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Classification of time series NDVI for the assessment of land cover change in Ghana using NOAA/AVHRR data

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Abstract: Land cover information is a key environmental information for many scientific, resource management and policy purposes as well as for a range of human activities. Land cover information is currently scarce for Ghana, which is undergoing rapid and wide-range changes in vegetation due to climate change, the practice of slash-and-burn or shifting cultivation. Although remote sensing technology has been used for mapping in Ghana for some time now, there have been little attempts to use either unsupervised or supervised classification methods for NOAA/AVHRR images for the whole of Ghana. Therefore a qualitative approach to the use of low resolution NDVI data to produce land cover maps of Ghana and also to evaluate the relative change in land cover from 1982 to 2002 is of essence. The study was carried out by applying principal component analysis and classification of average NDVI values. It showed that the dominant land cover change process was conversion of natural vegetation to savannah and shrub thicket, which occurred at an annual rate of 4% and 6.5% respectively. Most of the land cover change process occurred in the first period (1982-1992).The overall annual rate of change in land cover (1982-1992) was highest for agriculture (3.5%) and lowest for water (1.03%). The results suggest that, yearly phonological behavior as revealed by NDVI data can be used to map general patterns in the spatial distribution of Ghana's main vegetation formation.

Keywords: Principal Component Analysis (PCA), NDVI, Land cover, Multi-year analysis

1. Introduction

Since the 1970s it has been possible to receive radiometric data from meteorological and Earth resources satellites that allow us to analyze the interactions between the solar radiation spectrum and ocean, atmosphere and land properties. In particular, the high temporal resolution sensor, Advanced Very High Resolution Radiometer (AVHRR), of the meteorological satellite series TIROS-NOAA (National Oceanic and Atmospheric Administration) has been used to gain knowledge of the temporal, spatial and reflective behavior of vegetation. The daily coverage this series of satellites and sensors offers a unique and long-term dataset with which to investigate the magnitude of changes in vegetation at continental and global scales (Lambin, 1997; Malingreau, 1986). Land use and land cover has become increasingly important as Ghana plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands and loss of fish and wildlife habitat (Townshed et al., 1991). Time series of remotely sensed normalized difference vegetation index (NDVI) are valuable data sets in various Earth fields. For example, NDVI time series have been successfully used for environmental monitoring (Beck et al., 2006; White et al., 2009), for providing agricultural outlooks and yield (Rembold et al., 2013; Atzberger, 2013) and for modeling wildlife occurrence/movement and biodiversity (Kerr and Ostrovsky, 2003). Pheno-region specific normalized difference vegetation index threshold have been used to analyze the phonological behavior of group of pixels (Zhang et al., 2006). MODIS 250m time series data has been used to generate regional-scale crop mapping in the U.S. Central Great Plains (Wardlow and Egbert, 2005). They concluded that the MODIS time series based approach was a cost and time-efficient means of large scale mapping. Time series MODIS VI data have been used to determine winter crop area in north-western Victoria, Australia (Thankappan et al., 2008). Other techniques incorporate multiple bands to be processed to determine the changes within the periods. Several studies have demonstrated the use of principal component analysis (PCA) on multi-temporal image analysis (Byrne et al., 1980, Fung and LeDrew, 1987). The results of using PCA transform on two dates of imagery are contrary to that of its typical, one-date transformation. Image differencing using band ratio or vegetation indices is another technique commonly employed for land-cover change detection. For example, the NDVI was developed for use in identifying health and vigor in vegetation as well as for estimates of green biomas (Hayes and Sader, 2001). This study conducted specific investigations in the application of PCA to the selected image years with the objective of evaluating the change land cover in Ghana using 1982, 1992 and 2002 image data from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR). Prior research (Tucker et al., 1985; Townshend et al., 1987) has demonstrated the feasibility of applying PCA to AVHRR data for land cover assessment. To meet the urgent need of global change research, this research performed supervised land-cover classification of Ghana employing NOAA/

AVHRR and geo-spatial data by a multi-layers approach, and tested the effectiveness of the method by the application PCA to the datasets.

2. Study area

The Republic of Ghana lies on the western coast of tropical Africa. Ghana extends for a maximum of 672 km from north to south between latitudes 4.5° and 11° N, and for 536 km east to west between longitudes 3° W and 1° E. The location map of Ghana is given in figure 1. It is bordered to the east by Togo, to the west by Cote d'Ivoire, to the north by Burkina Faso, to the south by the Gulf of Guinea and the Atlantic Ocean (Clifford, 2000). Ghana is one of the five African nations along the northern coastline of the Gulf of Guinea. The total area of Ghana is 238,500 km^2.

Figure 1: Map of Ghana and showing towns/cities/capital cities (Oppong-Anane, 2001).

2.1 Description of dataset/ data acquisition

The NOAA/AVHRR dataset was downloaded from the Africa data dissemination website. The NOAA/AVHRR datasets from 1981 to 2002 was downloaded with pixel size of 8 km by 8 km and at interval of 10 days. The full extent of datasets (1982-2002) was not used, because most of the years did not have complete datasets. So images of 1982, 1992 and 2002 which were among the few with full extent of dataset and also free from clouds were selected to have equal intervals within the years. The 10 day NDVI datasets were stacked together corresponding to each of the selected year group. The yearly NDVI images were subjected to filtering/smoothing to remove undesired artifacts due to poor atmospheric conditions and undetected clouds. Field work was conducted in the dry season between December and March throughout the ten regions of Ghana to collect ground truth points which were used for the supervised classification.

2.1.1 NDVI image differencing

NDVI values were calculated by finding the difference between the NDVI images of each date by using the equation below

$$NDVI = {(NIR - \mathrm{Re}\, d)} \Big/ {(NIR + \mathrm{Re}\, d)}$$

2.1.2 Application of Principal Component Analysis (PCA)

The principal component transformation was performed on NDVI datasets (1982, 1992 and 2002) for each of the dates. Each of the three datasets contained six bands, the output of the standardized PCA applied to the datasets has six components but three (components 1, 2 and 3) out of the six components for each datasets were selected for the final classification and the rest was considered as noise and therefore rendered useless.

3. Methodology

The methodology adopted for the present study is as shown in flow diagram (fig. 2). The data of each year were analysed separately. A PCA of each year data was performed. A supervised classification with six broad land cover classes was carried out. These classes and their description is listed in Table 1.

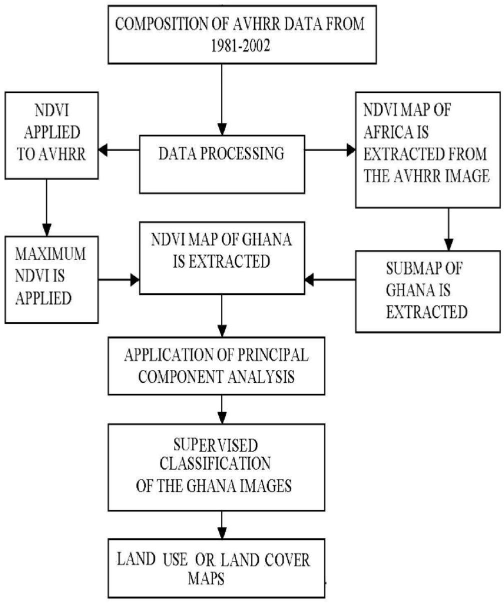

Figure 2: Flowchart of methodology

4. Results

The variances and eigenvalues are shown in Tables 2a (for the 1982 image), 2b (for the 1992 image) and Table 2c (for 2002 image). For both three transformations, the first component covers over 95 percent of the variance among the six bands (i.e. 98.146% for 1982, 97.256% for 1992 and 98.621 for

2002). The first three components represented 99.95% of the variance in the 1982 data set, 98.58% of the variance in 1992 and 99.86% in 2002. The remaining components represented 0.21% of the total variance in the 1982 datasets, and 0.19% of the total variance in the 1992 datasets and 0.14% of the total variance in the 2002 datasets which gather noise images and therefore considered as noise.

Table 1: Land cover classification scheme

LAND COVER CLASS	DESCRIPTION
FOREST	Mainly thick trees which are very high(>200trees/hec)
SHRUB THICKET	Mainly trees(75-150 tree/hec) with shrub undergrowth
GRASSLAND	Mainly mixture of grasses and shrubs without trees
AGRIC LAND	Agricultural land with crops, harvested agricultural land
SAVANNAH	Tropical grassland with more or less scattered dense tree
RIVERS	Rivers, inland water, Reservoirs

Table 2a: Variance and eigenvalues for 1982 data set

Component	Variance (%)	Eigenvalue
Comp 1	98.146	0.52222
Comp 2	0.978	0.005094
Comp 3	0.520	0.002708
Comp 4	0.087	0.000453
Comp 5	0.073	0.000380
Comp 6	0.052	0.000271

Table 2b: Variance and eigenvalues for 1992 data set

Component	Variance (%)	Eigenvalue
Comp 1	97.256	0.506561
Comp 2	0.954	0.004448
Comp 3	0.776	0.002479
Comp 4	0.079	0.000411
Comp 5	0.065	0.000338
Comp 6	0.046	0.000239

Table 2c: Variance and eigenvalues for 2002 data set

Component	Variance (%)	Eigenvalue
Comp 1	98.621	0.52470
Comp 2	0.861	0.004581
Comp 3	0.776	0.002033
Comp 4	0.079	0.000329
Comp 5	0.065	0.0002873
Comp 6	0.046	0.0001117

4.1 Land cover mapping results

The results of the classification for the years **1982**, **1992** and **2002** are illustrated in the Figure 3a, 3b and 3c respectively.

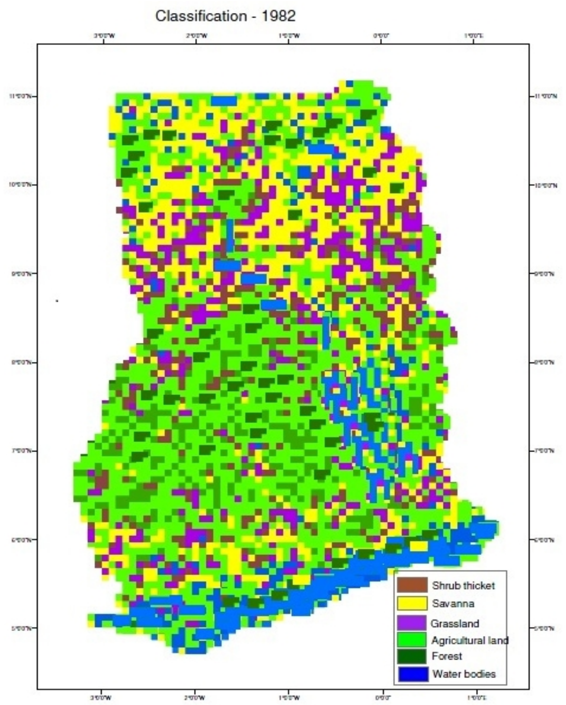

Figure 3a: Land cover map of the year 1982

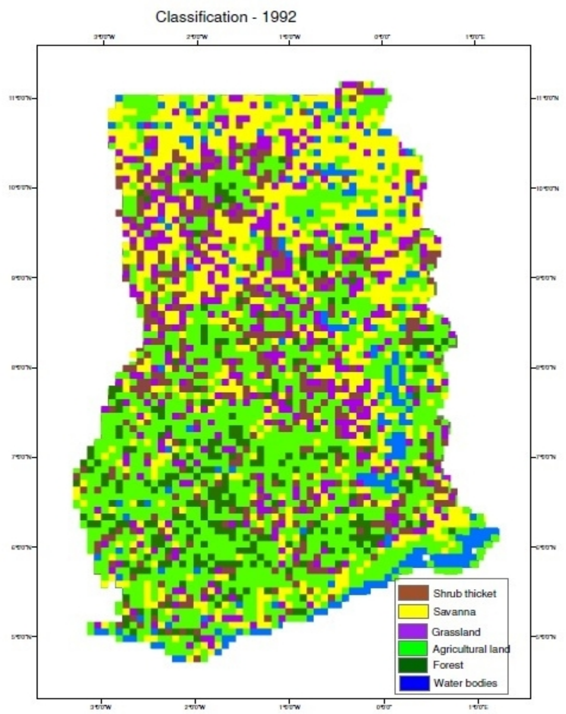

Figure 3b: Land cover map of the year 1992.

4.3 Contingency matrices

The contingency matrix (Table 3a, 3b and 3c) shows the accuracy of the classification results. It is derived by comparing the location and class of each ground truth pixel (columns) with the corresponding location and class in the classified image (rows). Each column of the contingency matrix represents a ground truth class, which defines the true class of the pixels. The values in the column correspond to the amount of pixels of that class which the maximum likelihood algorithm classifies to various classes. The main diagonal elements in Table 3a, 3b and 3c represent correct classifications, whereas off diagonal elements represents misclassification or errors. Overall classification accuracies (sum of diagonal elements divided by grand total, expressed as a percentage) were 86.0%, 89.1% and 89.9% respectively for the periods.

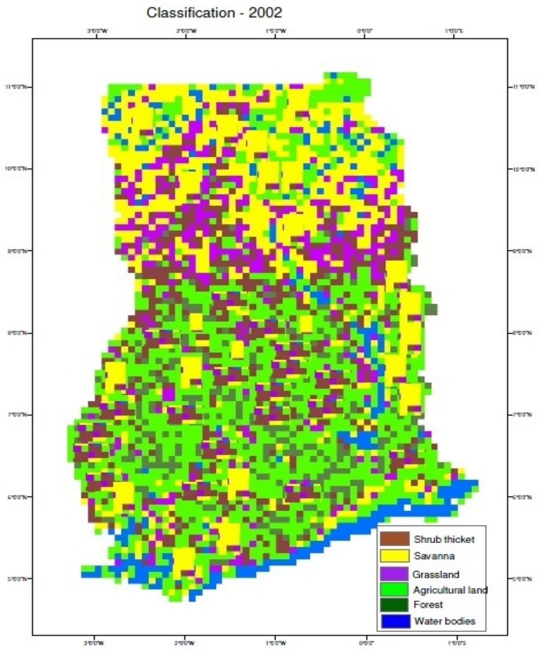

Figure 3c: Land cover map of the year 2002.

Table 3a: Contigencymatrix of 1982 classified image

CLASSIFICATION	GROUND TRUTH: Forest	Agric land	Grass land	Savannah	Shrub thicket	Water	Row Total	UA (%)	Error of Comm (%)
Forest	90	2	4	0	2	0	98	91.83	8.17
Agric land	7	85	8	2	2	0	104	81.73	18.27
Grass land	3	4	56	5	0	0	68	82.35	17.65
Savannah	6	8	8	63	0	0	85	74.12	25.88
Shrub thicket	0	2	1	3	60	1	67	89.55	10.45
Water	0	0	1	0	0	70	71	98.59	1.41
OVERALL ACCURACY = 86.00%									
Column Total	106	101	78	73	64	71	493		
PA (%)	84.91	84.16	71.79	86.30	93.75	98.59			
Error of Ommission (%)	15.09	15.84	28.21	13.7	6.25	1.41			

4.3.1 Accuracy assessment results

The overall accuracy of the land cover classification for the NDVI image is 88.3 % (kappa statistics of 0.86). Generally, the frequency of confusion of classification was low. Agricultural lands were sometimes confused with both forest and grassland. The user's accuracy ranged between 71.05% and 98.59% with relatively low errors of commission (excesses), varying between 1.41% and 28.93%.

Table 3b: Contigency matrix of 1992 classified image

CLASSIFICATION	GROUND TRUTH: Forest	Agric land	Grass land	Savannah	Shrub thicket	Water	Row Total	UA (%)	Error of Comm (%)
Forest	86	3	0	0	3	0	92	93.48	6.52
Agric land	7	80	5	0	4	0	96	83.33	16.67
Grass land	0	3	62	5	0	0	70	88.57	11.43
Savannah	4	2	9	75	2	1	93	80.65	19.35
Shrub thicket	0	0	4	0	68	1	73	93.15	6.85
Water	0	0	1	0	0	68	69	98.55	1.45
OVERALL ACCURACY = 89.05%									
Column Total	97	88	81	80	77	70	493		
PA (%)	88.66	90.91	76.54	93.75	88.31	97.14			
Error of Ommission (%)	11.34	9.09	23.46	6.25	11.69	2.86			

Table 3c: Contigency matrix of 2002 classified image

CLASSIFICATION	GROUND TRUTH: Forest	Agric land	Grass land	Savannah	Shrub thicket	Water	Row Total	UA (%)	Error of Comm (%)
Forest	88	2	1	0	0	0	91	96.70	3.30
Agric land	3	78	8	3	0	0	92	84.78	15.22
Grass land	0	3	60	4	0	0	67	89.55	10.45
Savannah	0	0	5	90	2	0	97	92.78	7.22
Shrub thicket	4	6	8	0	58	0	76	71.05	28.95
Water	0	0	1	0	0	69	70	98.57	1.43
OVERALL ACCURACY = 89.85%									
Column Total	95	89	83	97	60	69	493		
PA (%)	92.63	87.64	72.28	92.78	96.67	100			
Error of Ommission (%)	7.37	12.36	27.72	7.22	3.33	0.00			

4.4 Land cover statistics results

The land cover classification statistics obtained from the classified NDVI images are presented in the tables 4, 5a, 5b and 5c below.

Table 4: Area covered by classes of each period

Classifications	Area (km²) 1982	1992	2002
Forest	22,090.75	18,905.25	18,212.75
Shrubthicket	23,268.00	29,569.75	30,539.25
Grassland	38,780.25	31,508.75	25,830.25
Agricultural Land	108,722.5	95,703.50	87,462.75
Savannah	45,220.25	61,217.00	66,203.00
Water	18,559.00	14,888.75	16,273.75

Table 5a: Land cover change for the periods 1982-1992

Classifica-tions	Changes between 1982 and 1992			
	1982	1992	Increase	Decrease
Forest	22,090. 75	18,905. 25		3,185.50
Shrub thicket	23,268. 00	29,569. 75	6,301.75	
Grassland	38,780. 25	31,508. 75		7,271.50
Agricultural Land	108,722. 50	95,703. 50		13,019.50
Savannah	45,220. 25	61,217. 00	15,996.75	
Water	18,559. 00	14,888. 75		3,670.25

Table 5b: Land cover change for the periods 1992-2002

Classifications	Changes between 1992 and 2002			
	1992	2002	Increase	Decrease
Forest	189,05.25	18,212.75		692.5
Shrub thicket	29,569.75	30,539.25	969.50	
Grassland	31,508.75	25,830.25		5,678.50
Agricultural Land	95,703.50	87,462.75		8,240.75
Savannah	61,217.00	66,203.00	4,986.00	
Water	14,888.75	16,273.75	1,385.00	

Table 5c: Land cover change for the periods 1982-2002

Classifications	Changes between 1992 and 2002			
	1992	2002	Increase	Decrease
Forest	189,05.25	18,212.75		692.5
Shrub thicket	29,569.75	30,539.25	969.50	
Grassland	31,508.75	25,830.25		5,678.50
Agricultural Land	95,703.50	87,462.75		8,240.75
Savannah	61,217.00	66,203.00	4,986.00	
Water	14,888.75	16,273.75	1,385.00	

4.4.1 The proportion and rates of conversion of land cover types

Land cover statistics in Table 4 shows that the natural vegetation (forest and grassland) was 58.0% in 1992. After 20 years in 2002, these land covers decreased to 41.9%. The proportion of agricultural land decreased from 55.4 % in 1982 to 44.6 % in 2002. This loss can be attributed to the conversion of forest lands to agricultural lands and also the rampant bush burning occurring in the country. Table 5 (a, b and c) shows that the annual rate of decrease was 1.3% in the first period (1982-1992) compared to 0.8% in 1992-2002. Shrub thicket increased slightly from 43.2% in 1982 to 56.8% in 2002. The rate of increase was 2.3% for the first period (1982-1992) compared to 0.27% in second period (1992-2002). Savannah experienced the highest absolute annual change (increase of about 3%) in the first period, whereas grassland had the highest annual absolute change in the second period (1.5% decrease). Water decreased by 1.6% in1982-1992 but increased by 0.78% in 1992-2002. In Figure 4a, about 44% of the landscape experienced a cover change in the period which was considered to be the structural adjustment era (1982-1992), whereas the proportion of changed land in the post structural adjustment period (1992-2002) was about 56%. Between 1982 and 2002, the proportion of changed landscape was about 53%. Thus, annual rates of land cover was about 10% and 12% in the first and second periods respectively, where as the annual rate change (net rate) for the period 1982-2002 was over 8.5%. Changes in land cover proportions were unidirectional for all land covers except water (Figure 4b). Grassland, where the absolute annual rates of change was almost the same for the first and second period for the land covers. Most of the land covers change processes occurred in the first period. The overall annual rate of change in land cover (1982-2002) was highest for savannah (3.8%) and lowest for water (1.03%).

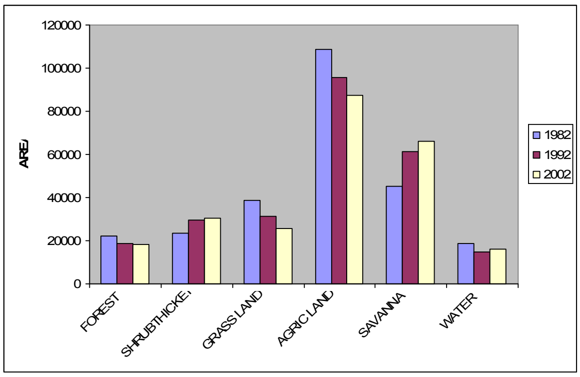

Figure 4a: Land covers proportion for 1982, 1992 and 2002.

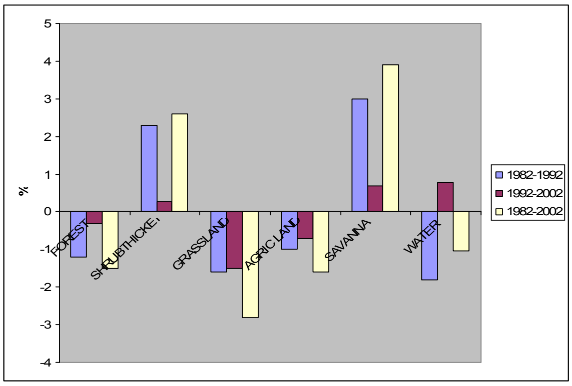

Figure 4b: Annual rate of change of land cover types

5. Conclusion

In light of the results and discussions, it can be concluded that the project produced a synthesis of available information on land cover changes on the national scale for the three stipulated periods. The land cover maps produced for each of the years are of high quality since each of them has high classification accuracy. The most dominant land cover change was conversion of natural vegetation to savannah and shrub thicket, which occurred at an annual rate of 4% and 6.5% respectively. In the first period, about 25% of natural vegetation was converted to Savannah and Shrub thicket, whereas a slightly higher fraction (28%) converted to savannah and shrub thicket in the second period. The net change from natural vegetation to cropland was 30%. The higher percentage of change in period (1992-2002) can be attributed to the changing economic opportunities and macroeconomic instability in the period.

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