LUL/IDRC/BRALUP

Tanzania LANDSAT Training

Programme Report

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Copy to
R. Archer
B. Wilson
8-8-77

July 25, 1977

Mr. J. Woolston
Director, Information Sciences
International Development Research Centre
P.O. Box 8500
Ottawa, Ontario
K1G 3H9

Dear Mr. Woolston:

The training period at Laurentian University for the BRALUP staff members involved in the LANDSAT Tanzania project is now over and the trainees have returned to Dar es Salaam. In accordance with the agreement of October 5, 1976 between Laurentian and IDRC, I have enclosed statements detailing expenditures during the training period and a narrative report of the training programme.

The first enclosure is the financial report prepared by the Treasury Office of Laurentian University. As you will observe, we kept a close watch over expenditures. The large surplus in the item of computing stems from the fact that CCRS agreed to provide us with free time on the IMAGE 100 system until the end of April, 1977. They have not yet advised me what their charges will be when I use the system again in October, 1977.

During their stay at Laurentian, Idris Kikula, Firoz Kurji, and James Ngana attended and completed the work of Professor G.O. Tapper's course GEOG 3037 Remote Sensing of the Environment. In addition, Professor Tapper and I provided extra instruction in the areas of statistics, computer mapping, soils geography, and photomechanical and digital techniques of enhancement and analysis of LANDSAT imagery.

Towards the end of the training programme the trainees were asked to write a paper which would do two things. Firstly, the paper was to summarize the work that each trainee completed; and secondly, to critically evaluate the training programme provided them at Laurentian. Drafts of the reports were completed a few days before the trainees departed for Tanzania. Copies of the unedited reports are enclosed. I believe they will be as instructive to you as they are to us.

The final enclosure is a duplicate of Professor Tapper's report which he submitted to you several weeks ago. That report provides a narrative of the training programme given at Laurentian and a fair assessment of the performance of the Tanzanian trainees.

I wish to take this opportunity to convey to you our pleasure in collaborating with IDRC on this project. The trainees worked hard, provided us with a great deal of academic stimulation, and are certainly credits to their country. I was personally gratified, as Chairman of the Department of Geography, by the welcome that our own students provided the Tanzanians as it benefitted both. Although the amount of extra work involved is quite considerable, the Department of Geography at Laurentian University looks forward to participating in this type of programme in the future.

Yours truly,

J Roger Pitblado

J. Roger Pitblado, Ph.D.
Chairman
Department of Geography

cc Dr. H. Best
President
Laurentian University

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REMOTE SENSING TRAINING PROGRAM

Report for General Review

Submitted to:

Professor J. R. Pitblado

&

Professor G. O. Tapper

* * * *

by

Feroz Kurji

May 30, 1977

REMOTE SENSING TRAINING PROGRAM

Report for General Review

This report aims at summarizing some aspects related to a training program undertaken by BRALUP/Dept. of Geography (Laurentian University) and funded by the IDRC. The program was carried out at Laurentian's Geography Department from January to May, 1977. The program aimed at providing an introduction to techniques of remote sensing as they apply to resource assessment and to assess the potentials and problems of using ERTS generated data for resource studies in two areas of Tanzania. The program was undertaken in the hope that the techniques learned would complement on-going BRALUP projects aimed at drawing up long range regional development plans for the Rukwa region of Tanzania. The other area of interest in the Serengeti-Eastern Lake Victoria region where the major requirement is of assessing the potential of ERTS imagery for ecological monitoring.

In this report the aspects covered during the training are briefly considered. At the end of this report is included information about the personnel involved in the program. The following studies were carried out either independently or in conjunction with other colleagues on the training progra. Some personal opinions are made.

i) Introductory Lectures on Remote Sensing:

Introductory lectures on remote sensing were regularly attended during the period January-April 1977. The lectures were presented by Prof. G. Tapper and covered the basic theory of remote sensing using different types of sensors and for different purposes of resource studies.

Techniques and sensors were considered as related to different parts of the electromagnetic spectrum. More specific considerations were given to the sensor systems on board the ERTS and imagery generated for various parts of Tanzania and the world were examined and interpreted. Specific attention was given to imagery of Rukwa and Serengeti areas of Tanzania.

On the whole I found the lectures very useful in that they made me aware of the whole range of techniques used in remote sensing (both operational and experimental) other than the familiar aerial camera systems and based largely on reflected visible light. Initially, I found the various sensor designs difficult to comprehend even superficially because they were not available at Laurentian for examination. This is understandable since Laurentian Geography does not have the resources to provide sensors as teaching aids. Some compensation came from attending the CASI symposium on remote sensing at Ottawa and in particular from the visit to CCRS facilities for remote sensing. Greater appreciation of the problems of sensor design was achieved after attending the various papers presented at the CASI symposium. However, a more in depth exposure to various types of sensors and their operational difficulties would be most useful in bringing about a better understanding of the basic theory exposed to us through the introductory lectures. I hope such an opportunity arises at a later date.

ii) Lectures on Soils:

Lectures on soils presented by Prof. R. Pitblado were also attended. These covered soil formation, classification and management. Comparative soils studies using examples from Tanzania, Canada, Europe and India were auditioned during seminars. These lectures were most useful as an introduction to soil studies that can be anticipated as a major task in any bio-physical resource assessment.

iii) ERTS-generated photo mosaic for Tanzania:

A photo mosaic of Tanzania was made using black and white ERTS generated imagery. This mosaic is the first that covers the country as a complete unit and with interpretive care should form a useful tool of comparative landscape studies. Regrettably, some gaps exist in the mosaic; imagery for the Ruaha-Kilembero-Rufigi drainage basins were not available. This may be due to extensive cloud cover or technical problems on the ERTS. It is hoped that imagery for these areas will be available in the near future to complete the mosaic. However, complete coverage of Rukwa and Eastern Lake Victoria areas is available. Considerable assistance was given by Prof. Tapper, Mr. R. Labbé, Mr. A. Frechette in putting together the mosaic.

iv) Inventory of ERTS imagery for Tanzania:

Under the supervision of Prof. R. Pitblado, an inventory of ERTS imagery covering Tanzania was made. The inventory consists of information on the photo coverage of various parts of Tanzania during 1972 - early 1976. It provides a useful reference for identifying and ordering imagery from EROS centre in the U.S.A. Maps of Tanzania showing the different coverage over various time periods were made using a computer program (GEOPAK). Programing skills were provided by Dr. R. Pitblado. Information on image quality, approximate cloud coverage, location co-ordinates, ERTS reference numbers, the bands in which images were produced and false colour composites available were also included. The information was extracted from an inventory supplied by EROS data centre. It is hoped that this inventory is published by BRALUP as a source report for use in Tanzania by those interested in

ERTS imagery.

v) Using the Darkroom:

a) Some training in the use of the darkroom facilities was also obtained. The processing of black and white photographic films was learned. Techniques of photographic enlargement and reduction were also considered. Prints were made from negatives for the ERTS photomosaic for Tanzania.

b) Training in the use of photographic density slicing techniques was also obtained. Agfa contour film was used to extract themes of interest from ERTS imagery for the Rukwa and Serengeti areas. ERTS positives in selected bands were taken and using a gray wedge, three-four gray levels were isolated. Negatives and positives were made for each isolated gray level that, in some cases, were identified as representing some themes, e.g. burnt areas in the Serengeti ecosystem. Using these negatives and positives, agfa contour or equi-density images were obtained. It is hoped that interpretation of the results can be undertaken once collateral data are available. Particular emphasis will be given to the Serengeti area since it is of greater personal familiarity. If computer generated theme maps for the Serengeti were available, as is the case with Rukwa, it would be useful to compare the results of using computer, photographic and "eye-balling" approaches to data analysis of ERTS. It is hoped that this can be undertaken when facilities and funds are available since considerably more colletral data exist for the Serengeti than most parts of Tanzania. However, the analysis of the Rukwa area should provide useful experiences in such comparative analytical approaches.

c) Diazo color prints were made using the density sliced negatives and positives for a part of the Serengeti area and were combined into color composites featuring certain themes; such as burnt areas of grasslands and lightly wooded grasslands; areas under subsistence-cash crop farming.

Given the restraints of available time, much experimentation could not be undertaken. It is hoped that with some facilities for using the above techniques becoming available at BRALUP, more experience and greater efficiency in using photographic analytical techniques will be gained. It is concluded that the monitoring of burn patterns in the Serengeti (and other wooded grasslands) is possible using ERTS imagery using the above techniques and if imagery in the form of 9"x9" positives is available (even 70mm negatives can be enlarged) on a regular basis, such information can be easily and cheaply derived to complement and extend the scope of fire monitoring in the whole of Eastern Lake Victoria region. Four images would cover the area lying between the eastern shores of Lake Victoria and the Ngorongoro highlands which is treated as an ecological unit. In this area, occupied by large numbers of livestock and wildlife, fire is an important factor influencing food supply for the herbivores, woodland and grassland dynamics and the agricultural potential and practices. Quantitative and qualitative analysis of fire incidence and extent can be undertaken on a spatial and temporal basis by using grid overlays or a planimeter. Imagery most suited for fire analysis would be in bands 5 or 7 and for the beginning and end of the dry seasons (June to October) at least. Spatial diffusion of fire incidence with respect to drying out of grasslands would be undertaken using 18 day and monthly imagery if available; data on soil moisture could be obtained using neutron-probe techniques as done hitherto at SRI (Jager, T:pers COMM) by the soils and SEMP studies. This information could complement studies on soils, vegetation change and agricultural practices.

The processing of these data could be undertaken at BRALUP facilities where color diazo paper, agfa contour film, etc. will be available. Some training could be undertaken at BRALUP as well.

The training of using such techniques, as outlined above, was carried out under the supervision of Prof. Tapper and much assistance was made available by Mr. R. Labbé and Mr. A. Frechette. Work on the ERTS mosaic, inventory of ERTS imagery and density slicing-theme extraction was carried out in conjunction with my colleagues from Tanzania.

vi) <u>Landscape Classification - Eastern Lake Victoria & Serengeti Ecosystem</u>:

Using the available ERTS imagery for the above area as a photobase, a preliminary classification of landscapes was attempted. Both black and white and colour composites were used. Due to the very small scale of availablve imagery, detailed classification could not be undertaken though the imagery was useful in that it covered a large area on just four images and was more practical for grass analysis and differentiation of landscapes. Burn patterns were found to mask landscape differences and hence impede classification; multitemporal imagery could provide a useful alternative. Cloud cover also remains another source of noise for such analysis but can be overcome by using digital analysis to partially compensate for this problem. To date, and as shown by the ERTS inventory, this part of Tanzania is completely covered by imagery for three time periods. Larger scale imagery was examined in the case of Rukwa (1:500,000; 1:250,000) and it seems that if such imagery were available for the Serengeti, a classification could be undertaken. It is concluded that such a classification be carried out for the following reasons:

a) As an extension of the BRALUP-approach to development planning as undertaken for Rukwa that is based on ecological rather than strictly administrative planning units.

b) To provide a comprehensive assessment of the Mara Region, Mwanza and Shinyanga regions and the Eastern Lake Victoria zone as a major population bloc of the country numerically, its importance as a livestock and cash crop area (cotton in particular), as a wildlife conservation area (Serengeti Ecosystem) and as an emerging industrial belt as proposed by national plans (centred on Mwanza and Musoma).

c) Such a classification would complement the one carried out for the Arusha region by the EarthSat Corporation using ERTS imagery. Consequently a large part of northern Tanzania would be classified on basis of agro-economic and ecological zones. A judicious choice of classification objectives is essential.

d) It would be an extension of the landscape classifications carried out for about 30% of the area involved that has been and is being classified by Gerresheim and Epp at the Serengeti Research Institute. To date, the Serengeti Ecosystem has been already classified into land region and land systems and is being extended to a landfacet level. The above would require this classification to be spatially extended to include the lakeshores and the North Mara district that are not currently considered under the SRI projects. Larger scale photography for the area is available for two time periods as well to complement ERTS imagery (1950's, 1972; scales 1:30000 and 1:68500 respectively).

e) It would help to train and set up a base of Tanzanian expertise for such projects elsewhere; to consider the existing Shinyanga regional plan on an ecological framework as well and also use the considerable amount of collateral data existent at SRI on a large part of the Eastern Lake Victoria region.

f) It would present some idea of the kind of landscape diversity existent and help in drawing up a more judicious approach of gathering socio-economic and agricultural data by the regional and local authorities. It would also provide a preliminary base for integrating the existent data as gathered by regional, local authorities, by SRI and the UN Hydromet project covering Lake Victoria. The latter is largely held up because currently no spatial framework exists that can integrate data from two administrative regions but covering one ecological unit.

g) This would be a useful alternative to evaluating the digital analysis of ERTS data should the latter be undertaken at a later date. A brief consideration of the Rukwa digital analysis leads to the conclusion that such analysis requires preliminary information as input to "supervised classification" or as a reference to evaluate "unsupervised classification" of landscapes and such data requirements are considerable, particularly in areas of large ecological diversity. It is concluded that existing data from all sources first be collated, a visual landscape classification using ERTS and other imagery be carried out and then a specific area be targeted for digital analysis so that classification control or evaluation can be made. The dangers of a "digital shot in the dark" cannot be more emphasized if the objective of using the approach is concrete results rather than a gross appraisal.

A greater exposure to techniques of data analysis, particularly of ERTS, using automated procedures, would be a pre-requisite. Given that such exposure is available at only a few centres e.g. CCRS in Ottawa, it is understandable that at Laurentian this was not possible. Following a review of the Rukwa analysis and as emphasized by Profs. Pitblado and Tapper, the need for independent data to implement or evaluate the results of electronic or photographic analysis of ERTS imagery are vital and considerable. Then there are the little understood but peculiar conditions found in, for example, the East African environment. Digital analysis could not identify easily villages in Rukwa because housing is made largely from materials that have similar spectral-radiometric signatures as their background. Plots of land cultivated by farmers could not be identified because their sizes are below the ground resolution capability of the current ERTS-MSS system. Currently, as indicated by a select review of digital analysis applications, most such studies have been carried out in the developed world where different conditions exist.

The question of central concern is whether applications to Tanzanian resource assessment objectives would be experimental rather than that of proven technique. Secondly, would "tangentially related" methods research be required and if so, how much would be necessary to apply the existing techniques so that they are suited to Tanzanian situations. This is important because the priority aim is resource assessment applications and not development of remote sensing techniques. On the other hand, can comprehensive resource assessment be undertaken without using the advantages of ERTS imagery and automated analytical approaches? There is little doubt that ERTS imagery is a complimentary source to other approaches of designing and evaluating resources rather than a complete tool in itself and hence its uses could be narrowed down to the most useful contributions it can make to Tanzanian conditions. This could be done without getting involved in non-applications research. Either way, only an understanding of and experience with the use of such remote sensing techniques can help in assessing its significance to resource studies in Tanzania.

vii) <u>Resource assessment and the use of ERTS Imagery</u>:

To gain a perspective of some uses of ERTS imagery for resource studies a brief consideration of its applications and potentials was undertaken. It also aimed at putting together the aspects covered in the introductory lectures, subsequent reading, the experiences of visual analysis of imagery and digital analysis as related to Rukwa. There is little doubt that such a review is aimed for my own appraisal of the training rather than an authoritative text on remote sensing. Largely, it is a record of my understanding and more so of my limitations and only as such it is hoped to be. Specifically the following aspects are of interest and are being covered:

a) Development objectives and resource assessment - as they relate to Tanzanian conditions

b) Remote Sensing and Resource assessment - basic theory and principles considered generally

c) ERTS Imagery and Resource assessment - the derivation, characteristics and general nature of ERTS imagery

d) The Pre-processing of ERTS Imagery - a consideration of enhancement techniques as a preliminary process in image analysis

e) The interpretation of ERTS Imagery - development and use of interpretive keys for object identification and analysis; Serengeti imagery used as an example.

f) Automated analysis of ERTS Imagery - some approaches, methodological potentials and limitations; the question of analytical control and evaluation as relating to Tanzanian situations.

g) ERTS generated information and Resource Management - use of row data from ERTS analysis; questions relating to geographic interpretation; the testing of hypotheses and nature of ERTS data; the problems of normality, homogeneity, spatial autocorrelation, regionalization, etc.

h) Use of ERTS Imagery - some considerations for use in Tanzania and a proposal of applications for monitoring in Eastern Lake Victoria area.

The first four of the above mentioned themes have been considered and written up; the others need to be considered more judiciously and will be written in due course. Useful comments and discussion were provided to me by Profs. Pitblado, Tapper, Sabourin, the Martins, and my colleague, Mr. I. Kikula at various times related to analysis of ERTS imagery, methodology as applied to geographic research, the results of digital analysis of Rukwa imagery, etc.

viii) Settlement Studies around Serengeti National Park:

Time was spent on some selective analysis of data obtained on the above study as well as on raw data on Labour Migration and Employment (the case of Tanzania National Parks). Without Prof. Pitblado's constant and ready assistance this analysis would have not been possible. This involved computer mapping of settlement surfaces around the Serengeti and basic statistical treatment of the labor migration data.

On the whole, the training has been for me a period of most useful

exposure to techniques of remote sensing. This was particularly due to the ready and cheerful availability of the various members of staff of the geography department at Laurentian and the facilities in the darkroom, etc. My only regret is that it was of a short duration. However it is appreciated that the training was aimed at preliminary exposure to rather than creating "instant expertise" in remote sensing. The bringing together of Prof. Pitblado's Tanzanian expertise and Prof. Tapper's own authority in remote sensing research provided an extremely useful balance in the training. That such training should complement the on-going BRALUP project in Rukwa provided the practical focus and the framework in which to consider the relevance and problems of using remote sensing.

Finally, I would like to thank various members of staff who made this training possible and my stay at Laurentian a useful and happy time. At the risk of omission and offence I would like to thank Prof. Pitblado for all that he taught me, gave me encouragement and made available his expertise. Prof. Tapper provided a stimulating and cheerful atmosphere of work and made the study of remote sensing a pleasure and most informative. Monsieur Labbé showed us his many photographic skills and gave invaluable help in the darkroom and in processing of ERTS data. Art Frechette and Ron Skitch provided likeable companionship during our work and at other times. The Martins and J. Sabourin provided useful discussion in their fields of expertise. I would also like to thank the many others who helped to make our stay a pleasure. My very special thanks are due to Mrs. Mary Catherine Porter who, with much patience and cheer, typed this report and many other documents.

Special thanks are due to the IDRC and Mr. M. Mercier and his staff for having provided the funds and worked out the logistics of our training. My deepest gratitude is due to Prof. A. Mascarenhas of BRALUP and his staff for their constant guidance, encouragement and assistance in my work and for having made this training possible. My colleagues, Mr. Kikula and Mr. Ngana provided a useful and cheerful atmosphere of cooperative work at all times.

<u>Personnel Involved with the BRALUP/IDRC/LAURENTIAN Training in Remote Sensing Techniques</u>

At BRALUP:
Prof. A. Mascarenhas (Director, BRALUP)
Mr. A. Sporrek
Dr. R.B. King

At IDRC:
Mr. Marcel Mercier
His staff

At Laurentian:
Dept. of Geography
Prof. R. Pitblado (Chairman, Dept. of Geography)
Prof. G. Tapper (Lecturer, Remote Sensing)
Mr. R. Labbé (Technologist, Geography Department)
Mrs. M.C. Porter (Secretary, Geography Department)
Mr. A. Frechette (assistant)

Tanzanian Trainees:
Mr. I. Kikula - BRALUP, Rukwa Project; Vegetation Studies
Mr. J. Ngana - BRALUP, Rukwa Project; Water Resources Studies
Mr. F. Kurji - BRALUP-SRI; Serengeti Ecological Monitoring Program

A REPORT ON THE REMOTE SENSING TRAINING COURSE CONDUCTED BY PROFESSORS G.O. TAPPER AND R. PITBLADO AT LAURENTIAN UNIVERSITY, SUDBURY, CANADA AND FINANCED BY I.D.R.C. FOR THE BRALUP/IDRC RUKWA PROJECT IN TANZANIA

by

I.S. Kikula (B.Sc. Hons.)

May 24th, 1977

A. INTRODUCTION:

The course on the Remote Sensing of the Environment lasted from January to May, 1977. The purpose of the programme was to provide the participants with some basic skills on remote sensing, and in particular, the LANDSAT imagery. LANDSAT data are being tried in the Natural Resource inventory for the Integrated Regional Planning of Rukwa Region, Tanzania. The project is a joint undertaking between the Bureau of Resource Assessment and Land Use Planning (BRALUP) of the University of Dar es Salaam, Tanzania and the International Development Research Centre (I.D.R.C.) of Canada. It is the latter institution which financed the course on Remote Sensing as part of the aid to the project. This form of aid is making a remarkable milestone in the aid programmes that have existed for many years. Addressing the Second Canadian Symposium in Remote Sensing, John A. Howard, a senior officer (Remote Sensing) from FAO, said that, "Whereas, in the past, developing countries have received direct assistance in the form of remote sensing undertaken by expatriates, commercial companies, the request for indirect assistance in the form of technological advice and the supply of equipment will increase in future. Many countries need help in the training of their nationals in Remote Sensing either through short courses or through the establishment of regional training centres. This is an aspect of overseas aid to which you may wish to give greater attention in the future". Indeed, Howard's prayers have been answered and I hope this trend will continue. Because unlike the direct assistance, this type of aid provides a nucleus of activity for other projects in the countries concerned after one project has been completed. In other words in the long run the need for expatriates or commercial companies will be minimal or non-existent, making the developing countries self-reliant. If I were to comment in detail on the economics and politics of aids to the developing countries I would be defeating the purpose of this section of my report. It is supposed to be an introduction to a report on the Remote Sensing training programme and nothing else. And after all, I am a simple general Biologist and not an economist or a politician. So, I reserve them.

The training program was conducted in two major sessions which I conveniently refer to as the theory and the practical parts. The theory covered the basics and principles of Remote Sensing while the practical session covered the actual interpretation techniques of LANDSAT imagery, some darkroom demonstrations and operations and the compiling of the mosaic for Tanzania.

A Conference on Remote Sensing was attended in Ottawa in March, 1977. After the Conference, a tour of the Canadian Centre of Remote Sensing (CCRS) was made.

On the way home, the EROS Data Centre in the United States was toured.

B. The Traning Program

The theoretical part of the training program was covered in a class of about twenty-five students and it was conducted three times a week. The topics covered can be summarized as below:

Physics of Electromagnetic Radiation
Electromagnetic Spectrum
Remote Sensing - Spectral Regions
Imaging Remote Sensors - Photographic
Imaging Remote Sensors - Thermal Infrared
Imaging Remote Sensors - Microwave Sensors
Imaging Remote Sensors - Multispectral Systems

Remote Sensing of the Natural Environment
Remote Sensing of the Lithosphere
Remote Sensing of the Lithosphere
Remote Sensing of the Atmosphere
Remote Sensing of the Hydrosphere
Remote Sensing of the Biosphere
Man's Impact on the Land
Man's Impact on Agriculture
Man's Impact on Forest-Ranger Management
Man's Impact on Water Resources
Man's Impact on Urban-Suburban Land Use
Remote Sensing - Special Applications and Techniques

One needs a fair amount of theoretical background on the principles of Remote Sensing in order to be able to effectively interpret and appreciate what is on the imagery. For that matter the theory part of the program formed the backbone of the whole course. However, since the format was prepared for the whole class it was difficult to cover adequately in class, areas of one student's specialization. For example, if areas of biological interest were to be covered in detail in class they would have been quite stimulating to me but most probably be a bunch of bull-shit to a hydrologist, a human geographer or a geologist. Although however the land resources are very closely related, so much that interpretation of imagery has to take two, three or more of them into consideration. These areas of personal interest had to be pursued privately and sometimes by consulting the instructors. In order to do this satisfactorily I thought it was wise enough to make a literature survey on the applications of the LANDSAT data. The result of this work is a 50 page typed material.

The practical aspects covered in the program are best summarized below in the IDRC/BRALUP Training program made by my instructors.

IDRC/BRALUP Training Program

January - April

1. GEOG 3037 - Remote Sensing of the Environment: complete all normal assignments.

2. Instruction in the use of Dark Room.

3. Produce LANDSAT mosaics of Rukwa and Tanzania.

4. General interpretation of Rukwa photos.

5. Become familiar with some of the theoretical and practical aspects of automated classification techniques of LANDSAT digital data.

6. Become familiar with the use of Agfacontour film.

7. Sit in on soils and stats. courses; examine hydrological and climatological data from Rukwa.

May - June

8. CCRS (possibly a February or March visit).

9. EROS Data Centre.

10. Goddard Centre.

11. Tidy-up work from above.

After some instruction and demonstrations in the darkroom, we were put into action to produce prints for making a mosaic for Tanzania. Unfortunately, however, the mosaic was not completed because some frames were missing. The job will be completed at home when the missing negatives become available.

The other major practical job I was involved in apart from the normal class assignments was the visual interpretation of the Rukwa imagery, for vegetation mapping. This was done by first making broad but precise enough classification of the vegetation of the area. The categories used were forest, woodland, scattered trees and bushlands, and grasslands. The making of this classification was made possible from the information I gathered during two trips to the area.

The five frames were then put together and the map produced is attached to this report. It should, however, be emphasized that this is a very generalized map which will be subjected to corrections as will be pointed out below. The map so produced was to scale 1:1,000,000 from which a map of 1:500,000 was later produced. General as it is, the map was very useful when I was picking out areas to be analysed by the Image-100 and later on, by Agfa-Contour film. A number of factors were put into consideration when selecting these test sites. But all in all at least one site from each vegetation category was selected. Both the areas of certainty and uncertainty during the interpretation were selected. Whichever method one employs it is almost impossible to quantify the structure and determine the species composition of the vegetation. The latter is especially the case for the tropical vegetation with very high species diversity. This renders the characteristic signature for different species impossible to isolate. These pitfalls are among the major drawbacks of the LANDSAT data in vegetation ecology.

As it should be expected it is very difficult to make detailed interpretation of vegetation by visual interpretation. Mainly so because of the limited visual ability to pick out different levels of gray tones. For this reason an attempt to make a detailed analysis of data was made by using the Image-100 and Agfa-Contour film. My most sincere credit goes to Professor Pitblado for his untiring zeal in making sure that the impossible to me were made available for me. He tirelessly spent hours to analyse the data by the Image.-100 at CCRS in Ottawa. This analysis would have been exceedingly difficult if it was left entirely in my hands. The results of the analysis are given in forms of thematic maps (8 themes for each test site), good printouts coloured slides of the themes, the pictures of which were photographed during the analysis. The hard work put in by Dr. Pitblado and Mr. Tapper added by their unique sense of humor, is a very big impetus for me to work even harder lest I disappoint them.

The interpretation of the data analysed by the Image 100 is a big job. This is made so by the fact that in the unsupervised classification the computer does not tell you what it has mapped. One has to figure out on his own. This is made even more difficult because it maps eight themes for each test site. Consequently, the results were not ready when this report was being written. If anybody shows interest in the results I will be just too pleased to make them available sometime later. In the course of trying to interpret the results I am learning a lot about the use of the Image-100 in mapping, i.e. the drawbacks and advantages. These observations will also be made available in the subsequent reports.

The test sites analysed by the Image-100 were also analysed using the Agfa Contour equidensity film. This was done during the last week of my stay in Canada. What I will do with the results is to correlate them with aerial photographs (where they are available) and the Image-100 analysed results. I hope this will form the basis of my field-work.

C. Others

Item seven in the IDRC/BRALUP training program includes some of the things done during my five months stay at Laurentian University. A rainfall map for Rukwa is now available. Modifications had to be made by correlating it with the available topographical maps of the area. Further modifications will have to be made again when an accurate enough vegetation map is made ready. I also compiled a topographical map of scale 1:500,000 for the area which was not available. When in the final analysis, the vegetation, rainfall and topographic maps are superimposed, I should be able to produce eco-climatic zones for the Region. In addition, I made a fair amount of literature survey on vegetation ecology, my present field of study.

D. Was the Training Worthy?

Most definitely, my sponsors, the IDRC, my Director of BRALUP, Professor Mascarenhas and needless to mention, my instructors at Laurentian University will be very eager to hear of my personal judgment on the training which has been undertaken.

Without intending to please anybody, I personally feel the trip was worthwhile. The worth of it will probably have been appreciated from the account of activities that have been mentioned above. Most important, however, is that the course has opened up both my eyes and ears as far as LANDSAT data are concerned. Such that I now feel that I know at least some of the different ways of handling the data, their advantages and drawbacks. As far as I am concerned this is the most important of the achievements of the training. But that is not all, because I now think I know what is done until the data are in the form that they are.

These aspects mentioned above summarize a heck of a lot of information which if I were to put it all in writing would have formed another literature review on the use of LNADSAT data, which I believe is not the intention of this report. Furthermore, this would have been a duplication of the work which I have already done elsewhere.

Another very important achievement in the course is the actual working on the imagery of the Project areas. Without the proper supervision which I received here I can confidently say that the final product of the project would have not been what it will be. Never in my life had I ever been in a darkroom. But this time I have spent a good number of hours in it and I have picked out at least some of the fundamental procedures.

The visit to the CCRS is left to be admired. Not only was it a source of inspiration it also showed me how fast we should run if at all we have the intentions of establishing centres of Remote Sensing in our countries. We also saw aircraft with cameras on board, Density slicer, color additive viewers and the Image-100 in action. At this juncture, then, I feel it is proper to mention something I feel I should have been trained on. This is the use of the different machine enhancement techniques. I am not intending to demean anybody, but the fact is that I never touched a machine of the category mentioned above. However, this can be partly understood because there is none at Laurentian as far as I know. All the same this is a very large disadvantage given the rumours that BRALUP is going to receive one of of these machines. One would be right to expect me to be able to use it, but I am as ignorant as I left BRALUP as far as using it is concerned. Although, however, I know the principle of its operation.

Some people put forward funny arguments concerning us students from the developing countries being trained how to use machines in the data analysis. They claim that since the technological level is still at the baseline it makes no sense in training these students how to use the machines. Any realistic person will see why I call this type of argument a funny one. The argument is not only funny but more to that it has some bad feelings against us. I am not saying this out of emotions as some people will attempt to think but I am putting things in their true colours. Given the right economic and political atmosphere everybody is bound to advance in all works of life. If not to the extent of developing a new piece of technology but to at least having enough economic surplus and being able to afford it. Nobody knows when this is going to come. But trends show that it is not very long due. What if it comes tomorrow, if we can give room for optimism, who is going to be the expert, the expatriate? Even if this does not happen tomorrow, what harm does it make to learn something? I feel there is more harm in not learning something than in learning about it. Having said this I feel I must put things straight to remove room for misinterpretation. I have not said this in view of the lack of machine training in my course. I have said this purely from the long discussions I held privately with some delegates attending the symposium on Remote Sensing in Ottawa. I don't in any way imply that anybody involved with my training is sharing this argument. This has been pointed out just as a side issue.

E. Acknowledgements

For conclusion I think it should suffice to say that the training was worthwhile. But it would be very unbecoming to just end there. In light of this I should on behalf of my Government, my Director, Professor Mascarenhas, and on my own behalf, thank the IDRC for this revolutionary attitude towards aid to the young nations. Because my training will not only be useful for the Rukwa Project, but also in other Projects in the country. My most special regards go to Professor Pitblado and Mr. Tapper. Not only did they seriously work hard in our training but they also made sure that our social life was not rough. I am sure without this humourous attitude my stay in Canada would not have been what it has. It would be a serious crime to omit the entire Geography Department staff in my acknowledgements. Despite their different backgrounds, the staff members of the Geography Department have a common quality. This quality is the power, love. Last but not least I wish to express my sincere appreciation to the entire University Community without whose good service and company my stay would have been very miserable.

THE APPLICATION OF LANDSAT-1 IMAGERY IN HYDROLOGICAL STUDIES IN RUKWA PROJECT

By

James O. Ngana

May, 1977

THE PREFACE

The following study attempts to use LANDSAT I Imagery in Rukwa Region in Tanzania. Both lack of data, size of the area, few accessible roads, necessitated the use of this tool to do some hydrological study. The method adopted is described and the problems encountered mentioned. Several aids had to be consulted to overcome any inherent drawbacks. The results achieved are assessed and the overall importance of the Imagery evaluated.

The project was made a success by the Geography Department of Laurentian University. The constant guidance from the two Professors: R. Pitblado and G. Tapper was highly appreciated. In preparing the maps, frequent consultations were made with Mr. Labbé, the gentleman in charge of the Cartographic Technology. Mrs. Porter typed all manuscripts. In fact, all members of the Department, in one way or another, made our stay very lively, enabling us a successful completion of our project.

THE APPLICATION OF LANDSAT-1 IMAGERY IN HYDROLOGICAL STUDIES IN RUKWA PROJECT

INTRODUCTION:

Tanzania, like any other developing nation, is confronted with the problem of having adequate data for her resource evaluation. For any development strategy the available resources are of paramount importance to be known.

The problem of adequate data is very severe in several parts of the country. The most affected area is that of the south, and the south-western part of the country. In the south-western part of the country, regions like Mbeya and Iringa happen to have a fair documentation of their resources available. The southern part of the country which comprises the regions of Ruvuma, Mtwara, and Songea are the most seriously affected. Rukwa is another region in the south-west which is equally plagued by the same problem. The following study attempts to use LANDSAT 1 Imagery in Rukwa Region to alleviate the situation insofar as the hydrological data are concerned.

Rukwa Region lies between Latitude S5^{o} 12' and S9^{o} 4' and Longitude E29^{o} 55' and E32^{o} 46'. The Region is approximately 68,000 km^{2} in area. The physiography from East to West ranges from the Rukwa Valley, then the Plateau, and lastly the Lake Tanganyika shore. All these physiographic regions run approximately north-south. Figure 1 shows the general location of Rukwa Region in Tanzania.

OBJECTIVES:

For the Region to optimally use its resources, a need for a study of the existing resources was felt. This study attempts to map the existing hydrological network using the imagery of different months. In doing the mapping, an updated outline of the main features (e.g. the two big lakes in the area: Lake Rukwa and Lake Tanganyika) is achieved. This helps substantially for any shifts or changes that might have occurred after so many years of different climatic changes.

The type of maps available for this area during the period of study were topographical. These maps were of different scales and the latest compilation for these maps were in 1968. Actually the aerial surveys were done some years back at different places and at different times, and the revised version was brought out in 1968. Therefore, the main aim of the study is to update the hydrological network over the Region.

METHODOLOGY:

The scale chosen to work with was 1:500,000. Thus, the images considered for the study were of that scale.

The images used for this study were: MSS black and white images as well as the MSS false colour composite. As for the black and white images, two bands were used. These were bands 5 and 7. The MSS false colour composite consisted of three bands; 4, 5 and 7. Often band 7, black and white images, showed better than band 5. Rivers appear black in band 7 image. This was very helpful in mapping. But only those large rivers like Rungwa, Momba, and a few others showed distinctly on black and were not difficult in mapping. Although band 7 was useful, the other images were especially helpful. The false colour composite was just as good or probably even better than band 7 image. Band 5 image was helpful on several occasions where band 7 failed to show well.

The technique used was to put the image on the lamp table and do the tracing using a tracing paper. This tracing paper was used for all the images available for those rivers in the area. For example, after tracing over the false colour composite, the same tracing paper is used for the band 7 frame showing that same area and the available rivers traced. If from both the false colour composite and the band 7 images, the details are not satisfactory, then band 5 image was used as well. The same technique was carried out for all the frames of the study area. These tracing papers (carrying all the hydrological network that were on the image) were combined to make one big map of the study area.

However in certain instances, problems were encountered. These ranged from seeing a trace of a particular river, to not seeing a river completely. Sometimes it was due to cloud cover or fire burns. As for the images used, a short summary is shown below:

Date of Images
10.9.72
11.9.72
25.9.72
28.9.72
29.9.72
9.6.73
31.7.73
1.8.73
19.8.73
4.9.73

Areas where the above problems occurred are as follows:

1. Southern part of Rukwa: Some of the tributaries of the Saisi River did not show up quite well, e.g. the Kamawe River. The other tributary was that of Kalambo River. This was the Kamyare tributary. For all these tributaries, the problem behind them was partially due

to their smallness and also due to burns, and thick vegetation. Cloud cover was also a factor though not as serious as the above ones. Also some small rivers entering Lake Rukwa from the West - a little north of Momba river, could not show well. This was due to thick vegetation.

2. <u>North-western part of Rukwa</u>: Fire burns were another drawback in depicting the river course. In false colour composite a burned area would just appear dark blue. A river passing through such an area would hardly show its course. This problem was mainly encountered when mapping Itume river tributaries. These tributaries were Shangwe, Kamba and Katanta.

3. <u>Rukwa Valley</u>: The most affected area by cloud cover was in the valley. This comprises the area stretching from Runfwa River across to Muse way up the valley to Katan plains. Of all the areas affected or hindered by clouds - this was the most affected. Even big rivers like Mfwizi did not show up as distinctly as it should.

4. <u>The Plateau (The area between Kaengesa to Muse)</u>: Rivers in this area include Luiche, all the tributaries of Mfwizi and a few rivers running down the escarpment to Lake Rukwa.

   Luiche river was of particular interest while mapping those rivers around this area. This was because it is near the Regional Headquarters - Sumbawanga and is considered a priority for immediate study for hydropower. The mapping of these rivers was fairly good only that the resolution with the imagery was not so good. Fairly because of cloud cover and sometimes because of dense vegetation. The area around Sumbawanga and way up along the Luiche river past Muse to Lake Rukwa was unfortunately in the same frame as that of the previous case - the Rukwa Valley. A number of tributaries for Luiche River showed up pretty well. But those tributaries starting from Mbizi forest mountains and slightly north of here, did not show up at all. Extra effort was employed and the best that could be achieved from the imagery is shown in Figure 2. Further attempts were also carried out for Luiche river. In this case IMAGE 100 computer was used. The computer was made to train on the Luiche river so that with this information stored in the memory it could map all the areas with that particular theme. In this case this would mean that the computer would map the Luiche river within the frame considered in the digitized computer compatible tapes. However, the computer did not map out the river course. The reason behind this is discussed in the results section. Now from above, four areas have been mentioned with special problems encountered during the mapping process. Those areas which were not mentioned in the four categorized sections did not have many problems. The most easily mapped rivers (due to their size and the quality of the imagery) were for example Rungwa river, Ugalla river, Malagarassi river and Momba river. Expecially most rivers and their tributaries in the north and north-east of Rukwa Region showed up quite well.

As for the above mentioned four areas some aid was needed to successively draw up those rivers. First all the imagery available for those areas was collected. These were studied very carefully one after the other. Besides these, topographical maps at a scale of 1:250,000 were also used as a general guide to the approximate location and direction of the river in question. Here, it must be stressed that the topographical maps were not used solely to draw up the rivers. Instead, they were just used as an approximate reference guide. In so doing, the mapping was greatly improved and the drawbacks mentioned earlier were eliminated.

RESULTS:

Figure 2 summarizes all the rivers that showed up fairly well with the LANDSAT 1 imagery.

Another point of interest to look at would be the poor results with IMAGE 100 computer when attempting to map Luiche river. As mentioned in the previous section above, the procedure with IMAGE 100 computer is first to train it on that particular area of interest (in this case on Luiche river). This information is stored in the computer to put it simply. But the basic principle behind this computer is that it analyses the digitized computer tapes pixel by pixel. And a pixel in size is approximately 1.13 acres. Also, the equivalent area size would be a rectangle of 57m x 79m. But the width of Luiche river is neither 57m, or 79m. The width of this river is smaller than this. So the training area considered in the Luiche river was less than the size of a pixel which the computer could handle. That is to say the computer did not achieve any information from the training due to the size of the river. One would probably tend to think why not use this computer for mapping all over the Region, especially for the big rivers. In a way this could be a good idea, but one thing for those big rivers is that usually they show up easily without any aid. And furthermore, to do the mapping for the whole Region would really need many computer hours - and this means paying a lot of money. To achieve a particular target one always chooses the cheapest and reliable alternative. In this case, the IMAGE 100 should not be. However, if there is an easy access of these sophisticated techniques the better. For, in a way they might improve the mapping - in this case the hydrological network.

The last but least achievement was the appearance of a different shape of Lake Rukwa. From the available topographical maps Lake Rukwa appears to be in two parts. With the Landsat imagery the present outline of this lake was nicely revealed. Lake Tanganyika seemed to have not shifted as much. There are few areas where the aerial surveys disagree with the LANDSAT 1 mapping. But in most areas the two mappings superimpose on one another.

ASSESSMENT OF ROLE OF LANDSAT 1 IMAGERY

From the results achieved in Figure 2 there is no need to overemphasize the importance of this tool. The present outline of the Lakes was achieved. Most rivers were successively mapped. Another major input is that the relative position of one feature to the other is more accurate with the imagery. This is because one frame of the imagery carries a very extensive area. One single frame carries an area of 185km x 185 km. For example one frame within this Region carried both the outlines of Lake Rukwa and Lake Tanganyika. This included some part of the Lake Rukwa Valley, the Plateau and the Lake Tanganyika shore. Also on top of this extensive coverage in one frame is the overlap achieved between two adjacent frames. There is a 10% forward overlap and 16% side overlap.

In mapping the hydrological network large rivers are easily mapped. As for the small rivers one has to get good quality imagery and should have a fair knowledge of the area. Or else topographical maps of big scale could be of great help.

Fire burns, cloud cover, thick vegetation have always been the drawback of the imagery mapping. Using images of different seasons might alleviate the situation. For at one time there could be only thick vegetation without other drawbacks like fire burns, or cloud cover, or vice versa. It is after handling images of different seasons and making all possible adjustments in the mapping that one can effectively evaluate the accuracy of the imagery versus aerial photography or any other survey. However with the topographical maps available and the results achieved without their aid, a high accuracy is achieved.

Hopefully, the situation might be improved using the images from LANDSAT II which is already operating. Thus, in summarizing, the following is worth noting. For large, extensive areas with little data, hydrological network mapping is fairly accomplished. For small rivers other information, i.e. topographical maps will be of help. Different images for different seasons will highly alleviate the situation when encountering problems like cloud cover, fire burns or thick vegetation.

RUKWA REGION REMOTE SENSING PROJECT

IDRC/BRALUP TRAINING PROGRAM

Summary Report on the Training of

BRALUP Personnel at Laurentian University

Presented to the

International Development Research Centre, Ottawa

By

G. O. Tapper

Department of Geography

Laurentian University at Sudbury

Ontario, Canada.

June, 1977

PREFACE

Based on the rationale outlined by Dr. J.R. Pitblado, in his background report to IDRC of October, 1975, I was invited to participate in the training of three Tanzanian scientists. My involvement was twofold: first to instruct the above personnel in the rudiments of Remote Sensing and to train them in the application of various remote sensing techniques; and second, to escort them on a visitation to various U.S. government facilities concerned with the acquisition and use of LANDSAT imagery. Therefore the summary report has been separated into two parts.

PART I

IDRC/BRALUP TRAINING PROGRAM AT

LAURENTIAN UNIVERSITY, SUDBURY, ONTARIO

INTRODUCTION

The training program which was set up for the visiting Tanzanians required them to enroll in Geography 3037, Remote Sensing of the Environment and complete its requirements and to learn various darkroom techniques. As an adjunct to the above program a series of seminars were conducted to allow the Tanzanians to obtain advice and our expertise relative to their specific research objectives.

COURSE WORK

The course, Remote Sensing of the Environment is designed to present an interdisciplinary approach to remote sensing. Emphasis is placed on the application of various types of imagery and remotely sensed data, specifically to geographic research and applied studies in related disciplines. The interpretation of the imagery involved familiarization of the students with various types of remotely sensed spatial data as collected by sensors onboard aircraft, and spacecraft, and the application of such imagery to specific types of studies. The course was modified somewhat to accommodate the Tanzanians, with greater emphasis directed to African and tropical imagery, specifically the LANDSAT imagery of Tanzania. The research areas specifically emphasized were: Geology, Forest Cover, Hydrology, and Land Cover Classification. Each of the Tanzanians were encouraged to utilize and research the various textual materials available at Laurentian, specifically those directly related to their area of interest.

In keeping with the objectives of the program, a number of special projects were designed to increase their expertise in interpreting small scale imagery (LANDSAT). Once a level of general ability was reached, more specific examples of Tanzanian imagery were added to the program and the students were allowed to work according to their own research objectives and interests with advisement from both J.R. Pitblado and myself.

DARKROOM INSTRUCTION

Parallel to the course, the Tanzanians received intensive darkroom instruction. Initial exposure to darkroom technique and methodology was provided by me. Further advice and assistance was given by Ray Labbé, Department Technologist and Arthur Frechette, my student assistant. This was done during the normal course of their work, with the Tanzanians observing and receiving direct training.

Among the techniques learned by the Tanzanians were: black and white photography, lithophotography, black and white and colour printing, slide copying, diazo processing, and Agfacontour preprocessing. The availability of a fully equipped darkroom facility at Laurentian enabled the students to obtain a fairly high level of compentence in each of the above techniques. Special instruction in the processing and application of Agfacontour film for enhancing small scale imagery was provided.

SEMINARS

A series of seminars were conducted on a weekly basis between myself and the Tanzanians. The seminars allowed the Tanzanians to gain further insight on special topics: application of radar, thermal imagery, image enhancement, and various other esoteric topics.

Three of the seminars are included (Appendices I, II and III) in this report, these are statements by each student about their specific research objectives in Tanzania. The seminars gave us, Dr. Pitblado and myself some insight as to what and where, and types of application remote sensing might have in these study areas, and were a very useful device for obtaining such information.

EVALUATION OF THE STUDENTS AND THE IDRC/BLALUP TRAINING PROGRAM

STUDENT EVALUATION

Both Kikula and Kurji, attained a better than average level of competence in the basics of remote sensing, and were able to demonstrate this to me through examinations and written work. No doubt they benefited from being here for the full term. Ngana, on the other hand, never reached the level of competence of his colleagues. It is felt that this was partly due to his missing half of the classroom instruction, though by the end of the sojourn at Laurentian he was capable of interpreting small scale imagery as well as the others. In terms of darkroom work, Kikula and Ngana were each as capable as the other. While Kurji was technically less capable, he was cognizant of the various techniques and applications. Probably this difference in the darkroom represents the interests of the students, as well as previous training background, Kikula and Ngana having more technical background, while Kurji is more of an academian.

By perusing the seminar reports (Appendices I, II and III) the organization and level of expertise is readily apparent in Kurji's work, also Kikula while Ngana definitely lags behind. The overall general rating of these students is as follows:

Kurji:	excellent student		
	Geog 3037	A-	74%
	Darkroom technique	B	66%
	Seminars	A	75%
Kikula:	above average student		
	Geog 3037	B +	72%
	Darkroom technique	A	75%
	Seminar	B +	72%
Ngana:	average student		
	Geog 3037	C-	60%
	Darkroom Technique	B-	72%
	Seminars	C-	60%

PROGRAM EVALUATION

The overall impression of the training program is that it was a success. It is the considered opinion that the Tanzanians involved in this pilot program benefited a great deal not only in terms of the knowledge and expertise they gained, but also the exposure to a culture different from their own, broadened their outlook. Each student now has some idea of where to acquire remote sensor imagery and how to apply it to specific research problems which was one of the prime objectives of the program.

RECOMMENDATIONS

If the IDRC/BRALUP training Program or any other such program is undertaken or continued there are some basic parameters which should be followed:

1. The number of students in the group should be kept comfortably low (3 - 7 students).

2. The students should be industrious and have both academic and technical background (i.e. trained in one of the natural or earth sciences) screening of students would be beneficial.

3. The training program should follow somewhat the lines of the program conducted here at Laurentian (i.e. classroom experience, applied techniques, and seminar programs).

4. There should be some adjunct to the program where the involved personnel would get together both pre and post training program to prepare and provide retrospective insight into the value of the program.

PART II

TRAVEL AND VISITATION TO U.S. FACILITIES

The second part of my consultancy involved the arrangement and accompaniment with the Tanzanians to two U.S. government facilities: the EROS Data Centre and the U.S. Geological Survey's National Centre. At each of the facilities an intensive series of seminars were planned with key personnel, especially the ones involved in research which would have direct utility in Tanzania.

EROS DATA CENTER, SIOUX FALLS, SOUTH DAKOTA

The first seminar of the day spent at the EROS Data Center (EDC) was an overview of the function and purpose of the EDC. The seminar involved a slide presentation, and brief introductory talks by key members of the EDC Applications staff. It was chaired by Ms. D. Kekraai, the Protocol Officer. The initial seminar was followed by a tour of the EDC facility.

Following lunch, the second seminar was scheduled with Dr. W. Todd, an urban geographer in the Land Use Planning Applications Branch. Included in Todd's presentation was a lengthy discussion on the utility of small scale (LANDSAT) imagery in mapping the land cover of large areas, the example used was the 1976 Land Use/Cover Map of South Dakota (LUSD). Another topic discussed was the Pacific Northwest Land Use Project (NWLUP) which was similar to the South Dakota Project, with one exception. The NWLUP was an integrated project involving three state governments and the various internal departments in which each department mapped its specialty, for example forestry - forest cover, geology - geology. The LUSD on the other hand was a project that was completed by EROS Data Centre staff, primarily geographers. A third topic presented was a land use change monitoring project at Sioux Falls which was being directed by Dr. Todd. The project uses the sequential capability of LANDSAT to provide data for monitoring and updating land use changes on the periphery of Sioux Falls.

The next seminar was presented by Dr. W. Rohde, who is the Principal Forestry Application Scientist at EDC. Dr. Rohde's presentation was a discussion of "a technique used in the prototype EROS Digital Image Enhancement Systems" (EDIES). A summary discussion of this technique is provided in Appendix IV. The image quality obtained with this system, which is essentially an edge contrast enhancing technique, is excellent. The apparent resolution of the resultant enhanced imagery is such that minor variations are readily interpretable especially with vegetation communities. The EDIES system is a prototype, therefore any imagery generated by it is fairly expensive ($1,000. - for first time colour composites, $75.00 if a negative has been previously generated). The high cost of the imagery, will decrease when the production model EROS Digital Image Processing System (EDIPS) is brought on line by early 1978. Costs should then be the same as or slightly higher than normal false colour composites.

After a brief examination of the Data Reference File the visit was terminated and travel to Washinton, D.C. commenced.

U.S. GEOLOGICAL SURVEY NATIONAL CENTRE 'RESTON' VIRGINIA

We were met at the National Center by Dr. R.W. Witmer, a former colleague of mine, and following a short tour of some exhibits and the library facility, we were taken up to the Geographical Applications offices (GEOGAP) and introduced to Dr. James R. Anderson, Chief of GEOGAP. Dr. Anderson and Dr. Witmer then briefly outlined the function of GEOGAP within the Geological Survey and discussed the major research underway within GEOGAP. Dr. Witmer then followed with a seminar on the National Land Use Mapping Project which he is directing.

The next seminar was presented by Dr. John L. Place. He discussed the function of the Geological Survey within the Department of the Interior. One of the main functions of U.S.G.S. is the mapping of the United States and its territories. Dr. Place then conducted a tour of the mapping facilities at Reston. After the tour Dr. Place presented a seminar on the U.S.G.S. Urban Atlas Project which he is involved in, and discussed the applications of Small Scale Imagery, both LANDSAT and SKYLAB in mapping large urban metropolitan areas.

Dr. W.B. Mitchell, then presented a Seminar on "A Geographic Information Retrieval and Analysis System" or GIRAS which is essentially a land use/land cover change information system and is designed to produce computerized and plotted maps of land use for any region of the United States. The basic data included in GIRAS are: land use, political units, hydrologic units, census county subdivisions, Federal land ownership, and State land ownership. All the land use data provided by GIRAS was obtained from medium scale imagery by the NASA U2/RB57 platforms. The base map scale is 1:250,000 while the original imagery used was at scales smaller than 1:60,000. The GIRAS system is designed to be the largest information system in existance when it becomes fully operational by 1982. An outline copy of Dr. Mitchell's Seminar may be perused in Appendix V.

After a brief break for lunch, Dr. Witmer presented a seminar on a land cover mapping project in Alaska, which is presently in its early stages. The project involves the mapping of vegetation communities on the North Slope of Alaska, and will apply EDIES generated LANDSAT imagery.

Though the EROS Data Center is located at Sioux Falls, the Head Office of EROS is in Reston. The next series of seminars were presented at that office. There we were given insight into new data retrieval methods, and various arid lands research projects conducted by EROS.

The highlight of the visit, for the Tanzanians, was a seminar presented by Dr. Morris Deutsch. Dr. Deutsch is the EROS African Specialist and has conducted numerous short courses on remote sensor applications in Africa, one of the most recent was the East Africa Seminar and Workshop on Remote Sensing of Natural Resources and Environment held at Nairobi, Kenya in 1974. The seminar had been attended by BRALUP personnel. Dr. Deutsch presented an interesting and thought provoking seminar on some of the problems and utility of applying remote sensor data for mapping underdeveloped regions in East Africa.

As was expected, the Reston Facility was the highlight of the trip. The next day was spent visiting the various governmental offices in Washington specifically the NASA offices and the Library of Congress. We also toured the Air and Space Museum and the Museum of Natural History of the Smithsonian Institute. In terms of these places the Tanzanians were impressed with the ability to actually see the LANDSAT satellite and to climb aboard the SKYLAB vehicle at the A.S.M. I believe that the sightseeing and touring in Washington provided the Tanzanians with a natural and complementary end to a five month sojourn away from their homeland.

G. O. Tapper
Laurentian University

APPENDIX I

THE VEGETATION ECOLOGY OF RUKWA

BY

IDRIS S. KIKULA

PROPOSED STUDY

PRESENTED TO PROFESSOR G.O. TAPPER

BY

IDRIS S. KIKULA

Classification Scheme?

THE VEGETATION ECOLOGY OF RUKWA

Below is a summary of the study I intend to do in Rukwa, using Remote Sensing.

The Rukwa Region in the south-west of Tanzania is one of the most undeveloped regions of my country. Thousands of acres of land are just lying unexploited. Presently, one of the major problems towards exploiting this dormant land is the lack of relevant data for land-use planning, especially so for agriculture. Therefore, the objective of my study is to achieve this goal in the shortest possible time.

I have selected to pursue this problem from an ecological approach, using vegetation as the main criteria. The title of the study will be "The Vegetation Ecology of Rukwa".

Before I go into how I intend to go about this study, let me briefly justify my choice of vegetation as the main criteria for my ecological study. First, vegetation of an area can be regarded as an expression of the environment, soils, effects of grazing and other of man's activities. Secondly, in land-use planning it is not easy to interpret the climatic and soil data and the evaluation of the various forces in terms of their effects on plant growth. Especially so in a large area where one can't make enough soil samples for a valid conclusion. Vegetation ecology can, in addition, be useful in interpreting meteorological data.

I am convinced that a knowledge of the interrelationship between plant (animals) and the physical environment is important for a proper measure of the utilization and conservation of land resources for the present and future generations. The pattern of communities disclosed by vegetation surveys can be used as a framework for agro-ecological research and work on other biological phenomenon.

The choice of vegetation has been made while bearing in mind some of the drawbacks of vegetation as a criteria of ecological studies. The major one is that vegetation pattern is complicated by the effect of man's activities imposed on the effect of climate, soil and wild fauna. Hence the present appearance and composition often gives poor indication of the true potential in terms of either vegetation or land use. But: By relating the secondary stages on the natural climax vegetation it is possible to deduce much about the history and indication of its potentialities.

The study will be pursued in two major steps: First, will be to map the vegetation; here, both the floristic and physiognomic considerations will be observed. The second step will be to correlate the vegetation map to the climate (mainly rainfall and other aspects of water in area, e.g. water balance, etc.) topography, altitude and soils.

In the final analysis, this will probably give me Ecoclimatic and Ecological zones..

It is in the first step that I want to use Remote Sensing. I will use mostly satellite imagery and also some IR aerial photographs which most probably will be taken soon.

Bearing in mind the rich floristic composition of the area, as is the case to most of the tropical areas, I envisage that it will be difficult to determine the floristic composition. But, I hope to get more from your experience as regards this issue. In any case, most of the floristic composition shall be determined by ground survey.

I decided to use the satellite imagery because the area is too large for a ground survey and that there are no aerial photographs to cover the whole area. In addition I was just curious to see how the new technology can be put into practice in this line of study.

I expect to learn many things from this course, especially to be able to interpret the different aspects of land use and land aspects in general, e.g. vegetation, agriculture, topography, and the physical characteristics of soil. It is in these lines that I would expect from you, sir, to receive more rigorous training.

APPENDIX II

SERENGETI RESEARCH PROPOSAL

BY

FEROZ KURJI

PROPOSAL SUBMITTED TO PROFESSOR G.O. TAPPER

BY

FEROZ KURJI

I INTRODUCTION:

In 1969, the Serengeti Ecological Monitoring Program was set up by the Serengeti Research Institute to monitor an ecosystem of about 30,000 sq. km. and an ungulate population of about 2.2 million. The ecosystem was defined on the basis of the migration range of the Serengeti's dominant ungulate population; that of the wildebeest. The aim of the program is to monitor various aspects of the ecology so as to advise in the management of the ecosystem and to follow up the effects of the management policies undertaken. The program also aims to provide "basic data" to complement the requirements of other projects such as the ecology of various carnivores, etc. in turn to provide a framework within which other studies can be integrated. Consequently the program undertakes studies on the population dynamics of the various ungulate populations by carrying out periodic surveys and censuses; it collects and processes data on rainfall and in some parts of the ecosystem, information on soil moisture using neutron probes. Periodic surveys are also made to obtain information on the extent of burning, on vegetation changes and population dynamics. During 1969-72 in particular, systematic reconnaissance flights were carried out throughout the ecosystem every month to monitor the spatial dynamics of the major populations of the ecosystem and to obtain information on environmental factors with the aim of defining the ecosystem structure and its spatial-temporal trends. Since 1972 such systematic surveying has been carried out on a less regular basis depending on specific objectives to complement the general trends as indicated by the 1969-72 analysis.

Apart from ecological monitoring in the Serengeti, the SEMP has responsibilities to undertake specific studies in other national parks of Tanzania as required by management objectives. Hence, population censuses have been undertaken in Manyara, Tarangire, Ruaha, Arusha National Parks along with projects undertaken outside Tanzania as well.

II HUMAN SETTLEMENT MONITORING

In 1972, a project was undertaken in the SEMP to also monitor another important factor influencing the ecosystem dynamics. The impact of man on the ecology of the area has become one of the major themes of the program's research activities due to a number of reasons. First, human impact influences the ecology of the area by man's activities such as hunting and poaching, the use of fire and its influence on vegetation dynamics, food supply for the various ungulates and the competition between the wildlife and livestock populations in areas of collective habitat. Secondly, since early 1960's, the ungulate populations have been increasing quite dramatically in some cases (e.g. wildbeest pop. in 1964 ≃ 300,000; in 1972 ≃ 850,000 and in 1976 ≃ 1.1 million) and since the Serengeti National Park itself covers only a half of the total migration range, the impact of human settlement development in the ecosystem needs to be understood and monitored. Such an assessment is central to the question of the future survival of the Serengeti which has become an issue of national and international concern. Finally, there is need to integrate wildlife conservation as a long-term, viable form of landuse within the national development planning framework so as to become a sustained basis of resource utilization through tourism and wildlife cropping in areas outside the National Park to provide subsistence for the local human population. The latter is important because National Parks form about 12% of the mainland of Tanzania and the Serengeti forms about 30% of the total area of the administrative districts in which it is located.

(a) The settlements study was undertaken to investige three major, interrelated themes. First, was the study of human population trends in the area between the eastern shores of Lake Victoria and the western boundaries of the Serengeti National Park. Secondly, an analysis of landuse patterns and trends was undertaken since it forms a direct spatial expression of the human population. There was particular emphasis to identify human settlement development with respect to the major migration corridors of the ungulates. Finally, analysis to understand the overall impact of settlement development on the ecosystem and the role of the national park in the local and regional economy was undertaken.

(b)Methods: The analysis of human population trends was carried out using census data from the National censuses as well as other information obtained by other regional surveys. Such an analysis has already been extended to other populations around other Tanzanian wildlife conservation areas. In the analysis basic demographic aspects were reviewed.

The analysis of landuse patterns was carried out using a systematic area-sampling framework on aerial photographs available for 1950's and 1972. Proportions of area as sheer slopes, rock outcrops, riverlines, ridgetop, sideslope, valley bottom were recorded using stereo-images, proportions of area as under agricultural use (fallow + under crop + under plough) were also recorded. Hut counts were also carried out. Variables were also derived from map analysis with an aim to understand the factors involved in the development and diffusion of settlement. These data are partially analysed and the analysis is being extended.

The studies on human impact on the ecology of the Serengeti draws upon data collected by the SEMP on the spatial and population dynamics of the wildlife populations and reviewing the trends and their implications for ecosystem management or planning. Questionnaire surveys were carried out to assess the impact of the National park on the local economy and the influence of national parks in the migration of labour from the local hinterland of the park as well as other parts of the country. A substantial part of these analyses are also completed.

III FUTURE CONSIDERATIONS AND DISCUSSION:

It seems very clear from the study around the Serengeti and preliminary assessments around other national parks that detailed settlement studies will have to be undertaken to provide the data needs of ecological management and local and national land use planning and development. Data on these aspects will need to be multi-dimensional and involve large areas and often a complex domain of environmental and cultural factors will be involved. Apart from the prohibitive costs of detailed surveys and time involved, such studies may have to be undertaken in areas where information basic to planning such surveys on a limited scale may be non-existent e.g. around Selous Game Reserve or Rukwa Game Reserve. New technologies may have to be adopted to allow future projects to be undertaken; there are strong indications that such settlement studies may become of great priority around Manyara National Park, Arusha National Park and Mkomazi Game Reserve in Northern Tanzania.

In recent years, the development of remote sensors mounted on earth orbiting platforms has been regarded as a major step in the monitoring of large areas on a multivariable basis. It is suggested that such a technology is available to developing nations such as Tanzania and has great promise in the field of resource assessment and monitoring since it is relatively cheaper, more extensive and more rapid than detailed ground surveys.

The SEMP and SRI are interested in the application of the above technology to the monitoring of ecosystem dynamics in the Serengeti and its surroundings as well as to undertaking "base-line" and monitoring studies to other parts of the country. In the Serengeti, a substantial amount of baseline work has been accomplished and the major requirement is for purposes of monitoring the following aspects:

i) The role of Lake Victoria in the meterology of the Serengeti - cloud cover development, wind patterns and rainfall distribution.

ii) The study of grassland dynamics (productivity, etc.) and its relationship to soil moisture, herbivore offtake and the impact of fire. It is, however, realized that herbivore offtake will have to involve sensors based on lower altitude platforms than orbiting satellites.

iii) The study of woodland dynamics; particularly the reduction of woodland by the impact of fire and animals. This forms a major issue for concern in the management of the Serengeti, Tarangire and Ruaha national parks.

iv) The study of settlement development and its spatial diffusion in the area lying between the eastern shores of Lake Victoria and the Serengeti's western boundaries. Such monitoring will cover the mapping of "settlement fronts", areas of settlement abandonment and expansion, the types and intensity of landuse and related environmental monitoring. There is need to identify surrogates that can help to detect areas of overpopulation, areas of environmental deterioration (soil erosion, overgrazing, overburning etc.)

v) The extension of landscape classification to areas within the whole region to act as units for data collection, storage, analysis, retrieval and planning. Such a classification has been carried out within the Serengeti National Park, where there is need to extend its resolution to a smaller spatial unit and undertake monitoring of various parameters. Currently the regions of the classification are about 2000 sq. km. and landsystems are about 60 sq. km. in size. A project is extending the analysis to a higher spatial resolution in some parts and a capability to extend this to the whole ecosystem is also of great interest.

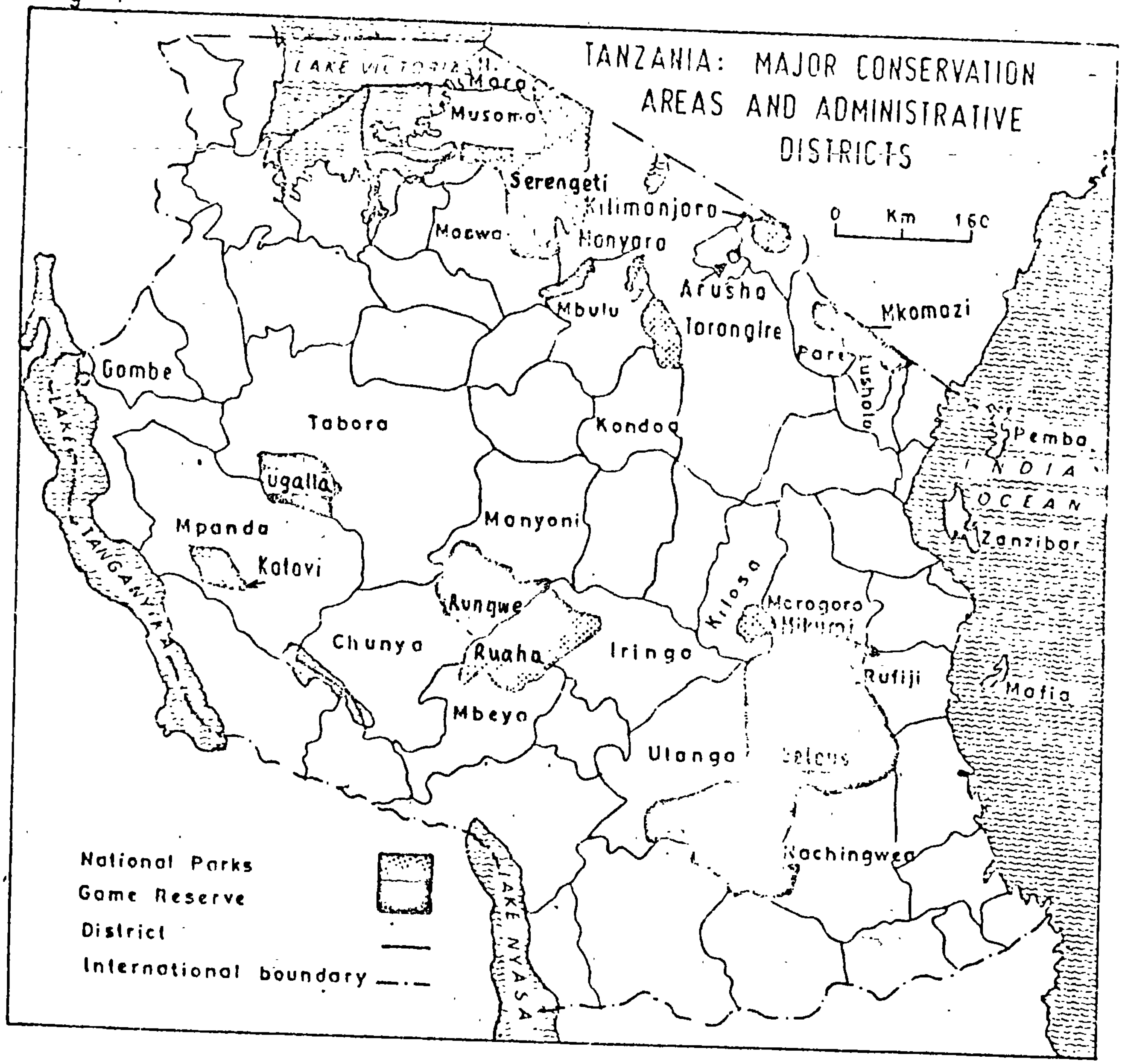
IV

In the above sections I have indicated the kinds of research I have been directly involved with and particularly the studies on settlement development have been my specific responsibility. I believe that as a result of my job requirements and interest in ecosystems modelling, I shall continue to be involved in such projects. However, it seems that settlement monitoring and local-regional planning will become the focus of my future research involvement and hence developments of remote sensing applicable to such studies will be of considerable interest to me personally. My present feeling is that if I finish the present Laurentian-IDRC-BRALUP training without exposure to the human-computer interactive analytical techniques as applied to remote sensing, I shall not be able to extend the type or scope of research undertaken in the Serengeti. There is no doubt that the course is of a short duration, facilities are limited and expensive and hence I cannot expect the present brief training to encompass successfully the research demands of a complex and large ecosystem. I am certain that the present course has been invaluable in exposing to me the whole range of remote sensing techniques that I have had no prior knowledge about and in making clear a lot of aspects badly understood before. Hence, the present exposure in itself could be a great personal step forward. But as a result of my research involvement since June 1972 at SRI I am familiar with the use of aerial photography in landscape classification settlement studies. To extend the use of readily available ERTS-LANDSAT and other imagery it seems that analysis for the Serengeti area will have to be other than that involving visual interpretation of imagery. The potential seems to be relevant to other areas of Tanzania where data are not available on the extent it is in the Serengeti after almost two decades of research. For the Serengeti in particular, the potential seems to lie in the man-computer interactive analytical techniques used in a large number of the computer based digital analysis of imagery. These involve multivariate analysis, discriminant analysis and clustering analysis to identify, classify and demarcate boundaries between phenomena in both the probabilistic and deterministic modes. I think exposure to aspects of spectral differentiations, image enhancement and the actual operationalization of above applications would be my primary interest.

V CONCLUSION:

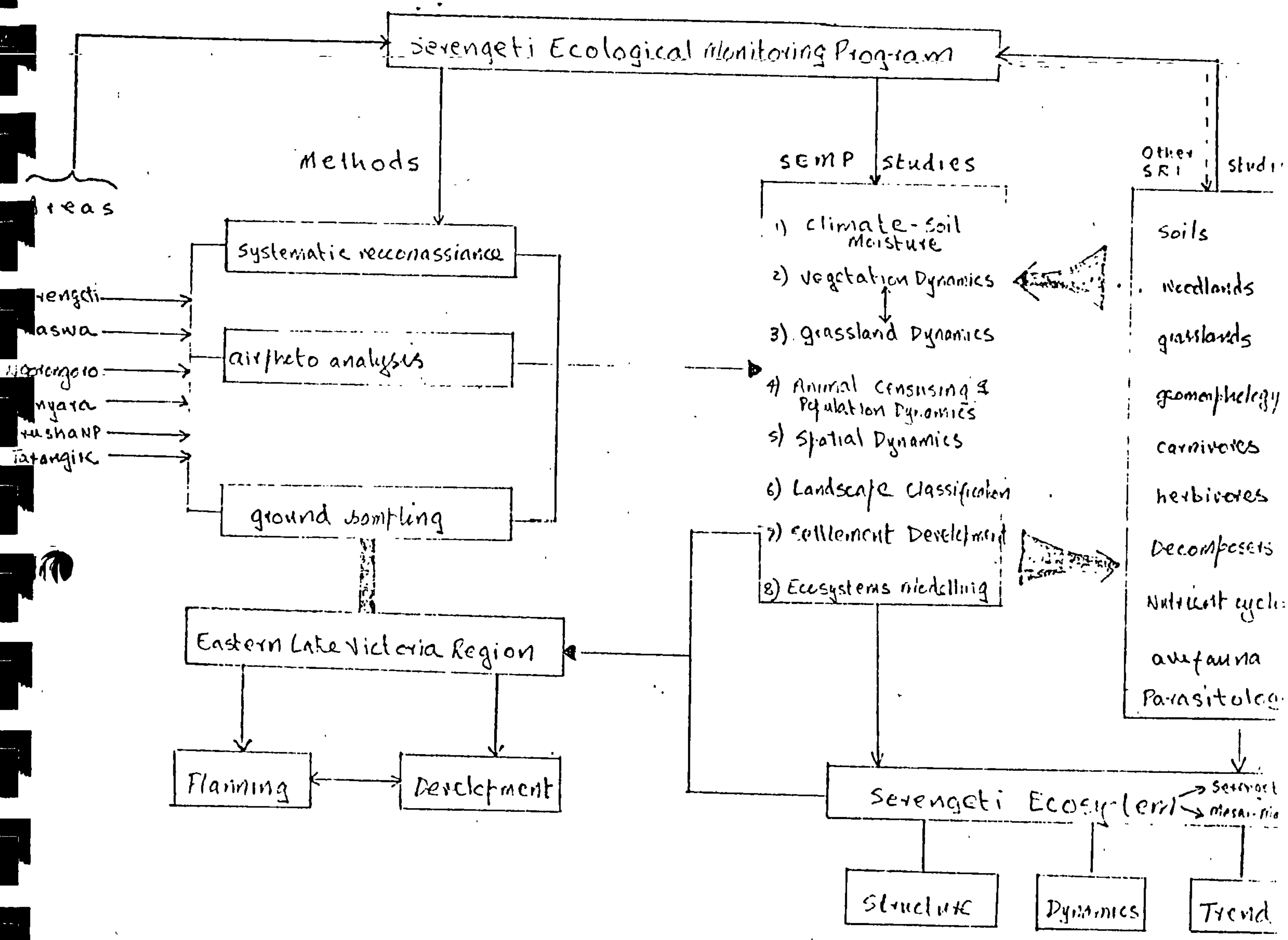
The present report attempts to present the kinds of research involved and undertaken within a major wildlife conservation area of Tanzania. It discusses the specific research interests and aspects that could be considered for the application of remote sensing techniques, particularly that of Landsat data. It shows the different training requirements to test the feasibility of applying Landsat data as in establishing "baseline data" and monitoring systems in the various conservation areas of Tanzania. These requirements range into training on man-computer interactive analytical techniques if they are to extend the scope of research in the Serengeti Ecosystem in particular. Hopefully, such training can be realistically considered after exposure to the theoretical basics of remote sensing.

Fig 1



TANZANIA: MAJOR CONSERVATION AREAS AND ADMINISTRATIVE DISTRICTS
LAKE VICTORIA
Mara
Musoma
Serengeti
Kilimanjaro
Maswa
Manyara
Arusha
Mkomazi
Mbulu
Tarangire
Gombe
Tabora
Kondoa
Pemba
INDIAN OCEAN
Ugalla
Monyoni
Zanzibar
Mpanda
Katavi
LAKE TANGANYIKA
Kilosa
Morogoro
Mikumi
Rungwe
Chunya
Ruaha
Iringa
Rufiji
Mafia
Mbeya
Ulanga
Selous
Nachingwea
LAKE NYASA
0 Km 160
National Parks
Game Reserve
District
International boundary

Fig 2: Research in the Serengeti Ecosystem: a general summary.



APPENDIX III

HYDROLOGICAL STUDIES IN RUKWA

BY

JAMES NGANA

HYDROLOGICAL STUDIES IN RUKWA

PROPOSED STUDY SUBMITTED TO PROFESSOR G.O. TAPPER

BY

JAMES NGANA

RE: HYDROLOGICAL STUDIES IN RUKWA

What I am expected to do with "my" knowledge of Remote Sensing is, to be able to:

(1) Map out all the rivers in Rukwa

(2) Map out the geology of Rukwa

(3) If possible, to delineate zones of same soil moisture ?

(4) To tell in detail, for Luiche Basin (just west of Lake Rukwa) the following basin characteristics: basin slope
- vegetation
- soil moisture
- soil condition, type
- basin size

(5) If possible to tell the groundwater potential ?

[illegible]
[illegible] Study
[illegible]
Flood [illegible]

AN OUTLINE OF M.Sc. THESIS

PROPOSAL PRESENTED TO PROF. G.O. TAPPER

by

James Ngana

April 4, 1977

OBJECTIVES:

Rukwa is one of the much neglected Regions in so far as hydrological and climatical data collection is concerned.

As outlined in Fig. No. 1 rainfall stations are scattered sparsely over the region. The need for more rain gauges is inevitably seen. This was stressed in a former report when the mean annual rainfall map was being prepared using isohyetal method. Hopefully, the rainfall data were brought along and Prof. Pitblado is working out a program to give out a printout which can help us in the comparison for the already prepared map. Obviously the printout will have to be adjusted when taking into consideration the altitude, nearness to big water bodies, wind direction, other topographical features, etc. The rainfall data available for the stations indicated in Fig. 1 have been collected on a voluntary basis, mostly by missionaries. Sometimes the missionaries leave the place and the recording practice dies a natural death. However, the figures indicated on the map are fairly accurate for many years of record. For most stations, the period of record is above 15 years. The range of period of record is 7-35 years. So this creates a fair amount of data for the project.

Then comes the streamflow data. So far the instrumentation for these data is still going on, for not all the rivers are gauged. The recent gauged rivers were as far back as 1974. So if the data were consistently collected, there should be a record of (1974-1977) about 4 years. Unfortunately, the location of these gauging stations was not possible to record, for the Project Manager was not in office at the time of my departure. Hopefully, in one week's time, I should get the latest list of gauges and their locations and extent of data collection.

The above paragraphs were describing the type of data available in Rukwa and the length of records.

Within the Region there is a Project going on to install both the Hydrometric and the Hydrometeorologic network. So far, they have concentrated more on the Hydrometric installation.

In their fieldwork report, they recommended Luiche River as an appropriate one for the Hydro power for Sumbawanga as the Regional Headquarters. This is the nearest river to the town and the river has a potential head for tapping. The suggested site for the location of the dam is about 20 km. from the town.

So it was from this report that I decided to make a study of this river. The main aim is firstly to build a model which can extend the short record so far collected so that some designs could be based on the model, and secondly to test this model for other selected rivers within the Region. Other models as recommended by various Hydrologists for areas of substantial mean annual rainfall figures (e.g. for this Region the range is 800 - 1200 mm) will also be tested for a number of basins.

METHODOLOGY:

The forthcoming techniques are just postulates for the basins that I am going to study. These are not yet confirmed as to the best models for the basins in Rukwa. Perhaps the anticipated models might not work effectively and hence alterations will have to be opted for. Briefly the procedure will be as follows:

Drainage Basins:

Luiche basin is about 360 km^2. It has several tributaries. A detailed study will have to be made. This includes basin characteristics - preferably using aerial photography and big scale contoured maps. In here one looks for basin area, slope, drainage density, bifurcation ratio,, vegetal cover and soils.

The studies will be of use in generalizing the infiltration and runoff coefficient of the basin. A fair study will also be done on other selected basins. The selection will depend on the availability of streamflow data and a rainfall gauge within the basin. For there are sometimes certain basins with rain gauge without a streamflow gauge or vice-versa. So basins will be selected on this criterion.

Proposed Models:

Sumbawanga is selected as the representative precipitation station for Luiche Basin. It is not so a representative station for that basin but the lack of data necessitates so. The rainfall data will be studied statistically to see the coefficient of variation. This is important to study because first Order Markov chain assumes that the past events are equally likely to occur in the future.

Then the collected streamflow data will be studied graphically and the Spectral Analysis from the power spectrum will tell us the stochastic components in the data.

Then Markow chain first Order will be applied to the data available and the deviations from the observed data will tell us how much this model has worked within Luiche. It should be noted that for the above analysis only streamflow data have been used. This technique will have to be tested on some other basins depending mainly on the basin characteristics. Then next will be to test other suggested models to hold quite well in this area of (800-1200 mm) rainfall amount.

Three models are going to be tested and they will all need monthly discharges as well as monthly rainfall figures.

The three models are:

(1) $Q = a(P-b)^2$ (2) $Q = aP^h$ (3) $Q = b\log P + a$

where Q stands for discharge) monthly
P stands for precipitation)

What are the values of a, b, & h?

a, b, h are constants to be determined using log transformations and non-linear regression techniques.

Note (i) These considered for precipitation is that period which the streamflow data have been collected.

(ii) Sophisticated models were not opted for, simply because of lack of data. Yet a model need not be complicated to fully explain the flow characteristics of a basin.

Conclusion:

The above techniques are attempted to extend the flow records for selected basins in Rukwa. The findings will help very much in understanding the hydrology of Rukwa and might give some first approximations for the so-called hydropower design number. In reviewing several materials for modelling, note has been kept for sketchy data available and the possible low cost techniques for this project. It is unfortunate in that all the hydrometeorological data: evaporation pan values, radiation, wind measurement, R.H. and also automatic gauge recorders for streamflow data are so few that rainfall intensity, duration, distribution is so difficult to study for a precise hydrograph analysis for any basin in question. This is just a general direction of my proposal. Changes and mostly additions are definetely going to come in.

NOTE: Enclosed 1. <u>Luiche Basin</u> map

2. Map of rivers in the Region