obeid, El Fula) has been examined from black-and-dispositives and prints (Mitchell, 1973). Selected areas are in the process of being examined using computer generated data (Baumgardner, 1973) and some checking of ground-truth against print-outs has been completed (Ramsay, 1973). The author has made a comparison of these two sources of information. Prints at 1:1,000,000 can be magnified to about 1:200,000 before film graininess becomes conspicuous, but multi-spectral additive colour viewing is possible at about 1:70,000 using 1:1,000,000 black-and-white chips. On the multi-spectral colour mosaic and on the multi-spectral additive colour imagery, an aureole of weathered material surrounding the inselbergs could be identified. Several vegetal types, two dune formations and soil-types are readily observed. Areas of induced vegetation may be delineated. Drainage patterns are conspicuous and often characterize the types of bedrock. It is also practicable to divide the areas into land-systems. A temporal desk-study of imagery in the vicinity of El Fula indicates major changes in the surface features due to the rapid evaporation of surfaces water during the dry season.

DISCUSSION AND CONCLUSIONS

As a basis to integrated land-use and resource surveys, a number of authors have described and discussed the significance of land-units as observed on conventional aerial photographs (see Howard 1971). These papers provide adequate evidence of the role of aerial photo-interpretation in integrated surveys. Now, on the basis of the separate information derived to date from the FAO studies of the ERTS imagery, the imagery seems satisfactory for use in integrated surveys. The approach recommended by the author is to apply a hierarchical subdivisive system in which the largest land-units are identified and delineated on the imagery on the basis of a paramount discipline, (vide Table B). These land-units are then further sub-divided into smaller and smaller land-units on the basis of other paramount disciplines. Eventually small land-units are obtained, which are homogeneous in a number of environmental factors useful to future rural planning and development, and including the preparation of thematic maps.

Checking in the field will be necessary; but this can be minimized by attempting to identify beforehand the land-units of varying magnitude.

Table B provides a brief description of the hierarchical land-units to be observed on satellite imagery (cf. Howard 1971, 1970a, b). Land-unit is used here as a general term. The paramount disciplines, used to subdivide the ground area portrayed on the imagery into smaller and more homogenous units, is also given in column 2. The final column summarizes the attributes considered most useful to integrated surveys. It will be observed that land units at the level of the land-system and land-catena are uniform in macro-climate, lithology and landforms; and land-facets, if identified, are uniform not only in these factors but also in terms of natural vegetation soil type and certain environmental characteristics which may be imbued in the vegetation (e.g. aspect, macro-climate, water table).

Table B

Land-Units Observable on ERTS Imagery

Land-unit	Paramount Discipline	Comments and Description
Land-division ↓	Regional geography	The synoptic view provided by the satellite imagery is valuable for the identification of these extensive land-units having a gross landform expressive of a continental structure and in which its regional climate is evidenced by the uniform fit of the vegetation (panformation) to its landform.
Land-province ↓	Physical geography	The synoptic view provided by the satellite imagery is valuable for the identification of these extensive land-units, which are recognizable as a distinctive assemblage of surface forms expressive of a second order structure.
Land-region ↓	Geology	A land-unit, usually of considerable magnitude, which is identifiable mainly through the image characteristics of its land-system(s). The land-region has surface properties of a lithological unit with a small range of surface forms.

Table B (Continued)

Land-unit	Paramount Discipline	Comments and Description
Land-system	Geomorphology	A recurrent landform pattern of geographically and geomorphologically related smaller land-units. Its drainage pattern is distinctive and provides boundaries coinciding with geomorphic features.
Land-catena	Geomorphology	These land-units are often difficult or impossible to identify from small-scale imagery (e.g. 1:1,000,000); but large-scale computer based and additive viewing techniques are providing encouraging results. A land-catena constitutes a major recurrent (geomorphic) unit of the land-system (vide Howard, 1971). Each land-catena contains a distinctive grouping of geographically and geomorphologically related land-facets.
Land-facet	Phyto-geomorphology (Botany/ Geomorphology)	Not normally recognizable from small scale imagery; but large-scale techniques indicates that some land-facets are identifiable provided they are extensive in ground area. A land-facet comprises a distinct unit of topography with which is associated an equally distinctive vegetal structure at the level of the plant subformation. Usually, climatic uniformity can be inferred from the vegetal structure; and the soil-type should be found to be uniform.
Land-element	Botany	Not observed on ERTS imagery.

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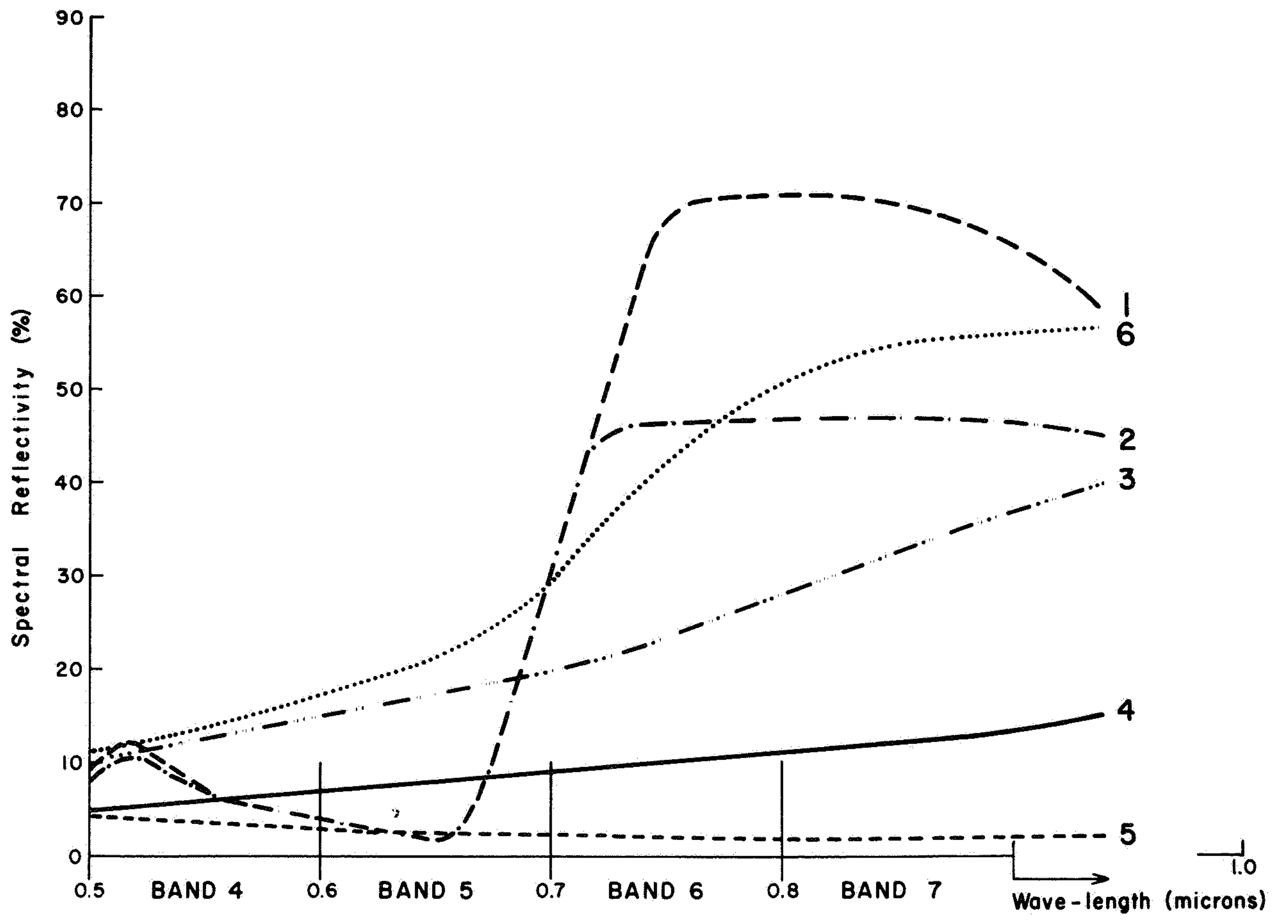
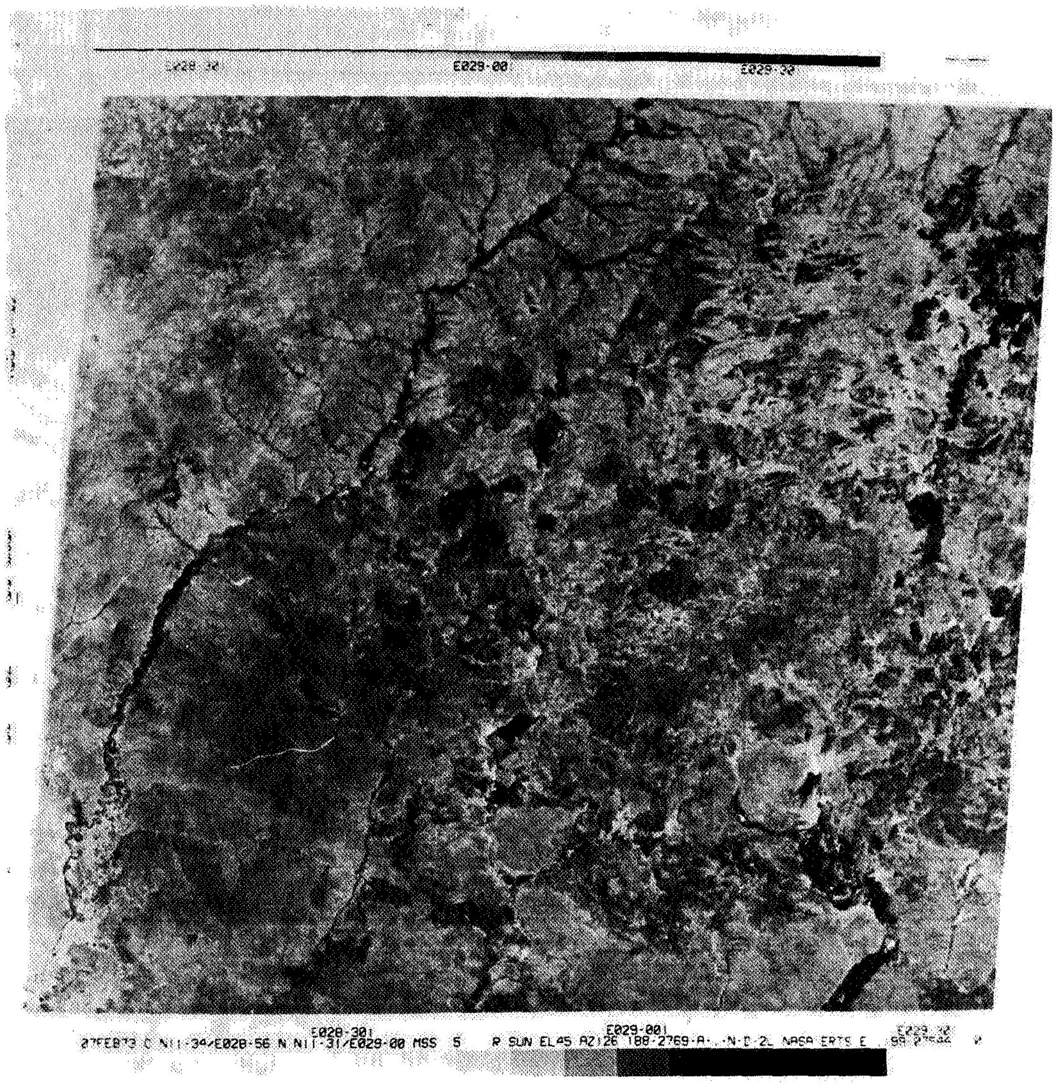
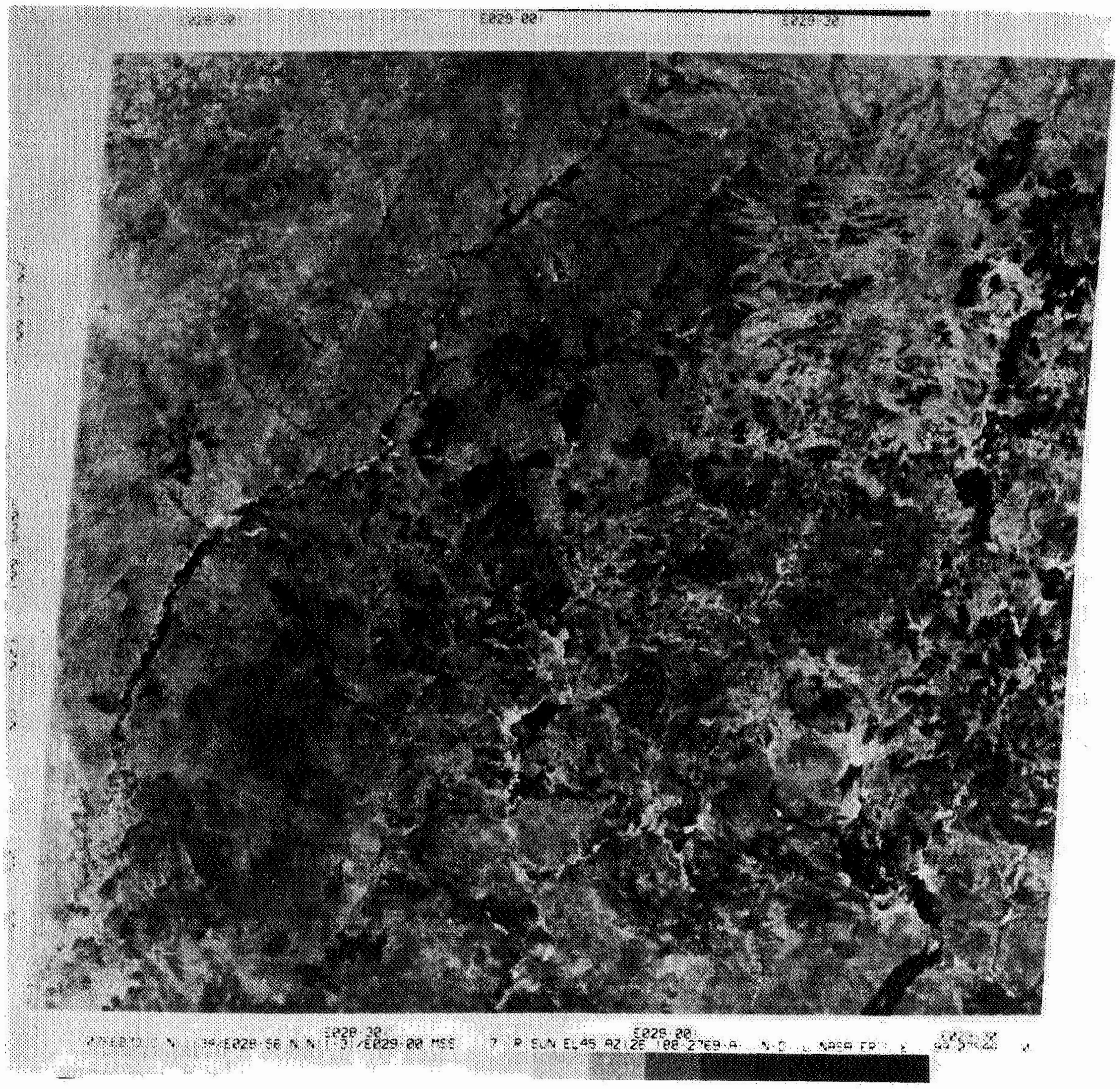


Figure 1. Characteristic spectral reflectivity curves of several natural surfaces: (1) healthy green vegetation (leaf area index: 4); (2) healthy green vegetation (leaf area index: 1); (3) dry loam; (4) wet loam; (5) water surface; (6) dry grasses.



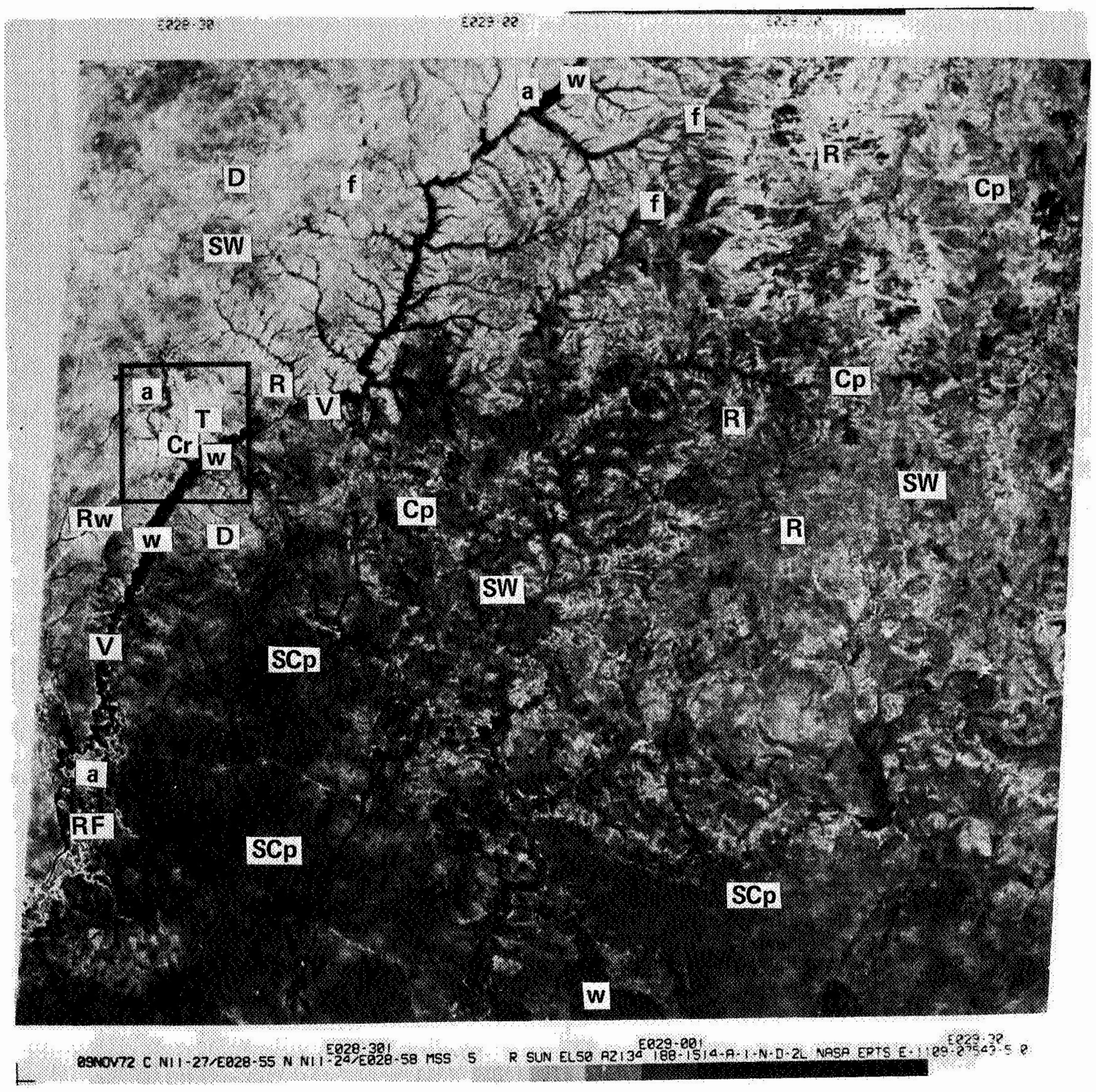
(a)

Figure 2. ERTS imagery, El Fula, Sudan. (a) and (b) provide a comparison of spectral bands 5 and 7 taken on 27 February 1973 (dry season) (1:1,000,000). Note the better definition of the drainage system in band 5, but band 7 (infrared) enables water surfaces (moist areas to be easily identified. (c) band 5 taken 29 November 1972 at end of wet season. A comparison with (b) (i.e. time-dependent study) shows changes related to vegetation and water moisture. (d) Part of a multi-spectral colour mosaic (1:158,000) obtained from the magnetic tape replays (29 November). Note the easier recognition of features than in black-and-white, including soil boundaries and water surfaces/ moist areas.



(b)

Figure 2 (Continued)



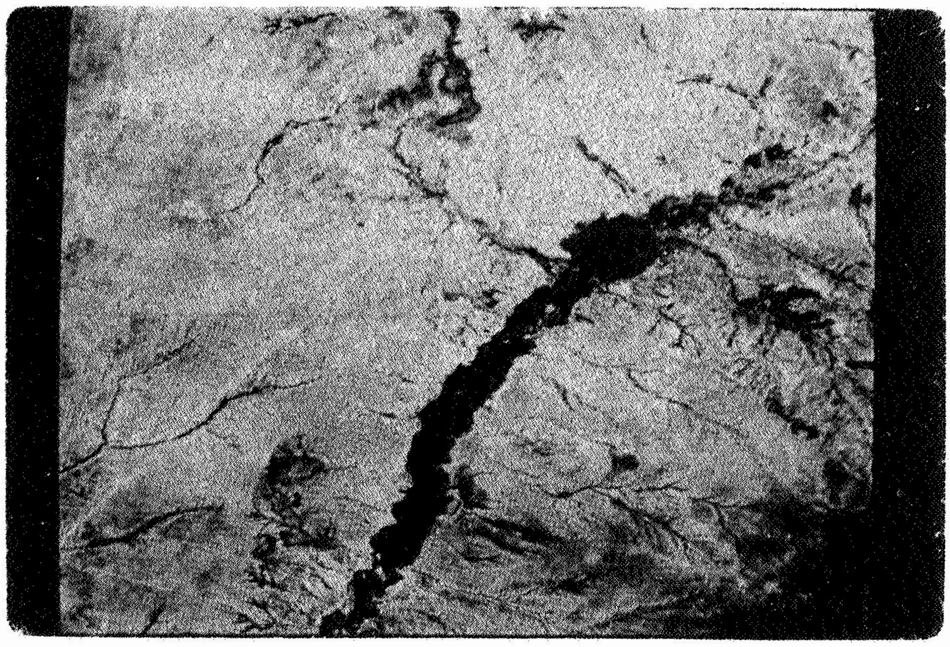
(c)

Figure 2 (Continued)

Key

f: fault
D: dunes
a: alluvian
w: water surfaces
Cp: clay plain
SCp: smooth clay plain
R: rock outcrop
V: main valley

RF: ripavian forest
SW: sayanna woodland
Cr: cultivation (crops)
T: town
Rw: railway
d: dense
s: sparse
h: hydromorphic



(d)

Figure 2 (Continued)

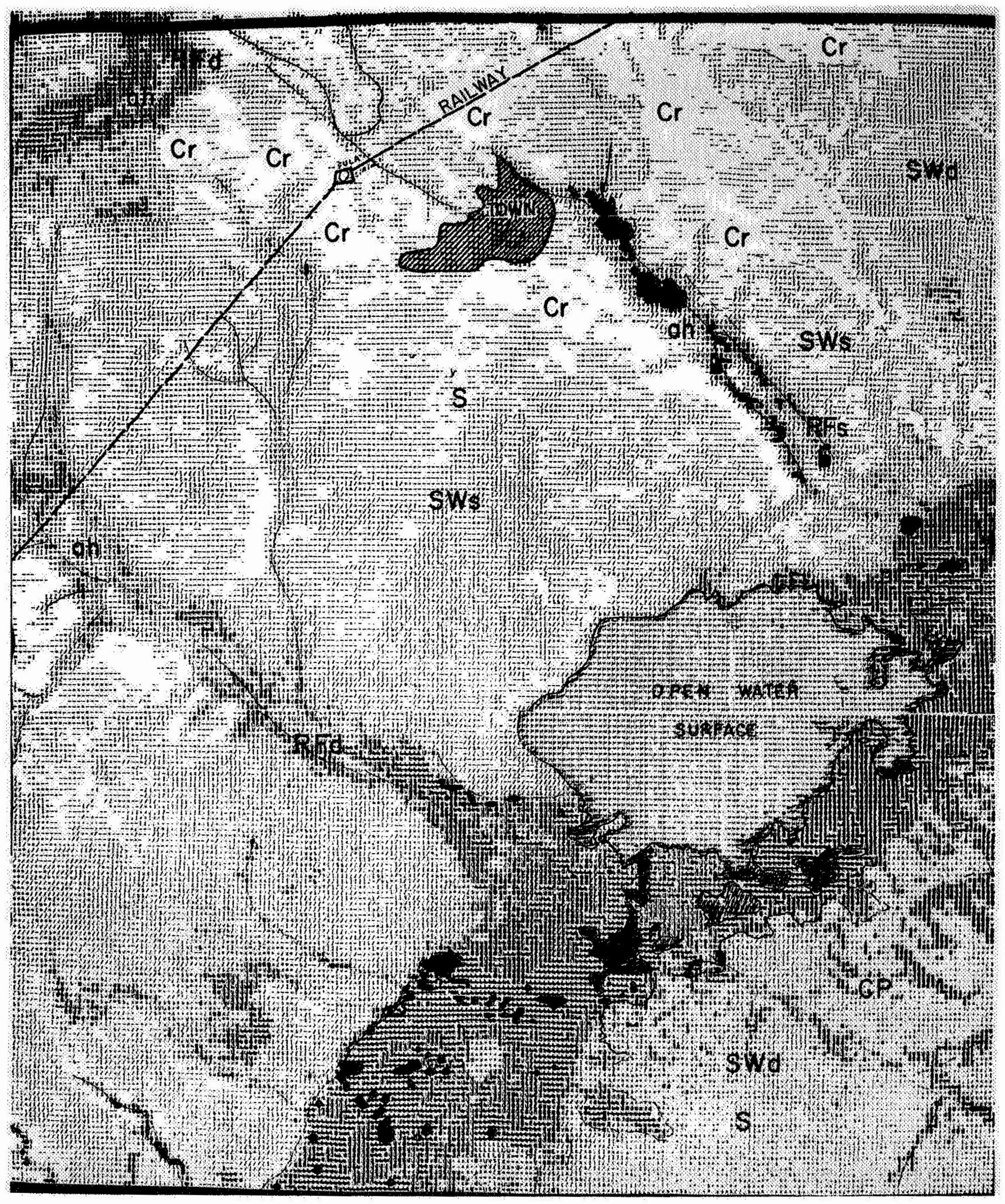


Figure 3. Computer print-out at 1:25,000 from tapes of 29 November of area within small square (2c). Note the further increase in ground information as compared with Figure 2. Black areas and water surfaces/areas of very high moisture content.