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PHOTO-INTERPRETATION AND DATA PROCESSING OF INTEGRATED LOW LEVEL AERIAL PHOTOGRAPHY AND RADIOMETRY

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INTRODUCTION

The accuracy, precision and interpretation of satellite radiometer data in the assessment of vegetation cover has been the subject of much research and considerable speculation. In July 1985, the ILCA/UNEP NOAA AVHRR Calibration Programme was established with the primary objective of 'determining the accuracy of AVHRR data for monitoring vegetation cover and phenology on a national basis'. One of its specific aims was to assess the relationship between NOAA AVHRR NDVI measurements and actual vegetation parameters, by comparison of the satellite data with information derived from low level aerial photographs and airborne radiometer readings.

Aerial surveys were flown at regular intervals over the major ecological zones of Kenya, taking in a full range of the environmental conditions found there. Vertical 35mm aerial photographs were taken at fixed intervals from a constant height above ground level. These were synchronised with radiometer readings, enabling close comparison between the two sets of data. The resulting information was then condensed into segment averages which could then be compared with the available satellite readings.

As a backlog of unanalysed data had amassed, and in view of their experience in the techniques required, staff of the Environmental Research Group Oxford (ERGO) were commissioned by the Food and Agriculture Organisation of the United Nations to carry out the necessary photointerpretation and preliminary data manipulation and processing of the information collected, prior to detailed analyses by project personnel.

Terms of Reference

ERGO's terms of reference were:

> To analyse and pre-process approximately 7,500 35mm aerial photographs and associated radiometer readings of selected areas in Kenya, as provided by FAO/ILCA; in particular:
>
> a). To extract vegetation cover classes and soil type data from the photographs and to enter the data into a computer in VAX-compatible format;
>
> b). To decode the radiometer data, transform the data into VAX-compatible format and integrate with the photo analysis results under a) above;
>
> c). To pre-process the photo and radiometer data in such a way that the data sets are sorted, consistent and cross referenced (matched);
>
> d). To provide the analytical data in a format suitable for further analysis and processing by ILCA (Kenya);
>
> e). To prepare a final report which summarises the above activities and also describes the processing procedures used and the file structure; recommends procedures for further analysis and processing; and includes all data entered on computer compatible tape in VAX-compatible format.

METHODOLOGY

Introduction

The organisation of photointerpretation, data entry, and data processing of the aerial survey information collected by the ILCA/UNEP team is shown in Chart 1. Once received from Kenya, the photographs were individually examined and the required data extracted. This was matched to the available airborne radiometer data, and subsequently entered into a micro computer. The resulting database was then transferred to a mainframe, for preliminary calculations, case sorting and case aggregation prior to matching with the available satellite AVHRR readings.

The three dataset types (processed, aggregated and matched) were then subjected to detailed regression analyses, in order to establish the correlations between the vegetation data, aerial and satellite radiometry.

The following sections describe the various stages outlined above, and detail the structure of the various datasets, together with the coding and variable names assigned.

CHART 1: DATA PROCESSING AND ANALYSIS

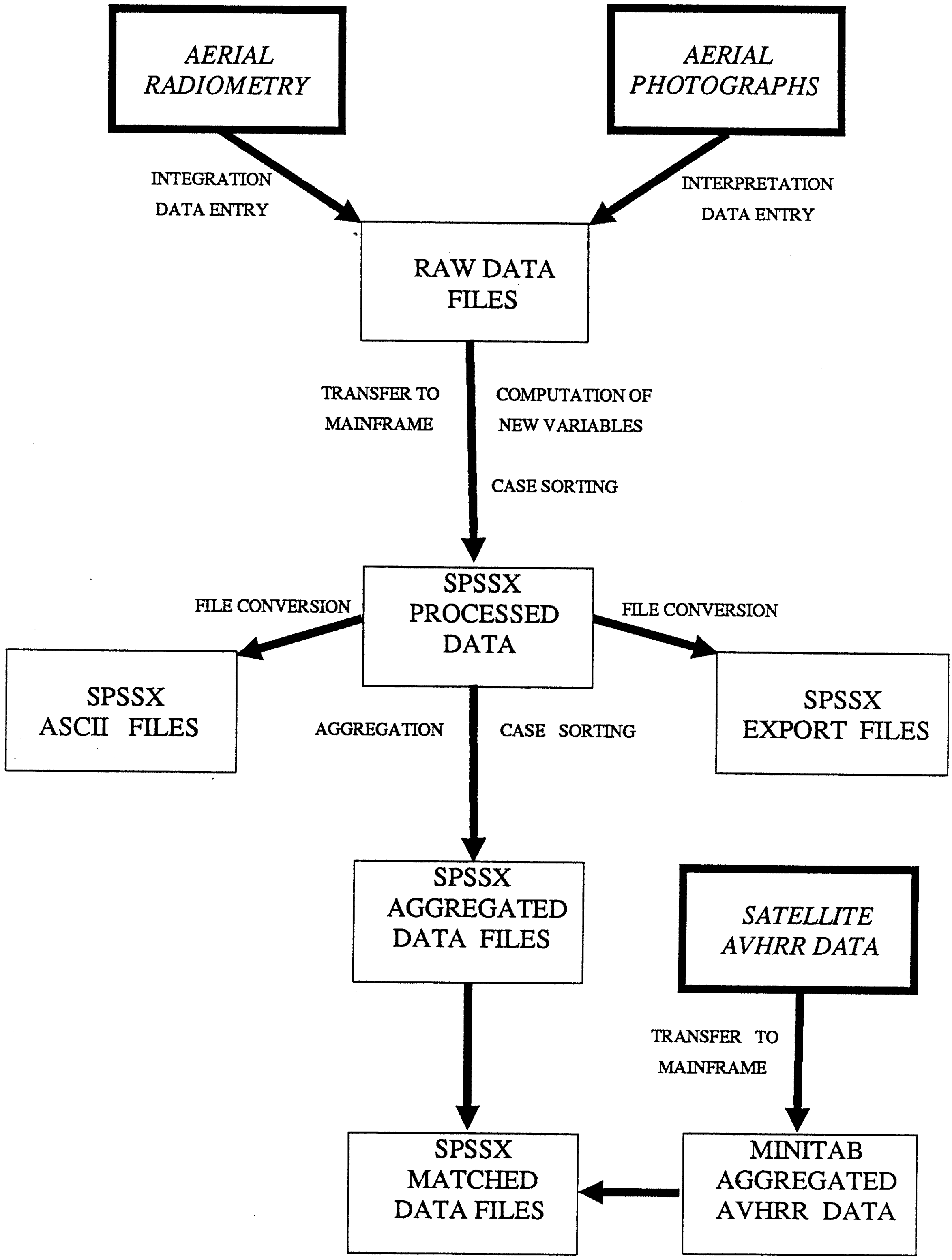


DIAGRAM 2: GRID LOCATIONS FOR SURVEY BLOCKS

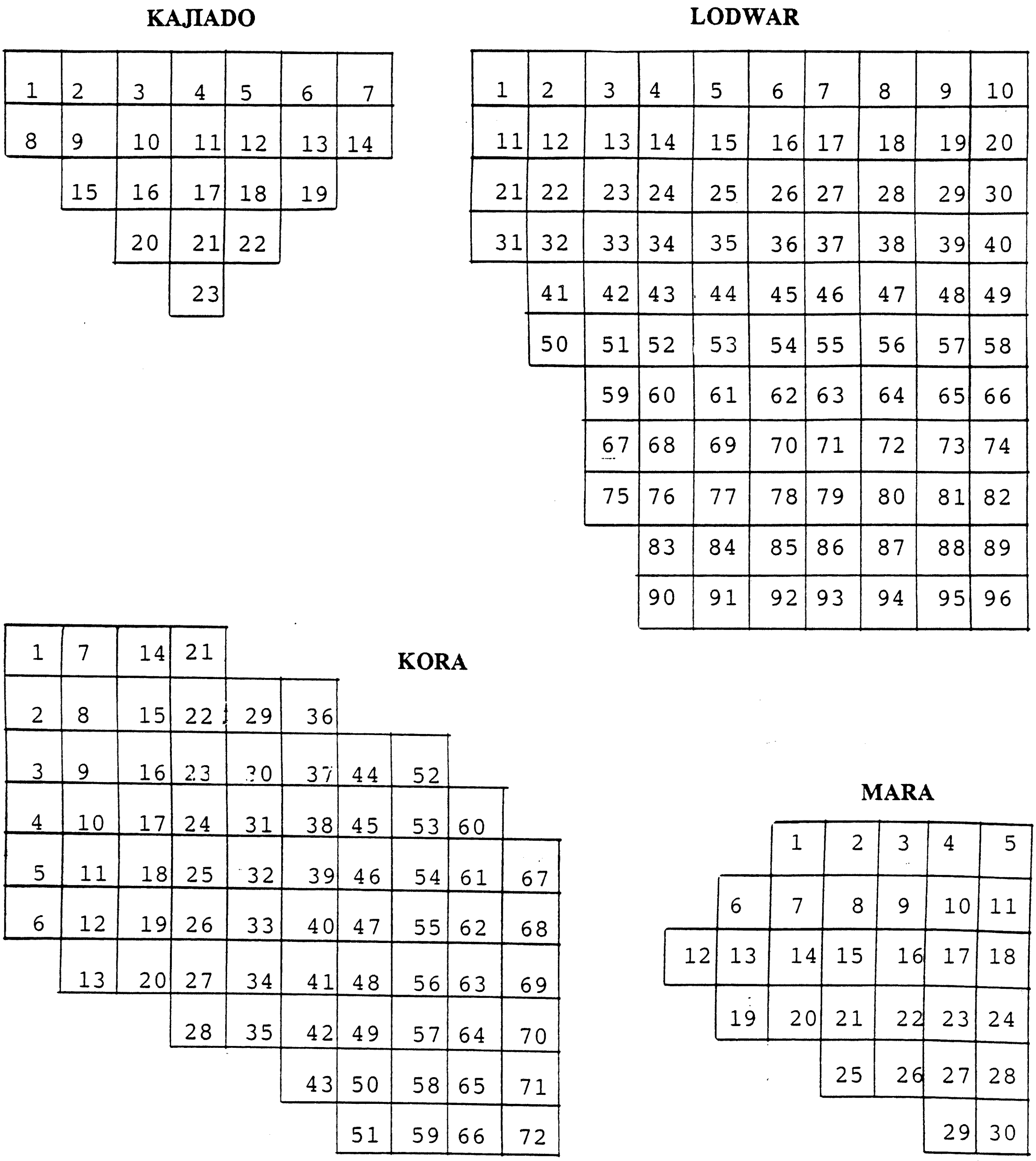


Photo-interpretation

The aerial photographs were provided on 35mm Ectachrome 200 Professional film, in 250 frame continuous strips. Each frame was labelled with the survey area, date and time, using a data back attachment, and blank frames were exposed to mark the beginning and end of transects or flight lines. This information was necessary to verify the location of each frame, and matched accurately to the radiometry readings.

Each aerial photograph was projected, at a scale of approximately 1:500, onto a screen with a systematic grid of 96 dots in an 8 by 12 array, using a large format Leitz projector equipped with a custom built bulk film feeder.

Two categories of information were extracted from each frame: the number of dots which touched a range of vegetation types; and a series of overall frame characteristics.

The first parameter assessed was the number of dots which touched herbaceous vegetation and crops, followed by the overall % greenness of that category. This process was repeated for woody vegetation. The amount of cultivation was then estimated by the number of dots which touched prepared or cultivated ground (i.e within the current cultivation cycle), as well as those which coincided with annual, perennial and unclassified crops. The frame was then assessed for the greenness of the agriculture present.

In addition, a number of variables which may have affected the radiometer readings were scored for each frame: the soil colour; and the amount of cloud shadowing, burning and water. The parameters assessed are summarised in Table 1, below.

Table 1: Parameters assessed during Photointerpretation.

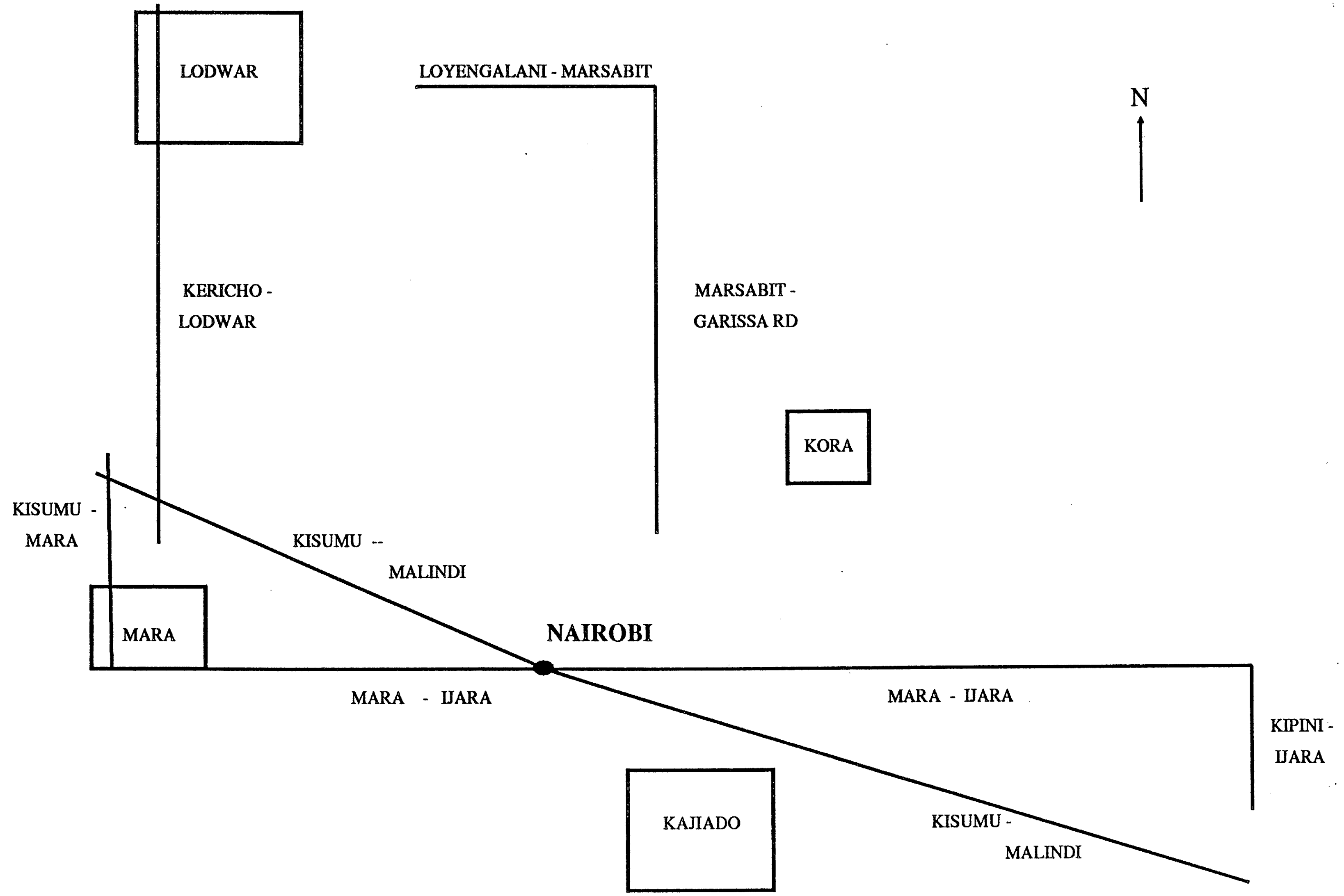
<u>Dot Counts</u>

Grass and Crop cover; Tree cover; Agriculture; Perennial Crops; Annual Crops; Unclassified Crops;

<u>Variables scored for each Frame</u>

Soil Cover (1-4); % Grass Greenness; % Tree Greeness; % Crop Greeness; Cloud Shadows (0-3); Burning (0-3); Water (0-3);

DIAGRAM 1: BLOCKS AND TRANSECTS



Once the interpretation was completed, the number of frames per transect or flight line was counted, and the average number of photographs per grid or transect segment calculated. Block surveys were divided into 10 km. grids and transects into 20 km. segments. Each photograph was then assigned to a grid or transect segment, based on the recorded exposure timing and the calculated location of the centre of the frame.

In total, approximately 8,000 photographs were examined from various flights between November 1985 and January 1986, and regular surveys from October 1986 until September 1987.

To these data were added the airborne radiometer readings, matched to each frame. The frequency of radiometer readings varied according to the survey, and it was therefore first necessary to identify the reading which matched the first photograph of a transect, using the blank frame location markers and comparing the film and radiometer exposure times. Thereafter, those records which were synchronised with the film exposures were extracted and incorporated into the dataset..

The radiometer data varied according to the survey concerned and the type of radiometer used. It consisted of either the readings for the red, infrared and solar channels from which the NDVI was calculated, or, if available, the pre-calculated NDVI, in which case the red, infrared and solar readings were omitted from the dataset. Details of the radiometers used can be found in Lamprey and De Leeuw (1987)*.[1]

Data entry

The photointerpetation results were entered onto an IBM compatible Micro computer using the Wordstar 2000 Wordprocessing Package. Whilst any data entry package that can provide Ascii text files would have sufficed, this package was used because it is both simple to operate, and has the facility for column editing and manipulation.

The data from each frame was entered onto a single line, together with details of the survey area, grid, survey date, time, and frame number. Diagrams 1 and 2 illustrate the locations and grid assignments for each survey flight, and the relevant codes are shown in Table 2, below.

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1. * Lamprey, R.H. and De Leeuw, P.N. (1987): UNEP/ILCA NOAA-AVHRR Calibration Project, 2nd Year Report. Presented to the GLobal Environment Monitoring System (GEMS) of the UNited Nations Environment Programme (UNEP).

Whilst values were ascribed to each variable for each frame where possible, there were inevitably frames from which some parameters could not be extracted, or for which radiometry data was not available. In order to maintain a consistent data structure, any missing data was entered as 999. This procedure obviates the need for specific formatting statements within any data transfer or file reading programmes.

Table 2: Codes Assigned to Each Survey Area and Survey Grid.*

Area	Code	Grids	Grid Assignment
Line Transects			
Kisumu-Malindi	21	1-33	NW to SE
Kipini-Ijara	30	1-5	N to S
Mara-Ijara	31	1-31	W to E
Kisumu-Mara	33	1-8	N to S
Loyengalani-Marsabit	40	1-7	W to E
Kericho-Lodwar	41	1-19	S to N
Marsabit-Garissa Road	42	1-17	N to S
Blocks			
Kajiado	11	1-72	(see Diagram 2)
Lodwar	51	1-96	(see Diagram 2)
Kora	60	1-23	(see Diagram 2)
Mara	70	1-30	(see Diagram 2)

* Detailed Descriptions of the Survey Areas may be found in Lamprey and De Leeuw (1987).

Micro/Mainframe Transfer

Once entered and checked against the original data sheets, the Wordstar 2000 files were converted to ASCII text files, using the 'Print to Disc' facility. The resulting transfer files were then moved to either a VAX or ICL 2988 mainframe computer, depending on filestore availability, using the standard KERMIT file transfer package, operating at 9600 baud. Once uploaded onto the mainframes, the data files were edited (using ECCE or EDT) so as to remove the file header and variable name information.

The data was divided into five separate text files: ILCAPH1.VAX, ILCAPH2.VAX, ILCAPH3.VAX, ILCAPH4.VAX and ILCAPH5.VAX. Each file contains information in slightly different column orders and variable identifications, as a result of the disparate organisation on the raw data. Details for each are given in Appendix 2.

It is recommended that these files be considered as backup information only, as all the relevant information is more readily accessible and in a more consistent and complete form in the processed files described below.

Data processing

Introduction

All the preliminary data processing was performed using the SPSSX Statistics Package. This package reads ASCII text files and is able to carry out a wide range of data manipulation, computation, sorting and analyses functions. The results are stored as binary system files, which must be converted to 'export' files for transfer between computers, and these then 'imported' for use with SPSSX. An example of the required control file needed to 'import' an 'export' file is given in Appendix 2 (IMP1.TXT). Both the system and export file types contain all the relevant variable identifications, which can be accessed from within the SPSSX package using either the MAP or LIST commands.

The system files may also be converted to ASCII text files, which can then be used with other statistical packages. However, these files do not contain any variable identification tags, so care should be taken to check the column identifications before further analysis is performed. These tags can be found in Appendix 2.

All SPSSX operations are carried out using control files which can be written with any standard editing facility, and then executed either interactively, or as batch jobs. The control files used in these analyses are listed in Appendix 3, and can be used to determine the variable names assigned and computations or manipulations performed.

Stage One Manipulations

The raw data files were first read into the SPSSX package, the dot counts converted to frequencies, new vegetation parameters computed, and, where necessary, the NDVI calculated from the red and infra red radiometry readings (see Table 3). The cases were then sorted and stored in order, according to Area, Grid and Date codes. The resulting five SPSSX files are provided on disc (PROCDAT*.EXP), and the variables listed in order in Appendix 2.

For convenience of analysis these five processed data files were amalgamted into a single large data file, which has been provided as an SPSSX export file (PROC1TO5.EXP), in which the red, infrared and solar columns have been dropped, and all the NDVI readings consistently named NDVI. The relevant SPSSX control file (PROCJOIN.TXT) is listed in Appendix 2.

In addition, the amalgamated export file has been converted into two ASCII text files the first (PROC1TO3.WRT) containing the processed data from surveys between November 1986 and April 1987; and the second (PROC4TO5.WRT) consisting of the processed data from surveys flown between April and August 1987. These are very large files which, when combined, amount to approximately 1.6MB. The variable identifications are the same as for the amalgamated export file and are given in Appendix 2.

Table 3: Variable Names and Definitions for Processed Files

Variable Name	Definition (Range)	PROCDAT Files Containing Each Variable
Area	Survey area coded as per Table 2.	All
Grid	Grid number	All
Date	Survey Date	All
Phono	Photo Number (film frame number)	All
Socol	Soil Colour (1=pale, 2=red, 3=black)	All
Ptrgr	% Tree Greenness (0-100)	All
Pgrgr	% Grass Greenness (0-100)	All
Paggn	% Crop Greenness (0-100)	All
Cld	Cloud Shadow Score (0-3)	All
Bng	Burning Score (0-3)	All
Wat	Water Score (0-3)	All
Red	Red radiometer reading	1,2
Ired	Infrared radiometer reading	1,2
Solar	Solar radiometer reading	1
Ndvi	NDVI [(I-R)/(I+R)]	1,2,4,5
Exot	Exotech Radiometer NDVI	3
Ptrcov	Propn Tree Cover (Trcov/96)	All
Pgrcov	Propn Grass and Crop Cover (Grcov/96)	All
Pagdt	Propn Agriculture (Agdt/96)	All
Pcpdta	Propn Annual Crops (Cpdta/96)	All
Pcpdtp	Propn Perennial Crops (Cpdtp/96)	All
Pcpdtu	Propn Unclassified Crops (Cpdtu/96)	All
Pcptot	Propn Total Cropping (Pcpdta + Pcpdtp + Pcpdtu)	All
Pcpag	Propn Cultivated Land which is cropped (Pcptot/(Pagdt + 0.5))	All
Pcpgn	Propn Green Crops (Pcpag*(Paggn/100))	All
Pgreent	Propn Green Trees (Ptrcov*(Ptrgr/100))	All
Pgreeng	Propn Green Grass and Crops (Pgrcov*(Pgrgr/100))	All
Pgreena	Propn Green Cultivation (Pagdt*(Paggn/100))	All
Ptotcov	Propn Total Cover (Ptrcov + Pgrcov)	All
Pbagnd	Propn Bare Ground (1-Ptotcov)	All
Ptotveg	Propn Green Vegetation (Pgreent + Pgreeng)	All

Stage Two Manipulations

Regression analyses were performed by ILCA staff on the processed data files produced by the Stage One manipulations, i.e. including every frame from every survey as individual samples. However, some of the satellite and airborne radiometry data was available only in the form of single values for each survey grid. Thus, in order to be able to investigate the relationships between the photographic data and these mean radiometry values, it was necessary to calculate mean values of the photointerpreted parameters for each survey grid. This was accomplished using the SPSSX 'Aggregation' facility.

To the aggregated files were matched the mean grid radiometry values, according to area, grid and date, using the SPSSX 'match' facility. The resulting files therefore incorporated all the photographic and radiometer data in compatible format for subsequent regression analysis.

Two matched files were produced; the first (provided as MATCHDAT.EXP) incorporating the aggregated aerial data from October to December 1986 and satellite AVHRR readings for the equivalent period (SATDAT1.VAX); and the second (AGGNDVI.EXP) consisting of the aggregated survey data from all the aerial surveys (i.e from PROC1TO5) combined with some additional airborne radiometer readings which were provided in October 1987 (APPEN.DAT). The variables included within these files are defined in Table 4 above. The second of the matched files has also been provided in ASCII format (AGGNDVI.WRT).

A series of manipulations were applied to the data in these matched data sets: all proportions, were given the arcsine transformation in order to normalise their distributions; and any gaps in the airborne radiometry readings per frame were filled from independently calculated mean Exotech NDVI values (if available) to create a new variable in the AGGNDVI dataset called 'combndvi'.

The SPSSX control files used to produce the two matched files (AGGMAT1.TXT and AGGMAT15.TXT respectively) are listed in Appendix 2.

Table 4: Variable Names and Definitions in Matched Files (MATCHDAT.EXP and AGGNDVI.EXP)**

Variable Name	Definition	File
Area	As Table 3	Both
Grid	As Table 3	Both
Date	As Table 3	Both
Calcndvi	Mean Exotech NDVI per grid	AGGNDVI
Asocol*	Average Soil Colour (Socol) per grid	Both
Aptrgr*	Average % Tree Greennes (Ptrgr) per grid	Both
Apgrgr*	Average % Grass Greenness (Pgrgr) per grid	Both
Apaggn*	Average % Agricultural Greenness (Paggn) per grid	Both
Ared*	Average Red radiometer reading (Red) per grid	MATCHDAT
Aired*	Average Infrared radiometer reading (IRed) per grid	MATCHDAT
Asolar*	Average Solar radiometer reading (Solar) per grid	MATCHDAT
ANDVI*	Average calculated airborne radiometer NDVI (NDVI) per grid	Both
Aptrcv*	Average propn Tree Cover (Ptrcv) per grid	Both
Apgrcv*	Average propn Grass and Crop cover (Pgrcv) per grid	Both
Apagdt*	Average propn Agriculture (Pagdt) per grid	Both
Apcpdta*	Average propn Annual Crops (Pcpdta) per grid	Both
Apcpdtp*	Average propn Perennial Crops (Pcpdtp) per grid	Both
Apcpdtu*	Average propn Unclassified Crops (Pcpdtu) per grid	Both
Apcptot*	Average propn Total Cropping (Pcptot) per grid	Both
Apcpgn*	Average propn Crops which are green (Pcpgn) per grid	Both
Apgreent*	Average propn Green Trees (Pgreent) per grid	Both
Apgreeng*	Average propn Green Grass and Crops (Pgreeng) per grid	Both
Aptotcov*	Average propn Total Cover (Ptotcov) per grid	Both
Apbagnd*	Average propn Bare Ground (Pbagnd) per grid	Both
Aptotveg*	Average propn Green Vegetation (Ptotveg) per grid	Both
Exot	Mean Exotech radiometer NDVI per grid	MATCHDAT
AVHRR	Mean Satellite AVHRR NDVI per grid	MATCHDAT
Combndvi	Andvi with calcndvi substituted if Andvi missing	AGGNDVI

* Variables Arcsined

** Abbreviated Names in Definition Column refer to Variables in Table 3.

Recommendations for Future Analyses

The interpretation and processing procedures described in the preceding pages were specifically developed to provide the basic data needed for the first stages of the detailed analyses required. Experience has shown that a number of features are a prerequisite to maximum efficiency in any future projects.

1.) It is recommended that all photointerpretation be performed by a single interpreter, in order to ensure the consistency of the results produced. Further, it is desirable that the interpreter be familiar with all stages of data collection. This ensures that the interpretation stages do not have to be closely supervised by survey personnel.

2). Whilst it is possible to enter the photographic data into either mainfame or micro computers, it was found to be more efficient when micros were used, and the data entry was performed by the photointerpreter. This ensured the maximum flexibility and precision during data entry.

3). In contrast, whilst the data processing stages for each survey could be carried out using micros, the detailed analysis requires that the data from each additional survey be added to the existing data set. This means that the data processing is most efficiently conducted on a mainfame capacity machine. As a result, it is highly desirable that the interpretation and processing stages be carried out in a single location, so that data transfer can be achieved most effectively.

4). The need for data compatibility between surveys implies that the interpretation and processing of any future surveys be performed using identical interpretation, data entry and processing methods. In particular, any future processing should continue to use statistical packages that are capable of data aggregation and conditional case matching, by using several case identifiers. This permits the incorporation of additional information into existing datasets, such as further AVHRR readings, or parameters derived from supplementary photointerpretation.

5). The package used for the detailed analyses and interpretation should continue to be the same as that used for the data processing, so that the information does not have to be transferred between packages. In particular, the analyses package should be capable of performing stepwise linear regressions, preferably with a facility for forced variable entry, for case selection according to quantitave range criteria, and for holding specific parameters constant during regression.

Whilst a considerable amount of information has been extracted from the aerial photographs to date, there remain a number of additional procedures which merit consideration.

The aerial photographs cover a land area which does not exactly coincide with the 'field of view' of the radiometers used. However, the entire frame was consistently examined during the interpretation and the data extracted compared with the radiometer readings, because it was considered that information taken from the whole frame was a better indicator of prevailing vegetation cover.

Thus, it would be instructive to subsample the existing photographs and assess the vegetation parameters from that portion of the frame which exactly matched the radiometer field of view. Such a procedure could also be used to assess the smallest frame size needed to provide reliable estimates of the vegetaion cover, and the camera's focal length (or flying height) adjusted accordingly. In this way, the detail visible on the photographs could be maximised.

Sub-sampling trials were carried out in the initial phases of this study, and the relevant techniques established, but full scale investigations were not deemed to be feasible given the time available.

A discussion of the detailed analyses required to interpret and assess the relationship between the photographic radiometric data is beyond the scope of the present terms of reference. Furthermore, these analyses are still in progress and the latest AVHRR values have yet to be made available. It is therefore premature, at this stage, to make specific recommendations for future analysis.

APPENDIX 1: DATA DISCS

Types and Descriptions of Files Provided

a). Vax raw data files

Ascii files, with no variable names in Header, readable by any package that can accept text files. Format free (i.e. with spaces between variables); all missing data coded as 999.

Table A1.1: Description of raw data files provided

Name	Description	Disc Number
ILCAPH1.VAX	Raw photographic and radiometric data, October, November and December 1986	1
ILCAPH2.VAX	Raw photographic and radiometric data, February, March and part of April 1987	1
ILCAPH3.VAX	Raw photographic and radiometric data, April 1987, January 1986, and November 1985	1
ILCAPH4.VAX	Raw photographic and radiometric data, June and July 1987	1
ILCAPH5.VAX	Raw photographic and radiometric data, August and September 1987	1
SATDAT1.VAX	Extracted AVHRR readings, by grid	1
APPEN.DAT	Independently calculated airborne Exotech Radiometer readings, by grid	1

b). <u>Processed Data Files</u>

Files of processed data, with new variables computed. Missing values either 999 or system missing. Rows ordered by Area, Grid and Date.

i). SPSSX Export Files

SPSSX system files, 'exported' for file transfer, only readable by SPSSX package.

Table A1.2: Description of SPSSX Export Files Provided

Name	Description	Disc Number
PROCDAT1.EXP	Processed ILCAPH1.VAX	2
PROCDAT2.EXP	Processed ILCAPH2.VAX	2
PROCDAT3.EXP	Processed ILCAPH3.VAX	2
PROCDAT4.EXP	Processed ILCAPH4.VAX	2
PROCDAT5.EXP	Processed ILCAPH5.VAX	2
PROC1TO5.EXP	Amalgamted PROCDAT*.EXP	3
PROCSAT1.EXP	Raw Satellite AVHRR readings, by grid	2
APPENDAT.EXP	Independently calculated Airborne Exotech Radiometry readings, by grid	2
AGGNDVI.EXP	Aggregated PROC1TO5 matched with APPEN.DAT, by grid	3
MATCHDAT.EXP	Aggregated ILCAPH1.VAX matched with PROCSAT1.DAT	3

ii). SPSSX Written Files.

Processed data in Ascii format with no header information; spaces between variables; all missing data coded as 999. Readable by any package which can accept text files. Converted from .EXP files, and consequently with identical variable identification, order and format.

Table A1.3: Description of ASCII Files Provided

Name	Description	Disc Number
PROC1TO3.WRT	From PROC1TO5, November 1986 to March 1987 data	4
PROC4TO5.WRT	From PROC1TO5, April 1987 to August 1987 data	5
AGGNDVI.WRT	From AGGNDVI.EXP	4

iii). Control Files

Text files containing the processing/analysis instructions for use by SPSSX package.

Table A1.4: Description of SPSSX Control Files provided

Name	Function	Disc #
DATPROC1.TXT	Processing ILCAPH1 to PROCDAT1	1
DATPROC2.TXT	Processing ILCAPH2 to PROCDAT2	1
DATPROC3.TXT	Processing ILCAPH3 to PROCDAT3	1
DATPROC4.TXT	Processing ILCAPH4 to PROCDAT4	1
DATPROC5.TXT	Processing ILCAPH5 to PROCDAT5	1
PROCJOIN.TXT	Joining all PROCDAT files into PROC1TO5	3
PROC1TO5.TXT	Writing PROC1TO3.WRT and PROC4TO5.WRT from PROC1TO5	5
AGGMAT1.TXT	Aggregating ILCAPH1 and Matching with PROCSAT1	3
AGGMAT15.TXT	Aggregating PROC1TO5 and Matching with APPENDAT	3
IMP1.TXT	Example of control file required to 'import' PROCDAT1.EXP for subsequent analysis using SPSSX	2

APPENDIX 2: DATA FILE VARIABLE LISTS

The variable lists shown below are given in the order in which they occur in the data files. All the variables for a single case are contained on one line. Any missing data is coded as 999 or, in the *.EXP files, as SPSSX 'system missing'.

a). Raw Data Files

ILCAPH1.VAX
Area Grid Date PhNo Scol Trov %TGr Grcov %GrGr AgDt CpDtA
CpDtP CpDtU %AgGn Red IRed Sol Cld Bng Wat

ILCAPH2.VAX
Area Grid Date PhNo Time Scol Trov %TGr Grcov %GrGr AgDt
CpDtA CpDtP CpDtU %AgGn Cld Bgn Wat Red IRed NDVI

ILCAPH3.VAX
Area Grid Date PhNo Time Scol Trov %TGr Grcov %GrGr AgDt
CpDtA CpDtP CpDtU %AgGn Cld Bgn Wat NDVI IRed Sol

ILCAPH4.VAX
Area Grid Date PhNo Scol Trov %TGr Grcov %GrGr AgDt CpDtA
CpDtP CpDtU %AgGn Cld Bng Wat NDVI

ILCAPH5.VAX
Area Grid Date PhNo Scol Trov %TGr Grcov %GrGr AgDt CpDtA
CpDtP CpDtU %AgGn Cld Bng Wat NDVI

SATDAT1.VAX
Area Grid Date Exot AVHRR

APPEN.DAT
Area Grid Date Calcndvi

b). Processed Data Files

i). SPSSX Export Files

PROCDAT1.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Red Ired
Solar Cld Bng Wat Ndvi Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp
Pcpdtu Pcptot Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov
Pbagnd Ptotveg

PROCDAT2.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Cld Bng
Wat Ndvi Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp Pcpdtu Pcptot
Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov Pbagnd Ptotveg

PROCDAT3.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Cld Bng Wat Exot Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp Pcpdtu Pcptot Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov Pbagnd Ptotveg

PROCDAT4.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Cld Bng Wat Ndvi Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp Pcpdtu Pcptot Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov Pbagnd Ptotveg

PROCDAT5.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Cld Bng Wat Ndvi Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp Pcpdtu Pcptot Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov Pbagnd Ptotveg

PROC1TO5.EXP
Area Grid Date Phono Socol Ptrgr Pgrgr Paggn Cld Bng Wat Ndvi Ptrcov Pgrcov Pagdt Pcpdta Pcpdtp Pcpdtu Pcptot Pcpag Pcpgn Pgreent Pgreeng Pgreena Ptotcov Pbagnd Ptotveg

MATCHDAT.EXP (* = arcsined)
Area Grid Date Asocol* Aptrgr* Apgrgr* Apaggn* Ared* Aired* Asolar* ANDVI* Aptrcv* Apgrcv* Apagdt* Apcpdta* Apcpdtp* Apcpdtu* Apcptot* Apcpgn* Apgreent* Apgreeng* Aptotcov* Apbagnd* Aptotveg* Exot AVHRR

AGGNDVI.EXP (* = arcsined)
Area Grid Date Calcndvi Asocol* Aptrgr* Apgrgr* Apaggn* ANDVI* Aptrcv* Apgrcv* Apagdt* Apcpdta* Apcpdtp* Apcpdtu* Apcptot* Apcpgn* Apgreent* Apgreeng* Aptotcov* Apbagnd* Aptotveg* Combndvi

APPENDAT.EXP
Area Grid Date Calcndvi

PROCSAT1.EXP
Area Grid Date Exot AVHRR

ii). SPSSX Written Files

PROC1TO3.WRT	Variables as PROC1TO5.EXP
PROC4TO5.WRT	Variables as PROC1TO5.EXP
AGGNDVI.WRT	Variables as AGGNDVI.EXP

APPENDIX 3: CONTROL FILE LISTINGS

Control Files for Data Processing

DATPROC1.TXT

```
FILE HANDLE PHOTAN/NAME='ILCAPH1.VAX'
DATA LIST FILE=PHOTAN FREE
     /AREA GRID DATE PHONO SOCOL TRCOV PTRGR GRCOV PGRGR
     CPDTA CPDTP CPDTU PAGGN RED IRED SOLAR CLD BNG WAT
MISSING VALUES ALL (999)
COMPUTE NDVI=(IRED-RED)/(IRED+RED)
COMPUTE PTRCOV=TRCOV/96
COMPUTE PGRCOV=GRCOV/96
COMPUTE PAGDT=AGDT/96
COMPUTE PCPDTA=CPDTA/96
COMPUTE PCPDTP=CPDTP/96
COMPUTE PCPDTU=CPDTU/96
COMPUTE PCPTOT=PCPDTA+PCPDTP+PCPDTU
COMPUTE PCPAG=PCPTOT/(PAGDT+0.5)
COMPUTE PCPGN=PCPAG*(PAGGN/100)
COMPUTE PGREENT=PTRCOV*(PTRGR/100)
COMPUTE PGREENG=PGRCOV*(PGRGR/100)
COMPUTE PGREENA=PAGDT*(PAGGN/100)
COMPUTE PTOTCOV=PTRCOV+PGRCOV
COMPUTE PBAGND=1-PTOTCOV
COMPUTE PTOTVEG=PGREENT+PGREENG
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCDAT1.SPS'
PRINT FORMATS NDVI (F6.3)
SAVE OUTFILE=DATA
 KEEP=AREA GRID DATE PHONO SOCOL PTRGR PGRGR PAGGN RED TO WAT
NDVI TO PTOTVEG
GET FILE=DATA
LIST
FINISH
```

DATPROC2.TXT

```
FILE HANDLE PHOTAN/NAME='ILCAPH2.VAX'
DATA LIST FILE=PHOTAN FREE
    /AREA GRID DATE PHONO TIME SOCOL TRCOV PTRGR GRCOV PGRGR AGDT
    CPDTA CPDTP CPDTU PAGGN CLD BNG WAT RED IRED NDVI
MISSING VALUES ALL (999)
COMPUTE PTRCOV=TRCOV/96
COMPUTE PGRCOV=GRCOV/96
COMPUTE PAGDT=AGDT/96
COMPUTE PCPDTA=CPDTA/96
COMPUTE PCPDTP=CPDTP/96
COMPUTE PCPDTU=CPDTU/96
COMPUTE PCPTOT=PCPDTA+PCPDTP+PCPDTU
COMPUTE PCPAG=PCPTOT/(PAGDT+0.5)
COMPUTE PCPGN=PCPAG*(PAGGN/100)
COMPUTE PGREENT=PTRCOV*(PTRGR/100)
COMPUTE PGREENG=PGRCOV*(PGRGR/100)
COMPUTE PGREENA=PAGDT*(PAGGN/100)
COMPUTE PTOTCOV=PTRCOV+PGRCOV
COMPUTE PBAGND=1-PTOTCOV
COMPUTE PTOTVEG=PGREENT+PGREENG
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCDAT2.SPS'
PRINT FORMATS NDVI (F6.3)
SAVE OUTFILE=DATA
 KEEP=AREA GRID DATE PHONO SOCOL PTRGR PGRGR PAGGN TO PTOTVEG
GET FILE=DATA
LIST
FINISH
```

DATPROC3.TXT

```
FILE HANDLE PHOTAN/NAME='ILCAPH3.VAX'
DATA LIST FILE=PHOTAN FREE
    /AREA GRID DATE PHONO TIME SOCOL TRCOV PTRGR GRCOV PGRGR AGDT
    CPDTA CPDTP CPDTU PAGGN CLD BNG WAT EXOT
MISSING VALUES ALL (999)
COMPUTE PTRCOV=TRCOV/96
COMPUTE PGRCOV=GRCOV/96
COMPUTE PAGDT=AGDT/96
COMPUTE PCPDTA=CPDTA/96
COMPUTE PCPDTP=CPDTP/96
COMPUTE PCPDTU=CPDTU/96
COMPUTE PCPTOT=PCPDTA+PCPDTP+PCPDTU
COMPUTE PCPAG=PCPTOT/(PAGDT+0.5)
COMPUTE PCPGN=PCPAG*(PAGGN/100)
COMPUTE PGREENT=PTRCOV*(PTRGR/100)
COMPUTE PGREENG=PGRCOV*(PGRGR/100)
COMPUTE PGREENA=PAGDT*(PAGGN/100)
COMPUTE PTOTCOV=PTRCOV+PGRCOV
COMPUTE PBAGND=1-PTOTCOV
COMPUTE PTOTVEG=PGREENT+PGREENG
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCDAT3.SPS'
PRINT FORMATS EXOT (F6.3)
SAVE OUTFILE=DATA
 KEEP=AREA GRID DATE PHONO SOCOL PTRGR PGRGR PAGGN TO PTOTVEG
GET FILE=DATA
LIST
FINISH
```

DATPROC4.TXT

```
FILE HANDLE PHOTAN/NAME='ILCAPH4.VAX'
DATA LIST FILE=PHOTAN FREE
    /AREA GRID DATE PHONO SOCOL TRCOV PTRGR GRCOV PGRGR AGDT
    CPDTA CPDTP CPDTU PAGGN CLD BNG WAT NDVI
MISSING VALUES ALL (999)
COMPUTE PTRCOV=TRCOV/96
COMPUTE PGRCOV=GRCOV/96
COMPUTE PAGDT=AGDT/96
COMPUTE PCPDTA=CPDTA/96
COMPUTE PCPDTP=CPDTP/96
COMPUTE PCPDTU=CPDTU/96
COMPUTE PCPTOT=PCPDTA+PCPDTP+PCPDTU
COMPUTE PCPAG=PCPTOT/(PAGDT+0.5)
COMPUTE PCPGN=PCPAG*(PAGGN/100)
COMPUTE PGREENT=PTRCOV*(PTRGR/100)
COMPUTE PGREENG=PGRCOV*(PGRGR/100)
COMPUTE PGREENA=PAGDT*(PAGGN/100)
COMPUTE PTOTCOV=PTRCOV+PGRCOV
COMPUTE PBAGND=1-PTOTCOV
COMPUTE PTOTVEG=PGREENT+PGREENG
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCDAT4.SPS'
PRINT FORMATS NDVI (F6.3)
SAVE OUTFILE=DATA
 KEEP=AREA GRID DATE PHONO SOCOL PTRGR PGRGR PAGGN TO PTOTVEG
GET FILE=DATA
LIST
FINISH
```

DATPROC5.TXT

```
FILE HANDLE PHOTAN/NAME='ILCAPH5.VAX'
DATA LIST FILE=PHOTAN FREE
    /AREA GRID DATE PHONO SOCOL TRCOV PTRGR GRCOV PGRGR AGDT
    CPDTA CPDTP CPDTU PAGGN CLD BNG WAT NDVI
MISSING VALUES ALL (999)
COMPUTE PTRCOV=TRCOV/96
COMPUTE PGRCOV=GRCOV/96
COMPUTE PAGDT=AGDT/96
COMPUTE PCPDTA=CPDTA/96
COMPUTE PCPDTP=CPDTP/96
COMPUTE PCPDTU=CPDTU/96
COMPUTE PCPTOT=PCPDTA+PCPDTP+PCPDTU
COMPUTE PCPAG=PCPTOT/(PAGDT+0.5)
COMPUTE PCPGN=PCPAG*(PAGGN/100)
COMPUTE PGREENT=PTRCOV*(PTRGR/100)
COMPUTE PGREENG=PGRCOV*(PGRGR/100)
COMPUTE PGREENA=PAGDT*(PAGGN/100)
COMPUTE PTOTCOV=PTRCOV+PGRCOV
COMPUTE PBAGND=1-PTOTCOV
COMPUTE PTOTVEG=PGREENT+PGREENG
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCDAT5.SPS'
PRINT FORMATS NDVI (F6.3)
SAVE OUTFILE=DATA
 KEEP=AREA GRID DATE PHONO SOCOL PTRGR PGRGR PAGGN TO PTOTVEG
GET FILE=DATA
LIST
FINISH
```

Control Files for Data Aggregation and Matching

AGGMAT1.TXT

```
FILE HANDLE SATDAT/NAME='SATDAT1.VAX'
DATA LIST FILE=SATDAT FREE
   /AREA GRID DATE EXOT AVHRR
SORT CASES BY AREA GRID DATE
FILE HANDLE DATA/NAME='PROCSAT1.SPS'
PRINT FORMATS (F6.3)
SAVE OUTFILE=DATA
FILE HANDLE AGDATA/NAME='PROCDAT1.SPS'
GET FILE=AGDATA
MISSING VALUES ALL (999)
SELECT IF (AREA NE 999)
SELECT IF (GRID NE 999)
SELECT IF (DATE NE 999)
DO REPEAT R=PTRGR PGRGR PAGGN
COMPUTE R=R/100
COMPUTE R=ARSIN(R)
END REPEAT
DO REPEAT R=PTRCOV TO PTOTVEG
COMPUTE R=ARSIN(R)
END REPEAT
FILE HANDLE AGPHOT1/NAME='AGDAT1.SPS'
AGGREGATE OUTFILE=AGPHOT1
        /BREAK=AREA GRID DATE
        /ASOCOL APTRGR APGRGR APAGGN=MEAN(SOCOL PTRGR PGRGR
PAGGN)
        /ARED AIRED ASOLAR ANDVI=MEAN(RED IRED SOLAR NDVI)
        /APTRCV APGRCV APAGDT APCPDTA=MEAN(PTRCOV PGRCOV PAGDT
PCPDTA)
        /APCPDTP APCPDTU APCPTOT APCPAG=MEAN(PCPDTP PCPDTU PCPTOT
PCPAG)
        /APCPGN APGREENT APGREENG APTOTCOV=MEAN(PCPGN PGREENT
PGREENG PTOTCOV)
        /APBAGND APTOTVEG=MEAN(PBAGND PTOTVEG)
FILE HANDLE MATCH/NAME='PROCSAT1.SPS'
FILE HANDLE DATA1/NAME='AGDAT1.SPS'
MATCH FILES  FILE= DATA1/ FILE=MATCH/BY AREA GRID DATE
FILE HANDLE OUT/NAME='MATCHDAT.SPS'
SAVE OUTFILE=OUT
LIST
FINISH
```

Specimen Control File for Data Export and Writing

PROC1TO5.TXT

```
FILE HANDLE PROC/NAME='PROC1TO5.SPS'
GET FILE=PROC
RECODE ALL (MISSING=999)
SELECT IF (DATE LT 8704)
FILE HANDLE WRITE/NAME='PROC1TO3.WRT'
WRITE OUTFILE=WRITE/ALL
WRITE FORMATS NDVI (F7.3)
EXECUTE
GET FILE=PROC
RECODE ALL (MISSING=999)
SELECT IF (DATE GE 8704)
FILE HANDLE WRITE2/NAME='PROC4TO5.WRT'
WRITE OUTFILE=WRITE2/ALL
WRITE FORMATS NDVI (F7.3)
EXECUTE
GET FILE=PROC
RECODE ALL (MISSING=999)
FILE HANDLE EXP/NAME='PROC1TO5.EXP'
EXPORT OUTFILE=EXP/MAP
FREQUENCIES VARIABLE = CHECK
FINISH
```

Specimen Control File for Data Import

IMP1.TXT

```
FILE HANDLE EXP/NAME='PROCDAT1.EXP'
IMPORT FILE=EXP
FILE HANDLE SVE/NAME='PROCDAT1.SPS'
FREQUENCIES VARIABLE=CHECK
SAVE OUTFILE=SVE
FINISH
```