European Union

AU-IBAR

INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

Farming in Tsetse Controlled Areas
FITCA

Environmental Monitoring and Management Component

E M M C

Project Number : 7.ACP.RP.R. 578

Landscape and land use analysis Using SPOT 5 satellite imagery In Kenya and Uganda Short term consultancy 18 september to 7 october 2004 Mission report

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FITCA-EMMC Report Number W R7

Natural Resources Institute

CIRAD

TABLE OF CONTENT

LIST OF ACRONYMS

AOI	Area of Interest
AU/IBAR	African Union - Inter-African Bureau for Animal Resources
CIRAD-AMIS	Centre de Coopération Internationale en Recherche Agronomique pour le Développement - Advanced Methods for Innovation in Science
DRSRS	Department of Resource Survey and Remote Sensing
EDF	European Development Fund
EMMC	Environmental Monitoring and Management (of the FITCA project)
FITCA	Farming in Tsetse Controlled Areas
GCP	Ground Control Points
GIS	Geographic Information System
GPS	Global Positioning System
ILRI	International Livestock Research Institute
RCMRD	Regional Centre for Mapping of Resources for Development
STC	Short Term Consultancy

1. INTRODUCTION :
BACKGROUND OF THE PROGRAMME FITCA-EMMC

Human and animal trypanosomosis transmitted by tsetse flies represent important constraints on human health and livestock productivity in Kenya, Uganda, Ethiopia and Tanzania.
The FITCA programme has been conceived and is implemented to improve the livelihood of the rural population and reduce poverty by helping farmers to control tsetse fly, increase livestock productivity and enhance agricultural production by improving their agricultural system.
The European Union finances the FITCA program with regional and national indicative fonds under the EDF VII, agreement #5682/reg. The Regional Tsetse Co-ordination Unit based at AU/IBAR offices supervises the FITCA Regional programmes.
Funded by the EU, the Environmental Monitoring and Management Component (EMMC) is part of the regional FITCA program. EMMC is contracted to ILRI (TAC signed on March 28t 2001 for 2 years, extended until December 2003, and new TAC signed on February 28th 2004 until December 2004). EMMC is supporting national FITCA in terms of assisting with the formulation of plans to reduce the likelihood of impacts of the tsetse control techniques applied.

2. SHORT TERM CONSULTANCY

2.1 Background of the consultancy

Tsetse infestation is for a long time considered as a major threat for human and livestock; important national programmes were implemented in the aim to control the fly transmitted diseases and allow rural populations to access new arable lands.
Controlling tsetse has several environmental impacts, separated into two distinct types: direct and indirect. Most of the former tsetse control programmes had direct impacts on natural resources. As a result of the vector control, people are likely to settle in newly cleared lands after these are freed of the tsetse fly. The indirect impacts on the environnent are the effects through the settlement of human populations on wild areas, the expansion of livestock populations, and land-use change.

The environmental monitoring is partly based on the analysis of land use and land cover change. Indicators of land transformation for agriculture, land use changes and land cover evolution combine several statistical data combining land use mapping and socio-economic surveys, which is compared in a spatial location and within temporal interval of several years. The trends of environmental consequences can be deducted form these changes.

2.2. Place of the consultancy in the project

The methodology combines:

- Data collection on the ground on small sample areas (4 km2), using GPS, to produce maps of land use and adapted typology (already realized on 5 areas by an ILRI's ecologist and a GIS specialist).
- Assessment of recent and present land use and farming system changes and trends, using questionnaires among farmers (conducted by sociologists).
- Assessment of vegetation on sample areas localised by GPS (done by botanists).

- A generalisation of land use and land cover analysis to the FITCA areas using satellite imagery analysis, to produce land use maps.

This last step is the objective of this consultancy.
FITCA-EMMC organised a first consultancy (April 2002) on use of remote sensing for monitoring landscape and land use at regional levell. The methodological information is extracted from the report~ . The report gave the useful guidance to prepare this phase of activity.

The characteristics of landscape and the objectives of the monitoring influence the degree of accuracy needed.

- An analysis of land use changes has still be done in Ethiopia using LANDSAT-TM imageries and a ground truth mission. The objective was to compare situations at ten years interval.
- In Kenya and Uganda, the small size of the fields led the first consultant in remote sensing to recommend the use of high-resolution imageries.

Reviewing the indicators of land use change and considering the budget and the costs involved, it has been decided to use a high resolution (2.Sm) SPOT 5 image which is expected to capture and differentiate some of the indicators such as différent crops, fallows, woodlands and settled or homestead areas.
A typology of land use and land cover has been defined during the field studies on the samples areas. For example, the natural vegetation areas include forests, woodlands, shrubs, bushes, swamps, river line, grasslands and a mixture of these cover classes. The analysis of imageries will confirm if remote sensing can captures this typology.

~ G. De Wispelaere, Landscape and land use analysis using satellite imagery at the FITCA regional and national level. CIRAD-EMVT / FITCA-EMMC / ILRI, 2002.

2.3. Objective of the Consultancy

The Terms of Reference of EMMC emphasizes the necessity to assess the changes in land use after tsetse control and the effects of land use changes on vegetation, biodiversity and soil fertility. This Short Term Consultancy refers to the activity 1.2 of the work plan and the logical framework for FITCA-EMMC: *“purchase of remote sensed imageries and interpretation of the land use and land cover to monitor environmental change in the long term “*. The work plan explains the aim: *“The satellite imagery is the best tool to extend the information gained through the detailed ground mapping of land use to a wider area, and also to serve as a baseline for future monitoring of change after the end of the FITCA project”*.

This present consultancy is placed at methodological and training level, whose objectives are to help the ILRI GIS specialist working on the project and one or two members of national institutions to analyse high definition satellite imageries and produce land use mapping.

The consultant was expected to assist the project and the GIS specialists:
- in the image acquisition and pre-treatment,
- in the image classification,
- in the evaluation of this methodology in the perspective of a sustainable monitoring process, after the end of the project.

3. OPERATIONAL PROCEDURES

The STC started in Nairobi ILRI campus with a briefing and preparation of the fieldwork with the EMMC working group.

Delivery of digital data: DVD's and CD's with :

- Original SPOT 5 multispectral data,
- Original SPOT 5 panchromatic data,
- Georeferenced and aligned SPOT 5 XS and P data,
- P + XS composite: extracts on Angurai, Matayos and Tororo.

Conference room was prepared to accommodate the training workshop that took place on 22 and 23 of September.

Training workshop in ILRI.

After the phase of pre-processing and unsupervised classification, the specialists went in Western Kenya and Eastern Uganda to compare the satellite data with the situation at ground level.

A technical debriefing was organised in ILRI with the EMMC working group at the end of the mission.

3.1 Calendar

18/09/2004 :	Montpellier-Nairobi
19/09/2004 :	Nairobi, preparation
20/09/2004 :	ILRI : Introductory meetings,delivery of data
21-22/09/2004 :	Training workshop
22-23/09/2004 :	ILRI
24/09/2004 :	Nairobi-Malaba
25-26/09/2004 :	Angurai
29-30/09/2004 :	Tororo
01-02/10/2004 :	Matayos and journey back to Nairobi
03-06/10/2004 :	ILRI : data processing and technical debriefing
07/10/2004 :	Nairobi-Montpellier

3.2 Key-people met :

Title	First name	Last name	Institution	Function	Town	Country
Dr	John	McDERMOTT	ILRI	Deputy Director General-Research	Nairobi	Kenya
Dr	Bernard	TOUTAIN	FITCA-EMMC	Project Coordinator	Nairobi	Kenya
Mr	H.Ade	FREEMAN	ILRI	Director Targeting R&D Opportunities	Nairobi	Kenya
Mr	Harald	ROJAHN	AU/IBAR/FITCA	Technical Assistant	Nairobi	Kenya
Dr	Joseph	MATERE	ILRI/FITCA	GIS Analyst	Nairobi	Kenya
Dr	Joseph	MAITIMA	ILRI/FITCA	Regional Ecologist	Nairobi	Kenya
Ms	Lucy	KINUTHIA	FITCA		Busia	Kenya

4. TRAINING

Thirteen trainees, GIS specialists, attended an adapted training, giving them the sufficient skip to analyse satellite imagery and particularly other SPOT 5 images :

NAME	INSTITUTION
Patrick Gang	DRSRS
Dan K. Marangu	DRSRS
Crispus Kinyua Ruitha	Vet. Research Labs TseTse Control
Joseph N. Matere	ILRI
Kiros Lekarsia	ILRI
Jennifer Kinoti	ILRI
Abisalom Omolo	ILRI
Rispha Muraya	RCMRD
Lawrence Ochieng Okello	RMCRD
Patrick Chege Kariuti	ILRI
Mohammed Yahya Said	ILRI
Michael Arunga	ILRI
Vincent Oduor	ILRI

The training covered :
1. Introduction to Spot 5 imagery: recent developments.
2. Image interpretation and analysis.
3. Monitoring, forecasting and management of land use using Spot 5.
4. Impact studies using Spot imagery.

The trainees had the opportunity of working on Spot 5 data on their personal computers.
General information on high resolution imagery was given too, including practical work on consultation of online catalogs.
We emphasized that monitoring of landuse and impact studies must be based on an organised perception of landscape: land use is related to geomorphology, pedology and climatology. This will be developed later. As an example of morpho-pedological survey, the trainees were shown the map of Nzoia Sugar Estate *[1]. This survey made by IRAT (former Tropical Food Crops Research Institute of CIRAD), located near the AOI, dealt with landscape organisations close to Busia landscapes and soils .

5. IMAGE ACQUISITION AND PROCESSING

For this consultancy, the study area was limited to the FITCA area in Western Kenya, and a limited extension in Eastern Uganda (Tororo).

5.1 Available data

Two Landsat ETM scenes have been acquired by ILRI on the project area.The first one (179-60, 02/05/2001) on the Kenya sample areas and the second one (171-59 03/2001) on the Uganda sample areas. More recent scenes are now freely downloadable on GLCF ESDI website. All these scenes have a 30 meter pixel in multispectral and a 15 m pixel in panchromatic. Provided that the XS and panchromatic data are very carefully aligned, pan-sharpening may (if technical quality is very good) give 15 m colour images, comparing with 20 m XS SPOT for visual interpretation.

5.2 Image acquisitions and pre-processing

Acquisition

The high resolution SPOT 5 Images for the project area of interest (AOI) are not readily available. This implies that an order has to be placed to program our AOI and acquire the images. The participation of the expert to this process of ordering the images to SPOTIMAGE was a part of the consultancy.

The SPOT 5 image required is: 133/349, including the EMMC sample areas Busia Township, Matayos, Angurai and Tororo sites.

The steps of the acquisition were:
-location of AOI from maps and available satellite imagery (free Landsat ETM scenes)
-asking SpotImage for a programmation : this demand requires informations on location (as above), cloud cover, angle necessary to cover the whole AOI , especially for Tororo (Uganda) west of the regular path of Spot satellite. Date of programmation was chosen to suit best field information as well as cloud constraint.

Separate multispectral (XS) at 10 meters resolution and panchromatic (P) at 2.5 metres resolution data were ordered.

[1] N'Zoia Sugar Project, Morpho-pedological Survey- Nucleus Estate, M.Bach, J.-M. Gregoire, M. Raunet, 1976 Technisucre IRAT

A first attempt was made on 03/08/2004. This attempt was unsucessful due to excessive cloud cover. A second attempt was successful on 29/08/2004:
- validation of the later SpotImage proposal after checking location of the scarce clouds.
- agreement, and downloading data through FTP.

Pre-Processing

The vendor usually corrects the geometric and radiometric distortions caused by the rotation of Earth, the angle of the sensor, atmospheric and other interference on the recorded sensor data. The purchased Level 2A Spot images are set in standard WGS 84 projection.

The user is mainly involved in georeferencing or registering the image to fit into the geographic co-ordinate system that is used by the user. This involves rectification using known Ground Control Points (GCP) derived from existing Maps or GPS measurements. The expert had to contribute to this step with the GIS specialist.

We must be aware that Kenya has a specific projection system (in : Progress in the Development of Global Map in Kenya, H. NYAPOLA, Director of Surveys, Nairobi) :

Projection : Universal Transverse Mercator

Reference Ellipsoid : Clarke 1880

Local Geodetic system : Arc 1960

Transformation parameters for Local geodetic System to WGS 84 System :

$\Delta X = -160$
$\Delta Y = -8$
$\Delta Z = -300$

False Northings 10 000 000
False Eastings 500 000

We think that all processings of satellite imagery should be done on standard WGS 84 system, to avoid too many resamplings (georeferencing, pan-sharpening, reprojection…) and that only final products should be reprojected in Arc 1960.

Spot 5 data are supposed to have a precision of location better than 50 metres. This was checked before the mission by comparing them with ETM Geotiff Orthocover data.

XS and P data do not match exactly. A precise superposition of XS on P was done to allow the next step:
Pan sharpening: since we acquired separate data , a pan-sharpening had to be done. This provides radiometric information of the XS data with an improved resolution (2.5 m.), and allows printing of appealing maps for ground truth. The pan-sharpening was done with Erdas® Imagine 8.6. The method was Brovey transformation with cubic convolution resampling (see Appendix 1). Pan-sharpening has been done for image subsets of the areas of Angurai, Matayos and Tororo.

Printing maps for training and ground truth:
Maps were edited at different scales to show the potential of Spot 5 imagery for visual analysis up to 1:10 000.

Following the availability of plotters, the area covered with the different paper sizes and scales are:

Paper	Size (cm)	1: 100 000	1:50 000	1:25 000	1:10 000
A_0	80 x 120	Whole scene 60 x 60 km	40 x 60 km	20 x 30 km	8 x 12 km
A_1	60 x 80	Almost whole scene	30 x 40 km	15 x 20 km	6 x 8 km
A_2	40 x 60	40 x 60 km	20 x 30 km	10 x 15 km	4 x 6 km
A_3	30 x 40	30 x 40 km	15 x 20 km	7.5 x 10 km	3 x 4 km
A_4	20 x 30	20 x 30 km	10 x 15 km	5 x 7.5 km	2 x 3 km

Ground truth mission showed that A1 1:100 000 are useful for trips and general overview. A2 1:50 000 and 1:25 000 for semi-detailed studies when driving. For very detailed studies (and walking), A3 1:10 000 proved to be the most convenient.

6. GROUND TRUTH

6.1 Georeferencing the scenes:

Level 2A Spot 5 data have a precision of location “better than 50 m”. Waypoints were collected from a GPS Garmin III+. 25 among them seemed accurate enough to be used as Ground Control Points for a precise georeferencing.(see Appendix 2, Appendix 3 picture 31). The resolution of the data overpasses GPS accuracy. Thus, expecting a really precise georeferencing (using polynomial models with many GCP) without a Differential GPS (DGPS) is illusory. It appeared easier and more reproductible to make a translation in X and Y on the data according to the means of the deviations between GCP and their matching points on the scene:

GCP	dx	dy
buscp1	8	8
buscp2	15	9
buscp3	15	11
gcp+	3	12
gcp01	5	14
gcp02	1	12
gcp03	19	7
gcp04	16	6
gcp05	-5	27
gcp06	9	11
gcp07	18	9
gcp08	24	3
gcp09	21	8
gcp10	13	12
gcp11	3	14
gcp12	12	10
gcp13	11	13
gcp14	11	9
gcp15	19	10
gcp16	12	11
gcp17	16	10
gcp18	16	10

GCP	dx	dy
gcp19	15	7
gcpTilda	16	8
gcptri	3	11
mean pixels	**11,84**	**10,48**
mean meters	**29,6**	**26,2**

Mean distance between matching points = 39.5 meters (better than 50 m). After translation; distances between GCP and image points range between 5 and 10 m.

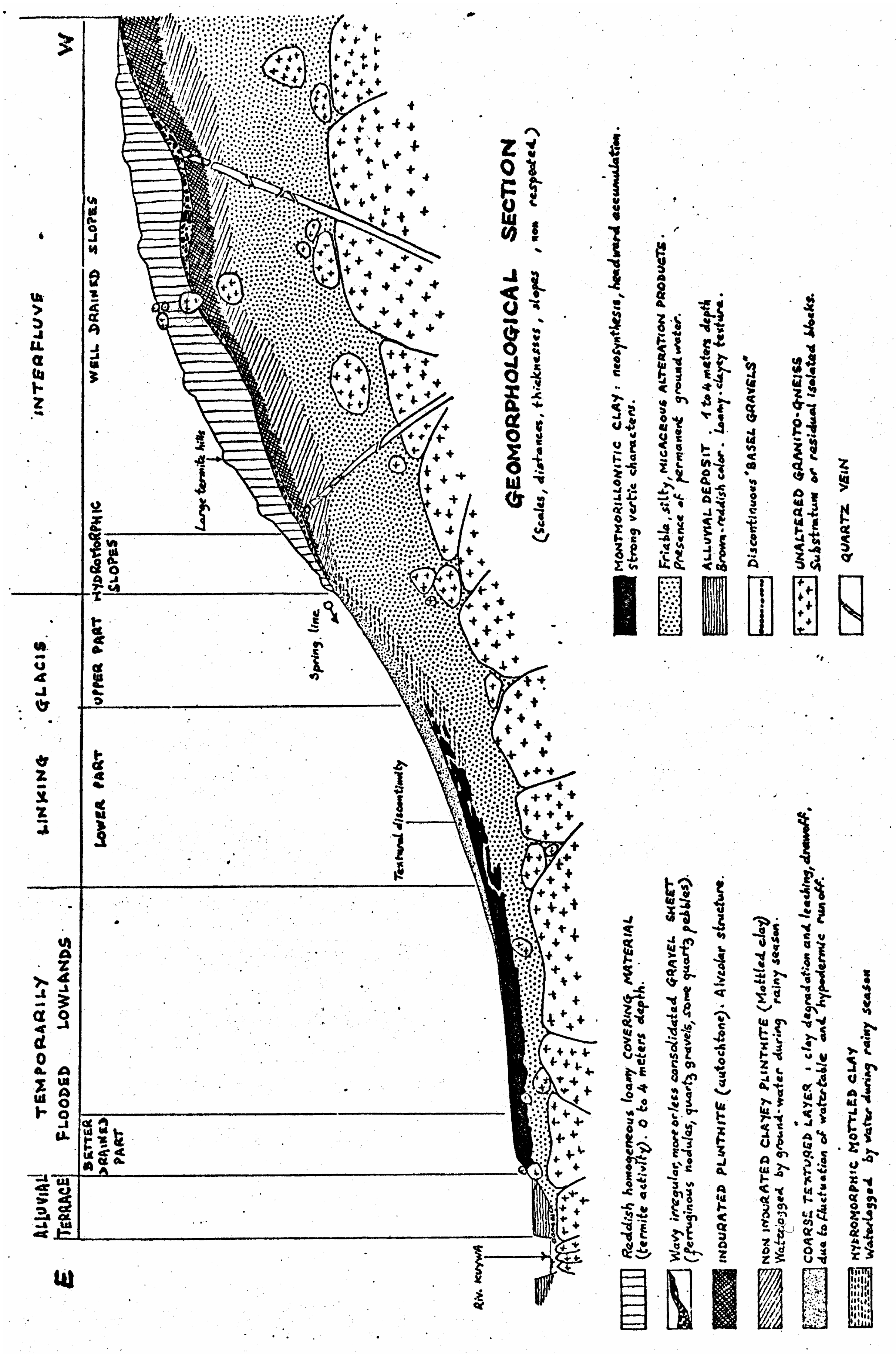
6.2 Identifying landscape units and cropping systems for later classification

All the components of the environment (landform, nature of the material, hydrological regime, pedogenesis processes) are strongly linked by reciprocal interrelations. Land cover and land use are themselves linked with these components, which also modify spectral response of the soils. Whether one uses unsupervised or supervised classification, one will need a great number of classes to cover all the situations. Moreover, due to lateral variations of lithology and climate, the greater the AOI, the greater the number of classes. Its necessary to organize the observations and have the images segmented to reduce the number of significant classes to handle and limit radiometric confusions. An other and important reason for stratifying the physical environment is that modifications in land use/ land cover induced by tse-tse control will depend on the present land use which varies with landforms.

Landforms:

The general pattern for **Busia, Matayos and Tororo** is, from top to bottom of a toposequence:
- An interfluve, on granite or sedimentary (Kavirondian) substratum. Convex slopes.Well drained soils widely cultivated (Appendix 3, pictures 7, 9)
- A linking glacis, imperfectly drained, scattered on the upper part with wooded hills (maybe old giant termite hills) linked with this imperfect drainage. (pics 4, 5, 6). Sometimes (Busia), line of springs or seepage along upper part of the glacis.Concave to straight light slopes. Natural vegetation : bushes, grasses; land use : grazing, and a few crops.
- Temporarily flooded narrow lowlands .
- A flat-bottomed inland valley, with free water, and according to hydrological regime, papyrus , *Typha,* associations of ferns and sedges, ferns and grasses.(pics 2,4).

This toposequence is quite similar to the following one, described by M.RAUNET along Kuywa River, near N'Zoia sugar Estate :



Example of a toposequence near N'Zoia Sugar Estate (op. cit.)

Angurai is a particular area, with distinct landforms:

- Hilly landscape with straight slopes, scattered with granite boulders (pic. 8).
- Perched swamps: resulting from seepage at the top of a flat area along a dry valley (Pic.3).
Some of these swamps are already cultivated (Pic. 3: this example shows it may not be the best for maize and crops generally, due to water logging and iron toxicity: these area collects reduced iron by lateral drainage of the slopes). These swamps should be protected as a wealth of biodiversity (especially birds, crested cranes for instance). When in their natural state, they can be identified on satellite imagery.
- Rivers and brooks (often temporary) are hemmed with steep banks.

<u>Cropping systems</u>:

Far all that follows, reference to satellite imagery will rest on colors of coloured composites brought for training workshop and ground truth mission, as well as examples in the present report.All the compositions were, for SPOT imagery:

Red:	channel 3
Green:	channel 2
Blue:	channel 1

This colour composite RGB 3-2-1 is close from RGB 4-3-2 with Landsat ETM channels.

End of August, most of the crops of the former cultural season were harvested, and few of the crops of the future season were settled. Ground truth mission took place on the last days of September. We had to interpolate the situation at the date of acquisition from the actual state of the land cover. The only invariable feature on the whole area is the school yards whose shortly grazed lawn appears in a very particular shade of pink. The sample areas of Angurai, Busia, Tororo and Matayos show specificities:

Angurai: very widely cultivated area. Crops lately settled, except cassava of different ages and conditions (pics 25 & 26) . Some grazed fallows. Natural pastures closed with hedges (pics. 21 & 22), some cultivated pastures (Napier grass) closed with hedges too (pic.19).

Cultivated plots appear like bare soils, fallows (mainly grass fallows) in a dark grayish pink, pastures in red.

Because of the variability of age and condition, cassava looks either like other crops (bare soils scarcely covered with vegetation for young cassava: pic.25) either like fallows (old cassava, virused, often with dense weeds: pic. 26).

Busia: <u>fallows</u> are more spread out, as well on the interfluves than on the linking glacis. One can note differences between grass fallows (young fallows on interfluve: pic.17 or grass falows on the glacis) and bush fallows (old grazing fallows on the interfluves: pic.18).

Crops appear usually as bare soils with different colours according to soil colour: blue for the black soils of glacis, cyan for brown soils of the interfluves, green for red soils).
Some early crops like maize (pic.22) or well growing cassava (pic.27).
No cultivated pastures.

Tororo: large inland valleys and wide linking glacis (pic.5) are typical of this area, large cotton fields are developping on the glacis. Interfluves are very low. On some of them coexist late crops like on other areas and early crops (maize cotton…) wich appear in red. No closed pastures.

Matayos: landscape clearly organised in narrow inland valleys, linking glacis and low interfluves. The specificites are:

- large sugarcane fields appearing in a characteristic violet-pink colour
- cultivated pastures (Napier gras) closed with barbed wire.
- extension of cotton fields in the wider parts of the glacis.

6.3 Factors modifying spectral response

Colour of the soil:

Colour of the soils is linked with lithology, topography and hydrological regime (Appendix 4).
In well drained situations (slopes and interfluves), surface colour of the soil is related to clay and iron oxydes content. Spectral response may be modified by surface sate (sand or silt deposits, crusts).
Appendix 4 summerizes landscape units, geology, drainage, soils (classification, texture and colour) of Bungoma, Busia and Siaya districts (* occurrence in Angurai, Busia and Matayos, no such data available for Tororo).
Brown, light brown, yellowish brown or light red bare soils (pics.7, 9, 10, 13,14) appear light blue or cyan on the CCs.
Red, dark red soils appear green on CCs.
Along a toposequence, surface colour varies from top to bottom : hue from red to yellow, chroma decreasing , value decreasing towards black (Munsell Book of Color) (Pictures 13 to 15).

Land cover:

State of the crops: at a given instant, radiometries will vary with the age of the crops (date of planting) , density of weeds, nutrient and sanitary status of the plant. The best example is cassava (pics 25 to 27)
Density of trees and hedges, through their shadows, will lower the radiometries. The area south west of Matayos, appears in dark green dus to combination of red soils (green on CC) and numerous hedges (dark shadows): pics 11 and 28.
Climatic and technical gradients: our attention was attracted on these factors by important differences between radiometries of sugar cane observed in Busia, Matayos and Mumias. In Busia Compound, only one large plot of sugar cane was observed: though quite developed it appeared merely like bare soil, because of low plantation density, too many dry leaves… In Matayos, sugar cane is very distinct from other crops, but does no still appear as we expected The usual aspect of sugar cane is observed near Mumias Sugar Factory : well developed canes, without dry leaves and strong red radiometry. This gradient from north-west to south-east could be related with a rainfall gradient or a technical gradient : farmers near Mumias benefit from advices, fertilizers and other inputs, optimized periods of collecting, which Matayos may be too far to benefit from. The most distant Busia sugar cane is a fringe case.

7. PROCESSING: EXAMPLE OF MATAYOS

The consultant was expected to guide the GIS specialists during the whole process of image classification on, successively:

- A previous unsupervised classification ;
- A mission for ground truth ;
- The production of a supervised classification ;
- The results of the analyses would be data included in a GIS and maps of land use and land cover.

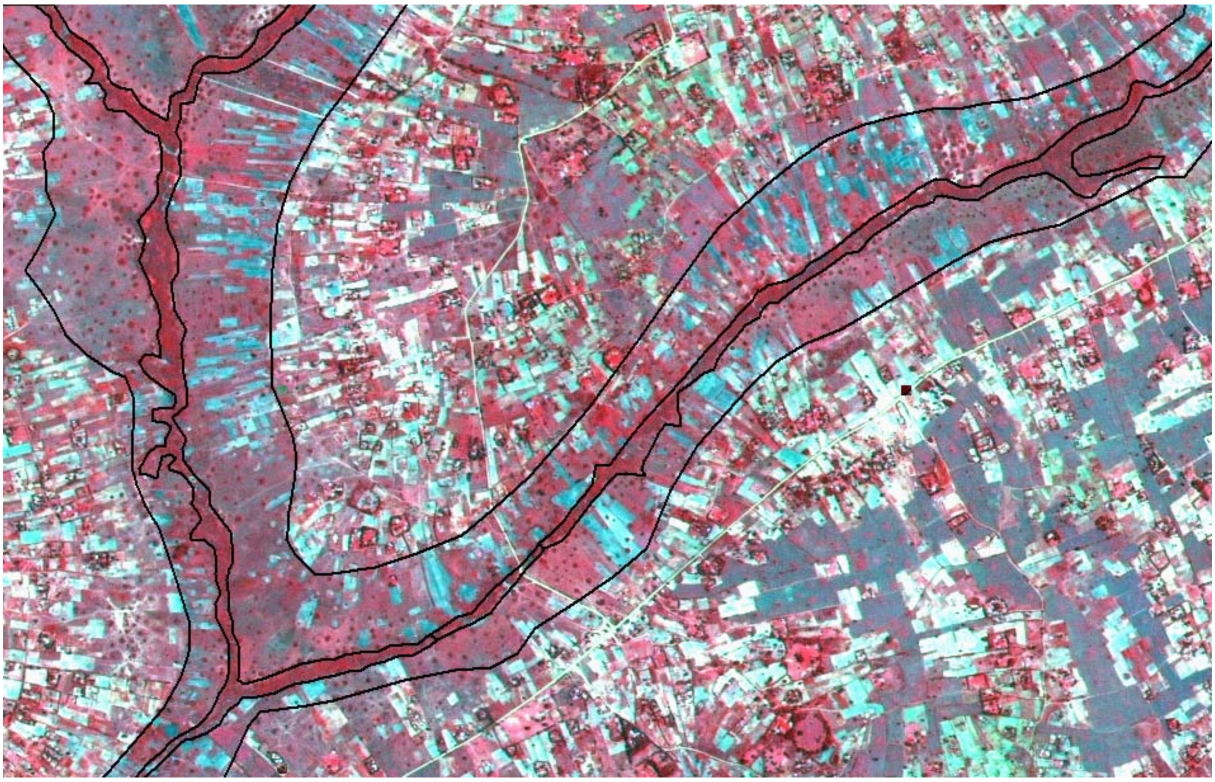
The methodology used must be robust enough to be described for use by other GIS specialists and reproduced in the future for comparative studies.
Dr Joseph MATERE was appointed to attend this practical training, during ground truth mission and image processing when back to ILRI. The following example sums up the methodology of image processing that we proposed to him at the end of the consultancy. His general competence and the skills acquired during the consultancy make him able to generalize the methodology to the whole area of the project.

<u>Steps in image processing:</u>

Matayos area will be used for an example. Processing was done with ArcView 3.2 and ImageAnalysis 1.1 extension. Same processings could be done with Erdas Imagine for instance.

The first step is a segmentation of the image following to the most relevant criterium. This criterium could be administrative subdivision, geological, climatic areas; we saw above that the organisation of landscape suggested a stratification following landforms: inland valleys, linking glacis and interfluves. The stratification is done by visual interpretation and manual digitalisation on the screen.

STRATIFICATION (Matayos)



Interfluve	Sugar cane, fallow, settlements, bare soils (green, light blue, white on display according to soil colour). Rectangular plots without preferential direction on top of interfluve, along the slope on the lower part.
Linking glacis	Grass fallow, wooded hills, cultivated plots along the slope : bare black soils (blue on display).
Inland valley	Dense riparian vegetation (red).

This step allows the creation of separate masks for glacis and interfluve.

Step two: separate classifications for glacis and interfluve (the inland valleys have not been classified); A number of 24 classes has been choosen for these unsupervised classifications. This is enough for a demonstration on a small area. More could be convenient for a better discrimination on a wider area with a greater number of observations on training spots, which we had no time to collect during a ground truth mission that was as much a methodological and training mission than a real operationnal ground truth for a detailed mapping. An unsupervised classification (the only one that ArcView Image Analysis can do) will give the same results than a supervised one, provided one gets the same number of observations. In this case, the observations will be used to assign a class name to *a priori* defined classes.
Amongst the 24 classes several may be related to objects close to one another.

CLASSIFICATION ON THE LAND COVER OF THE LINKING GLACIS

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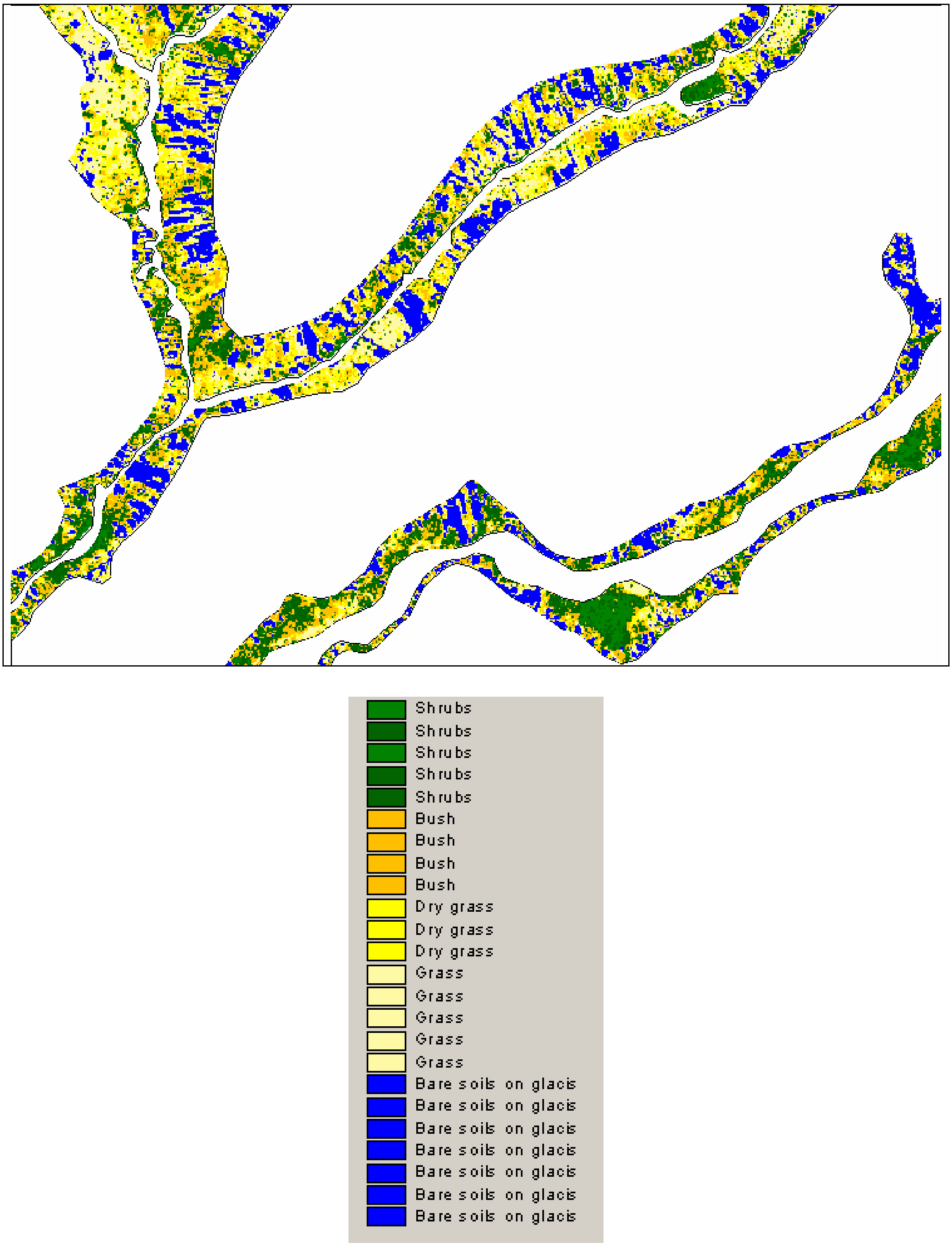
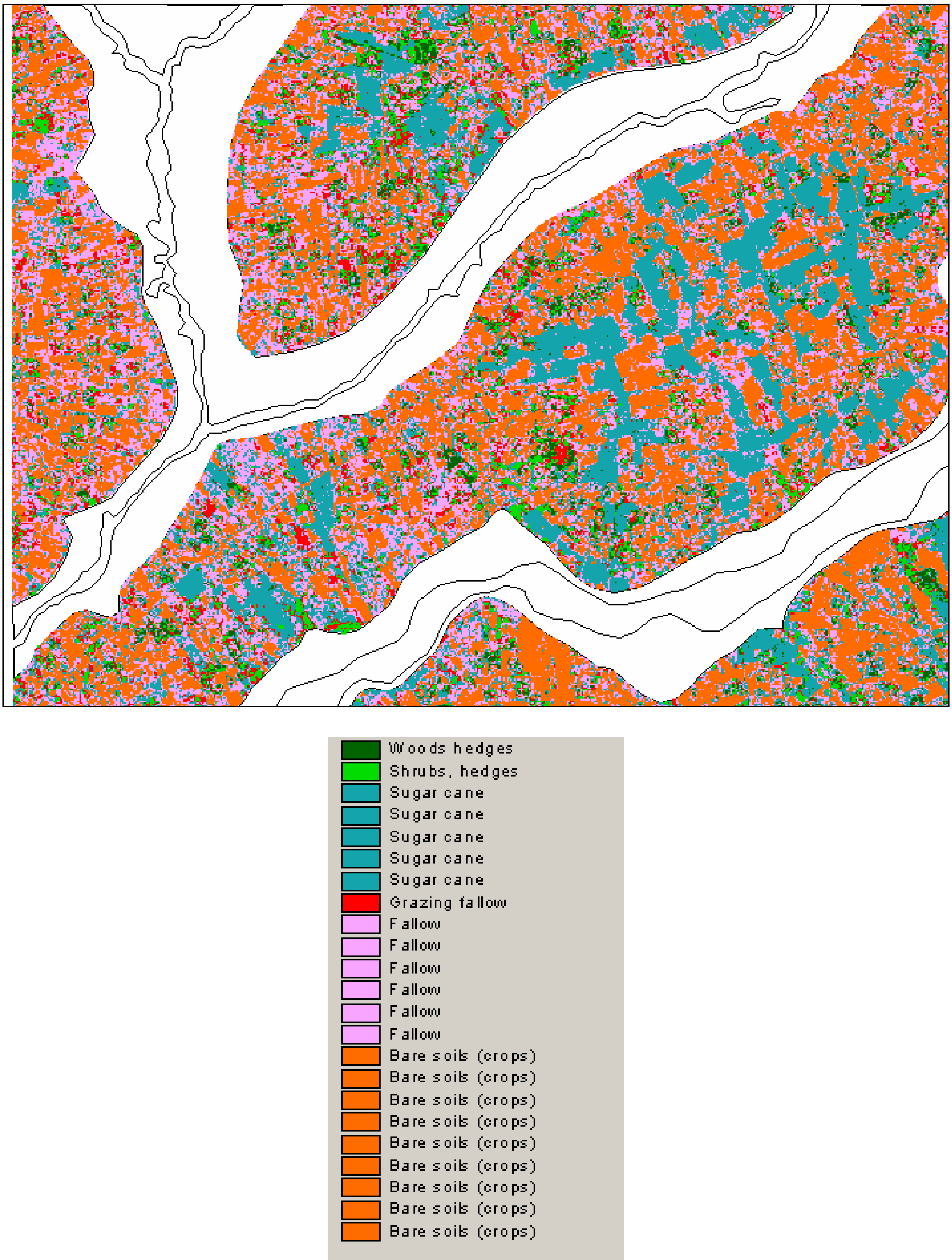
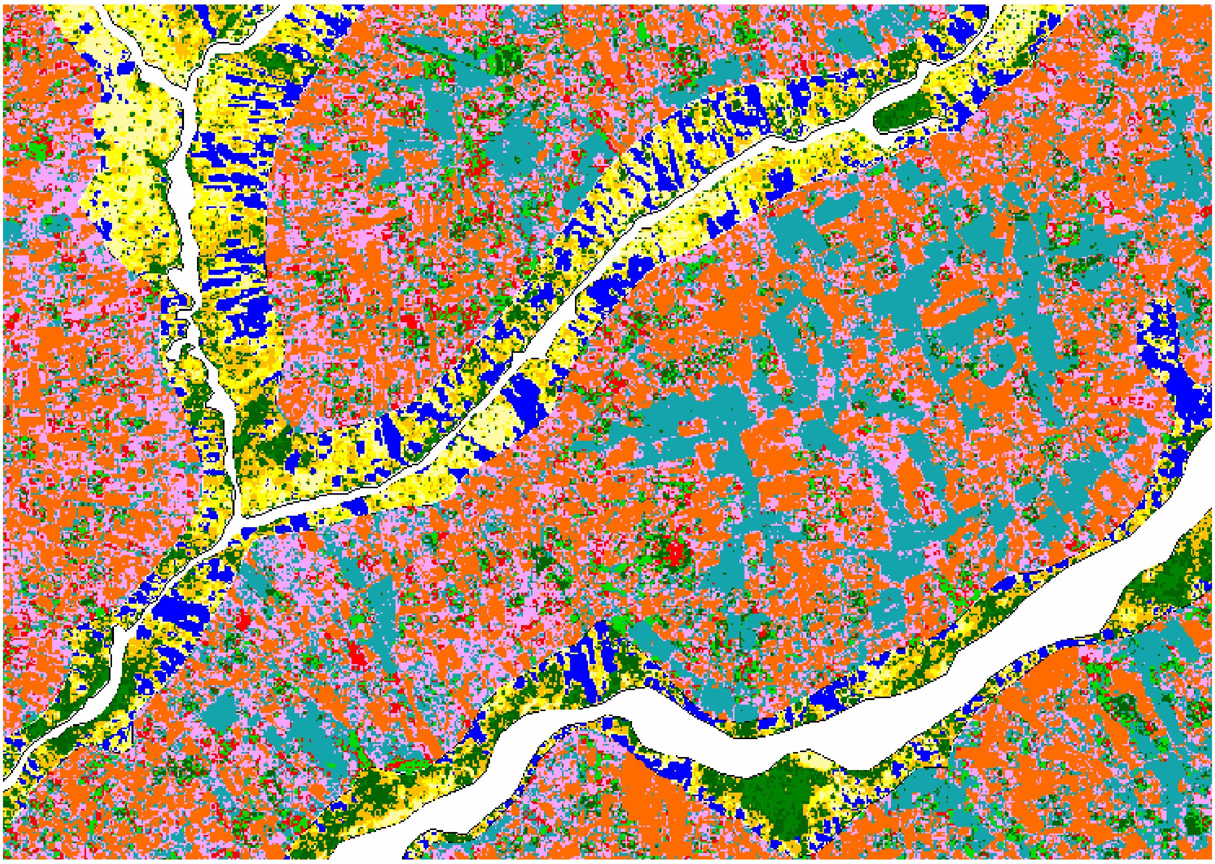
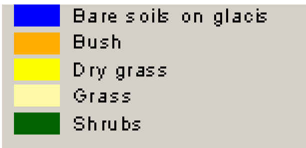


CLASSIFICATION OF THE INTERFLUVES



FUSION OF GLACIS AND INTERFLUVE CLASSIFICATIONS





Glacis

Interfluve

Step three:

Converting raster classification files into vector files. Each area of the classification is converted to a polygon and an attribute table is created. In the present case, the number of polygons can reach one hundred thousand. To make the attribute table more simple and extract statistics, we used Geoprocessing Wizard "Dissolve features based on an attribute". The attribute for this aggregation is class_name. We get an attribute table with a number of lines reduced to the number of the different classes. The areas of each class can be calculated.

Areas (ha) Glacis		Areas (ha) Interfluves	
Class_Names	area	Class_Names	AREA
Bare soils on glacis	125	Bare soils (crops)	633
Bush	105	Fallow	443
Dry grass	99	Grazing fallow	99
Grass	109	Shrubs, hedges	94
Shrubs	123	Sugar cane	449
		Woods hedges	69

Percentage of each class in the land cover is derived from the previous table :

Class names	Glacis , areas %	Class names	Interfluves, areas%
Bare soils	22	Bare soils	35
Bush	19	Fallow	25
Dry grassland	18	Grazing falow	6
Grassland	19	Shrubs, hedges	5
Shrubs and hills	22	Sugar cane	25
		Woods, hedges	4

8. RECOMMENDATIONS FOR GENERALISATION

During ground truth mission, Dr. Matere took down informations to achieve classifications on Tororo, Angurai an Busia sample areas to achieve classifications on these sites in accordance with the method decribed above for Matayos example.

An extensive ground truth mission should be done on the whole area since some large regions with specific appearance have not been covered during the short ground truth mission.
In the same way, more GCP should be collected. These GCP will be evenly distributed on the whole area.

To generalise classifications to the whole FITCA area, it will be necessary to apply the same method to the whole scene : first, a segmentation of the image : identify and delimitate by computer assisted photo-interpretation the main landscape units with the aid of geological documents (see Appendix 4): inland valleys network that will be the framework of the segmentation, next, hills and lower middle-level uplands areas on granite (region of Angurai), lower level uplands areas with low interfluves on granite or sedimentary rocks (as Kavirondian mudstones) , then going down from general to particular features, delimitate secondary landscape units like linking glacis. This segmentation will provide the masks for separate classifications.

Very particular features like protected forest areas, towns and excavations, irrigated paddy fields (Tilda farm in Uganda : pic. 29) should be manually delimitated to be excluded from classifications.

At this stage of the recommendations, we must point out that very high resolution imagery (Spot 5 as well as Ikonos or Qickbird) are a huge wealth of information. Their processing as we described it appeals to visual interpretation for image segmentation. Advances could come in a near future from object oriented processing softwares like Definiens eCognition® (the only one presently available).

9. CONCLUSION

At the level of a sample area, Very High Resolusion Remote Sensing imagery allows to draw visually elementary units of land cover/land use: plots , fallows, bushes and shrubs , improved pastures, etc… Concerning annual crops, due to the constraint of cloud cover, the images will always be acquired at a time when the different crops cannot be distinguished (already harvested or too yound to significantly cover the soil). Parcipatory mapping with the villagers and animators could overcome this difficulty.

At a regional level, if working with a more simple typology, this type of imagery allows a convenient and cost effective mapping of land cover/landuse. The method described for classification is necessary for efficient classification and mapping. Since the effects of controlling trypanosomosis indirect impacts on the environment will not be the same on the different landform units, this approach is also necessary to monitor this effects through land use/land cover changes.

APPENDIX 1

PAN-SHARPENING

PAN-SHARPENING (source: Erdas Imagine Help)

Resolution Merge: this dialog enables you to integrate imagery of different spatial resolutions (pixel size). Since higher resolution imagery is generally single band (for example SPOT Panchromatic 2.5m data), while multispectral imagery generally has the lower resolutions (for example SPOT XS 10m), these techniques are used to produce high resolution, multispectral imagery. This improves the interpretability of the data by having high resolution information which is also in color. Resolution Merge offers three techniques: Multiplicative, Principal Components, and Brovey Transform.

Multiplicative is based on simple arithmetic integration of the two raster sets.

The **Principal Components** merge operates on PC-1 rather than the input raster image.

In the **Brovey Transform** option, all bands are used according to the following formula:

[DNB1 / DNB1 + DNB2 + DNBn] x [DNhigh res. image] = DNB1_new
[DNB2 / DNB1 + DNB2 + DNBn] x [DNhigh res. image] = DNB2_new
etc…
where B = band

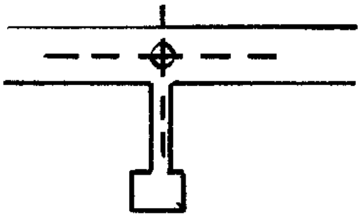
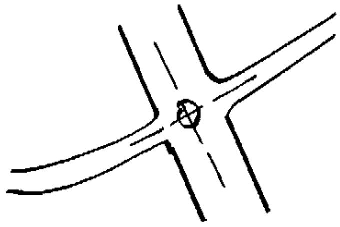
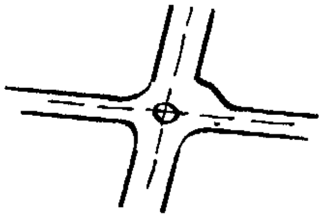
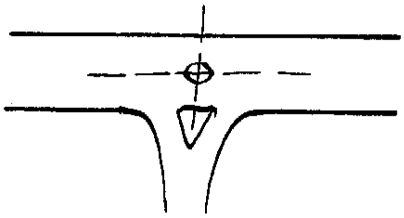
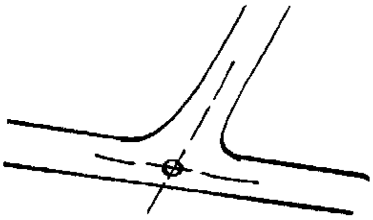
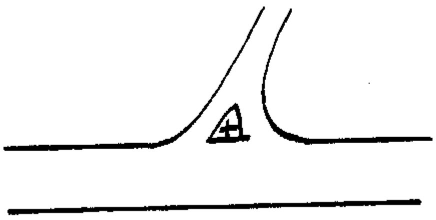
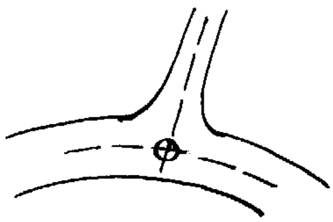
Principal Component : this method calculates principal components, remaps the high resolution image into the data range of PC-1 and substitutes it for PC-1, then applies an inverse principal components transformation.
The Principal Component method is best used in applications that require the original scene radiometry (color balance) of the input multispectral image to be maintained as closely as possible in the output file. As this method scales the high resolution data set to the same data range as Principal Component 1, before the Inverse Principal Component calculation is applied, the band histograms of the output file closely resemble those of the input multispectral image.
Unfortunately, this radiometric accuracy comes at the price of a large computational overhead. The Principal component method is consequently the slower of the three methods offered and requires the most system resources.

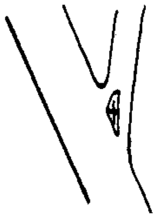
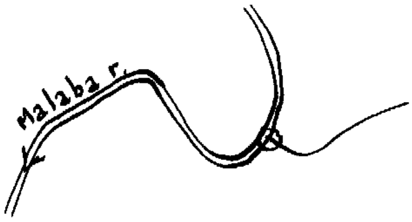
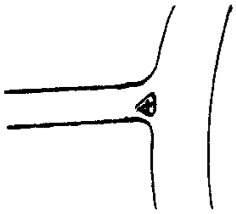
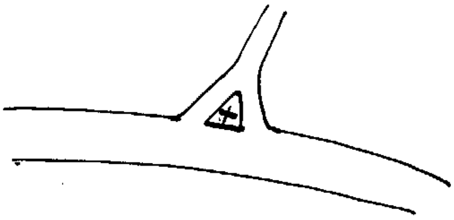
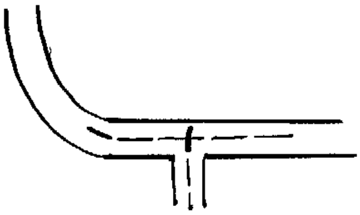
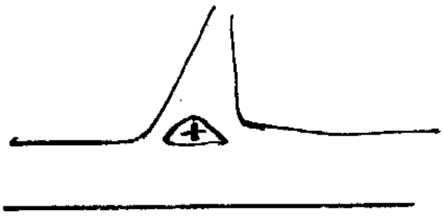
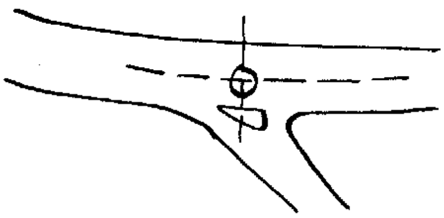
Multiplicative: this method applies a simple multiplicative algorithm which integrates the two raster images.
The Multiplicative Method is the simplest of the three methods. As it is computationally simple it is generally the fastest method and requires the least system resources. However, the resulting merged image does not retain the radiometry of the input multispectral image. Instead, the intensity component is increased, making this technique good for highlighting urban features (which tend to be higher reflecting components in an image).

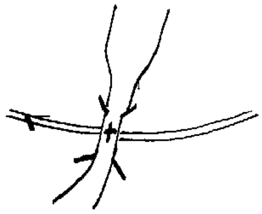
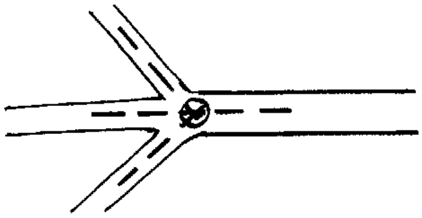
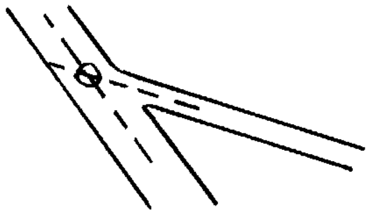
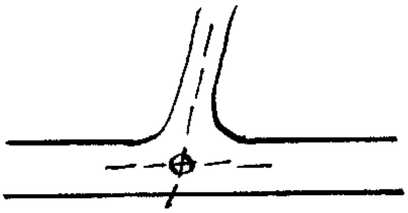
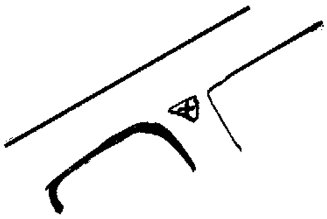
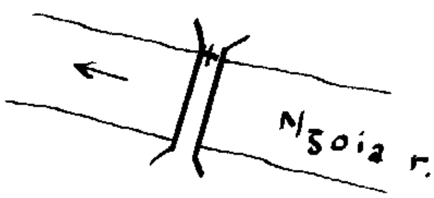
Brovey Transform: this method uses a ratio algorithm to combine the images as shown above.
The Brovey Transform was developed to visually increase contrast in the low and high ends of an images histogram (i.e. to provide contrast in shadows, water and high reflectance areas such as urban features). Consequently, the Brovey Transform should not be used if preserving the original scene radiometry is important. However, it is good for producing RGB images with a higher degree of contrast in the low and high ends of the image histogram and for producing "visually appealing" images.
Since the Brovey Transform is intended to produce RGB images, only three bands at a time should be merged from the input file.

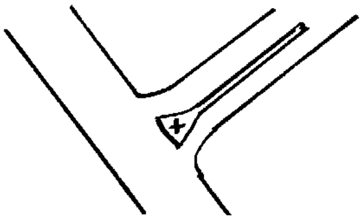
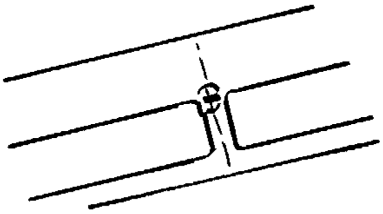
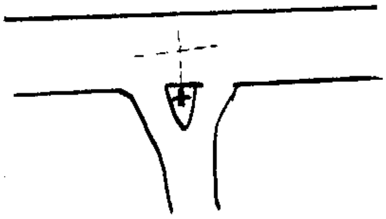
APPENDIX 2

GROUND CONTROL POINTS

NAME	**X**	**Y**		Precision of location	Shift (X, Y) 2.5 m pixels
BUSCP1	623747,9199	49897,36296		+	8 8
BUSCP2	623935,6583	48074,97202		-	15 9
BUSCP3	624170,5324	46391,95090		+	15 11
GCP+	645086,1341	69505,31498		-	3 12
GCP01	642913,3137	70236,63727		-	5 14
GCP02	648996,6784	76632,91260		++	1 12
GCP03	651575,3057	76727,95077		-	19 7

NAME	X	Y		Precision of location	Shift (X, Y) 2.5 m pixels
GCP04	650295,2692	78656,33238		-	16 6
GCP05	646236,9853	77173,03513		--	-5 27
GCP06	648573,3438	80855,01791		+	9 11
GCP07	646859,6556	81491,48836		+	18 9
GCP08	650016,8481	83282,39683		-	24 3
GCP09	647403,6566	83142,81231		+	21 8
GCP10	652251,5987	83223,78334		+	13 12

NAME	X	Y		Precision of location	Shift (X, Y) 2.5 m pixels
GCP11	650661,8175	80793,36838		-	3 14
GCP12	613184,3827	61540,43407		+	12 10
GCP13	612632,0738	62071,68772		+	11 13
GCP14	617130,2436	66266,98847		+	11 9
GCP15	634628,7783	46311,66300		+-	19 10
GCP16	634237,9473	44777,35134		++	12 11
GCP17	665466,9743	40815,68253		+	16 10

NAME	**X**	**Y**		Precision of location	Shift (X, Y) 2.5 m pixels
GCP18	665462,7996	40785,43216		+	16 10
GCP19	665657,6852	39412,36619		++	15 7
GCPTilda	598244,1297	59017,18061		+	16 8
GCPTRI	645081,3585	69502,34837		+	3 11

APPENDIX 3

PICTURES

LANDFORMS

Pic. 1

Malaba River

Pic. 2

Inland valley (Busia)

Pic. 3

Perched swamp (Anguraï)

Pic. 4

Linking glacis and inland valley (Busia)

Pic.5

Linking glacis with (termite ?) hills

(Tororo)

Pic.6

Spectacular hill on a glacis

(Tororo)

Pic.7

Gently ondulating granite interfluve

(North of Tororo)

Pic.8

Slopes and granite boulders

(Anguraï)

Pic.9

Low interfluve

(Busia)

SOILS

Pic.10

Light brown soils on granite

(Anguraï)

Pic.11

Dark red soils on Kavirondian formations (South –west of Matayos)

Pic.12

Black soils, lowest part of a glacis (Tororo)

COLOUR GRADIENT ALONG A TOPOSEQUENCE

Pic.13

Red soils (top of interfluve)

Pic.14

Reddish brown soils
(lower part of the interfluve)

Pic.15

Black soils, near inland valley
(palm trees)

LAND USE

Pic.16

School yard (Anguraï)

Pic.17

Young fallow (Busia)

Pic.18

Old fallow with *Lantana* and *Tithonia* (Busia)

Pic.19

Closed pasture (barbed wire and hedges) with Napier grass (Anguraï)

Pic.20

Closed (hedges) natural pasture (Anguraï)

Pic.21

D°, close up

Pic.22

Early maize (Busia)

Pic.23

Maize fallow (Anguraï)

Pic.24

Maize stacks (Angurai)

Pic. 25

Young cassava (AnguraÎ)

Pic. 26

Virused cassava with dense weeds (Anguraï)

Pic. 27

Healthy cassava (Busia)

Pic. 28

Hedges, south-west of Matayos

Pic. 29

Paddy fields
(West of Tororo)

Pic. 30

Cut back coffe trees (Busia)

MISCELLANEOUS

Pic. 31

Ground Control Point :

BUSCP1 (Busia)

Pic. 32

Maize Streak Virus
(Anguraï)

APPENDIX 4

LANDSCAPE UNITS, GEOLOGY AND SOILS
OF
BUNGOMA, BUSIA AND SIAYA DISTRICTS

Soil Description from Kenya Soil Survey : Exploratory Soil Map and Agro-climatic Zones Map of Kenya, Scale 1:1 000 000, Re. E1, Nairobi 1982

Soils of Busia, Siaya and Bungoma Districts, organised according to landscape units.

* : units significantly present in Fitca Areas in Kenya (data not available for Tororo)

Large landscape units	Geology	Units	Drainage	Soils	Texture	Color	ANGURAI	BUSIA	MATAYOS
Mountains and major scarps	Olivine basalts and ashes of majors older volcanoes	4 M	Well drained	Nito-humic CAMBISOLS	Stony clay loam	Dark reddish brown			
		5 M	Imperfectly drained	Dystric HISTOSOLS	Loam to clay loam	Dark greyish brown			
Volcanic footridges	Tertiary basic igneous rocks	76 R	Well drained	Ando-humic NITHOSOLS	Friable and slighly smeary clay	Dark reddish brown			
		77 R	Well drained	Humic NITHOSOLS	Friable clay	Dusky red to dark reddish brown			
Footslopes	Colluvium from basic igneous rocks	90 F	Well drained	Calcic CAMBISOLS	Moderately calcareous clay	Dark reddish brown			
	Colluvium from Basement System rocks	98 F	Well drained	Ferralic ARENOSOLS	Varying	Dark reddish brown to dark yellowish brown			
Hills and minor scarps	Tertiary volcanic rocks	14 H	Well drained to moderately well drained	Eutric REGOSOLS	Clay loam to clay	Dark brown			
	Basic igneous rocks	20 H	Excessively drained	Humic CAMBISOLS	Friable, gravelly clay	Dark reddish brown			
	Granites	23 H	Excessively drained	Dystric REGOSOLS	Varying, rocky		*		
	Quartzites	24 H	Excessively drained	RANKERS	Sandy loam to clay loam	Dark brown			
	Basement System rocks	27 H	Excessively drained	Dystric REGOSOLS	Friable, sandy clay to loam	Dark red to brown			

Large landscape units	Geology	Units	Drainage	Soils	Texture	Color	ANGURAI	BUSIA	MATAYOS
Upper middle-level uplands	Tertiary or older basic igneous rocks	121 U	Well drained	Mollic NITOSOLS	Friable clay	Dark reddish brown			
	Granites	131 U	Well drained	Humic ACRISOLS	Sandy clay to clay	Dark red to yellowish red			
	Biotite gneiss	137 U	Well drained	Humic NITOSOLS	Friable clay	Dark reddish brown			
	Various rocks	139 U	Well drained	Ferrolo-chromic-orthic ACRISOLS	Loam to clay	Dusky red to yellowish red			
Lower middle-level uplands	Basic igneous rocks	143 U	Well drained	Dystric NITOSOLS	Friable clay	Dark reddish brown			
		144 U	Well drained	Rhodic FERRALSOLS	Clay	Red to dark red	*		
	Granites	151 U	Well drained	Ferrolo-orthic ACRISOLS	Sandy clay to clay	Brown to dark brown	*		
	Kavirondian sediments	168 U	Well drained	Rhodic to orthic FERRALSOLS	Friable clay	Dark reddish brown			
Lower level uplands	Basic igneous rocks	69 U	Moderately well drained	Verto-luvic PHAEOZEMS	Firm clay	Dark brown			
	Intermediate igneous rocks	172 U	Well drained	Chromic LUVISOLS	Friable clay	Dark reddish brown			
		174 U	Well drained to moderately drained	Association	Shallow soils or friable clay	Dark reddish brown to strong brown		*	*
	Granites	179 U	Well drained to moderately drained	Orthic FERRALSOLS	Friable clay	Reddish brown to yellowish brown	*	*	*
	Granites and quartz-feldspar gneiss	181 U	Well drained	Ferralic CAMBISOLS	Sandy clay loam to sandy clay	Strong brown to reddish brown			
	Biotite gneiss	182 U	Well drained	Orthic FERRALSOLS	Sandy clay to clay	Red			
		183 U	Well drained	Rhodic FERRALSOLS	Sandy clay loam to clay	Dark red to dark reddish brown			
	Kavirondian sediments (mudstones)	188 U	Well drained	Rhodic FERRALSOLS	Friable clay	Dark red to strong brown		*	*
Plateaus and high-level stuctural plains	Intermediate igneous rocks	62 L	Well drained	Nito-rhodic FERRALSOLS	Friable clay	Dark reddish brown			

Large landscape units	Geology	Units	Drainage	Soils	Texture	Color	ANGURAI	BUSIA	MATAYOS
Bottom lands	Unfill from undifferentiated Basement System rocks	345 B	Imperfectly to poorly drained	Dystric PLANOSOLS with pellic VERTISOLS	Sandy clay to clay	Dark grey to brown		*	
		346 B	Imperfectly to very poorly drained	Dystric GLEYSOLS	Firm clay, in places peaty topsoil	Very dark grey			
		347 B	Poorly drained	Pellic VERTISOLS	Very firm, cracking clay	Greyish brown to black			
Floodplains	Sediments (recent floodplains)	368 A	Well drained to imperfectly drained	Eutric FLUVISOLS	Varying	Dark greyish brown			
Swamps		370 S	Very poorly drained	GLEYSOLS	Cracking clay with humic topsoil	Dark grey to black			
		371 S	Very poorly drained	Humic GLEYSOLS	Firm clay with acid humic topsoil	Dark grey to black			
Minor valleys		383 V	Well drained to poorly drained	Complex	Firm, silty clay to clay	Dark reddish brown to black			
Lacustrine plains	Sediments from lacustrine mudstones	325 PI	Poorly drained	Pellic VERTISOLS	Very firm, slightlu sodic, cracking clay	Very dark grey to black			
Coastal or lake-side beach ridges	Beach ridges along Lake Victoria	381 Z	Imperfectly drained	SOLONCHAKS	Sandy loam to sandy clay	Dark brown to greyish brown			