Use of remote sensing for land use and natural resources investigations in the Volta Basin

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Overview

The primary objective of the application of remote sensing techniques in the framerwork of the "Land Use" sub-project is to provide the project with in-sights into the complex issue of land use and land use change. The use of different sensor data and several image processing techniques is now providing the first current information on the principal factors driving land use and land cover change within representative areas of the Volta Basin.

The following achievements were required to the GLOWA "Land Use" group:

- produce current (2000) and historical (1990) land use and land cover maps of the Volta Basin of Ghana;
- apply suitable methods for detection and quantification of the land use / cover changes throughout the Basin at various scale.

The results, which are so far at a local to regional scale, can be up-scaled to a national to Basin-wide scale to meet the needs required for the implementation of the SVAT and MM5 models.

Land use and land cover maps of 1990 and 2000

So far, two land use and cover maps for the Ghanaian part of the basin for the years 1990 and 2000 have been issued. A number of field campaigns have been carried out to collect ancillary data to classify the study region. The whole Volta Basin area is covered by about 19 LANDSAT-TM scenes (see fig. 1, one scene is roughly 180x180 km^2 in area). In the first year the Land Use group focused on the Ghanaian part of the Basin and carried out two land use and land cover classifications for the years 1990 (F.Vescovi) and 2000 (S. Duadze). LANDSAT-TM images from January and February 1991 and from December 1999 to February 2000 (dry season) were pre-processed for atmospheric corrections, mosaiked and georeferenced to the UTM projection WGS 84 (see layout in fig. 2). For 1991 the heavily cloud covered areas (4% of the images) were cut out and replaced with corresponding pixels of images from 1984. The classification process mapped the main vegetation classes. Some vegetation attributes like vegetation structures and tree

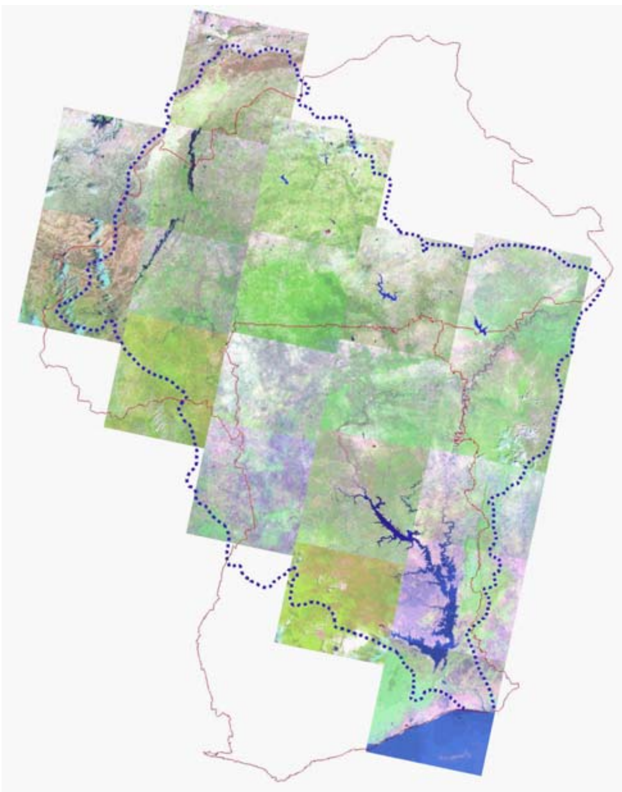

Fig. 1 - LANDSAT TM scene composite of the Volta Basin. October 1999 – October 2000.

densities were also defined. The maximum likelihood classification algorithm was applied. It is a very common and used method which assumes a previous supervised knowledge of parts of the land to be classified. Therefore a number of polygons for each class, which were known from the field survey, have been selected on the image. Some of the polygons though were recognized visually on the image by similarities with well known areas. The spectral signatures of each class were derived from the selected polygons (training areas) and the whole image was subsequently classified on the basis of their spectral statistics. Several classifications were launched on different subsets of the image (see example in fig. 3). The subsets had to be homogeneous for atmospheric conditions and status of the vegetation. At least 8 to 10 polygons for each class were defined in each subset. The most heterogeneous classes, like grass savannah or woodland types, needed more and larger training areas. The image subsets were then mosaiked and the relative percentages of coverage of the classes were calculated. Finally the accuracy of the maps was evaluated.

As shown in the legend (fig. 4), the classification scheme adopted was the one proposed by the GLOWA Volta Land Use Group (Soojin Park) which is a modification of the Land use / cover map in 4 levels applied by CERSGIS (Centre for Remote Sensing and Geographical Information Services, former RSAU, University of Ghana, Legon). It consists of 3 hierarchical levels of cover types. The latter is the most detailed and the different vegetated classes are defined as a function of the dominant vegetation structure (tree-, shrub- or grass- type) and tree population density (>300, 150-300, 10-150 and <10 trees/ha). For the purpose of this mapping exercise, it is here intended for tree any plant higher than 3 m. These vegetation attributes were derived from the ancillary information of the land truth campaign.

The two maps shown in fig 4 and 5 are final products so far produced (Sept. 2002) which are still under construction. The land use / cover maps for the whole Volta Basin are expected in the second phase of the GLOWA-Volta project. However, some important preliminary conclusions for an area covering about 40% of the basin (162.000 km^2) can already be drawn:

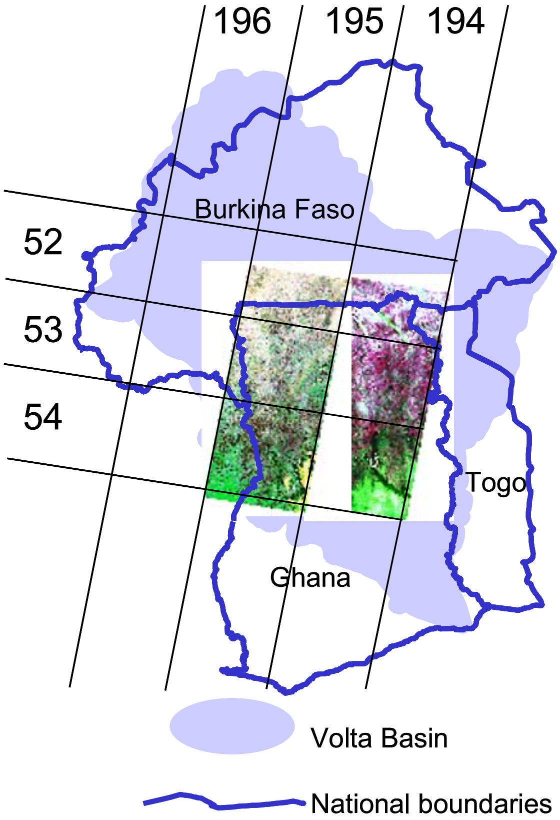

Fig. 2- Classified area. Paths and rows of LANDSAT-TM .

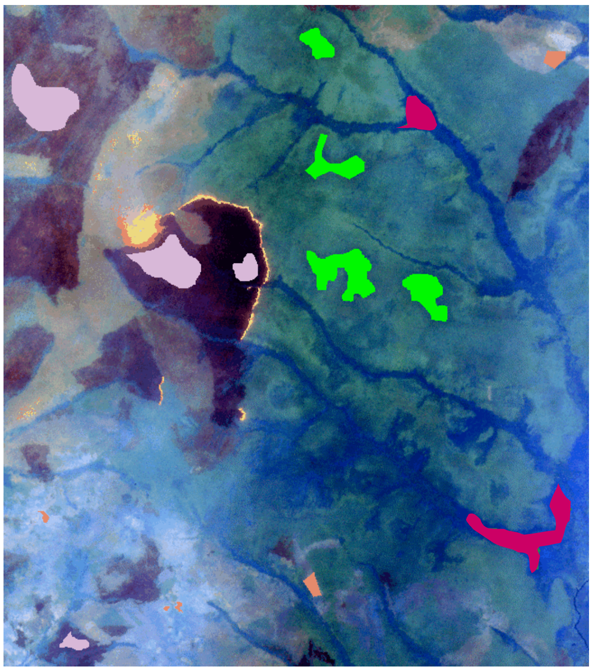

Fig. 3 – Example of selected polygons (training areas) for the calculation of the spectral signature statistics.

- the **tree population density** for the different land classes can be estimated with acceptable accuracy and therefore the evapo–transpiration coefficients needed for the model exercise of the project can be easily derived from the tree densities and up-scaled;
- a link between the intensity **agricultural patterns and the road network** seems to be evident**;**
- the occurrence of the **bush fires** in the dry season is a dominant human factor in shaping the vegetation structure and modifying the landscape patterns;
- the low rainfall regime in the North (no more than 1000 mm per year on average) necessitates the construction of new irrigation systems and **dams** (see land use change analysis).

Level I	**Level II**	**Level III**			**Coverage (%)***		
		Class	Code	Description	1991	2000	Diff.
Vegetated 1	Cultivated terrestrial 11	**Cultivated**	111	Recently cultivated in bare land and constructed surface with or without scattered trees (< 10 trees/ha).	17,7	22,0	+4.3
	Natural and seminatural forest 12	**Forest**	121	Closed natural forest (60% of the canopy) or forest plantation (> 300 trees/ha).	0,9	n.r.	n.r.
	Natural and seminatural savannah 13	**Closed woodland**	131	Mainly trees over 3 m hight, riparian vegetation, only few shrubs, thick understorey (150-300 trees/ha).	6,6	4,6	-2,0
		Open woodland	132	Open savannah woodland with shrubs and grasses (10- 150 trees/ha).	23,5	39,5	+16,0
		Grass savannah	133	Mixture of grasses shrubs with or without scattered trees (< 10 trees/ha).	28,6	32,5	+3,9
		Fire scars	134	Recently burned vegetation. In the rainy season it merges with grass savannah and open woodland (133 and 132)	19,1	n.r.	n.r.
Non vegetated 2	Terrestrial non vegetated areas 21	**Towns and roads**	211	Urban settlements and transport. Overlayed layer.	n.r.	n.r.	n.r.
		Bare soil	212	Rocky land, gravel pits.	2,3	n.r.	n.r.
	Aquatic non vegetated areas 22	**Rivers**	221	Permanent rivers.	0,6	1,3	0
		Lakes and dams	222	Artificial water bodies, inland waters, reservoirs.	0,7		
Unclassified 3	Clouds 31	**Clouds**	311		n.r.	n.r.	n.r.

Fig. 4 – GLOWA - Volta classification legend. The statistics for the two years were calculated for corresponding areas in the two maps.

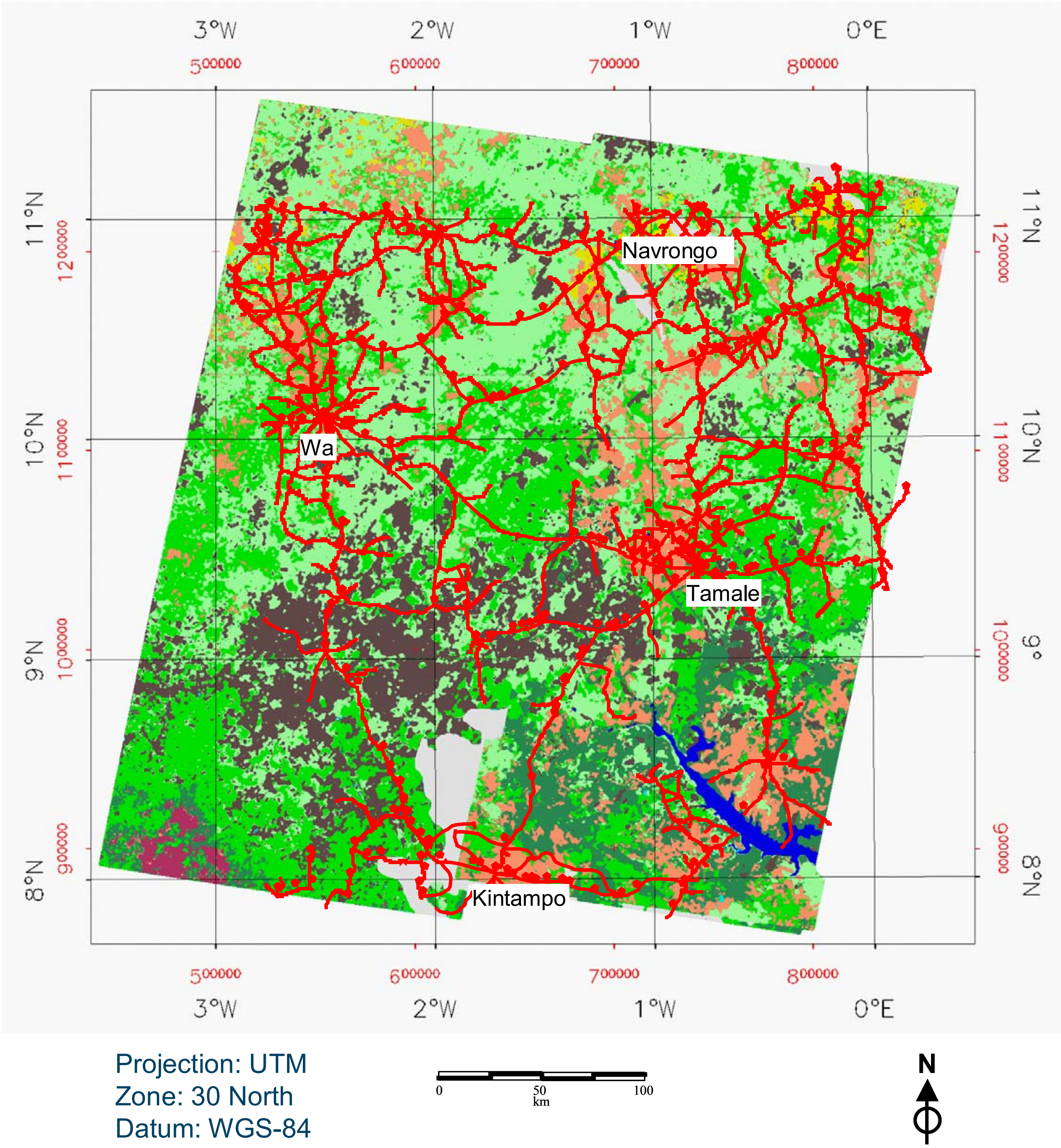

Fig. 5 – Land use land cover map 1990: classification result.

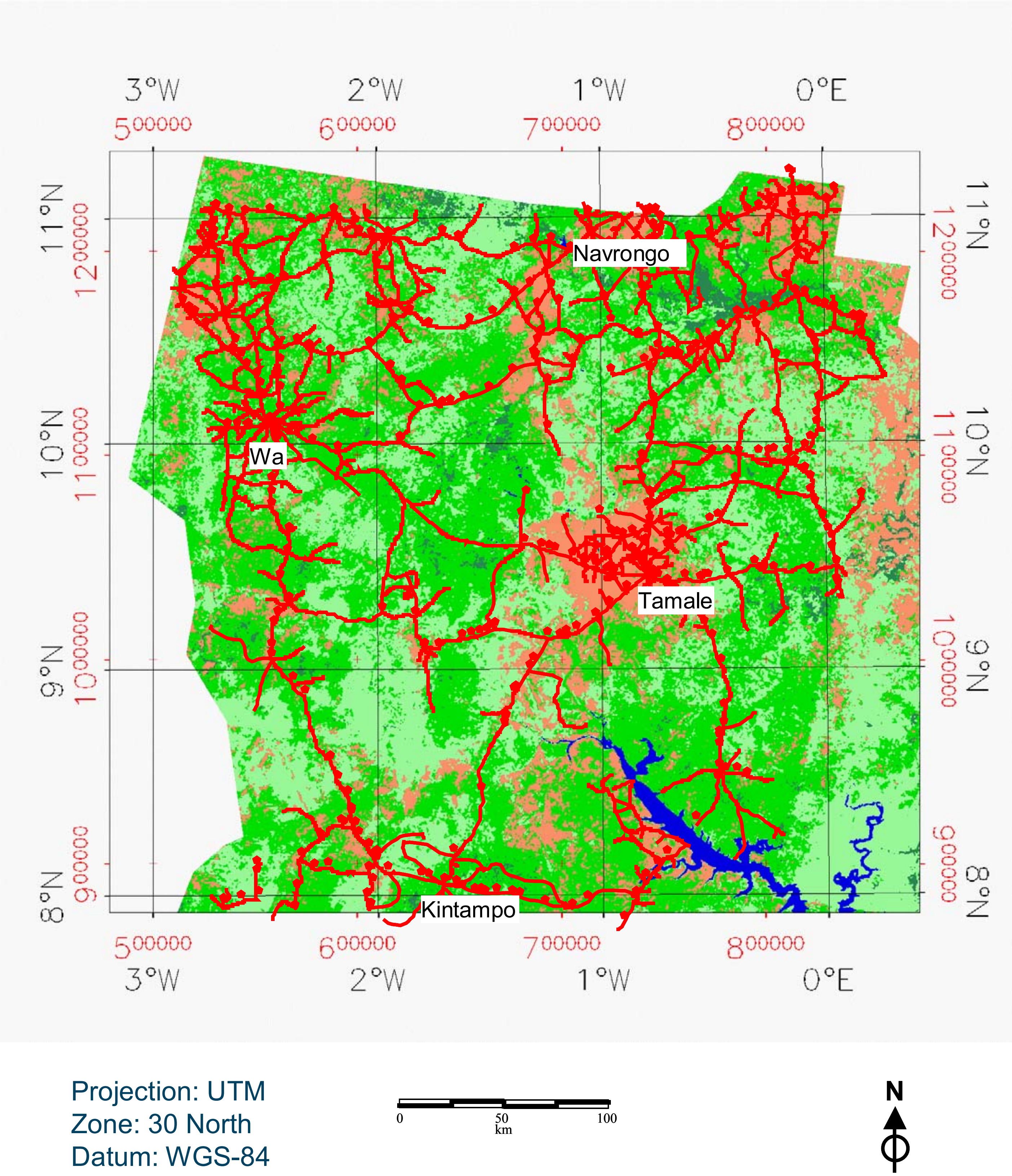

Fig. 6 – Land use land cover map 2000: classification result.

Land use change detection methods

As it is not possible to complete a land use change study for the whole Volta Basin at very fine spatial resolution, there is a need to select key areas to for high resolution pilot studies. Therefore, a number of hot spots have been so far detected applying different change detection techniques on a multitemporal datasets consisting of NOAA-AVHRR and LANDSAT sensors data. Some examples of human induced changes on the natural patterns (deforestation, urban change and increment of the dams) are reported and discussed.

Several methods have been applied to the different satellite data sets currently available in the GLOWA Volta project. The change detection methods so far tested are: NDVI differences, classification comparisons and NDVI/Ts index with vector quantification. The potentialities of the different methods are demonstrated in this short report on a selection of typical case studies on:

- Deforestation
- Urbanisation
- Intensification of the water use through the construction of new dams

Deforestation. Monitoring of NDVI (Normalized Difference Vegetaion Index) changes is of great interest in detecting short term as well as long term vegetation changes like seasonal variations, agriculture activities, deforestations, bush fires. In the case of the hot spot in Wuripe village a representative example of deforestation was detected (fig. 6). Wuripe village was founded and grew up in the last 10 – 12 years. After clearing the forest the farmers started cultivating in small fields (bright spots in the image in the middle) corn, millet, yam in association with cassava, cow-pea. They are seasonal farmers who spend the farming season in the village. At the end of the rainy season they leave the village to sell the products at the market of big villages like Tamale. Differences between two correspondent NDVI images of the area acquired in two different years were calculated and the resulting image gave the changes in the vegetation amount and status occurred between the two time points. In order to display and enhance these differences some empirical thresholds were fixed on the resulting values following the method of Borak et al. 2000. The values close to zero represent the "no change pixels" (black colour in fig. 7), whereas the negative or positive values show the areas that underwent a net increase (green) or decrease (red) of the vegetation cover respectively (Borak et al. 2000). This process enhances the cleared area in the forest and allows a quantification of the area under change of about 2090 ha.

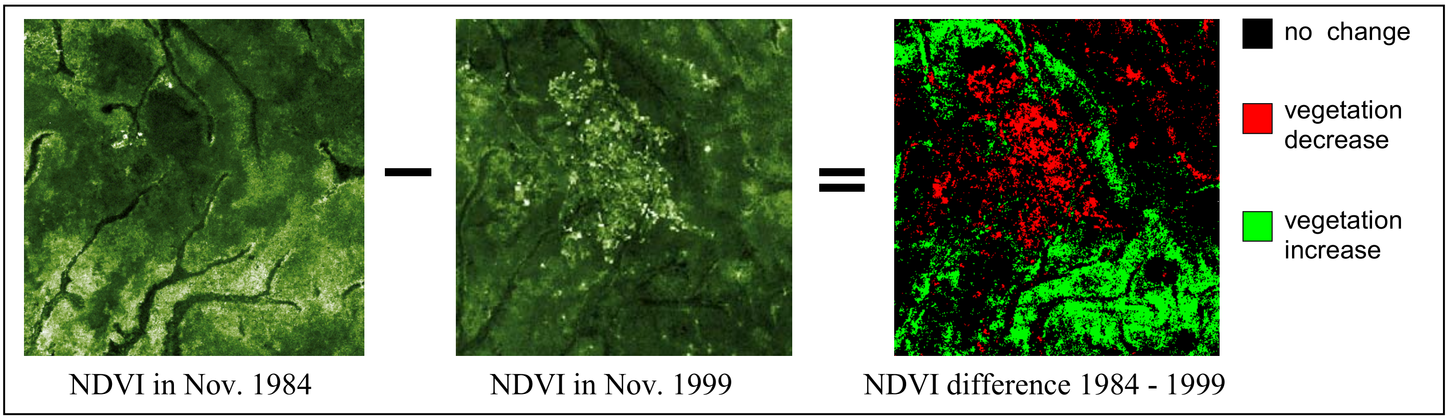

Fig. 7 – NDVI difference method applied to Wuripe village.

Urbanization. Another approach adopted to enhance differences in two time marks is the classification of the two images and the subsequent calculation of the mapped areas class by class in the two years for comparison. In fig. 8 the increase of the urban areas in Ouagadougou Town as well as the absolute values of the cover changes occurred over a 15-year period is shown. Moreover, the adapted SPARK classifier, a contextual classification method (Vescovi, 2001), was applied on the pre-processed LANDAST data. Subsequent calculations of the urban areas through a cross table filter analysis were applied to the classification results.

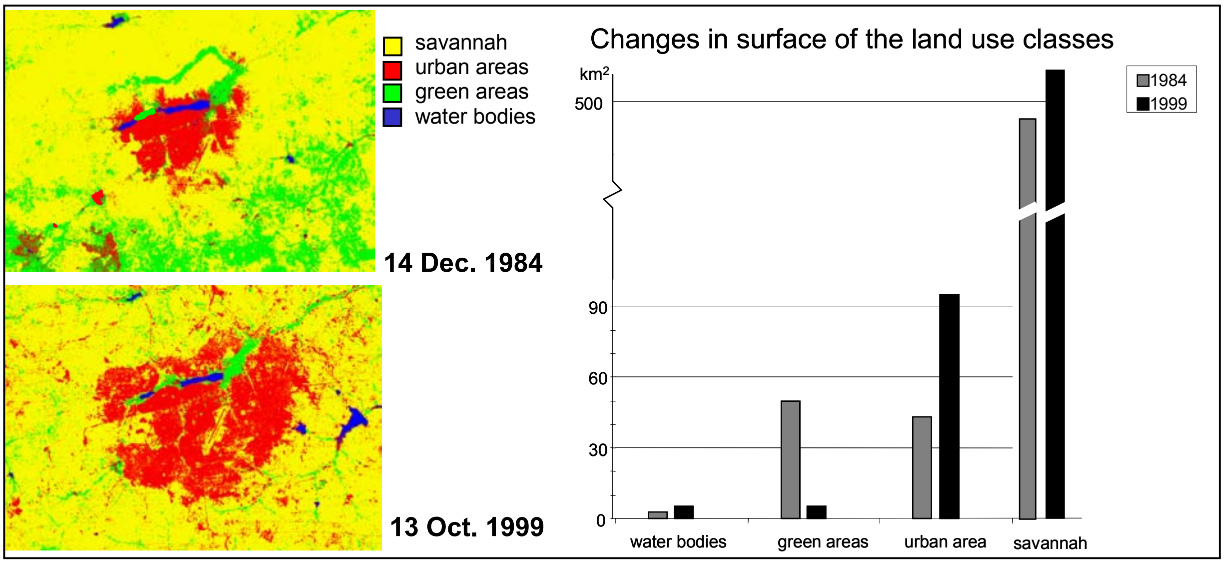

Fig. 8 - Land use classification of Ouagadougou Town area (left) and related statistics (right).

Increment of dams. In a similar way the increment in number and surface of the dams for a large area (fig. 9) has been monitored over the past 25 years. The number of the dams increases more or less linearly, whereas the consequent increment of the total water body surface for this study region seems to follow an exponential trend. All dams are included in the Volta Basin and could affect the catchment of the downstream water in the Volta Lake.

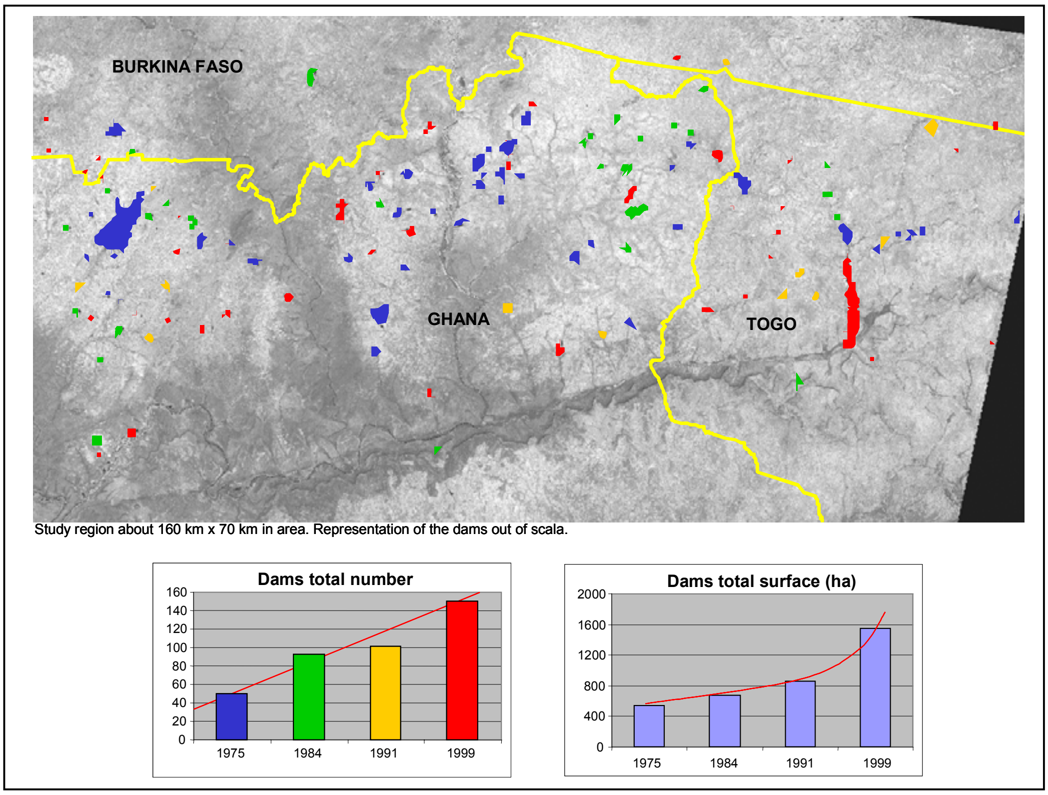

Fig. 9 – Comparison of the increment in number and flooded areas over 25 years. The image above is a representation out of scala of the distribution of the dams of a large area (about 160 km x 70 km) between the Upper East Region, Togo and Burkina faso (the administrative boundaries are in yellow). The dams are artificially enlarged and coloured for different years according to the plot below left.

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