CHANGE DETECTION OF NATURAL HIGH FORESTS IN ETHIOPIA USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

Historical sources indicate that an equivalent of 35 % of Ethiopia's land area had once been covered by natural high forests. At present, no reliable information on the extend and the location of the past and/or actual forest cover was existing for the country. Therefore, a forest monitoring was performed based on airborne and satellite remote sensing data to assess the depletion of Ethiopia's natural high forests within the last 25 years.

The change detection analysis, based on satellite images of 1973 to 1976, indicate that in the seventies, natural high forests covered around 4.75 % of the country. Around 10 to 15 years later, only around 0.20 % of the country was still covered by undisturbed natural forests. The annual deforestation rate was calculated at 163,600 ha. Today, remarkable forest stands can only be found in remote and/or inaccessible southern and southwestern parts of the country. A detailed change detection analysis in this region was therefore conducted with airphotos from 1996/97. The results give clear evidence that most intact high forests concentrate within the boundaries of 'National Forest Priority Areas'.

The ongoing deforestation is a result of the very high human pressure on the natural resources. In this context, it is being proposed to design a national Forest Information System (FIS) for selected pilot areas, in order to analyze the processes that contribute to deforestation. In conclusion, the FIS will provide veritable information for improved planning and decision-making in forest management.

1 INTRODUCTION

The natural high forests of Ethiopia have been degraded by human impact since centuries. Historical sources indicate that 35 %, respectively 42 Mio ha of the country's area was once covered by natural high forest (EFAP, 1994). Dry coniferous montane forests naturally occur in the northern and central parts of the Ethiopian Highlands, where a semi-arid to sub-humid rainfall regime is prevailing. In the semi-humid to humid southern parts of the highlands, the climatic climax vegetation are mountain rainforests. The natural upper forest limit generally lies between 3200 and 3500 m.a.s.l.. In the western lowlands, along the border to Sudan, one could once find large areas of lowland rainforest. The fauna and the flora of Ethiopia's forest formations are unique in the world due to a large number of endemic plant species.

Up to now, no reliable data on the qualitative aspects, the quantitative extend and the dynamics of the forest degradation was available in Ethiopia. This deficit lead to the motivation to install a forest information system (FIS) at the Natural Resources Management and Regulatory Department of the Ministry of Agriculture. Based on multi-temporal remote sensing data, the FIS then served for a change detection analysis of Ethiopia's natural forest resources.

The results of the analysis are alarming and prove that within the last 25 years vast areas, which were then stocked by natural high forests, have been degraded or completely deforested.

2 METHODOLOGY

The countrywide change detection analysis of Ethiopia's natural high forests was realised with multi-temporal LANDSAT-TM satellite images of the seventieth and the eightieth. Apart from this, a detailed forest monitoring was performed in the once densely forested SW of Ethiopia. In this case, multi-temporal black & white aerial photographs served as input.

All remote sensing data that was used had been classified in scope of other projects. It was therefore necessary to integrate and condense the data within the FIS in order to perform the further analysis steps. The given preconditions restricted the forest monitoring to the following classes:

- closed high forest
- slightly degraded high forest
- heavily degraded high forest

After all data sets had been transferred to a digital format, a spatial overlay analysis was performed. During this process, the older classification results were compared with more actual data sets in order to detect changes. All technical procedures were realised with the commercial software products ARC/INFO, ArcView and IDRISI for Windows.
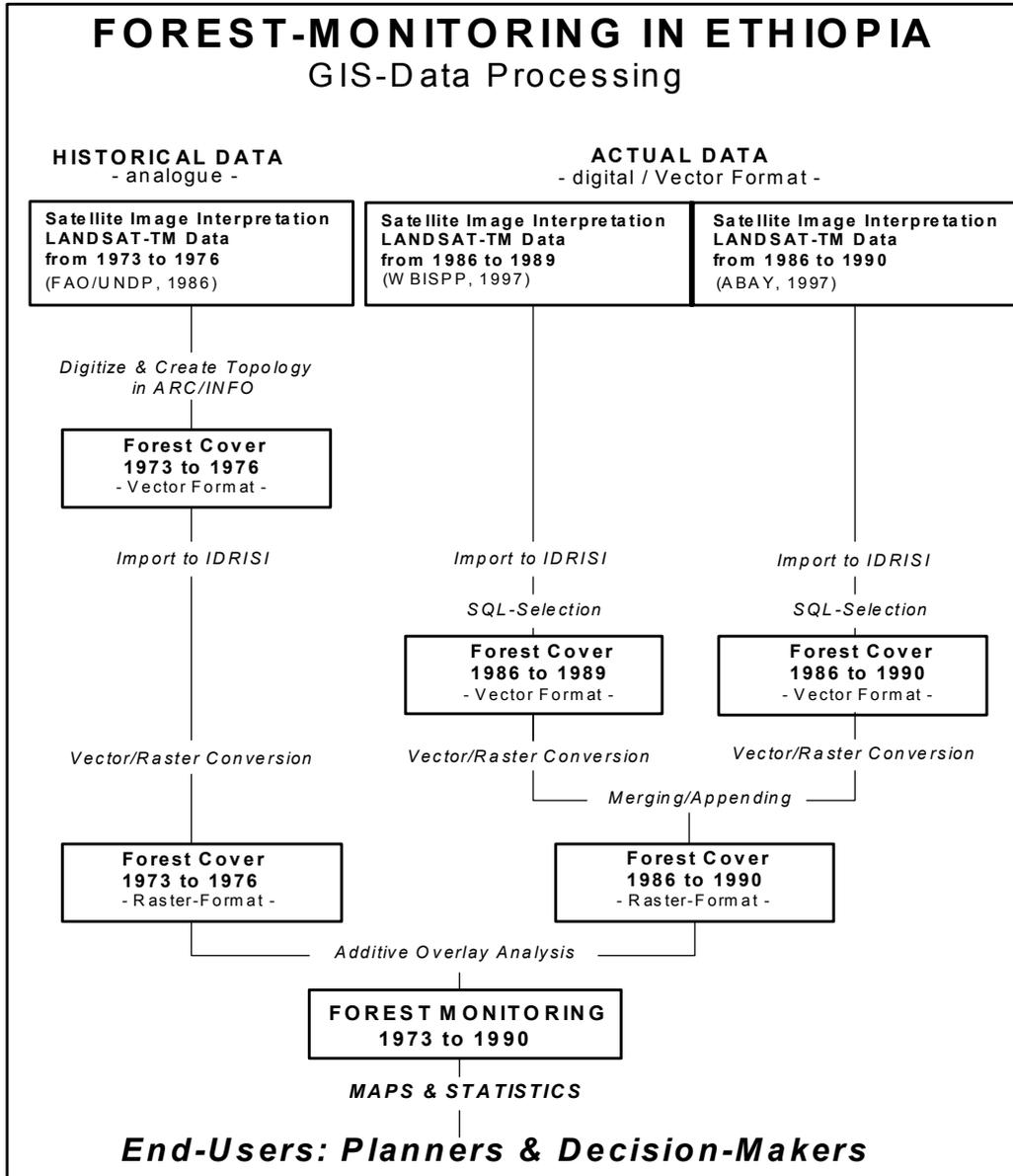
FOREST-MONITORING IN ETHIOPIA
GIS-Data Processing

HISTORICAL DATA
- analogue -

ACTUAL DATA
- digital / Vector Format -

| Satellite Image Interpretation LANDSAT-TM Data from 1973 to 1976 (FAO/UNDP, 1986) | Satellite Image Interpretation LANDSAT-TM Data from 1986 to 1989 (WBISPP, 1997) | Satellite Image Interpretation LANDSAT-TM Data from 1986 to 1990 (ABAY, 1997) |

Digitize & Create Topology in ARC/INFO

Forest Cover 1973 to 1976 - Vector Format -

Import to IDRISI

Import to IDRISI

SQL-Selection

Import to IDRISI

SQL-Selection

Forest Cover 1986 to 1989 - Vector Format -

Forest Cover 1986 to 1990 - Vector Format -

Vector/Raster Conversion

Vector/Raster Conversion

Vector/Raster Conversion

Merging/Appending

Forest Cover 1973 to 1976 - Raster-Format -

Forest Cover 1986 to 1990 - Raster-Format -

Additive Overlay Analysis

FOREST MONITORING 1973 to 1990

MAPS & STATISTICS

End-Users: Planners & Decision-Makers

Figure 1. Flowchart of remote sensing data and main FIS analysis procedures

3 DATA ANALYSIS

3.1 Forest degradation in Ethiopia between 1973 and 1990

The historical data set was based on a visual interpretation of 71 analogue LANDSAT/MSS satellite images, which were recorded between 1973 and 1976. The resulting land cover maps in scale 1:1,000,000 show closed and slightly degraded forest areas of different vegetation strata (FAO/UNDP, 1978). According to this data set 6.08 % of the country's area, respectively 69,599 sqkm was still stocked with natural high forests in the seventieth.

LANDSAT/TM satellite images from 1986 to 1990 show that Ethiopia's forest cover had since then been reduced to 3.93 %, or 45,055 sqkm (Ministry of Water Resources, 1997). The figures refer to an annual deforestation rate of 163.600 ha. This means that up to 1999, the size of Ethiopia's natural high forests has been reduced to 2.36 %, respectively 27,059 sqkm. Today, larger forest areas can only be found in very remote and inaccessible areas of S and SW Ethiopia.

A detailed analysis of the density classes shows that between 1973 and 1990, the area coverage of closed forest stands had been reduced from 30,243 sqkm (2.64 % of the country's area) to 2,346 sqkm (0.2 % of the country's area). The ongoing exploitation could be documented by the fact that within the same time span, the share of severely degraded high forest increased from 0.87 % to 3.08 %.

The following figure shows the extent and the area dynamics of the forest degradation by human impact in Ethiopia between 1973 and 1990.
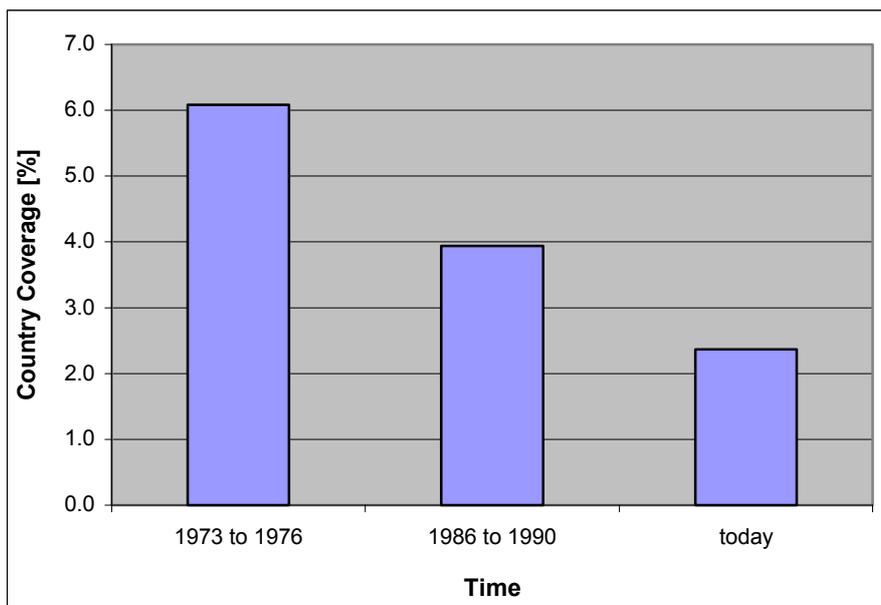

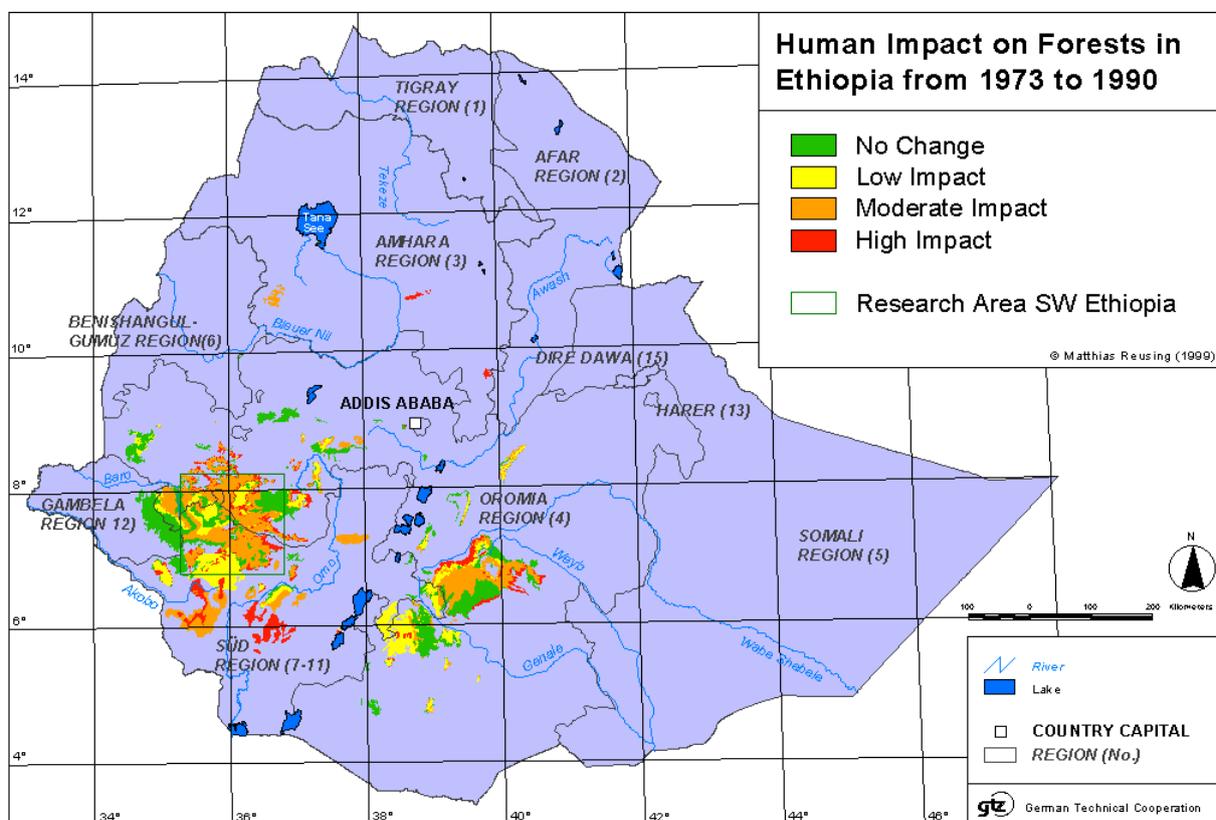Figure 2. Deforestation rates in Ethiopia

Figure. 3. Forest degradation in Ethiopia between 1973 and 1990

As already mentioned above, the forest cover was classified into three different density classes. In order to estimate the human impact on the natural high forests, the following classification scheme was being applied.

High forest 1973 to 1976	High forest 1986 to 1990	Impact class
closed	closed	no change
closed	slightly degraded	low impact
closed	heavily degraded	high impact
closed	deforested	very high impact
slightly degraded	slightly degraded	no change
slightly degraded	heavily degraded	low impact
slightly degraded	deforested	high impact
heavily degraded	heavily degraded	no change
heavily degraded	deforested	low impact

Table 1. Classification scheme of impact classes

In general, in Ethiopia it cannot be expected that forest areas recovered and regenerated within the last decades. The figures rather indicate that due to human impact almost 70 % of the natural high forests, which were still existing in the seventieth got degraded. This historical process affected more or less all-remaining forest areas in S and SW Ethiopia.

3.2 Forest degradation in SW Ethiopia between 1971 to 1997

At the beginning of this century, the south-western part of the Ethiopian Highlands had still been completely covered by montane rainforests. Shifting cultivation, which had been practiced since centuries within the area had not been really a threat for the forest resources. The situation changed with new settlers migrating from the central and northern parts of the country to SW Ethiopia. With the new settlers, a new farming system was introduced that was not adapted to the environmental conditions in the area.
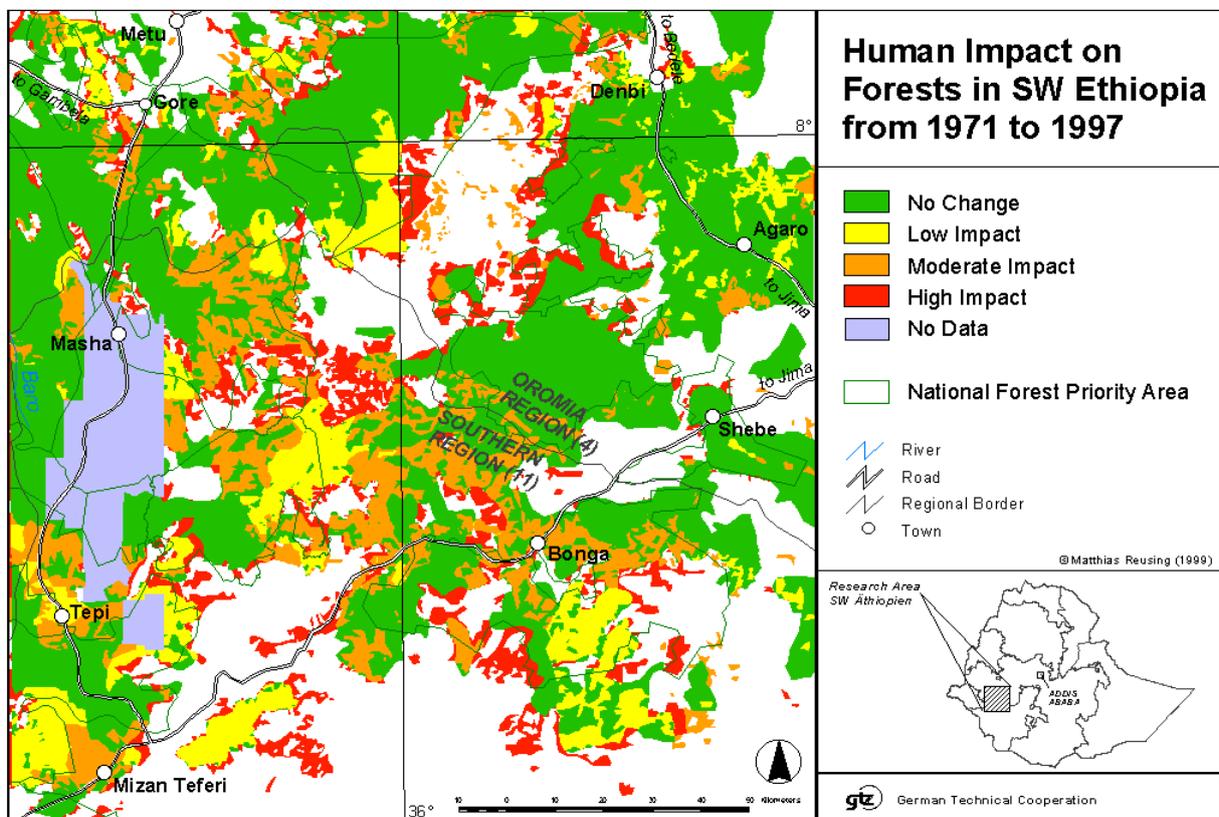

Figure 4. Forest degradation in SW Ethiopia between 1971 and 1997

In scope of a detailed spatial analysis, a forest monitoring was performed in a representative area in SW Ethiopia. In total, 30,600 sqkm was analyzed based on black & white aerial photographs of the years 1971-1975 and 1996-1997. The methodology and all spatial analysis steps are comparable to those, which were performed during the inventory of the whole country.

According to this the aerial photographs of 1971 to 1975 only 38.4 % of the once completely forested research area in SW Ethiopia were still covered by closed high forests (Chaffey, 1978). In 1996/97, only 18.4 % closed high forests were remaining (JICA, 1997). Nevertheless, 48.4 % of the area were still forested when considering also slightly and heavily disturbed high forests (Reusing, 1998). Today, undisturbed high forests can only be found in remote areas like on isolated mountain ridges or on unfertile soil substrates.

The human impact map of SW Ethiopia shows the whole dimension of the forest destruction in SW Ethiopia between 1971 and 1997. Obviously, major forest degradations occur around settlements like Bonga, Mizan Teferi, Tepi and Gore. Throughout the area one can register that the front of destruction continuously moves towards the inner parts of the forest stands.

Severe to very severe degradation and deforestation could be monitored on 27.4 %, respectively 494,100 ha. No change could be registered on 61.2 % of the area. Nevertheless, the spatial distribution of these forest relicts is already characterized by a very high fragmentation.

4 THE FOREST DEGRADATION PROCESS

The forest degradation in Ethiopia is closely linked to the ongoing population growth. More people generally lead to an increasing demand on land for living and for agricultural production.

The situation got more severe in the eightieth when large numbers of people moved to SW Ethiopia in scope of organized resettlement programs. Consequently the pressure on the forest resources themselves increased due to a higher demand on fuelwood and construction timber. Finally, uncontrolled logging and the illegal export of wood stems to urban centers like Addis Ababa is a threat for the natural high forest of the country.

The natural regeneration of the forest resources is difficult due to high populations of grazing and browsing livestock within the forests.

5 CONCLUSIONS AND OUTLOOK

By aggregating analogue and digital data from various projects that are active in the field of natural resource management and environmental protection, it was possible to perform a monitoring of the deforestation and degradation of Ethiopia's natural high forests.

The results of the forest monitoring prove that Ethiopia's natural high forests are under a very severe pressure. In long-term, this unique ecosystem with its large numbers of indigenous species can only be saved if all involved actors are willing to contribute to its conservation.

In order to preserve the remaining forest stands, already in the eightieth, so-called 'National Forest Priority Areas (NFPA)' were demarcated that should guarantee a better protection of the forest. Instead, experience shows that the degradation generally does not stop at the borders of those NFPAs. Therefore, it is indispensable to introduce more sustainable management systems, which consider the demands of both, the nature and the local population. In this context, the results of the presented paper should contribute to a selection of primary intervention areas for first activities.

Immediate action is necessary from the responsible administrative bodies and the beneficiaries within the villages. Otherwise, it can be expected that within a few decades, one of its most remarkable forest ecosystems of the world will be lost from the planet forever. With the destruction of the forests a rich flora and fauna element of the afro-montane zone would disappear before it was even understood and studied by the scientific society.

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