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ERTS Follow-On Program No. 28070

II Corrected

An Aid to the Development of Botswana's Resources

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SECTION ON HYDROLOGY

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I. Introduction

The Hydrological work on this program is divided between two test sites having different functions. The objectives may be summarised as:- to find out in Test Site 1 how far Landsat imagery may be used by simple means to determine the seasonally changing pattern of flooding at any period in the Okavango Delta and, in Test 2, to prepare a base line map of development, as at 1975, in the Okavango catchment outside Botswana, to be used for comparative purposes in the future at five or ten yearly intervals.

Progress may be summarised as follows: two to three Landsat 2 coverages of the Delta have been received and one to four coverages of the Okavango catchment. These have been subjected to preliminary scrutiny and comparison. Plans for the more detailed subsequent investigation are being developed. Quite extensive ground truth work has been done in the Delta, including commercial air photography, observation from low flying aircraft, field expeditions and hydrological measurements by ground parties. Unfortunately, owing to the unpredictable dates of imagery, much of the ground truth cannot be precisely related to it. However, the general pattern of change in the Delta is shown by both Landsat and ground truth. It is hoped that detailed work will show significant correlations and that in future some expensive field measurements may be eliminated or reduced by using Landsat instead. Related to the agreed co-operative Program between NASA and Botswana Government, but not forming official part of it, is a UN and Botswana Government programme of relating ground truth of ecological parameters, pixel by pixel, to CCT's, for which purpose a Consultant has been engaged.

II. Technique

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(a) ERTS 1

It had been hoped that ERTS 1 would enable 10 to 20 hopeful small areas of the Okavango Delta in Test Site 1 to be pinpointed in 1973 for detailed investigation. Unfortunately ERTS 1 imagery ceased after only six months operation, which did not include the period of rising flood. Also the ERTS 1 negatives at 70 mm received here were of a quality which could not be used by us. Although negatives were made here from the 1 in 1 million positives, resolution was lost and the density scale became too distorted for meaningful comparisons, which were therefore postponed until Landsat 2.

(b) Comparison of 1/500 000 prints

After various different preliminary approaches, paper prints of MSS 7 at 1 in 500 000 were prepared here from 70 mm negatives. Four frames, dates August and September 1975, were assembled into a mosaic. A 5 km square grid was made as a transparent overlay, corresponding to the 5 km grid used for low flying ecological studies by colleagues in a UN/Botswana Government study of the Okavango Delta.

The Aug/Sep '75 mosaic was then compared on the grid, square by square, with imagery for November 1975 (this being the greatest contrasting, but comparable, imagery available up to the present). Each square was rated subjectively on a scale 0 to 5 for detectable contrast between the two dates. Differences possibly wholly attributable to fire were marked "F". Otherwise an attempt was made subjectively to discount the component of change due to fire.

The marked ratings were then made readily visible by shading in colour on a code: red, half red, yellow, half yellow, white.

The results are shown and discussed in Section III below.

The next stage of the investigation, now beginning, is to use the results of the grid rating to select significant places where the degree of flooding can be quantified in one of the following ways:-

(i) Flooded/Not flooded.

(ii) mean width of channel etc.

(iii) visually planimetered area of flooding as percentage of the 5 km square

(iv) visually planimetered area of flooding as percentage of the area liable to flood in the 5 km square. (This last, though involving more preliminary work with air photos, can probably give a much more accurate and significant total, capable of extrapolation to the other areas.)

A "significant place" in the above paragraph means either a place which seems capable of relating to known, or easily determinable, ground truth, or one which would appear to be indicative of flooding over a large area.

(c) Consideration of Other Methods

(i) Planimetry

An attempt has been made to estimate the total swamp area (liable to uninhibited evapotranspiration) by planimetering the areas appearing to be flooded as revealed on false colour composites of ERTS 1 at 1 in 500 000.

This has been used as an input for the development of a simple mathematical model of the Delta for desk computer (Olivetti Programma 101). FCC's are better for this purpose than MSS 7 since the permanent swamp area is largely covered by aquatic vegetation, much of which gives a high reflectance on MSS 7.

As FCC's are expensive and subject to delays and the planimetry rather inaccurate with eyeball methods, this procedure for assessing seasonal flood change is not at present regarded to be as practicable as MSS 7. But FCC's should be used for occasional checks.

(ii) Contrasts and Seasonal Change by Colour Additive Viewer

After seeing demonstrations in Nairobi and Pretoria we regard this method as too expensive in hardware for immediate application here.

(iii) Contrasts and Seasonal Change by Density Slicing and Electronic Planimetering

This method is also too expensive in hardware. Also the advantages of the method would be somewhat nullified by the difficulty of distinguishing between fire and flood except by human judgement.

(iv) Contrasts and Seasonal Change by Stereoscope

An ordinary mirror stereoscope has been tried to compare MSS 7 at different dates. This proves to be a quick method of detecting change by winking the eyes. Possibly this, in the long run, using 1 in 1 million prints or transparencies, may prove to be better than the method of comparing 1 in 500 000 prints. It will, however, be necessary to use a completely transparent graticule in order to tabulate the information.

(v) Diazo Methods

These have not yet been tried but, on recommendation, materials have been ordered for some experiments, including, it is hoped, positive-negative masking.

(vi) Use of Bands Other than MSS 7

Apart from occasional use to prepare FCC's to reveal the total evapotranspiration area, use of the other bands seems to be a complication not at present applicable to our limited time and limited hydrological objectives. However the hydrologists engaged on this program have fruitful contacts with botanical and ecological colleagues and it may be that multiband work in co-operation with them may be revealing.

(d) Technique in Test Site 2

The objectives are being simply achieved by making a 1 in 1 million mosaic from selected MSS prints, using the other bands visually (or perhaps later with Diazo methods) to pick out agricultural development.

(e) Ground Truth

Water levels, discharges and, to a lesser extent, flooded areas have been recorded for a number of parts of the Delta during the whole of the period of ERTS 1 and Landsat 2.

Air photographs covering the whole flooded area were taken at a low water period in 1973 and at a high water period in 1974 at a cost of some Ø 50 000. Unfortunately Landsat was not operative during those two periods, and direct comparison of detail is not possible, though indirect comparisons are being made.

From mid 1975, low level flights on a 5 km grid have been flown at four - monthly intervals with detailed observations of ecological parameters including some of hydrological importance. A large mass of data has been accumulated. An attempt has been made to display the hydrological content visually in a simplified manner in 5 km squares for comparison with Landsat.

In the first two weeks of October 1975 some six field parties went into the remote parts of the Delta to determine water levels and extent of flooding in rather unknown areas. The dates were chosen because it was expected that Landsat would be operative over the area. Unfortunately Landsat was not switched on for the two successive passes nearest to the ground truth dates, nullifying the detailed tests of Landsat's ability to distinguish just-flooded and just-not-flooded land.

During 1975 seven special water level gauges were established to enable water levels to be determined from low flying air-craft. These have proved quite successful and it is easy to determine water levels to better than 1 cm accuracy. A modified gauge has now been designed and it is hoped to establish more of these gauges. The modified gauge is quite cheap to manufacture, but establishment in remote parts of the Delta is expensive in time and transport, requiring long journeys by rough track, boat, dugout canoe and on foot. The Department hoped to obtain a hovercraft early in 1975 to assist in this work but the manufacturer went into liquidation.

III & IV Accomplishments and Significant Interim Results

The interim accomplishments of this Program are two:-

(a) It is proved that FCC's can be used for a simple estimate of the total evapotranspiring area of the Okavango Delta, sufficiently accurate for preliminary inputs for the development of a mathematical model of the surface hydrology of the delta. With the limited equipment available to us here, we do not see any very great accuracy obtainable by this method alone.

(b) The subjective assessment of 1 in 500 000 prints MSS 7 at different dates shows the following results:-

Out of a total of 1102 matrix elements. (each one 5 km square):

Contrast rating	0	345 elements
	1	127
	2	76
	3	90
	4	123
	5	197
	F	24
Not yet analysed due to absence of suitable imagery		120

Although the intended purpose of the above preliminar procedure was simply to pick out useful test areas to relate to ground truth and to eliminate those of no use, the coloured matrix has in fact proved a stimulus to thinking about the hydrological mechanism of the delta, as it highlights the areas of seasonal change, leaving the permenantly flooded and the permenantly dry areas uncoloured. The colour coded matrix has also shown an interesting inverse correlation with an array on the same grid prepared by ecologists from air photograph study, assigning the elements as "percent liable to flood". Hydro/ecological information obtained from low flying aircraft on the same grid also shows promise of useful correlation.

V. Publications

Nil

VI. Problems

(a) Really effective use of Landsat, and in particular the accurate and sure correlation with ground truth in remote areas is hardly possible unless one knows in advance on which days the satellite is going to be switched on over Botswana. Much ground truth obtained in October 1975 was wasted when the satellite missed two passes. We cannot afford to repeat such a ground truth exercise. Is there any way we can be better co-ordinated with NASA in this matter?

(b) Although we are impressed by the speed and efficiency of the EROS Data Center's computerised service, some omissions have been detected, in particular the computer did not list the following FCC's although our Geological Survey Department were supplied with them by NASA in 1972/3:-

16 SEP. 72	08023
15 SEP. 72	07565
26 NOV. 72	07574
06 FEB. 73	07573
15 SEP. 72	07571
26 NOV. 72	07580
19 JAN. 73	07574

(This was in answer to our enquiry your ref BOX 8 53/S 18D S20D 30M E22D E24D date 02/27/76 Report DI002 Time 09;26).

(c) We do not quite understand how the standing order system works as no imagery was supplied for the period Feb, 1975 through June 1975 although listed by the EROS Computer as being available.

(d) There is still some delay in the receipt imagery.

(e) On our side we have had problems in making staff available for Landsat analysis (as distinct from ground truth) until recently.

(f) Our enlarger will enlarge 7 times only, i.e. up to 1 in 500 000 from 70 mm negatives. For greater magnification purposes we propose to ask for 1 in 1 million negatives, also useful for Diazo comparions.

(g) Bush fires complicate interpretation. We have not discovered any non subjective way of distinguishing fires from flood as the spectral signatures appear similar. Common sense enables the larger fires to be immediately eliminated and some of the smaller ones. The difficulty arises with small fires adjacent to channels, which might, on the face of it, be either fire or flood. Successive Landsat passes, when available, often indicate which is which, though the procedure is tiresome. We are working on methods of analysis which will enable suspect fire areas to be ignored without loss of significance.

VII. Data Quality and Delivery

Quality and resolution excellent.

Test site coverage:

Test Site 2 more than adequate,

Test Site 1 nothing received before July 1975 or after December 1975. This is inadequate for seasonal comparisons.

Two critical passes missed in Sept/Oct 1975 (see Problems above).

No knowledge of date of imagery until weeks afterwards.

Receipt of data somewhat delayed and never quick enough for feed-back to ground truth teams.

VIII. Recommendations

In general proceed as planned.

It is essential to extend the period of imagery obtainable under the Program, backwards to September, 1972 and forwards until December, 1976 or thereabouts.

IX. Conclusions

The interim conclusions are in general optimistic.