International Journal of Remote Sensing & Geoscience (IJRSG)
www.ijrsg.com

FAST FOURIER TRANSFORM (FFT) ANALYSIS ON NDVI TIME SERIES FOR ASSESSMENT OF VEGETATION PATTERNS IN GHANA

Gilbert Kobla Quarshie[1,2], Edward Matthew Osei Jnr[2], Benjamin E. Kwasi Prah[2], Adwoa Sarpong Amoah[3]
[1] Survey and Mapping Division, Lands Commission, Accra, Ghana
[2] Geomatic Engineering Department, KNUST, Kumasi, Ghana
[3] Department of Civil Engineering, Kumasi Polytechnic, Kumasi, Ghana
Emails: gilbertkoblaquashie@yahoo.com chief_osei@yahoo.com, benprah@yahoo.com, lawrena80@yahoo.com

ABSTRACT

Time series analysis of Normalized Difference Vegetation Index (NDVI) imagery is a powerful tool in studying vegetation phenology in data scarce and inaccessible areas. Application of these datasets involves typically, per-pixel analysis of multi-temporal vegetation indices (VIs), which are frequently subject to high-frequency fluctuations (i.e. noise) caused by changing atmospheric conditions and varying sun-sensor-surface geometries. A broad range of NDVI noise-reduction strategies are applied in an effort to either reduce or if possible remove completely such embedded noise in these dataset. In light of this, the Fast Fourier Transform (FFT), a noise reducing algorithm in Erdas Imagine was applied to two averaged NOAA - AVHRR NDVI images acquired from Global Inventory Modeling and Mapping Studies (GIMMS) for Africa. The two averaged images were calculated from 792 NDVI images representing 1996 (i.e. 1986 -1996, 396 images) and 2006 (i.e. 1996 -2006, 396 images). Supervised clustering and maximum likelihood classifications algorithm were used to classify the NDVI dataset and vegetation maps representing 1996 and 2006 produced. These maps were visually assessed for land cover changes during the 10 year period for Ghana, and the comparison shows an alarming 11.10% increase in Grassland / Bare Surface and Settlement most probably due to increase in population. Closed or Evergreen forest decreased by 0.39%, whereas Mixture of Closed and Open Forest increased by 5.95% due to conscious effort of reafforestation programs by the government.

1.0 Introduction

1.1Background

The study of recurrent vegetative, biophysical events such as springtime budburst, leaf-out, flowering and autumnal senescence is referred to as vegetation phenology (Badeck et al., 2004). Vegetation phenology is one of the most responsive and easily observable environmental traits that vary in response to climate, rendering it of particular interest in global climate change research (Badeck et al., 2004). Spectral vegetation indices (VIs) often form the basis for remote sensing-based phenological investigations (Townshend and Justice, 1986; Huete et al., 2002). Multi temporal datasets of the normalized difference vegetation index (NDVI) continue to be the principal dataset for numerous remote sensing based phenological studies (Pettorelli et al., 2005). Its ease of application, long tradition of use and a demonstrably close relationship with photosynthetic activity at the surface (Myneni et al., 1995) have contributed to the popularity of the NDVI over the past two decades. Notwithstanding the extensive use of NDVI time series datasets, the imbedded noise in them continues to be an issue of importance. This noise must be minimized before these datasets can be used efficiently and effectively for phenological investigations. Some pre-processing is possible and indeed, it is now standard procedure for many publicly available remotely sensed NDVI datasets to be composited before distribution. But despite the compositing, however, composited dataset still contain remnant noise that requires further consideration. There are multitudes of strategies for dealing with this remnant noise (Carreiras et al., 2003). In light of this, the Fast Fourier Transform (FFT), a noise reducing algorithm in Erdas Imagine was evaluated for its efficiency.

1.21.2 The Study Area

The study area, Ghana, depicted in figure 1.1 below is located in Sub - Sahara Africa. It extends for a maximum of 672km from north to south and lies within latitudes 4.5°N and 11°N, and 536km from west to east and lies within longitude 3°W and 1°E. It is bounded to the west (668 km) by Cote d' Ivoire, to the north (548 km) by Burkina Faso, to the south (877Km) by the Gulf of Guinea and the Atlantic Ocean and to the east (668 km) by the Republic of Togo. It has a total area of 238,500 square kilometres or 92,090 square miles.

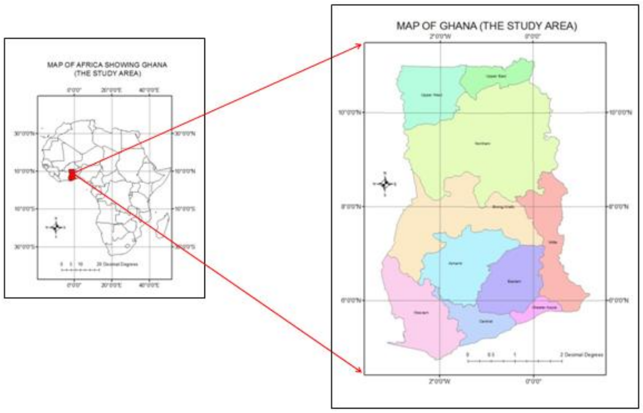

Figure 1.1: The map of Africa (left) showing the map of Ghana (right), (The Study Area)

Ghana's climate is a tropical one. It varies across the entire country and solely depends on temperature, rainfall and humidity. The topography is mainly undulating with most slopes being less than 5% and many not exceeding 1% (Boateng, 1998). It consists mostly of low plains in the south-central area with almost half of the country lying less than 152 meters (499ft) above mean sea level. A tropical rain forest belt, broken by heavily forested hills and many streams and rivers, extends northward from the shore, near the Côte d'Ivoire frontier. This area produces most of the country's cocoa, minerals, and timber. North of this belt, the country varies from 91 to 396meters (299 to 1,299ft) above mean sea level and is covered by low bush, park-like savanna, and grassy plains. Agriculture is the backbone of the Ghanaian economy and a major foreign exchange earner. It contributes about 35% to the Gross Domestic Product (GDP), employs 55% of the population on a formal and informal basis and contributes about 45% of all export earnings.

2.0 Method

2.1 Extraction of the Region of Interest, Ghana

The region of interest, shown in figure 3.1 and 3.2, was extracted using ArcMap 10.0 software. A shapefile of Ghana extracted from a shapefile of Africa with WGS 84 coordinate system and downloaded from the internet was used to clip the entire Africa NDVI datasets. These NDVI datasets prior to the clipping was georeferenced using the WGS84 shapefile Africa map. Values of the NDVI images of Ghana obtained after the extraction was reduced from an 8-bit digital number (DN) to NDVI values between 0 and 1 according to the following equation.

For 2 <= DN <= 183:

NDVI = [(DN-2)*0.0022099] - 0.2,

where DN = 0 is equivalent to water,

DN = 1 represents anomaly less than -0.2, DN = 184 represents anomaly more than 0.2 and DN = 185 is equivalent to no data.

The datasets were checked and corrected for NDVI values between 0 and 1 in order to prevent negative NDVI values that normally complicate the application of the FFT algorithm. Two separate NDVI averages of Ghana each based on ten years were calculated in ArcMap using the Raster Math in the 3D Analyst Tools. This is shown if figure 2.1 below. Finally average NDVI images representing 1996 (i.e. 1987 -1996, 360 images) and 2006 (i.e. 1997 -2006, 360 images) were used for the study.

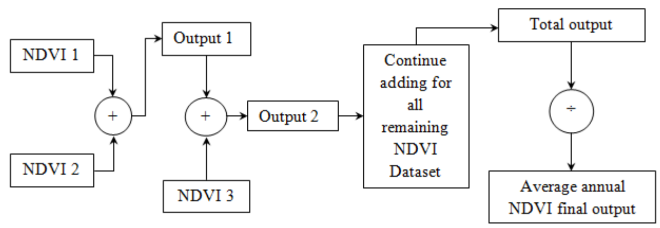

Figure 2.1: Flow chart of NDVI averages in ArcMap. (Provides answer to research question 1)

2.2 Image Noise Reduction using FFT

Before using these average NDVI images representing 1996 and 2006 to derive the vegetation zone variables, it was necessary to, as a focus of this research, reduce any inherent noise effect. The FFT tool in Erdas imagine 2010 was used to perform this task under the Convolution Spatial Enhancement option using a 3X3 Low-Pass filter. The transformation was performed as an enhancement in the frequency domain, then return to the original spatial domain by using the Inverse Fourier Transform tool. This procedure is illustrated in figure 2.2, and the result obtained is shown in figure 3.1 and 3.2.

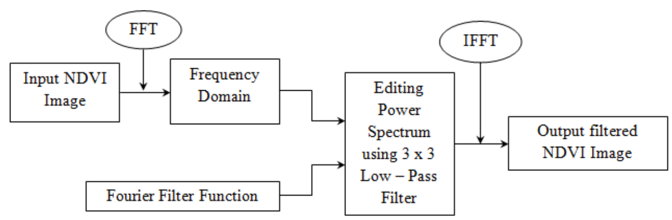

Figure 2.2: Diagram Summarizing the FFT application.

2.3 Classification of the averaged FFT NDVI dataset using Supervised Classification

"Ground truth" data obtained from three sources, ((i) 2000 land cover land use map, generated by the Centre for Remote

Sensing and Geographic Information System (CERGIS), University of Ghana, (ii) Digital topographic map of Ghana, also generated by the Survey and Mapping Division of Lands Commission and (iii) Global Positioning System data of some arbitrary selected points), were used for selection of training signatures in the NDVI images by determining which pixel of the “Ground truth” data matches that of the FFT NDVI dataset. The result of this classification is shown in figure 3.6 and 3.7 below.

3.0 Results and Discussions

3.1 Extracted average NDVI dataset for Ghana

Figure 3.1 and figure 3.2 represent the extracted average NDVI dataset for Ghana, the study area for 1996 and 2006 respectively.

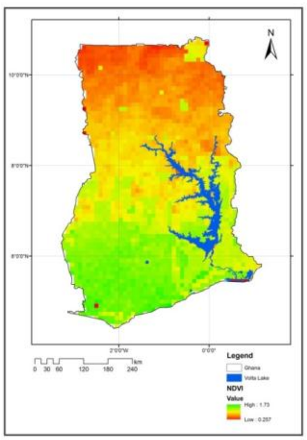

Figure 3.1: NDVI 1996

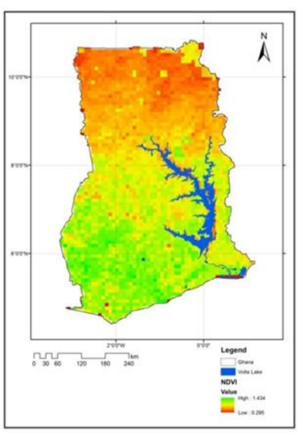

Figure 3.2: NDVI 2006

3.2 NDVI images of Ghana after applying the FFT algorithm

Figure 3.3 and figure 3.4 shows the NDVI images of Ghana after applying the FFT algorithm.

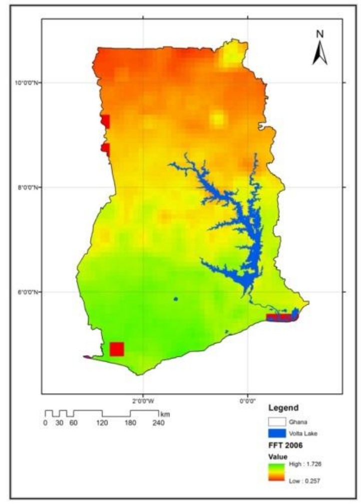

Figure 3.3: FFT NDVI 1996

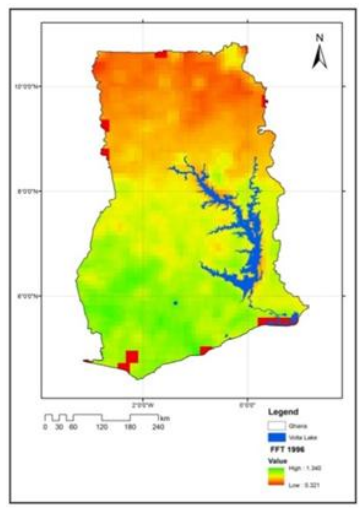

Figure 3.4: FFT NDVI 2006

3.3 The Vegetation Growth Trend Analysis

The two vegetation maps for 1996 and 2006 as shown in figure 3.6 and 3.7 were visually assessed for land cover changes during the 10 year period. The comparison shown in figure 3.5 and table 3.1 below shows an alarming change over the 10-year period.

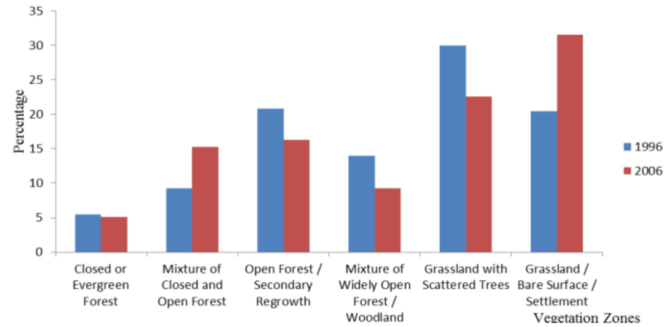

Figure 3.5: The percentage of the various vegetation types in 1996 and 2006

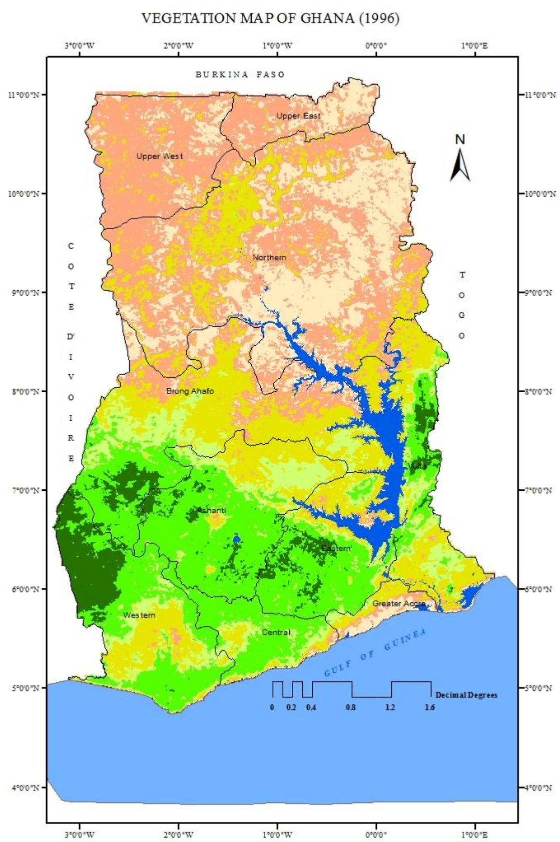

Figure 3.6: The Final FFT Vegetation Map of Ghana (1996)

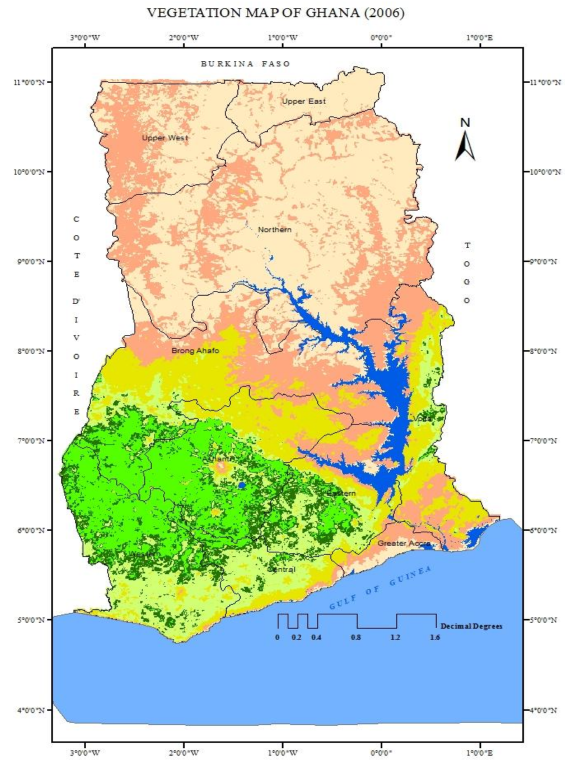

Figure 3.7: The Final FFT Vegetation Map of Ghana (2006)

Table 3.1: The area/percentage occupied by each vegetation type in 1996 and 2006

VEGETATION TYPE	1996		2006		+Δ	-Δ
	Area (km^2)	%	Area (km2)	%	%	%
Closed or Evergreen Forest	13011.56	5.47	12087.32	5.08		0.39
Mixture of Closed and Open Forest	22103.23	9.30	36259.78	15.25	5.95	
Open Forest / Secondary Regrowth	49523.41	20.83	38625.23	16.25		4.58
Mixture of Widely Open Forest / Woodland	33172.45	13.95	22008.79	9.26		4.69
Grassland with Scattered Trees	71234.23	29.96	53668.17	22.57		7.39
Grassland / Bare Surface / Settlement	48703.12	20.49	75098.71	31.59	11.10	

4.0 Conclusion

4.1 Summary of the Study

Analysis of NDVI time series proves to be a valuable tool for studying complex vegetation patterns in inaccessible and data-scarce regions. The derived results support a conclusion that areas with high value in AVHRR NDVI represent green vegetation. Application of the FFT did enhance the pictorial appearance of the NDVI time series data (comparing figure 4.1 and 4.2 with figure 4.3and 4.4). However, this benefit did not affect the subsequent extraction of the various vegetation types.

4.2 Vegetation zones that require urgent attention

Although all the six vegetation types deserve some sort of attention as far as land degradation is concerned, the Grassland vegetation requires urgent and immediate attention. These zones are considered crucial because of the fact that large parts of the population living in these zones depends on the land for crop cultivation and animal farming as the basic source of their livelihood. The Mixture of Closed and Open Forest, which serves as the corridor between the Closed or Evergreen Forest and the Grassland vegetation is equally a priority zone that also requires some intervention even though it increased in acreage from 1996 to 2006. This zone may quickly replace the existing Closed or Evergreen Forest when logging and farming actives expand over the entire forest ecological zone.

4.3 Recommendation

1) Apart from investigating the efficiency of a noise reduction technique, future studies could also look at the possibility of generating a GIS Database model for Early Warning System.
2) NDVI datasets from other satellites could also be evaluated.
3) Other noise reduction techniques could also be investigated.

5.0 References

[1.] Badeck, F. W., Bondeau, A., Böttcher, K., Doktor, D., Lucht, W., Schaber, J. and Sitch, S., 2004, Responses of spring phenology to climate change. *New Phytologist*, **162**, 295 309.

[2.] Boateng, E., 1998. Proceedings of Workshop a Land Use Planning. FAO Land Use Planning Project. TCP/GHA/67/6715/A.

[3.] Carreiras, J. M. B., Pereira, J. M. C., Shimabukuro, Y. E. and Stroppiana, D., 2003, Evaluation of compositing algorithms over the Brazilian Amazon using SPOT-4 VEGETATION data. International Journal of Remote Sensing, 24, 3427-3440.

[4.] Huete, A., DidaN, K., Miura, T., Rodriguez, E.P., Gao, X. and Ferreira, L.G., 2002, Overview of the radiometric and biophysical performance of the MODIS vegetation indices. *Remote Sensing of Environment*, **83**, 195-213.