Mapping the Effects of Anthropogenic Activities in the Catchment of Weija Reservoir using Remote Sensing Techniques*

[1]N. D. Tagoe and [1]S. Mantey
[1]University of Mines and Technology, P. O. Box 237, Tarkwa, Ghana

Tagoe, N. D. and Mantey, S., (2017), "Mapping the Effects of Anthropogenic Activities in the Catchment of Weija Reservoir using Remote Sensing Techniques", *Ghana Mining Journal*, Vol. 17, No. 2, pp. 6 - 11.

Abstract

Man has contributed to land cover alteration since time-immemorial through clearing of land for residential, agriculture, recreational and industrial purposes. The emergence of adapting wild plants and animals for human use as well as industrialisation have also contributed to the alteration of land cover. Over the years, anthropogenic activities have had great impact on the Weija catchment. This study seeks to map the catchment and determine the impact of anthropogenic activities using Remote Sensing techniques. Observations and measurements were made on the field as well as classification of land cover using Landsat images of years 1991, 2003 and 2017. Results showed an increase in built-up areas by 18% from 1991 to 2017. Other classes such as shrubs increased due to decrease in dense vegetation. This study confirms the use of Remote Sensing as a valuable tool for detecting change in land cover and determining the impact of anthropogenic activities in the Weija Catchment.

Keywords: Land Cover, GIS, Remote Sensing, Weija Catchment, Anthropogenic Activities

1 Introduction

Water bodies around the world are known to be the key source of sustainable life and good ecosystems. Ghana has many water bodies that serve as a source of water supply. The Weija reservoir is a major source of water supply for millions of residents in Accra East and West (Anon., 2015).

This water body has been affected by human activities along the banks and within the reservoir itself over the years. In recent years activities such as irrigation, pollution, sand winning and encroachment on the reservoir and along its boundary have caused serious effects on the water causing harm to the surrounding ecosystem and shortage in water supply. This has raised a series of environmental concerns.

Remote sensing techniques have been used over the years and it has proven to be of great value for monitoring changes at regular intervals (Ramachandra and Kumar, 2004; Zubair, 2006).
Many studies address the relationships between land use and water pollution (Yong and Chen, 2002; Bai *et al*., 2010; Tim and Jolly, 1994; Ahearn, *et al*., 2005). Generally, built-up and agricultural areas have significant positive correlations with water pollution (Huang *et al*., 2015; Tafangenyasha and Dube, 2008). Land use Land cover (LULC) is necessary in identifying and mapping natural resources and human activities which have a great effect on water quality deterioration. Areas that are dominated by industrial and agricultural activities are more vulnerable to water pollution (Roberts and Prince, 2010; Tafangenyasha and Dube, 2008).

This study seeks to determine the extent of human activities and its impact in the catchment of the Weija reservoir.

The Weija reservoir is located in the Ga south municipality which is part of the communities that receive water from the Weija treatment plant. The Weija reservoir, lies between geographical coordinates 5^0 33′ 0″N and 5^0 40′ 0″ N and 0^0 20′ 0″W and 0^0 24′ 0″ W (Anon., 2016). The Weija Catchment was selected because of the increase in human activities and also the importance of the Weija reservoir. The catchment lies in the coastal savannah agro-ecological zone with a bi-modal rainfall pattern and has an area of about 256 sq.km (Anon., 2017).

The Weija reservoir is 14 km long, 2.2 km wide and with a surface area of about 38 sq.km (Vanden Bossche and Bernacsek, 1990). The reservoir has been in existence for a period of 39 years after it was reconstructed by the Ghana Water Company in 1978. The reconstruction was initiated because the existing dam got breached by flood in 1968 (Asante *et al*., 2008). The effective storage capacity is approximately 133 million m^3, calculated as reservoir volume at maximum design level of 143 million m^3 (Anon., 2007). The Weija reservoir has its source from the Densu river. The Weija Catchment lies on the Western Lowlands of the Densu river and characterised by a low and rolling topography with a base of about 67 metres above

*Manuscript received September 06, 2017
Revised version accepted November 27, 2017
https://dx.doi.org/10.4314/gm.v17i2.2

mean sea level. It is broken by steep low ridges in several places ranging from 300 to 567 metres above mean sea level. The catchment comprises of mainly gneiss and granite to the west and sandstone, siltstone and shale in the east (Kuma and Ashley, 2008). There are two rivers that drain the catchment, they are the Densu and Ponpon river. The Densu river is the larger of the two drains from the eastern region through the western portions of the area where it enters the sea (Anon., 2017). Studies have shown that due to anthropogenic activities, the earth‘s surface is being significantly altered and the presence of man on earth and his use of land has had a great effect on the natural environment (Opeyemi, 2008).

Over the past years, data from Earth sensing satellites have become vital in mapping the earth’s features and infrastructures, managing natural resources and studying environmental change (Longley, 2005; Mayomi, 2009).

Land cover is composed of arrays due to a variety of natural and human-derived processes which includes vegetation, non-vegetation and man-made features such as roads, rivers, quarries, buildings, *etc*. (Rozenstein and Anon., 2011).

For land use, various approaches are proposed in literature (Mücher *et al.,* 2001). Two main “schools” may be distinguished. In terms of functional dimension, Land use agrees with the description of areas in terms of their socio-economic purpose in terms of functional dimension: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, *etc*. Links with land cover are possible; it may be possible to infer land use from land cover and conversely. But situations are often complicated and the link is not so evident. Another approach, termed sequential, has been particularly developed for agricultural purposes. The definition is a series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources. For example, a sequence of operations such as ploughing, seeding, weeding, fertilizing and harvesting (Mücher *et al.*, 2001).

2 Materials and Methods Used

2.1 Materials Used

The materials used for this study include; Landsat 4 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper and Landsat 8 Operational Land Imager (OLI) images obtained from the United States Geological Survey (USGS); Environmental System and Research Institute (ESRI) shapefiles of Weija catchment obtained from the Geomatic Engineering Department of the University of Mines and Technology (UMaT) were used for this study. Trimble Juno SB handheld GPS receiver was also used to collect data for ground truthing.

2.2 Methods Used

The methods used for this study have been grouped in stages as shown in Fig. 1.

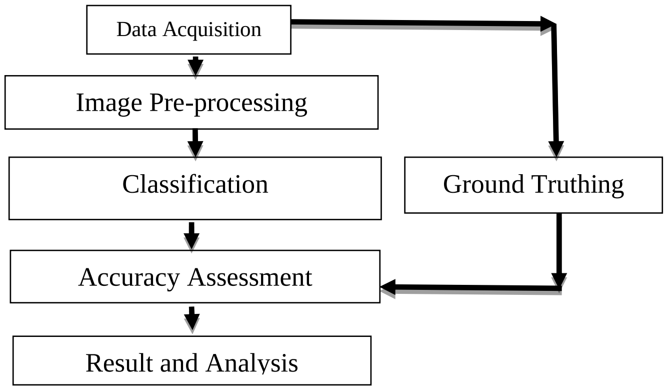

Fig. 1 Flowchart of Summary of the Methods Used

2.2.1 Image Acquisition and Pre-Processing

The initial stage of this work considered the collection of data. Data sets in the form of Landsat Imagery for the years 1991, 2003 and 2017 were collected from the U.S. Geological Survey. Geometric and radiometric corrections were performed on the imageries in order to correct for altitude and attitude, scanner distortions, earth motion, variable detector response, *etc*. using tools in ArcGIS software. The pre-processing involved conversion of digital numbers to Radiance then from Radiance to reflectance. The corrected images were then combined or stacked.

2.2.2 Unsupervised classification of images

An unsupervised (Iterative Self-Organising cluster) classification was then performed on the layers which were stacked together. The stacked layer was divided into five classes. The number of classes were determined after field reconnaissance. The output image was then analysed to obtained more information about the various land cover classes present.

2.2.3 Supervised Classification

Supervised classification was performed to classify the image into different LULC classes as supervised classification has higher accuracy compared to unsupervised classification since the classes were trained. Hence, selected control points that included the LULC classes were sampled to create a signature file to help train the algorithm to classify the entire study areas. Care was taken to minimise error by avoiding mixed pixels. Maximum likelihood classifier was used for the supervised classification and five land cover classes were generated as described in Table 1.

Table 1 Land Cover Classes and Composition

Land Cover Classes	Detailed Composition
Water Body	Lakes and rivers
Dense vegetation	A canopy of trees coverage
Shrubs	Areas were vegetation is dominated by shrubs
Built-up area	This include Residential and Commercial facilities
Barelands	Lands with exposed surfaces due to human activities

2.2.4 Accuracy Assessment

Accuracy assessment was performed on the classification results. The accuracy was assessed using the results of error matrix which provides a clear foundation for accuracy assessment (Congalton, and Green, 1993; Canters, 1997) was generated from this study on satellite imagery for 2017. Reference data for the various land classes was obtained from the study area by ground truthing. The overall accuracy of 85.00% was obtained for this study. This accuracy is acceptable from literature (Anderson *et al*., 2001; Congalton, and Green, 1993; Canters, 1997).

3. Results and Discussion

3.1 Results

Five land cover classes as shown in Figs. 6, 7 and 8 were obtained from each of the three satellite images acquired. The images were from the years 1991, 2003 and 2017. The results on the extent of change was found and the area of each land cover for the three years determined in sq. km of which percentages were also calculated as represented in Table 2, Table 3 and Table 4 for 1991, 2003 and 2017 respectively. Graphical representations of the areas were also shown in Fig. 2 for 1991, Fig. 3 for 2003 and Fig. 4 for 2017. Fig. 5 shows the proportions of landcover from 1991 to 2017.

Table 2 Land Use Area for 1991

Class	Sq. km	%
Water Body	26.437	10.327
Dense vegetation	89.140	34.820
Shrubs	41.007	16.018
Built-up area	19.967	7.799
Bareland	79.447	31.034
Total	255.998	100.000

Table 3 Land Use Area for 2003

Class	Sq. km	%
Water Body	29.055	11.350
Riverine vegetation	33.338	13.023
Shrubs	121.455	47.443
Built-up area	66.282	25.892
Bareland	05.867	02.292
Total	255.998	100.000

Table 4 Land Use Area for 2017

Class	Sq. km	%
Water Body	25.966	10.143
Riverine vegetation	75.910	29.653
Shrubs	71.798	28.046
Built-up area	67.664	26.431
Bareland	14.660	05.727
Total	255.998	100.000

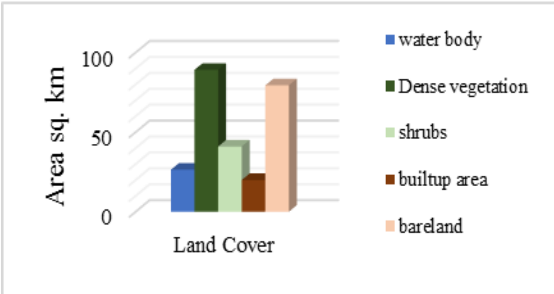

Fig. 2 Chart of Land Cover for 1991

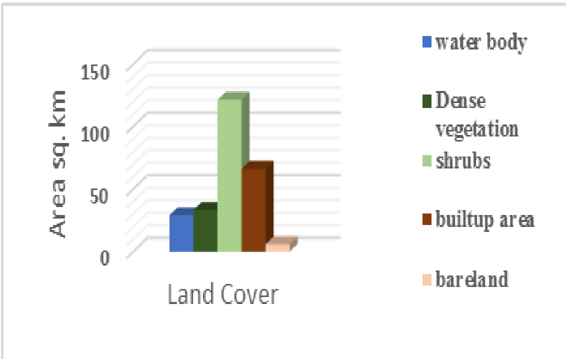

Fig. 3 Chart of Land Cover for 2003

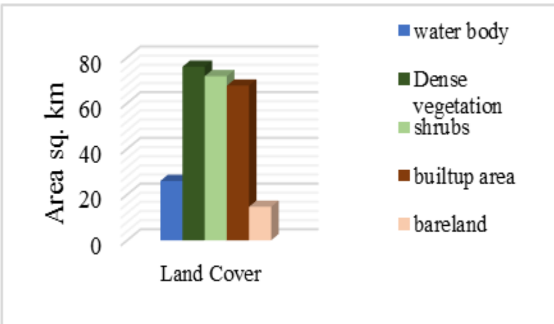

Fig. 4 Chart of Land Cover for 2017

Table 5 Land Cover Change from 1991 to 2017

Class	Change Sq. km	%
Water Body	-0.471	-0.184
Riverine vegetation	-13.229	-5.167
Shrubs	30.791	12.027
Built-up area	47.697	18.631
Bareland	-64.787	-25.307

Note: Negative sign indicates a decrease

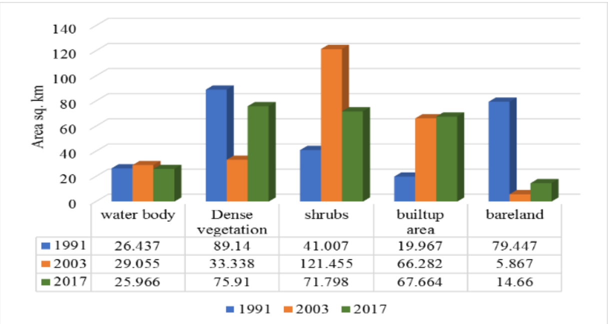

Fig. 5 Proportions of Land Cover:1991 to 2017

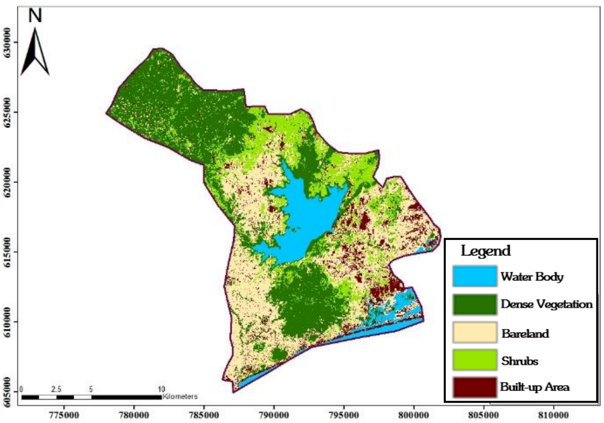

Fig. 6 A Land Cover Map of 1991

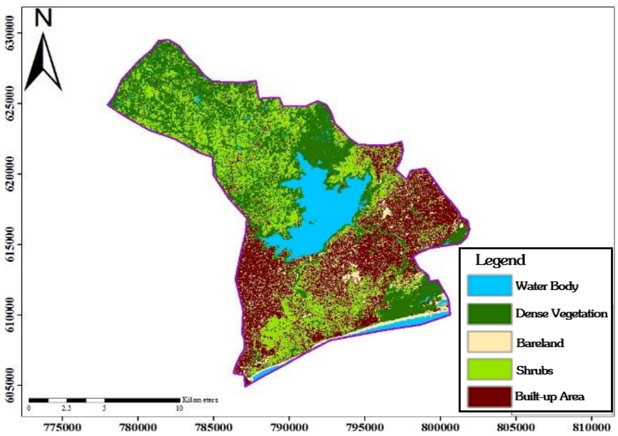

Fig. 7 A Land Cover Map of 2003

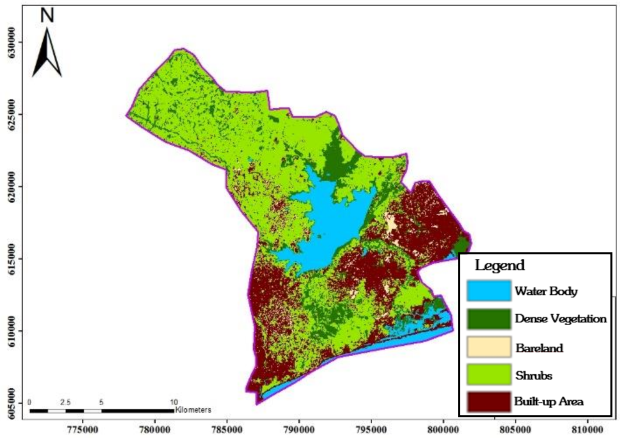

Fig. 8 A Land Cover Map of 2017

3.2 Discussion

The results obtained from the Landsat images show changes in the various land use over the period of 26 years. Between the years of 1991 and 2003 there was an increase in area of water body which decreased in the year 2017.

In 1991, Dense vegetation was at its peak but subsequently decreased in 2003 and increased again in 2017 as shown in Fig. 5. Dense vegetation decreased overall by 5.167% bringing about an increase in shrubs by 12.027% (Table 5). Built-up areas which have a positive correlation with water pollution increased by 18% in total from 1991 to 2017 in the catchment. Built-up areas was at a low of 7.8% in 1991 and increased massively to 25.892% in 2003 and also by 26.431% of total land cover in 2017.

Increase in urbanisation and industrialisation is seen to have been the cause of Increased in the rate of settlement in the catchment due to the inflow of people looking for barelands to put up structures.

4. Conclusions and Recommendations

4.1 Conclusions

In this study, five land cover classes were distinguished from the satellite images of 1991, 2003 and 2017 for the Weija catchment to monitor anthropogenic activities over a twenty-six-year period.

The catchment area has witnessed increase in built-up areas due to rapid urbanisation and industrialisation. The nearness of the catchment area to Accra and high demand for lands for residential purposes and other activities have resulted in population increase in the area.

Built-up area which have a positive correlation with water pollution (Pijanowski and Kanownik, 1997), increased by 18% in the catchment. Dense vegetation decreased by 5.167% bringing about an increase in shrubs by 12.027%. Bare lands were as a result of clearing of the lands for agricultural purposes and stone winning and this has decreased as a result of monitoring of the area by army personnel an initiative of the government of Ghana. The northern part of the area seemed to have a good amount of vegetation cover and this can be protected.

4.2 Recommendations

This study recommends that environmental by-laws and other laws regulating the acquisition of land, waste disposal, farming and fishing practices should be enforced by the GWCL and EPA to ensure proper management of the land in the areas. Also, a buffer should be created along the reservoir to protect it from further encroachment.

Tree planting or afforestation program should be implemented to increase the number of dense vegetation. Continuous monitoring of the perimeter of the reservoir should be continued.

Public awareness and Further studies such as regular water quality checks should be conducted in the area.

Acknowledgements

The authors are grateful to Jonathan Ansah, a graduate Geomatic Engineer from University of Mines and Technology for his support during data collection for this study.

References

Ahearn, D. S., Sheibley, R. W., Dahlgren, R. A., Anderson, M., Johnson, J., and Tate, K. W. (2005), "Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California," *Journal of Hydrology*, Vol. 313, no. 3-4, pp. 234–247.

Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E., (2001). A Land Use and Land Cover Classification System forUse with Remote Sensor Data, *Geological Survey Professional Paper 964*, United States Government Printing Office, Washington: 1976, 40 pp.

Anon. (2007), "Densu River Basin: Integrated Water Resources Management Plan", *Water Resources Commission*, 83 pp.

Anon. (2015), "Densu River Basin: Integrated Water Resources Management Plan", *http://www.wrc-gh.org/basins/densu/*. Accessed: March 19, 2017.

Anon. (2016), "Satellite Images of Weija", *http://www.maplandia.com/ghana/greateraccra/ga/weija/*. Accessed: 12th March, 2017.

Anon. (2017), "Climate and Drainage" *http://www.gsmaweija.com/climate_vegetatio.html*. Accessed: March 20, 2017.

Anon. (2017), "Topography and Drainage" *http://www.gsmaweija.com/topography_drainage.html*. Accessed: March 20, 2017.

Asante, K. A., Quarcoopome, T. and Amevenku, F. Y. K., (2008), "Water Quality of the Weija Reservoir after 28 Years of Impoundment", *West Africa Journal of Applied Ecology*, Vol. 13, pp. 125-131.

Bai, J., Ouyang, H., and Xiao, R. (2010), "Spatial variability of soil carbon, nitrogen, and phosphorus content and storage in an alpine wetland in the Qinghai-Tibet Plateau, China," *Australian Journal of Soil Research*, Vol. 48, no. 8, pp. 730–736.

Canters, F. (1997). Evaluating the uncertainty of area estimates derived from fuzzy land-cover classification. *Photogrammetric Engineering and Remote Sensing*, 63, 403 – 414

Congalton, R. G., & Green, K. (1993). A practical look at the sources of confusion in error matrix generation. *Photogrammetric Engineering and Remote Sensing*, 59, 641 – 644.

Huang, J., Huang, Y., Pontius, R. G. and Zhang, Z., (2015), "Geographically weighted regression to measure spatial variations in correlations between water pollution versus land use in a coastal watershed", *Ocean Coastal Manage*, 103, pp. 14–24.

Kuma, J. S. and Ashley, D. N. (2008), "Runoff Estimates into the Weija Reservoir and its Implications for Water Supply to Accra, Ghana", *Journal of Urban and Environmental Engineering*, Vol. 2, No. 2, pp. 33-40.

Longley, P., (2005), *Geographic Information Systems and Science*, John Wiley and Sons Inc, West Sussex, 517 pp.

Mayomi, I., (2009), "Assessment of Human Impacts on Land Use and Vegetation Cover Changes in Mubi Region, Adamawa State, Nigeria; Remote Sensing and GIS Approach", *Global Journal of Environmental Sciences*, Vol 8, No 2, pp. 12-22.

Mücher, C. A., Champeaux, J. L., Steinnocher, K. T., Griguoio, S., Wester, K., Heunks, C., Winiwater, W., Kressier, F. P., Goutorbe, J. P., Ten Brink, B. and Van Katwijk, V. F. (2001), "Development of a Consistent Methodology to Derive Land Cover Information on a European Scale from Remote Sensing for Environmental Monitoring", *The Pan-European Land Cover Monitoring Report*, 178 pp.

Opeyemi, Z. (2008), Monitoring the growth of settlements in Ilorin, Nigeria (a GIS and Remote Sensing approach), The International Archives of the Photogrammetry, *Remote*

Sensing and Spatial Information Sciences, pp. 225-232.

Pijanowski Z. and Kanownik W. (1997), Variability of selected concentrations of chemical substances in surface waters flowing through variously managed rural areas. Annals AR Poznan, *Land Reclamation and Env. Eng.* 19.2, pp. 347.

Ramachandra, T. V. and Kumar, U. (2004), "Geographic Resources Decision Support System for Land Use, Land Cover Dynamics Analysis", In *Proceedings of the FOSS/GRASS Users Conference*, pp. 12-14.

Roberts, A. D. and Prince, S. D. (2010), "Effects of urban and non-urban land cover on nitrogen and phosphorous runoff to Chesapeake Bay", *Ecological Indicators* Vol. 10 No. 2, pp. 459–474.

Rozenstein, O. and Karnieli, A. (2011), "Comparison of Methods for Land-Use Classification Incorporating Remote Sensing and GIS inputs". *Applied Geography*, Vol. 31, No. 2, pp. 533-544.

Tafangenyasha, C. and Dube, L. T., (2008), "An investigation of the impacts of agricultural runoff on the water quality and aquatic organisms in a lowveld sand river system in Southeast Zimbabwe," *Water Resources Management*, Vol. 22, no. 1, pp. 119–130, 2008.

Tim, U. S. and Jolly, R., (1994), "Evaluating agricultural nonpoint-source pollution using integrated geographic information systems and hydrologic/water quality model," *Journal of Environmental Quality*, Vol. 23, no. 1, pp. 25–35.

Vanden Bossche J.P. and Bernacsek G.M. (1990), Source Book for the Inland Fishery Resources of Africa, *CIFA Technical Paper*, Vol (1), No. 18/1, 240pp.

Yong, S. T. Y. and W. Chen, W. (2002), "Modeling the relationship between land use and surface water quality," *Journal of Environmental Management*, Vol. 66, no. 4, pp. 377–393.

Zubair, A. O. (2006), "Change Detection in Land Use and Cover using Remote Sensing Data and GIS: A case study of Ilorin and its environs in Kwara State", *MSc Thesis*, University of Ibadan, Nigeria, 54pp.

Authors

Naa Dedei Tagoe is a Lecturer at the Department of Geomatic Engineering of the University of Mines and Technology (UMaT), Tarkwa, Ghana. He holds a Bachelor of Science degree in Geomatic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. She obtained her Master of Science and Doctor of Philosophy in Photogrammetry degrees in Photogrammetry and Geoinformatics from Stuttgart University of Applied Sciences and University of Cape Town respectively. Her research interests include Close Range Photogrammetry, 3D Modelling of Cultural Heritage Sites, Remote Sensing, UAV and Web-GIS Applications. She is a Member of IFUW.

Saviour Mantey is a Senior Lecturer at the Department of Geomatic Engineering of the University of Mines and Technology (UMaT), Tarkwa, Ghana. He holds a Bachelor of Science degree in Geomatic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. He obtained his Master of Philosophy and Doctor of Philosophy degrees from University of Cambridge and University of Mines and Technology respectively. His research interests include application of Remote Sensing and GIS in Health and Environmental Analysis, UAV and Web GIS applications.