International Journal of Engineering and Applied Computer Science

Volume: 04, Issue: 03, April 2022 ISBN: 9780995707544

# Using Geographic Information Systems (GIS) to Model the Clustering Effect of COVID-19 in South-Western Zimbabwe

*Norman Karimazondo[1], Lawrence Mango[2], Michael Make Montana[3], Gideon Walter Mutanda[4]*

[1,2,3] Faculty of Environmental Management, Prince of Songkla University, Hatyai, Thailand.
[4] Department of Physics, Geography and Environmental Science, School of Natural Science, Great Zimbabwe University, Masvingo, Zimbabwe.

10.24032/IJEACS/0403/001



**Empirical Research Press Ltd.**
London, United Kingdom

# Using Geographic Information Systems (GIS) to Model the Clustering Effect of COVID-19 in South-Western Zimbabwe

***Abstract*—The purpose of the study was to model the clustering of COVID-19 in Bulawayo, Zimbabwe. A cross-sectional study design was used to provide a snapshot of the occurrence of COVID-19 in Bulawayo at a particular time. About 246 COVID-19 cases were randomly selected from the list of cases that occurred in Bulawayo as of 1 August 2020. The data was analyzed in ArcGIS using spatial autocorrelation and hotspot analysis. From the observed pattern, the results demonstrated a significant overall spatial autocorrelation and clustering of COVID-19 cases in Bulawayo. The hotspot analysis showed hotspot localities around the Western Suburbs such as Nkulumane, Cowdry Park, and Luveve. These are high-density suburbs, endorsing that pattern of COVID-19 infections is related to the population density pattern in Bulawayo. In conclusion, hotspot areas detected in this study can help identify future infectious disease surveillance.**

***Keywords- COVID-19, GIS, Hotspot Analysis, Spatial Autocorrelation.***

## I. INTRODUCTION

The "Novel Coronavirus 2019-nCov" (COVID-19), which began from Wuhan, Hubei Province of China in December 2019, resulted in severe acute respiratory syndrome (SARS) has rapidly spread to other countries around the globe, including Zimbabwe [2]. Despite substantial efforts to contain the disease within China, particularly in Hubei, a large number of countries are battling to slow down the spread of the "Novel Coronavirus 2019-nCov" through testing, rapid screening, isolation, contact tracing, case management as well as applying social distancing and lockdowns [21]. The study proposed additional ways to fight against COVID-19 using GIS in supporting early and easy detection of emerging hotspots to contain the disease. Therefore, this study specifically modeled the clustering of COVID-19 in Bulawayo using the Getis-Ord Gi* statistical method based on hotspot analysis. Global Moran's I statistic, is used to test the null hypothesis, "Covid-19 is randomly distributed in Bulawayo". This section has laid the introductory background to the study. The next section gives the related literature in detail. This is followed by the section on research methodology, which is then followed by a section on results and discussion. The final section gives the conclusion of the study.

## II. LITERATURE REVIEW

### *A. Health Mapping*

Health mapping can be described as the activities, tools, and techniques that are utilized to link geographic location as the common denominator which integrates community and health data [12, 23]. Health maps are good at showing the cartographic representation of the environmental setting, health services, and spatial distribution of diseases at the same time. Health mapping supports the core functions of public health such as targeting, surveillance, and intervention. Similarly, these functions are reinforced through public health practices that include policy development, assessment, and assurance [16]. The actual importance of health mapping arises when maps are associated with disease prevention and control efforts to prevent future infection [4, 11].

Health experts have historically considered both geographic information systems (GIS) and conventional mapping, as critical tools for combating and tracking infectious diseases. The first disease map that shows the association between health and geographic location was based on plague outbreaks at Bari, Italy in 1694 [5]. Since then, the importance of a map as a communication tool thrived up to today in the service of tracking and surveillance of infectious diseases such as yellow fever, cholera, and influenza pandemics [22]. However, the disease mapping tasks encountered several challenges during that time [19]. Firstly, the authors hardly documented some of the evidence which was used to create maps. Secondly, before the advancement of GIS, several errors arose in mapping tasks which were expanded exceedingly at global scales. Thirdly, there was a lack of reliable assessment of maps which resulted in inaccurate precision. With the advent of computerized geographic information systems in the 1960s, the possibilities for visualizing, analyzing as well as spotting patterns of infectious disease dramatically improved again [1]. According to [3], the latest review of health GIS literature established that 28.7% of the reviewed papers focused on infectious disease mapping.

Research on the distribution of infectious diseases across geographic space can be categorized into three main classes that are related to disease ecological analysis and clustering, and mapping. GIS-based disease mapping is influenced by several aspects such as the socio-economic data, environmental risk factors, and location as well as spreading patterns of disease [15]. Likewise, GIS-based disease clustering evaluates the spatial clustering of diseases [13]. Furthermore, disease clustering relies on the assessment of potential environmental risk factors prevailing at a particular geographic location that represents a possible hazard. Ecological analysis research is related to epidemiological inquiry since the main focus is on the analysis of the spatial distribution of diseases about explanatory covariates which are aggregated at spatial levels [24].

### *B. Modeling Diseases Clustering in GIS*

A set of analytics can be performed by GIS software to reveal COVID-19 clustering. These analytics can support studies on the spread of COVID-19 by integrating as well as modeling spatial data in a way that helps health experts to locate cases and exposures and identify disease clusters [6]. Previous studies have observed that infectious diseases tend to be clustered in certain geographic areas [7, 18]. Likewise, the spatial heterogeneity of infectious diseases such as COVID-19 is mostly ascribed to changes in environmental risk factors such as climate and land use [10]. As such, hot spots distribution usually coincides with high population densities hence those areas are at great risk of diseases [11].

There are three most important analytics for modeling disease clustering within GIS software. Firstly, is the Kernel Density Estimation Method, which is used to generate geographical distribution maps for epidemics by way of predictive modeling of disease risks [15]. Secondly, is the Weighted Standard Deviational Ellipses Method, which can match disease spatial distributions as well as identify the possible spatial directions [20]. Thirdly, is the Hotspot Analysis Method that calculates the Getis'Ord Gi* value to ascertain where the particular disease is more concentrated [25].

In the intervening time, the rapid development in GIS itself is showing unlimited potential as a way of sharing infectious disease information [8]. Infectious disease like COVID-19 travels so rapidly and information has to move even quickly hence the need for GIS become crucial [17]. Communication through maps improves data transparency and offers reachable information to the public [3]. According to [19] such disease surveillance requires many statistical epidemiological methods with geospatial features to investigate epidemics, if possible, from localized areas. This study is particularly focused on the city of Bulawayo in Zimbabwe, where the COVID-19 outbreak seems to emerge in small areas and then spread widely.

## III. MATERIAL AND METHODS

### *A. Study Area*

The study was carried out in Bulawayo (20°09′00″ S, 28°34′59″ E) Province, Zimbabwe. It is located 444km southwest of Harare and is the second-largest city in Zimbabwe (Figure 1). The area of Bulawayo is approximately 1,706.8 km2 and has an elevation of about 1,358 m above sea level.

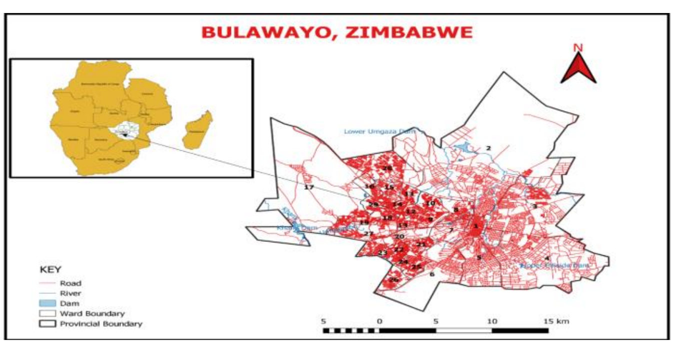


**Figure 1. Bulawayo Map Showing Hotspot Areas**

### *B. Materials*

About two software packages were employed for data processing, visualization, and analysis in this study. These include ArcGIS 10.5 for editing geodata in the graphical front end and Microsoft Excel for creating comma-separated value (CSV) files on point data.

### *C. Methods*

#### *1. Sampling*

In this study, a cross-sectional study design was used to assess the prevalence of COVID-19 in Bulawayo. As a cross-sectional study, the study was interested in COVID-19 cases that occurred in Bulawayo during a given period. Based on the study, the population consisted of 837 COVID-19 cases that occurred in Bulawayo between 21 March 2020 and 1 August 2020. About 246 COVID-19 cases were randomly selected from the list of cases that occurred in Bulawayo during that time.

#### *2. Data acquisition*

This study used both primary and secondary data sources to model the clustering of COVID-19 in Bulawayo. Secondary data used in this study include shapefiles for rivers, roads, suburbs, and provincial boundaries which were digitized from the topographic map of Bulawayo and were obtained from the Department of Surveyor General. The non-spatial data associated with these shapefiles include the number of COVID-19 patient cases for each suburb and contact addresses for confirmed COVID-19 cases, which were collected from the Ministry of Health and Child Care records

To suit the research needs for this study, the secondary data obtained from the Ministry of Health and Child Care was combined with primary data collected in the field. The contact list for sampled COVID-19 cases was updated to show the point location for each COVID-19 case. The points were collected during a field measurement using a single GPS, Garmin Etrex 20 with an average error of 3 m based on the UTM grid system.

#### *3. Data analysis in QGIS*

Spatial analysis was used to map the clustering of the COVID-19 to detect the trends of prevalence in Bulawayo. Initially, Global Moran's I, spatial autocorrelation statistic was used to identifying the spatial pattern of COVID-19 in Bulawayo. Global Moran's I technique indicates that a significant positive spatial autocorrelation of COVID-19 would mean that the geographical distribution is more spatially grouped than a random-based spatial process. Global Moran's I index stretches from −1 to +1, with the zero scores indicating that there is no clustering. Whereas, a positive score would indicate clustering of COVID-19 cases. Contrary, a negative score showed that neighboring areas are characterized by dissimilar C0VID-19 cases and indicate dispersal.

Finally, the Getis'Ord Gi* statistic was used to model the spatial spread of COVID 19. The application of this model was centered on the available COVID-19 datasets for each suburb in Bulawayo. This study used a hotspot analysis tool for calculating the Getis'Ord Gi* statistic for each particular COVID-19 case in the dataset. The subsequent z-scores and p-values from the results define where COVID-19 cases with either low or high values are spatially clustered. For statistically significant positive z-scores, the greater the z-score, the higher intensity of clustering for high values and this resembles the hot spot areas. For statistically significant negative z-scores, the lesser the z-score, the higher intensity of clustering for low values and this resembles cold spots. The results of hotspot analysis determine where COVID-19 will be highly concentrated which helps in the allocation of health services as well as the promotion of well-being and good health by scaling up COVID-19 interventions [14].

## IV. RESULTS AND DISCUSSION

### A. *Results*

Figure 2 illustrates the spatial autocorrelation results based on sampled COVID-19 cases in Bulawayo. Given a z-score of 2.49908507644, there is a less than 5% likelihood that this clustered pattern obtained could be a result of random chance. The results demonstrate that there was a significant overall spatial autocorrelation and clustering of COVID-19 in Bulawayo.

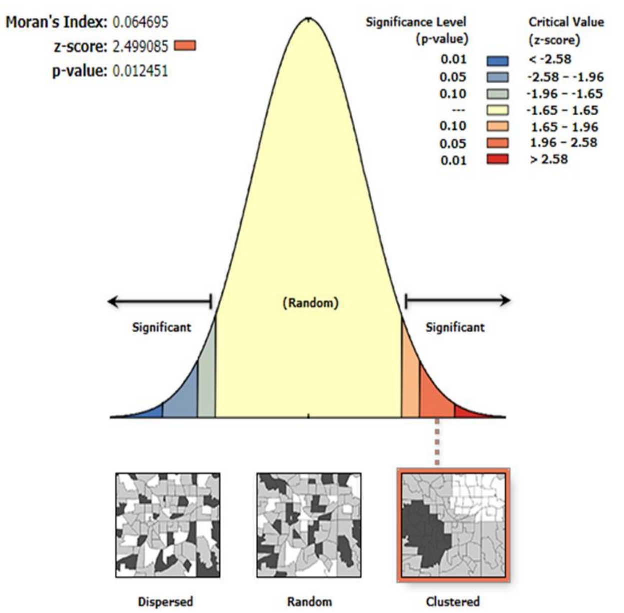


**Figure 2. Bulawayo COVID-19 Spatial Autocorrelation Report**

In this study, the Getis'Ord Gi* statistic was applied to the collected data to model the clustering of COVID-19. Figure 3 presents the hotspot analysis results. The hotspot analysis revealed hotspot locations in the Western suburbs and cold spot locations in the Northern, Eastern, and Southern suburbs. This confirms that COVID-19 is more concentrated in the Western part of Bulawayo (Figure 3).

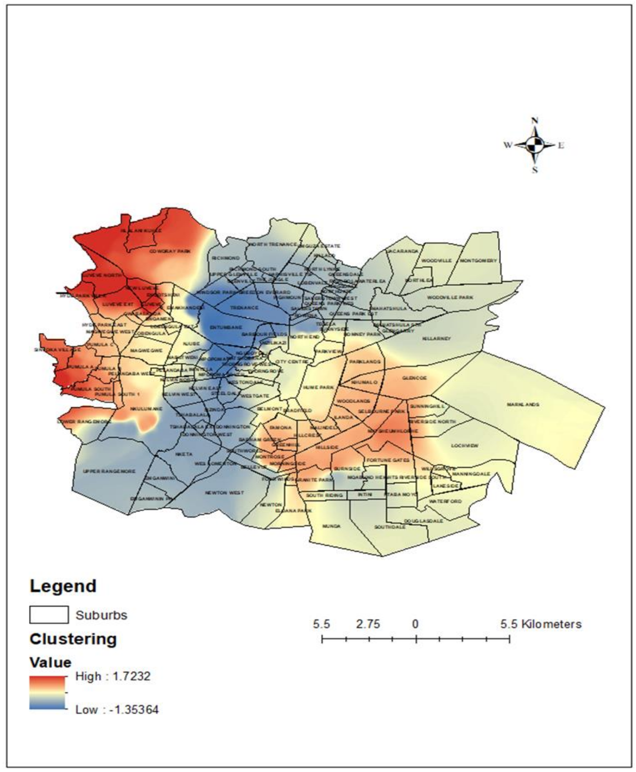


**Figure 3. The Clustering Effect of COVID-19 in Bulawayo**

### B. *Discussion*

The utilization of GIS in health care research is improving, and its application is becoming more sophisticated. In this study, GIS-based spatial statistical methods were successfully used to model the clustering of COVID-19 in Bulawayo, Zimbabwe. The study showed that COVID-19 is greatly concentrated in the Western part of the city as compared to the Eastern, Northern, and Southern parts of the city. This is supported by the significant spatial autocorrelation of COVID-19 cases, which demonstrates that the spatial distribution of COVID-19 follows a clustered pattern. Therefore, the results for this current study, confirms the findings from previous studies which observed that infectious disease tend to be clustered in certain geographic areas [7, 18]. Based on previous studies, the spatial heterogeneity of infectious diseases such as COVID-19 is mostly ascribed to changes in environmental risk factors such as climate and land use [10].

Based on the observed pattern, variation in COVID-19 coincides with hotspot distribution. The hotspot analysis showed hotspot locations in and around the Western suburbs such as Nkulumane, Cowdry Park, and Luveve. These suburbs are considered high-density areas, which confirms that patterns of COVID-19 infections follow the population density pattern in Bulawayo. These suburbs are often dominated by great levels of low socio-economic status. This demonstrates that COVID-19 clusters in Bulawayo are not occurring by chance and this reflects the spatial distribution of the population which is at great risk from the disease [9].

The GIS-based clustering methods used in this study are exploratory tools that assist policymakers and researchers to comprehend complex geospatial patterns. Indeed, GIS has provided knowledge on the existence of COVID-19 clusters in Bulawayo together with their respective locations which provide significant grounds for both policy and research formulation in the health sector. Therefore, as Zimbabwe gears toward COVID-19 elimination, there is a greater need to prioritize control efforts by focussing on high-risk areas since there are potential reservoirs of COVID-19 infections. Likewise, the discovery of statistically significant COVID-19 clusters is an important step toward spatial selection and targeting these areas to prevent future infections [4, 11]. The targeting of great risk areas for COVID-19 aligns with the Ministry of Health and Child Care's efforts which seek to promote well-being and good health by scaling up COVID-19 interventions [14].

## V. CONCLUSION

Because of GIS, this study was able to combine location-specific and attribute information on the COVID-19 cases to fully comprehend COVID-19 infection dynamics in Bulawayo. Such insights were not possible had the study only opted to purely investigate COVID-19 clustering without GIS-based input. The results of the study can now be utilized to plan the timing of COVID-19 control interventions by targeting areas where clusters are prevalent. Furthermore, the hotspot areas detected in this study can serve as important starting points for future infectious disease surveillance where resources are limited in cities such as Bulawayo. Therefore, the hotspot areas could be prioritized in the course of resource allocation to achieve real disease control in Zimbabwe. However, further research should be focused on these hotspot areas to fully appreciate local factors that cause elevated COVID-19 infections.

## ACKNOWLEDGMENT

For conducting this study, mostly we have used records from the Ministry of Health and Child Care and GPS data collected from the field. We are grateful to the Ministry of Health and Child Care officials and the research assistance team for helping us to conduct this research work.

## REFERENCES

[1] Aghajani, J., Farnia, P., & Velayati, A. A. (2017). Impact of geographical information system on public health sciences. Biomedical and Biotechnology Research Journal (BBRJ), 1(2), 94.

[2] Bello, I. M., Moyo, T. N., Munyanyi, M., Akpan, G. U., Isibor, I., Sunganai, L. C., Umar, A. S., Krishnan, R. S. S. G., Touray, K., & Rupfutse, M. (2021). Use of geographic information systems web mapping application to support active case search to guide public health and social measures in the context of COVID-19 in Zimbabwe: A preliminary report to guide replication of methods in similar resource settings. The Pan African Medical Journal, 38(159), 1-9.

[3] Boulos, M. N. K., & Geraghty, E. M. (2020). Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: How 21st century GIS technologies are supporting the global fight against outbreaks and epidemics. International Journal of Health Geographics, 9(12), 1-12.

[4] Bousema, T., Kreuels, B., & Gosling, R. (2011). Adjusting for heterogeneity of malaria transmission in longitudinal studies. The Journal of Infectious Diseases, 204(1), 1-3. https://doi.org/10.1093/infdis/jir225.

[5] Carballada, Á. M., & Balsa-Barreiro, J. (2021). Geospatial Analysis and Mapping Strategies for Fine-Grained and Detailed COVID-19 Data With Geographic Information Systems.

[6] Carroll, J.-A., Janda, M., Rodgers, J., Pollock, P. M., Choi, J. H., & Washington, T. L. (2014). 'Healthy mobile check-ins' study: Using GIS in smartphones to track use of the urban environment by survivors of endometrial cancer. Australasian Epidemiological Association Annual Scientific Meeting (AEA 2014).

[7] Eryando, T., Susanna, D., Pratiwi, D., & Nugraha, F. (2012). Standard Deviational Ellipse (SDE) models for malaria surveillance, case study: Sukabumi district-Indonesia, in 2012. Malaria Journal, 11(1), 1-2.

[8] Gao, S., Mioc, D., Anton, F., Yi, X., & Coleman, D. J. (2008). Online GIS services for mapping and sharing disease information. International Journal of Health Geographics, 7(1), 1-12.

[9] Gwitira, I., Mukonoweshuro, M., Mapako, G., Shekede, M. D., Chirenda, J., & Mberikunashe, J. (2020). Spatial and Spatio-temporal analysis of malaria cases in Zimbabwe. Infectious Diseases of Poverty, 9(1), 1-14.

[10] Lawson, A. B., & Kleinman, K. (2005). Spatial and syndromic surveillance for public health. John Wiley & Sons.

[11] Loha, E., Lunde, T., & Lindtjørn, B. (2012). Effect of Bednets and Indoor Residual Spraying on Spatio-Temporal Clustering of Malaria in a Village in the South. Plos One, 7(10), 1-11. https://doi.org/10.1371/journal.pone.0047354.

[12] Maher, P. J., MacCarron, P., & Quayle, M. (2020). Mapping public health responses with attitude networks: The emergence of opinion-based groups in the UK's early COVID-19 response phase. British Journal of Social Psychology, 59(3), 641–652.

[13] Martellucci, C.A., Sah, R., Rabaan, A.A., Dhama, K., Casalone, C., Arteaga-Livias, K., Sawano, T., Ozaki, A., Bhandari, D., & Higuchi, A. (2020). Changes in the spatial distribution of COVID-19 incidence in Italy using GIS-based maps. Annals of Clinical Microbiology and Antimicrobials, 19(1), 1-4.

[14] Ministry of Health and Child Care. (2021). Ministry of Health and Child Care—Covid 19 Daily Updates from Zimbabwe—Covid-19 Daily Updates. http://www.mohcc.gov.zw/index.php?option=com_phocadownload&view=category&id=15&Itemid=741.

[15] Murad, A., & Khashoggi, B. F. (2020). Using GIS for disease mapping and clustering in Jeddah, Saudi Arabia. ISPRS International Journal of Geo-Information, 9(5), 1-22.

[16] Nykiforuk, C. I., & Flaman, L. M. (2011). Geographic information systems (GIS) for health promotion and public health: A review. Health Promotion Practice, 12(1), 63-73.

[17] Rezaei, M., Nouri, A. A., Park, G. S., & Kim, D. H. (2020). Application of geographic information system in monitoring and detecting the COVID-19 outbreak. Iran. J. Public Health, 49, 114-116.

[18] Santos, A. da S., Medeiros, N. das G., Santos, G. R. dos, & Lisboa, J. (2017). Use of geostatistics on absolute positional accuracy assesment of geospatial data. Boletim de Ciências Geodésicas, 23, 405-418.

[19] Saran, S., Singh, P., Kumar, V., & Chauhan, P. (2020). Review of Geospatial Technology for Infectious Disease Surveillance: Use Case on COVID-19. Journal of the Indian Society of Remote Sensing, 48(8), 1121-1138.

[20] Silalahi, F. E. S., Hidayat, F., Dewi, R. S., Purwono, N., & Oktaviani, N. (2020). GIS-based approaches on the accessibility of referral hospitals using network analysis and the spatial distribution model of the spreading case of COVID-19 in Jakarta, Indonesia. BMC Health Services Research, 20(1), 120.

[21] Tabish, S. A. (2020). COVID-19 pandemic: Emerging perspectives and future trends. Journal of Public Health Research, 9(1).

[22] Tworek, H. J. (2019). Communicable Disease: Information, Health, and Globalization in the Interwar Period. The American Historical Review, 124(3), 813-842.

[23] World Health Organization. (2007). Use and potential of geographic information systems for health mapping in the Eastern Mediterranean Region.

[24] Zeb, I., Qureshi, N. A., Shaheen, N., Zafar, M. I., Ali, A., Hamid, A., Shah, S. A. A., & Ashraf, A. (2021). Spatiotemporal patterns of cutaneous leishmaniasis in the district upper and Lower Dir, Khyber Pakhtunkhwa, Pakistan: A GIS-based spatial approaches. Acta Tropica, 217, 105861.

[25] Zhang, H., & Tripathi, N. K. (2018). Geospatial hot spot analysis of lung cancer patients correlated to fine particulate matter (PM2. 5) and industrial wind in Eastern Thailand. Journal of Cleaner Production, 170, 407-424.

## AUTHORS PROFILE

**Mr. Norman Karimazondo** holds an MSc in Education Degree in Geography, MSc Human and Social Science specialty- Research in Education and Training, BSc-Education in Geography, Postgraduate Diploma in Teacher Training in Science and Technology, Postgraduate Diploma in GIS and Remote Sensing. He is a geography teacher and Head of Department at Rakodzi High School, Marondera, Zimbabwe. Currently, he is pursuing Ph.D. studies (Environmental Management) from the Prince of Songkla University, Thailand.

**Mr. Lawrence Mango** has completed his Master's Degree in Agroforestry, BSc Environmental Science, Executive Certificate in Project and Programme Monitoring and Evaluation, and Post Graduate Diploma in Education. He is a lecturer in the Department of Agricultural Management at Zimbabwe Open University, Bindura, Zimbabwe, and has published several research papers. Currently, he is pursuing Ph.D. studies (Environmental Management) from the Prince of Songkla University, Thailand.

**Mr. Michael Make Montana** is a Managing Consultant at Environmental Guardians Services, Bulawayo, Zimbabwe. He has completed his MSc Degree in Ecotourism and Biodiversity Conservation, BSc in Geography and Environmental Studies, Post Graduate Diploma in GIS and Remote Sensing, and Diploma in Environmental Health. He is pursuing a Ph.D. (Environmental Management) from Prince of Songkla University, Thailand.

**Dr. Gideon Walter Mutanda** is a lecturer in the Department of Geography and Environmental Science at Great Zimbabwe University, Masvingo, Zimbabwe. He has completed his Ph.D. in Geography and Environmental Science, MSc in Natural Resources Management and Environmental Sustainability, BSc Hons in Geography and Environmental Science, B.A. General (Geography and Religious Education), Post Graduate Diploma in GIS and Remote Sensing, Postgraduate Diploma in Education, Diploma in Human Resources Management, Certificate GIS and Remote Sensing.