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NATURAL RESOURCES RESEARCH AND DEVELOPMENT  
IN LESOTHO USING LANDSAT IMAGERY

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15. Abstract  
This report covers the first three months of the Lesotho LANDSAT-2  
project. During this period a surface drainage map of the country  
using LANDSAT imagery has been completed. The photographic imagery  
seems to be ideal for the definition of land systems (mapping units  
defined by a combination of geomorphology, soil type, vegetation  
cover, land use etc.) which are probably of more use in a developing  
country situation than are the more usual maps of the individual  
types of features. It has also been demonstrated that relatively low-  
cost programmable calculator systems can be of benefit in the inter-  
pretation of digital data.
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## A. INTRODUCTION

This report covers the period December 1975 to February 1976. During the reporting period, LANDSAT-2 imagery gathered during July to October 1975, as well as already existing LANDSAT-1 imagery, has been utilised for interpretation in the following fields: surface hydrology, soils, vegetation, agriculture, meteorology.

## B. TECHNIQUES

For most of the work, conventional aerial photointerpretation techniques were used. Photographic imagery, normally at a scale of 1:1 000000, was examined using light tables, stereoscopes, low-power microscopes and an optical pantograph. After tracing the relevant features, these were digitised using a Hewlett-Packard 9864A digitiser attached to an H-P 9830A programmable calculator and the data stored on magnetic tape cassettes. The data could then be plotted any required scale and any necessary coordinate transforms applied.

A start has been made on the development of programs for the programmable calculator for the direct, automated interpretation of digital data from LANDSAT CCT's. As the CCT's are not compatible with the calculator, some preprocessing on a larger computer system is necessary. This was carried out at the CSIR in Pretoria by Mr. W. de Boer. His pre-existing programs were used to remove the six line stripe, select test areas and dump the required data onto punched cards. For the experimental phase of this project, four test areas, each about 10km by 5km, were selected from a LANDSAT-1 image (1121-07315) covering the north-western section of Lesotho. The total number of pixels in each of the four test sections is 10800.

Various programs for the processing of the digital data have been written and tested. These include:

- (a) plotting of a 'digital colour composite' at any required scale.
- (b) pixel statistics and histograms of response distribution.
- (c) simple non-iterative clustering with plot or print output
- (d) maximum likelihood and probability ratio assignment of pixels for automated mapping.



C. ACCOMPLISHMENTS

For the first time, the LANDSAT coverage during the reporting period showed significant snow cover. The maximum snow cover shown on the imagery was on July 11-12 1975 when approximately 5% of the country was covered. The major snowfall of the season occurred on July 13-14, but by the time of the next satellite pass (July 29-30) most of this fall had melted. Although snow reports are received regularly from the various meteorological stations in the country, the availability of the satellite data allowed the accurate mapping of the snow cover for the first time. In certain places, estimates of the depth of cover could be made, especially at the edges of the covered areas due to the differential penetration of the snow by bands 5 and 7.

The availability of winter (dry season) coverage of the country has greatly facilitated the mapping of the various soil and vegetation types in the country. A reconnaissance map of the country for soils and vegetation, based on the LANDSAT data, is in the process of being produced. In the lowland regions, where the geomorphology is relatively uniform, the differentiation of at least the major soil divisions seems feasible. The lack of active vegetation and cloud cover in the latest images has facilitated this interpretation. In the highlands of the country, on the other hand, the character of the image, in terms of colour in the composites and texture, seems to be not directly related to the vegetation cover and soil type. The geomorphology of the highlands is somewhat varied. From previous work it is known that most of the mountainous region is covered by a sparse basaltic lithosol. The mappable units of the photographic images seem to be more closely related to land systems rather than to specific features of geomorphology and vegetation cover, even in regions of uniform soil type. The land systems, as mapped, relate to a combination of geomorphology, soil type, vegetation cover, land use etc. As such, these mapping units are probably of more use for planning purposes than are straightforward maps of each of these characters separately.

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During the reporting period map of the surface hydrology of the country has been completed. Streams up to the third order over the whole country, and to fifth order in certain regions, have been mapped from the photographic imagery. These data have been digitised as described above, and can be plotted at any desired scale. It is planned to use this map, at various levels of detail, as the base map for future mapping work within the country.

It was found, during the LANDSAT-1 investigation, that individual fields etc. are not discernable on the photographic imagery, even at the limit of useable enlargement. As one of the major points of the LANDSAT-2 investigation is in the field of agriculture, it was decided to start experimenting with digital techniques for the handling of CCT data. This was prompted by a consideration of the relative resolution, both spatial and radiometric, of the photographic and digital imagery. As explained in section B above, the standard CCT's are not compatible with the computing facilities currently available in the country. An assessment of the possible benefits which could accrue from the direct interpretation of the data led to the design of a software system which could handle modest amounts of digital data on the equipment which was already available. It must be emphasized that the system is still in the early stages of development but certain important features are already apparent. If some means of overcoming the incompatibility of the standard CCT's and most programmable calculators can be overcome, useful digital interpretation work can be carried out on small (10km by 5km) areas with hardware costing as little as \$15-20000. The time taken to carry out a single analysis of the order of hours rather than minutes, but with capital costs of this order of magnitude, it is not unreasonable to be able to dedicate the system to full time data interpretation. Similarly, in some developing country situations, large scale computer facilities are not yet available and the cost is prohibitive, whereas it is not unreasonable for an aid agency to be able to donate funds of the order required to establish a system such as that under development.

In order to produce 'digital colour composites', density maps of each of three selected bands are plotted out at the

required scale, usually 1:50 000 to correspond with the standard local topographic map series, Each plot is then transferred to diazo film of the appropriate colour and the three films sandwiched to produce the final product. For the initial experimental products, the digital colour composites were made to correspond as closely as possible to the standard band 4,5,7 composites. It was originally thought that these composites would be of use only for identifying the precise location of the digital data samples on the topographic maps, but the first one produced showed sufficient detail to enable the updating of the corresponding part of the pre-existing map.

Maximum likelihood and probability ratio programs have been written for automated mapping of features from training sets. As currently under development, these programs will cope with up to three recognised signatures plus 'unknown'. They are at present being modified to allow for the evaluation of 'mixed pixels' with proportional assignment. In one of the test areas, the use of these programs has brought to light a problem which may occur in similar situations elsewhere. In attempting to map standing water in dams, a large number of pixels were identified which were known to correspond to non-water sites. Refinement of the training set failed to eliminate the problem. Plotting of the multivariate probability distributions showed some overlap between the training set for dam water and the distributions for certain soil types and active vegetation. Examination of the dam sites concerned showed the cause of the signature degradation to be the amount of silt present in the dams and algal growth due to sewage contamination. It should be pointed out that the dams used to develop the signature are typical of those present in the country and have a very small surface area. This is of the order of 4 to 5 pixels.

#### D. SIGNIFICANT RESULTS

1. A map of the drainage of the whole country to include at least third order streams has been constructed from LANDSAT imagery. This has been digitised and can be plotted at any required scale to provide base maps for other cartographic projects.
2. A suite of programs for the interpretation of digital (CCT) LANDSAT data is under development for a low-cost programmable



calculator. Initial output from these programs has proved to have better resolution and detail than the standard photographic products, and has been used to update the standard topographic map of a particular region of the country.

#### E. PUBLICATIONS

Nil

#### F. PROBLEMS

The major problems encountered so far in the project relate to coverage and timeliness of the data, and are discussed below.

#### G. DATA QUALITY

The resolution of the photographic imagery received from LANDSAT-2 is generally superior to that received from LANDSAT-1. It is not possible to state whether the superior resolution is due to improved photographic processing or to greater sensitivity of the sensors on board the spacecraft.

Some difficulty has been experienced due to the distortion of paper prints of the photographic imagery. This has been particularly apparent on colour composites. Noticeable dimensional instability of the paper prints is observed when the paper prints are compared with positive transparencies of the same scene. The magnitude of these distortions and their consequent effect on the interpretation of the data is being investigated.

Problems have arisen due to the erratic nature of the cover provided and the time lapse between gathering of the images and the receipt of the data. The test area, which covers the whole of the Kingdom of Lesotho, requires four images for total coverage. Due to the orbital parameters, two scenes are required on each of two successive days in order to provide total coverage. This has only occurred once (orbits 2170 and 2171 11-12 July 1975). Listed below is the data coverage of the various sections of the country:

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<u>Section of Country</u>	<u>No. of Coverages</u>
North East	4
South East	1
North West	4
South West	7

The North East of the country and the South East are overflowed on the same orbit, as are the North West and the South West. The disparity in coverage between the two scenes overflowed on the same orbit is obvious, and is probably not due to differences in cloud cover.

The average time lapse between scene gathering and data receipt is 113 days.

If complete coverage of the test site were available on successive orbits, total data requirements could be reduced to one coverage each 36 days. As the situation is at the moment, however, much of the data is lost due to erratic coverage and long delays between gathering and data receipt. The long delay between gathering and receipt also precludes the investigation of short term anomalies in the images.

#### H. RECOMMENDATIONS

The usefulness of the data received would be much enhanced if total coverage of the test site on adjacent orbits were provided and the time lag between image gathering and data receipt were reduced.

#### CONCLUSIONS

##### I. CONCLUSIONS

During the reporting period the completion of a surface drainage map of the country has shown that LANDSAT data are eminently suitable for the mapping of such features. Further, the photographic images provide a useful synopsis of 'land systems' in regions of varied geomorphology and /or soil type.

It has also been shown that relatively low-cost programmable calculator systems may be used for the direct digital interpretation of limited quantities of LANDSAT data with significantly useful results.