

MAPPING OF SEVEN PROJECT AREAS - CONTRIBUTION TO THE TANZANIAN RESOURCE PROTECTION AND BUFFER- ZONE DEVELOPMENT PROGRAMME

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ABSTRACT:

The following presentation of a Mapping Project is giving an outline of measures, undertaken in order to support the Tanzanian RESOURCE PROTECTION AND BUFFERZONE DEVELOPMENT PROGRAMME which aims at the management of the conservation of biotopes and natural resources in seven reserve areas. The methodological approach included satellite data procurement, processing and analysis, flight campaign (colour infra red and black/white aerial images), DEM processing, slope/aspect analysis, production of ortho-corrected aerial photographs and image maps, interpretation of aerial photographs and satellite imagery, field survey, GIS data base design and generation and training of local experts in all related fields. As a main result, the projects have been provided with thematic maps at different scales showing agroecological zones, the present state of vegetation and land use, land use changes over the past, erosion, soil types and erodability. Additionally, all information collected during the mapping activities were supplied in digital format and - after installation of the respective hard- and software - implemented as a fully operational GIS.

1. INTRODUCTION

1.1 General Background

Buffer-zones have become widely known as an operational approach in nature conservation. At the same time buffer zones serve as distinctive features for integrated conservation and for the development of rural regions.

Areas surrounding Forest- and Game Reserves are very sensitive. Increasing population, inadequate land-use practices and the lack of land-use management are creating severe problems in these so called "buffer zones" as well as in the reserves themselves. The main problems consist of the degradation of the forests and arable lands. This leads to erosion, to loss of productive agricultural area and thus of income and eventual increase of illegal encroachment into protected areas. One possible way out is to develop and implement integrated concepts for agro-forestry, land use and socio-economical improvement in the related regions.

To support management and planning activities in the buffer zone areas, the availability of actual thematic information is essential. The information has to fully cover the related regions and has to be homogeneous, and detailed enough with respect to mapping units.

The German Agency for Technical Co-operation (GTZ) as well as the World Conservation Union (IUCN) assisted during the last decade the Tanzanian Natural Resources Management and Buffer Zone Development Programme (NRBZ) of the Ministry of Natural Resources and Tourism (MNRT) in the management

of the conservation of seven reserve areas. Some of the projects are still ongoing. These initiatives are related to:

- The GTZ - supported Tanzanian Forestry Action Plan in the North Pare Mountains (TFAP-North Pare)
- The GTZ - supported Soil Erosion Control and Agroforestry Project (SECAP) in the western Usambara Mountains
- The GTZ - supported Handeni Integrated Agroforestry Project (HIAP) in the south-western Handeni District
- The GTZ - supported Selous Conservation Programme (SCP) of the Selous Game Reserve
- The IUCN - supported Project „East Usambara Mountains“
- The IUCN - supported Project „Tanga Coastal Region“ (TCR),
- The Mkomazi Game Reserve Project financed only by the Tanzanian Government.

The location of the project areas is illustrated in Figure 1.

1.2 The Mapping Project

The Mapping Project was designed to support the above mentioned efforts by the provision of recent aerial photographs, recent satellite images, GIS hard-/software (including training measures), and individually different thematic maps (analogous and digital GIS compatible) with respect to present vegetation and land use, agro-ecology, land capability (soils, erodibility) and the change of land cover during the last years.

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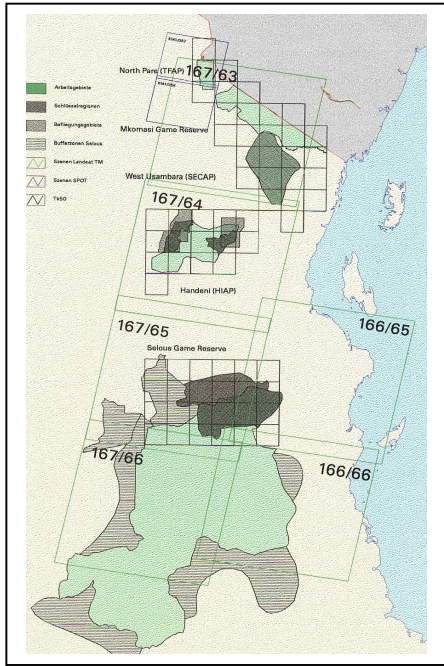


Figure 1. Overview of project areas, indicating Landsat, SPOT, Mapsheet and aerial Photograph coverage

To serve the information need of seven different projects by remote sensing application is a great challenge in a technical and organisational sense. Not only was it difficult to define clearly the intentions and expectations of the different projects and to match them with the financial possibilities. Once the project was running, the originally formulated requirements of the individual Projects with respect to the provision of maps, hard – and software and training measures have changed several times.

Finally, the seven project areas have been covered individually either by satellite images, or aerial photographs or both (see Table 1) In one case, the entire data assessment was performed by fieldwork without any support by remotely sensed data.

The Contract between the MNRT (represented by KfW) and the GAF (Munich, Germany) was signed with some delay in September 1995.

2. METHODS

2.1 Aerial Photographs

As a consequence of the delayed project start, the flight campaign had to be postponed for one year. Meanwhile, the originally foreseen photo flight for the Project „East Usambara“

had been cancelled by the client. During the photo-flying period between June and September 1996, the weather conditions had been very unfavourable. While for the area of North Pare no photographs could have been taken at all, for the other areas, cloud free image coverage only between 26% and 98% of the foreseen area have been achieved.

As a main consequence of the insufficient image coverage the data layers for inclination, necessary for the land capability map of North Pare had to be derived totally from field measurements supported by existing topomaps (1: 50 000). To a small extent the same was necessary also in the SECAP and the HIAP. This resulted in the fact, that for the related areas the erodibility information (as basis for the land capability), planned at a scale of 1: 25 000, did not achieve in all details the accuracy normally required for this scale.

Where aerial photographs were missing, more information had to be extracted from satellite data to establish the thematic maps.

Aerial Triangulation: Through the use of geodetic types of GPS-receivers on board of the aircraft and on ground, the coordinates of the projection centres of all photographs (x,y and z) could have been determined with such high accuracy, that in combination with only a few geodetic ground control points (obtained by using 1: 50 000 scale topographic maps), a sufficient coverage of control points for a high accuracy was achieved. The aerial triangulation ensued digitally with the aid of the Vision International Softplotter system. The aerial photographs 1: 54 000 were scanned at 20 microns with a XL Vision Model 950 scanner and the AT computation and adjustment was performed using the program PATB – RSG (Tang et al., 1997).

Preparation of Digital Ortho-Images: Special dia-positives of the aerial photographs 1:54 000 were scanned at 20 micron, corresponding to a resolution on ground of approximately 1m. The Terrain Model was calculated by digital methods and the scanned images were ortho- rectified using the AT results and the DTM (Baltasvias and Käser, 1998).

Calculation of Inclination Classes: Inclination information was derived from digital terrain models (DTM’s), generated by the correlation of the aerial photographs and in case of North Pare by digitised contour lines. For the calculation of the inclination classes the ARC/INFO software- TIN module was used.

| AREA | Satellite Images | Aerial photo B/W | Aerial photo CIR | Aerial photo natural color | Training and GIS hardware /software |
|---------------------------|------------------|------------------|------------------|----------------------------|-------------------------------------|
| TFAP, North Pare | | | | | |
| SECAP, Usambara Mountains | | | | | |
| HIAP, Handeni District | | | | | |
| Mkomazi Game Reserve | | | | | |
| Selous Game Reserve | | | | | |
| Tanga costal Region | | | | | |
| East Usambara Maountains | only fieldwork | | | | |

Table 1. Remote sensing data in project areas

2.2 Satellite Data

In consideration of cloud cover and technical quality the satellite scenes listed in Table 2 have been selected and used for the image processing.

To ensure geometric compatibility with other sources of information, the satellite data were geo-coded corresponding to the co-ordinate and mapping system of the national topographic maps.

| AREA | SENSOR | PATH/ROW | DATE | CLOUD COVER (%) | PROVIDER |
|----------------------|----------|----------|----------|-----------------|------------|
| TFAP North Pare | SPOT-Pan | 141/357 | 04.08.96 | 0 | SPOT-Image |
| | SPOT-XS | 141/357 | 04.08.96 | 0 | SPOT-Image |
| | TM | 167/63 | 28.01.97 | 0 | SAC |
| SECAP | TM | 167/63 | 28.01.97 | 0 | SAC |
| HIAP | TM | 167/64 | 02.07.95 | 10 | SAC |
| Selous Game Reserve | TM | 166/65 | 09.06.95 | 10 | SAC |
| | TM | 166/66 | 09.06.95 | 10 | SAC |
| | TM | 167/65 | 02.07.95 | 10 | SAC |
| | TM | 167/66 | 02.07.95 | 5 | SAC |
| Mkomazi Game Reserve | TM | 167/63 | 28.01.97 | 0 | SAC |

Table 2. Satellite data acquired for the project

Based on these maps (1: 50 000), well distributed ground control points (GCP's) were selected and the rectification carried out with an overall RMS-error of less than 1.5 pixel. Further image processing consisted of contrast enhancement and filtering of the different spectral bands.

In case of Landsat-TM data, two different band combinations and thematic processing approaches were used:

- TM bands 4,5,3 were displayed in RGB mode
- TM bands 3,2,1 were de-correlation-stretched and displayed in RGB mode

All image processing was carried out using the ERDAS and CIRRUS processing line (ERDAS, 1997). The processed data together with the boundaries of the Project Areas and the map sheet grid were recorded on 8" x 10" (10" x 10") master-film via the in-house high definition CIRRUS laser film-writer system.

From the master-film 4 sets of colour hard copies were produced in the case of Landsat-TM and 4 sets of black/white copies in the case of SPOT-pan.

2.3 Preparation of Thematic Maps

After the preparation of all remote sensing data, evaluation guidelines and desired thematic maps have been defined in detail during a joint workshop together with the remote sensing specialists, the different project managers and stakeholders of the Tanzanian administration.

On this workshop:

- Tanzanian experts, as well as the experts from the GTZ where familiarised with the Mapping Project,
- A standardised and harmonised nomenclature for vegetation and forest classes was defined respecting existing schemes (FAO, 1997; TIRDeP, 1980),
- A first training session was given on image interpretation and GIS-related mapping,
- Satellite images, aerial photographs and additional working materials were delivered to the mapping teams.

Generally, two different mapping approaches for obtaining thematic classes from satellite data are possible: 1) fully automated digital classification, 2) semi-automated classification utilising visual image interpretation with ensuing digitisation of the mapping results. The approach "visual interpretation by experts" was considered to be more feasible under the specific project conditions for the following reasons:

- aerial photographs and satellite images can be evaluated with comparable procedures,
- the knowledge of local experts can be integrated during interpretation,
- the evaluation could be performed in the field with nearly no technical equipment, allowing a direct and permanent cross check with the situation in the field,
- the method proved to be worthwhile under comparable conditions (Adeniyi and Omojola, 1999; Penders and Mills, 1999; BRSC, 1999).

Precondition for a reliable and consistent interpretation result is the establishment of an interpretation key, separate for each Project region and the different images (aerial photos, satellites scenes) by intensive field work (Sabins, 1986; Hildebrandt, 1996).

Image interpretation was performed directly on a crystal clear transparency overlaid onto the original satellite image prints or onto the aerial ortho-photos. Different land-use classes were delineated with a pen always respecting the interpretation keys and guidelines. These transparent sketch maps were then used as basis for the thematic GIS layers.

2.4 GIS Database and Thematic maps

The complete draft maps generated during the field activities were digitised using ARC Info software. All digitised data sets are based on the national co-ordinate and cartographic system. The digital GIS data sets are covering the respective project areas and the thematic data layers produced for the different thematic applications are in digital format map sheet independent. For the generation of soil erodibility and agro-ecological zone information, GIS analysis capabilities have

been used to derive slope, aspect and other relevant information by merging different input data layers.

Using ARC Info and ARC View cartographic tools a master layout scheme was developed for each map product. Basis for all layout work are the existing National Maps of Tanzania and acknowledged standards in the country (FAO, etc.). Prior to the final map production the map layout and map content was present to the client for approval.

Finally, all maps were produced in 10 copies, respectively 15 copies for the TFAP North Pare.

Besides the plotted maps, all information achieved during the mapping activities was delivered digital assembled to a GIS layer structured data base containing vector -, raster – and all relevant attribute data. The installation and introduction to the data base was carried out during the GIS training course activities in August 1998.

3. RESULTS

3.1 Maps

The following thematic maps have been produced in the frame of the project for the seven project areas as hard copies and in digital format:

TFAP-North Pare

- Vegetation and Land Use (1:25.000)
Separate data layers for vegetation/land use and boundaries of forest reserves
- Erodibility of Soils (1:25.000)
Separate data layers for land capability classes, morphological features and infrastructure

SECAP- Soil Erosion and Agroforestry Project

- Vegetation and Land Use (1:50.000)
- Inclination maps (1:25.000) for selected areas
- Erodibility of Soils (1:25.000) for selected areas

HIAP- Handeni Integrated Agroforestry Project

- Vegetation and Land Use (1:50.000)
- Inclination maps (1:25 000) for selected areas
- Vegetation and Land Use (1:25.000) for selected areas
- Agroecology (1 : 25.000) for selected areas
- Soils (1:25.000) for selected areas
- Hydrology including inclination classes (1:25.000) for selected areas
- Topomaps showing boundaries of villages and infrastructure (1:25.000) for selected areas
- Hydrology including Land Use (1:10.000) in 12 specific areas, separate data layers for Hydrology and Land Use for twelve areas

SCP- Selous Conservation Programme

- Tourist map (1:100.000) for the area of concentration
- Overview land cover and vegetation map with hunting blocks (1:400 000)

Mkomazi Game Reserve

- Vegetation and Land Use (1:50.000)

As far as the application of the provided information in the projects is concerned, three examples can be given:

The **Usambara Mountains (SECAP Project)** were formerly an area favourable to agriculture with large tracts of land use devoted to forestry. However, in recent years high population pressure upon land resources has led to an alarming degradation of natural resources, characterised uncontrolled exploitation of the remaining forest reserves. Thus it was deemed necessary to detect the land use changes during the last 20 years using remote sensing. Figures 2 - 4 are showing a time series of Landsat images 1987 – 1997 and a derived map of the same area. Planned reforestation in 1987 (yellow polygons) could only partly be realised. However, in the same time period, large forest areas disappeared.

The GTZ project's aim was towards improved sustainable management of the natural resources in the Usambara Mountains through enhancement of agricultural practices and conservation of the environment. Through the slope information derived from the Digital Terrain Models (DTM's) it was possible to identify sites necessary for terrace construction or afforestation.

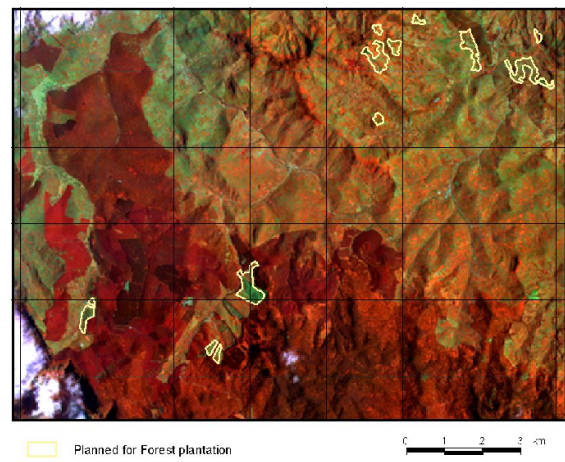


Figure 2. Usambara 1987: Forests and other land use. Landsat TM colour composite, bands 4-5-3; yellow polygons indicate areas foreseen for reforestation

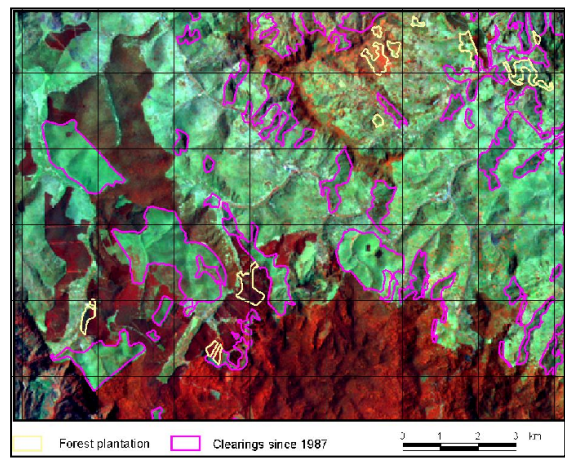
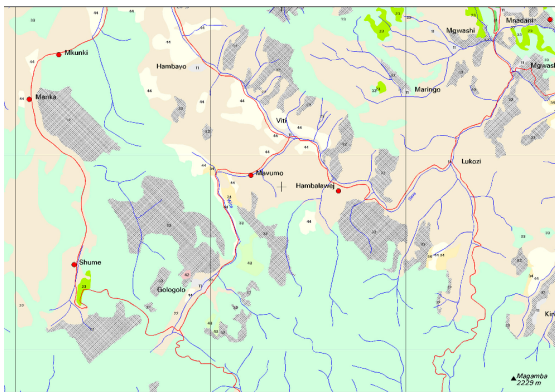


Figure 3. Usambara 1997: Forests and other land use. Landsat TM colour composite, bands 4-5-3, violet polygons indicate deforestation



Legend

- Settlement: 1
- Cultivated land: 2
- Forested and wooded land: 3
- Other land (e.g. grassland, bare ground, swampy areas): 4

Figure 4. Subset of forest and land use change map corresponding to satellite data in Figures 2 and 3

In **Handeni region (HIAP Project)** the main objectives were:

- to contribute towards stabilisation of the natural resource base and the agricultural productivity and
- to facilitate the villagers in planning the utilisation as well as the management of their natural resources.

Vegetation and land use maps were created to support the villages in planning and implementation of their Land use plans. To significantly reduce the conflicts between the Maasai tribes people and population of the local villages the GIS was used to find areas less suitable for agricultural productivity. Another important function of the GIS e.g. hydrology including slope classes was to find the best location for the construction of new dams.

The very special objectives in **Selous Game Reserve (SCP Project)** are:

- to safeguard the existence and ecological integrity of the Selous Game Reserve as a conservation area
- to reduce conflicts between the reserve and the local population

The GIS was used to map the reserve, to demarcate its borders and roads. The Selous Game Resource generates its revenue from tourism. Around 80% of the income is derived from 'safari hunting', the other from game viewing. Using GPS and GIS technologies all hunting blocks of the reserve as well as roads were mapped. The precise area of the whole Game Reserve and the area of the different hunting blocks was derived. A database of the hunting blocks including all relevant information was created. A Tourist map including all camps and special sights was generated for the northern part of the Reserve, which is open for game viewing.

3.2 Implemented GIS

To ensure the sustainable utilisation of the elaborated spatial data sets for on-going and future planning processes some basic

GIS hard and software equipment had to be procured and implemented at the different project offices (ESRI, 1997).

The layout of GIS hard- and software was compiled depending on the individual user needs. The most complete solution was installed at the Remote Sensing Institute of SUA. A fully equipped GIS was delivered, with PC ARC Info / ARC View SW, powerful HW along with sufficient storage capacity and all relevant in- /output devices.

The GTZ projects were more interested in editing and, updating data and to produce project related field documents. Therefore an easy to use GIS was installed in the SCP, the SECAP and the HIAP. It is based on PC ARC View SW, and equipped with a digitising tablet and an A3 colour printer for output production. As the NRBZ was focused more on a visualisation system, a Laptop with ARC View SW along with a A3 colour printer for output production for demonstrations of project results was delivered.

3.3 Training Courses

Along with the mapping activities and the GIS hard- and software implementation, a permanent training program was set up for the local experts involved in the different Tanzanian projects.

Basic training courses were given in use and maintenance of hardware to members of the SUA and the SCP in May/June 1997 followed by several courses in GIS basics and ArcView application. The GIS training was completed by problem-oriented training courses in 1998. The training content was composed of refreshing the ArcView-basics, data capture, data integration, data analysis, layout generation and system administrator tasks. Special attention was given on data, importing external data sets, link / join to existing, data analysis and producing statistics.

Supplementary, the experts of the Projects NRBZ, TFAP-North Pare, SECAP and HIAP have been trained in basics in cartography, theory and practical handling of GPS-receivers as well as integrating GPS measurements to GIS.

Image and aerial photo interpretation was taught permanently during the field work campaign by the German experts to the accompanying local experts. They made especially profit from the establishment of the different interpretation keys by comparing the situation on the spot with their representation on the images. In some cases the local experts were enabled to participate actively in the data evaluation procedure.

4. CONCLUSION

In the Buffer zone Mapping Project, several nature conservation and rehabilitation projects could be provided with baseline inventory data and monitoring tools by the utilisation of remote sensing and GIS technology. The thematic dimension of the derived information, the scale, spatial resolution as well as different possibilities in format and presentation of the data has shown, that remote sensing can contribute to

- inventory of land use
- monitoring of land use changes
- detection of land-use conflicts
- detection of human impacts

- decision process for planning measures
- qualitative and quantitative success control of measures.

TIRDeP, 1980. Land Use Atlas - Land Use Survey Tanga Region. Airphoto Interpretation Project. Tanga.

The Mapping Project demonstrated, that even under difficult organisational conditions, specific information for large areas can be derived from remote sensing data in relative short time period. To serve the information needs of the target groups has highest priority and must be the decisive factor for the choice of the technical evaluation approach.

It is to be hoped that the projects make widely use and profit of the new information.

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