Regionalization of the IGBP Global Land Cover Map for Western Africa (Ghana, Togo and Benin)

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ABSTRACT: The Global Land Cover Map produced by the International Geosphere Biosphere Programme (IGBP) based on NOAA-NDVI-LAC satellite data is a most valuable data basis for global environmental modelling. Global data sets used as input parameters for regional scale modelling purposes, though, are likely to require regionalization in order to adapt more closely to the area concerned. This study examines whether the IGBP Global Land Cover Map can be utilized as a land cover data set in a regional model for a part of Western Africa or whether a regional classification yielded significantly different results. As expected the overall pattern of classes in the regional and the global maps showed some concordance, but the regional map was more detailed and class distribution was better adjusted to the study area. From this study the development of special data sets for regional applications, which are of growing importance, seems advisable.

1. INTRODUCTION

Global change is dependent on natural and anthropogenic factors, which are interconnected in a variety of ways. Environmental research aims at monitoring changes and at better understanding these complex systems (Karweger 1993).

Environmental modelling requires data of earth surface parameters. The International Geosphere Biosphere Programme (IGBP) is concerned with a number of aspects of global environmental change and produced the IGBP Global Land Cover Map (DISCover v 1.0). This data set was created at a spatial resolution of 1 Km from the Normalized Difference Vegetation Index (NDVI) Local Area Coverage (LAC) satellite data produced by the U.S. National Oceanographic and Atmospheric Administration (NOAA) (Belward et al. 1999). DISCover distinguishes 17 land cover classes on the global scale. Because of the biophysical basis of its classification scheme it can be used as input parameter for global ecological modelling applications.

Currently, there is a growing demand for regional scale studies of climatic and environmental change. Initially, it would appear that DISCover does not include sufficient thematic detail for such regional applications. In this study, a new regional land cover data set was produced covering a portion of Western Africa. This new data set was then quantitatively compared with DISCover to evaluate thematic similarities and differences. Regionalization is expected to lead to a greater number of land cover classes and to a spatial distribution that more accurately reflects the study region.

The methodology used to derive the regionalized land cover map is identical to the one used for the creation of the IGBP Global Land Cover Map (Belward et al. 1999). A series of 10-day maximum-value NDVI composites were compiled for the period of April 1992 to March 1993. These composites were then used to produce monthly maximum-value composites. This set of 12 monthly maximum composites is then classified into areas with similar spectral and temporal characteristics by unsupervised multi-temporal classification: correspondences in NDVI values during the course of the year indicating similar vegetation/land cover. Post-classification procedures using class statistics and ancillary data are employed to yield the final classes.

2. STUDY AREA

The study region is located in Western Africa and reaches from 4.5° N to 13° N and from 4° W to 4.5° E. The study area includes the nations of Ghana, Togo and Benin, as well as portions of Côte d´Ivoire, Burkina Faso, Niger and Nigeria. A wide range of climatic and vegetation regimes exist within the study area, from the humid coast of the Gulf of Guinea to the semiarid savannah regions close to the transition to the Sahel (Figure 1).

Natural units within the study region include coastal plains and lagoons, the Volta floodplain, and the Atakora mountain range extending from eastern

Ghana through Togo to northwest Benin. In the northeast of the study area the Niger trends from northwest to southeast.

2.1 *Climate*

Due to the spatial location of the study area, seasonality is based primarily on the annual water cycle. Precipitation in western Africa generally decreases from the Guinea coast to the north. Our study area, however, is located within the reach of a climatic anomaly known as the "Dahomey Gap" which exists in the coastal regions of Ghana, Togo and Benin. This condition is caused by the cold Benguela ocean current, as well as the shape of the shoreline and results in a significant decrease in regional summer rainfall (Jenik 1994). Therefore, only in the northern portions of the study area are isohyetes generally arrayed latitudinally.

The tropical wet climate found in the southern portion of the study region (except within the anomalous drier areas discussed above) is characterized by very high precipitation of more than 1500 mm/year and at least 10 humid months. Precipitation decreases to 1000-1500 mm yearly and 6-9 humid months in the tropical semihumid climate and to only 500-1000 mm of precipitation per year and 3-5 humid months in the semiarid areas in the north (Knapp 1973). Within the study area, rainy seasons converge and extreme rainfall events and the frequency of dry spells within the growing season increase with distance to the Equator (Sivakumar 1991).

2.2 *Vegetation*

The vegetation of the study region can be divided into forested and savannah regions. Both have a more arid appearance further north (Figure 1). Between them transitional forms and mosaics are found. The various savannah associations must be regarded as anthropogenically degraded vegetation south of the Sahel, where the natural transition to shrub savannah is located. The natural vegetation to the south of this area consists of rainforests in the south and dry forests in the north (Anhuf, Frankenberg 1991).
The region between the Gulf of Guinea and the Sahel has been used by humans for thousands of years (Scoones 1991, Lane 1998, Nyerges 1997). Land use depends on physical geographic factors. Agriculture is the most important land use, even in the very north of the study region. With the exception of the northern areas rangeland use is impossible in large portions of the study site because of the occurrence of the Tsetse-fly. The forested areas included in the site also support a timber industry (Martin 1989).

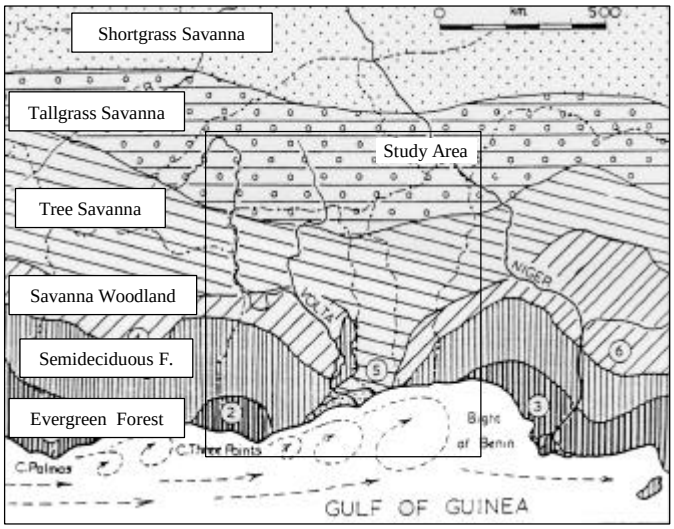

Figure 1: Vegetation zones in western Africa, and study site location (after Jenik 1994)

3. THE IGBP GLOBAL LAND COVER MAP

The International Geosphere Biosphere Programme (IGBP) is an environmental research programme concerned with global change. Its core projects need current and detailed land cover data as input parameter for different modelling purposes. Existing global land cover data are mostly outdated, have too coarse a resolution and often include climatic elements in classification, resulting in a mixture of potential and actual land cover (Belward et al. 1999). Therefore a Data and Information System (IGBP-DIS) was created to assemble environmental data on a global basis. From 1-km-resolution NOAA-AVHRR satellite data a global data set was developed and published (Belward 1996).

Additionally, the DISCover land cover project compiled a current, internally consistent global land cover map with 1 km spatil resolution. It was derived on a continent-by-continent-basis from 12 monthly maximum composites of NOAA NDVI LAC data by unsupervised classification and extensive post-classification refinement. 17 global land cover classes were distinguished (Belward et al. 1999, Loveland et al. 1999).

The data used for the global classification and for this study as well as the IGBP Global Land Cover Map can be found in the Internet at http://edcdaac.usgs.gov/dataproducts.html

4. METHODOLOGY

In order to insure comparability of the classification results, the regional land cover map was compiled using the same data set as used for DISCover. NOAA/NDVI/LAC 10-day maximum composites for the period of April 1992 to March 1993 were downloaded from the United States Geological

Survey Earth Resources Observing System (USGS/EROS) homepage. The methodology used to regionalize the test site was based on the procedures applied to the global data.

Monthly maximum composites were calculated using the NDVI 10-day maximum composites (Holben 1986). In this case the NDVI values, (normally scaled from –1 to +1) were rescaled from +1 to +200. This was done in order to capture the high variation in NDVI values due to climatic and vegetation conditions present in the study area. The high seasonality found in the study area (especially in the savannah regions) and corresponding biomass variations cause NDVI values to vary greatly during the course of the year. The distribution of NDVI values within the study region for each month is shown in Figure 2.

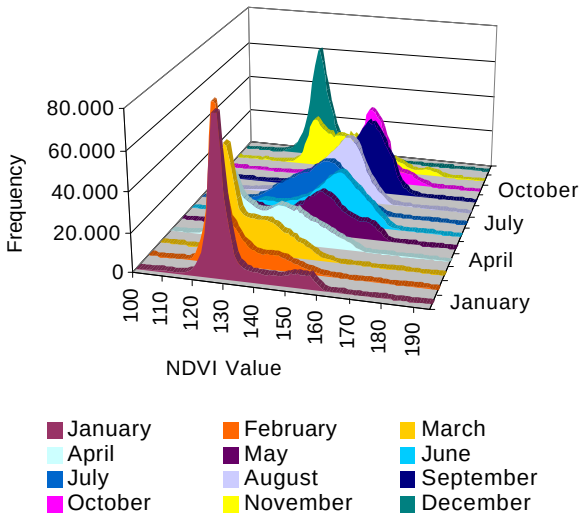

Figure 2: NDVI values in the study region from April 1992 to March 1993

An unsupervised multi-temporal classification was performed on this data set using the ISODATA algorithm (Ball & Hall 1967). Unsupervised classifiers segment the feature space into clusters with similar spectral and/or multi-temporal characteristics taking into account pixel values only, without additional information (Mather 1999). When evaluated against ancillary data and *in situ* field information (including direct knowledge of the area), the best classification results were obtained using 13 land cover clusters, including two for water.

The resulting cluster statistics and the spatial distribution of the clusters were then analyzed and compared with ancillary data. Clusters with similar seasonal NDVI characteristics were merged and minor revisions to spatial extent were made. This process resulted in 10 cover classes, including one water class. Splitting of cover classes, as done extensively in the IGBP Global Land Cover Map post-classification process, did not seem necessary due to the already detailed clustering result.

The labelling of clusters, i.e. the transformation into thematic classes, was again based on their statistical characteristics and spatial distribution. The comparison of the regionalized land cover map with the corresponding subset of the IGBP Global Land Cover Map revealed some marked differences.

5. RESULTS

The DISCover data set includes 12 cover classes for the study area. Of these, four classes (Closed Shrublands, Open Shrublands, Croplands and Urban and Built-up) are very small in extent and each includes less than 0.2 % of all pixels. The Water Bodies, Barren or Sparsely Vegetated and the Grasslands classes each contain less than 1% of all pixels. Five DISCover classes, then, comprise over 95% of the total land cover in the study area. Figure 3 shows the subset of the IGBP Global Land Cover Map for the study area.

In the southern (and especially the southwest) portion of the study area, the vegetation gradient from Evergreen Broadleaf Forest, through Woody Savannas to (grass-) Savannas is well defined in DISCover. In addition, the drier wedge of the Dahomey Gap reaching to the Guinea coast is clearly identifiable. The Cropland/Natural Vegetation Mosaics class is divided in two distinctive patches and appears both in the north and in the south of the study area instead of still a drier savannah formation to the north. A surprisingly large portion of the test site is classified as Wetlands in DISCover. In general, the class division for the study area seems quite coarse.

The new regional land cover map for the study area is shown in Figure 4. It distinguishes 10 cover classes, one of them representing water. Two classes, Barren and the Arid Coastal Plain, have in total extensions of less than 1%. Accordingly, the land area of the study site contains 7 principal classes. With two additional classes being available, the savannah regions in particular can be included in more detail than shown in the DISCover data set (See Figure 3 and Figure 4).

None of the spatially small DISCover classes (including the Wetlands class) appear in the regionalized data set. The Barren class shows a very different distribution in the two data. In the DISCover data set, this class is concentrated in the coastal regions while it appears mainly around Lake Volta in the Regional data set.

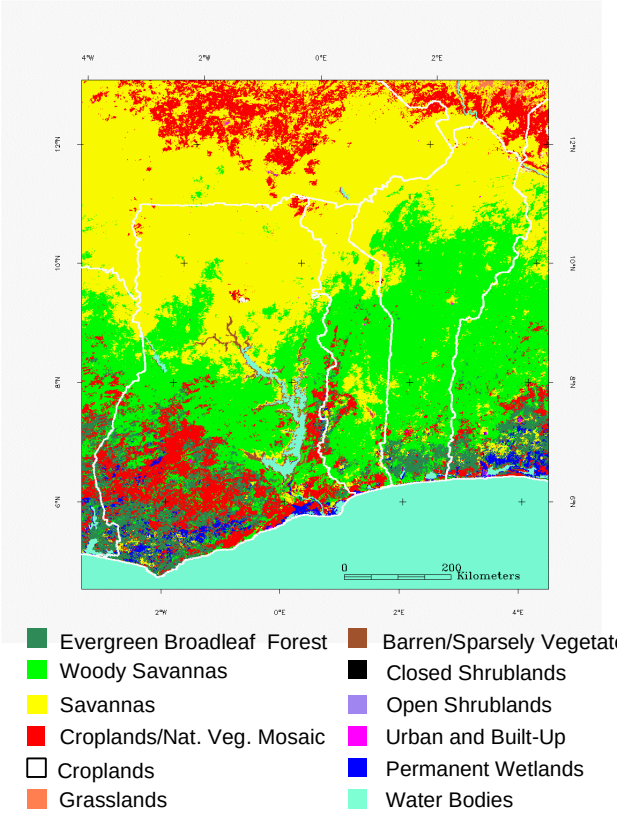

Figure 3: Subset of the IGBP Global Land Cover Map for the study region (data source: USGS)

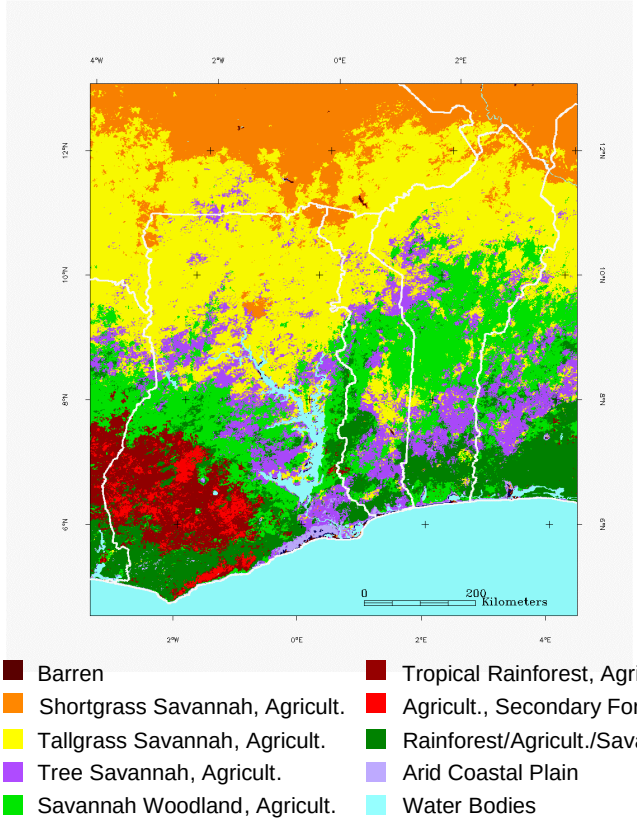

Figure 4: Regional land cover map for the study region (data source: USGS)

The arid coastal plain of Accra, easily recognized in the Regional land cover data set, is not identified in the DISCover data set. In this area, the NDVI mean values are low (as they are in all of the arid forms of tall-grass savannah), but show less variation during the course of the year. In the DISCover data set, parts of the Accra Plain are classified as Wetlands. This supports the conclusion that, within the DISCover data set, the Wetlands class seems to be overestimated for the study area.

The discrimination of agriculture from natural vegetation is complicated due to the annual similarities in NDVI values of these classes. This is further complicated by the small-scale farming practiced in the study area. As agriculture is present in regionally differentiated intensity in savannah and rainforest areas alike, it was integrated into all classes.

6. CONCLUSIONS

The overall pattern of class distribution of the IGBP Global Land Cover Map and the regional land cover map for the study area are similar. Although the Regional data set includes only 10 land cover classes compared to the 12 included within the study site in DISCover, the regional data set classification is better adjusted to the study area.

These differences are to be expected: DISCover was designed for global scale modelling and includes a higher degree of generalization. For regional scale applications more detail in land cover information is often necessary. Therefore the creation of regional land cover maps for these purposes is often advantageous.

An obstacle for the derivation of land cover information from satellite NDVI data is its dependence on seasonally and interannually varying precipitation regimes (Eklundh 1998, Richard & Poccard 1998). A comparison of the NDVI data with precipitation data for the region revealed high correlations. A supervised classification of 1995/96 NDVI data based on the class statistics of the 1992/93 land cover classes showed a significantly different class distribution because of a differing precipitation pattern. Because of the strong influence of precipitation, land cover changes could not be detected.

Therefore in regions with high variations in precipitation it necessary to use parameters more independent from precipitation for the acquisition of land cover information, in particular for land cover change detection. Some solutions are offered by different strategies: using either rain-use-efficiency (i.e. the quotient of NDVI and precipitation) as discussed by Nicholson et al. (1998), or the quotient of surface temperatures and NDVI, as done by

Ehrlich & Lambin (1996). Alternatively monthly NDVI means of a series of years can be used for classification (Ehrlich & Lambin 1996), thus evening out interannual variations, but at the cost of some loss of information content.

Other potential solutions to these problems may be derived through the use of improved and advanced sensor data and the possibilities of earth observation by means of remote sensing are going to further improve with advanced sensor systems such as MODIS and ENVISAT, with daily global coverage at higher spatial and enhanced spectral resolutions.

7. ACKNOWLEDGEMENTS

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United States Geological Survey – Global Land Cover Characteristics Database: http://edcdaac.usgs.gov/glcc/glcc.html

United States Geological Survey – Global Land 1-km AVHRR-Project: http://edcdaac.usgs.gov/1KM/1kmhomepage.html