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Juggling through Ghanaian urbanisation: flood hazard mapping of Kumasi

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Abstract More recently, driven by rapid and unguided urbanisation and climate change, Ghanaian cities are increasingly becoming hotspots for severe flood-related events. This paper reviews urbanisation dynamics in Ghanaian cities, and maps flood hazard zones and access to flood relief services in Kumasi, drawing insight from multi-criteria analysis and spatial network analysis using ArcGIS 10.2. Findings indicate that flood hazard zones in Kumasi have been created by natural (e.g., climate change) and anthropogenic (e.g., urbanisation) factors, and the interaction thereof. While one would have expected the natural factors to guide, direct and steer the patterns of urban development from flood hazard zones, the GIS analysis shows that anthropogenic factors, particularly urbanisation, are increasingly concentrating population and physical structures in areas liable to flooding in the urban environment. This situation is compounded by rapid land cover/use changes and widespread haphazard development across the city. Regrettably, findings show that urban residents living in flood hazard zones in Kumasi are also geographically disadvantaged in terms of access to emergency services compared to those living in well-planned neighbourhoods.

Keywords Urban flooding · Flood hazard · Kumasi · Urbanisation · Urban planning

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Introduction

Globally, climate change and rapid urbanisation are generating uncertain futures and threatening human survival (Cobbinah and Anane 2015; Cobbinah et al. 2015a). Whilst issues of climate change may perhaps be beyond human control, there are several cases of successful management of, and socio-economic dividends from urbanisation in developed countries (see Cohen 2006). However in Africa, it is often argued that urbanisation generates dual and contradictory outcomes: providing a means of, and a barrier to advancing human welfare (Cobbinah et al. 2015b). Owing to many negative outcomes associated with urbanisation in Africa, international organisations such as United Nations Human Settlement Programme (UNHABITAT) and United Nations Department of Economic and Social Affairs/Population Division (UNDESA/PD) have frequently described its occurrence as an impediment to sustainable development rather than a potential for socio-economic improvement and urban poverty relief. In this case, it is somewhat unsurprising that a number of studies also provide a litany of negative outcomes of urbanisation (e.g., poverty, congestion, unsustainable land development, slums etc.) across African cities (e.g., Cobbinah et al. 2015a, b; UNDESA/PD 2012; UNHABITAT 2014; United Nations 2014). This paper, however, describes urbanisation pattern in an African country (Ghana) and its association with urban flooding by providing a flood hazard map and accessibility zones to flood relief services in an African city—Kumasi, a rapidly urbanising city in Ghana.

The reason for examining urbanisation's role in urban flooding derives from the fact that many African countries are undergoing, or are expected to experience rapid urbanisation in the foreseeable future (UNDESA/PD 2012) amidst changing climate. In many of these countries with weak urban planning institutions and high urban poverty levels (see Cobbinah et al. 2015b), urbanisation induced-flood events have become a regular occurrence, affecting urbanites, urbanism and urban functionality (Amoako 2012; Scott et al. 2013). If these flood events remain frequent and extreme, how could urbanisation contribute to urban functionality and healthy urbanism? It is true that for some developing countries, urbanisation may be promoting socio-economic improvement (e.g., China, Singapore) (Cohen 2006), but for the majority, rapid urbanisation is providing chaotic scenes, environmental degradation, worsening poverty conditions, over-stretching the capacity of existing infrastructure, and exposing urbanites to environmental hazards particularly flooding (Adarkwa 2012; Amoateng et al. 2013; Cobbinah et al. 2015b; Lwasa 2014; Nwaka 2005). In this era of climate change and rapid urbanisation, flooding, for Scott et al. (2013), is one of the marked natural hazards in the twenty first century. Unfortunately, although there is emerging research on flooding in growing African cities (e.g., Amoako 2012; Armah et al. 2010; Campion and Venzke 2013), flood hazard mapping and access to flood relief services remain mostly a grey area. In this context, further analysis on flood hazard mapping and access to flood relief services within rapidly growing cities in Africa is tenable and necessary.

Evidence from previous research (see Ahmed and Dinye 2012; White 2008) suggests that urban areas in Africa are more susceptible and increasingly exposed to flood risk due to socio-economic pressures in determining land uses, often with limited recognition to open spaces, areas liable to flooding and ecologically sensitive areas, as development in water courses abounds. Others (e.g., Pradhan 2009; Uddin et al. 2013) have reported disastrous outcomes of flooding including loss of human lives, displacement and destruction of key infrastructure and services. In most cases, when flooding occurs, urban planning authorities are bereaved of ideas, and are forced to lurch from one reactive measure to another, such as demolition of structures, and eviction of people perceived to be in flood hazard zones (Gupta et al. 2010). While calls for adequate understanding of flood dynamics and their integration into spatial planning and management framework have resonated amongst researchers, and are increasingly growing globally (e.g., Restemeyer et al. 2015; Woltjer and Al 2007), an appreciation of flood hazard zones and places of human habitation in many cities in African countries particularly Ghana is urgent and timely.

In Ghana, a number of flood-related research have been conducted in recent years: from flooding and land use planning (Karley 2009), to impacts of flooding on livelihoods and adaptation (Amoako 2012; Armah et al. 2010; Campion and Venzke 2013). However, an understanding of city-wide flood hazard zones, which is fundamental in cases of emergency response, remains a relatively under-explored. This paper provides a context for understanding flood hazard mapping in Kumasi using multi-criteria analysis (MCA) with the aid of geographic information system (GIS). It would also involve a spatial network analysis with GIS to determine the effectiveness of emergency response in an event of flooding. This paper consists of five parts. Section. 2 provides theoretical understanding of urbanisation and urban flooding in Ghanaian cities. Section. 3 describes the case study location and examines the research methods used. Section. 4 presents the findings and discussion of the research. In Sect. 5, the paper provides some concluding remarks on urbanisation and flooding in African cities.

Urbanisation and flooding in Ghanaian cities: a review

Flooding has been frequently discussed in the context of its threatening effects on the structure and function of cities. Although traditionally flooding and related natural events were perceived mainly as the acts of God, recent cases of flooding in cities, especially in developing countries are mostly anthropogenically induced (Zevenbergen et al. 2012). Globally, cases and risks of flooding in cities are reported to be on the rise, with aspects of flooding linked to climate change and urbanisation (Dawod et al. 2014; Fernandez and Lutz 2010; Jha et al. 2011; Scott et al. 2013). For instance in developing countries, rapid urbanisation, coupled with changing climate, is frequently reported as compelling rural residents to migrate to cities and settle in areas that are highly prone to flooding (Jha et al. 2011; World Bank 2015). Urbanisation, according to Cobbinah et al. (2015b), refers to demographic patterns, ecological characteristics, sociological factors and economic phenomenon that concentrate population in urban areas and has the potential to either stimulate or hinder growth and development of these areas across the globe.

There are several cases where rapid urbanisation has contributed to improved socio-economic development in developing countries such as China (see Cohen 2006). Others (e.g., Cobbinah et al. 2015b; United Nations Human Settlements Programme (UNHABITAT) 2012) have argued that the process of urbanisation can create a platform for clustering of productive activities in industry and services which often result in low production costs and generates more benefits that translate into improved quality of life for urban residents. Yet, with recent rapid urbanisation described as a socio-economic risk in several African countries (Cobbinah et al. 2015b), many (Cobbinah et al. 2015a; UNDESA/PD 2012) believe that the relationship between urbanisation and improved livelihoods is inverse and mostly parasitic, as several African cities increasingly find it difficult to manage rapid, unplanned and unsustainable urbanisation which is eroding the benefits associated with urbanisation. The growing evidence of urban poverty, flooding and unsustainable exploitation of resources including land and energy in African cities is associated with rapid urbanisation (Cobbinah et al. 2015b). In such situations, it is not surprising that African urbanisation is variously described as demographically driven and is occurring without socio-economic and environmental benefits (see Cobbinah et al. 2015b for detailed discussion on Africa's urbanisation: its positive and negative implications for sustainable development).

In Ghana, although urbanisation is a recent phenomenon (see Table 1), over half of the total population now resides in urban areas (Cobbinah and Erdiaw-Kwasie 2016; Ghana Statistical Service (GSS) 2012). Between 2000 and 2010, the number of Ghanaian urban areas with population between 50,000 and 100,000 sharply increased from 9 to 36, with the trend set to continue in the future (World Bank 2015, p.2). As illustrated in Fig. 1, Accra and Kumasi are the most rapidly urbanising cities. It is worth acknowledging, however, that urbanisation in Ghana is only interpreted from the demographic perspective with human settlements having population threshold of 5000 described as urban (GSS 2012). This interpretation of urbanisation is simplistic and problematic as it ignores the socio-economic benefits and ecological characteristics of the urbanisation process. This, of course, is not to say that demographic characteristics are inconsequential in the urbanisation process, but rather oversimplification of the meaning of urbanisation may underline the many urban development challenges confronting Ghanaian cities: slum proliferation, waste management challenges, limited livelihood options and opportunities, uncontrolled informalisation and unplanned land development.

Ghanaian cities are highly prone to flooding (Amoako 2012), which remains a major cause of natural disasters (Okyere et al. 2012). Some (e.g. Jha et al. 2011; Okyere et al. 2012; World Bank 2015) have described flooding in Ghana largely as an urban phenomenon due to, among others, rapid urbanisation and poor urban planning, often creating urban configurations that are rapidly becoming visible in floodplains. For example in Kumasi, rapid urbanisation contributed to rapid expansion of the built-up area to nearly three times between 1986 and 2015 (see Figs. 2, 3). In 1986, the total undeveloped land was 158,563 m^2 (64 %) of the total land area of 250 km^2. This figure by 2015 has sharply shrank to 46,995 m^2 (19 %), with future projection indicating further decline. The situation in Kumasi is common across all the major cities in Ghana: Accra, Sekondi-Takoradi, Tamale, Cape Coast, and Tema. While it may be accurate to argue that the conversion of undeveloped area into built-up area is in response to growing population demand, Jha et al. (2011) argue that the practice of converting forest resources to built-up area has implication for flooding, because land use changes increase the risk of flooding as urban expansion reduces the absorptivity of soils and infiltration while increasing surface runoff. Complicating matters further is development of structures in watercourses by developers as they claim increasing demand and

Table 1 Ghana's population and percentage urbanised (1921–2010) *Source*: Adapted from Naab et al. (2013)

Year	Total population	Percentage urbanised	Urban population	Number of urban settlements
1921	2,298,000	7.8	179,244	N/A
1931	3,163,000	9.4	297,322	N/A
1948	4,118,000	12.9	570,597	41
1960	6,727,000	23.1	1,551,174	98
1970	8,559,000	28.9	2,472,456	135
1984	12,296,000	32.0	3,938,614	203
2000	18,912,000	43.8	8,278,636	364
2007	23,000,000	49.0	11,270,000	492
2010	24,658,823	51.0	12,545,229	636

N/A not available

pressure for housing in Ghanaian cities by growing population is compelling them (Cobbinah and Korah 2015). According to Yankson and Bertrand (2012), Ghanaian cities, particularly Accra is one of the fastest growing but uncoordinated cities in West Africa.

Given the poor and uncoordinated physical development in Ghanaian cities in the face of increasing housing demand, many suburbs remain underserviced in terms of provision of drain infrastructure and solid waste management services, while others are located on floodplains. The characteristics of haphazard physical development across Ghanaian cities are variously reported as the major causes of flooding (Campion and Venzke 2013; Karley 2009; Owusu-Ansah 2015). In this case, it is not unexpected that flooding in recent years has become an annual occurrence in Ghanaian cities. Although the persistent nature of flooding in Ghanaian cities has been recognised as a major hurdle for city authorities and other stakeholders in flood management, a common scene in a flood event has been the distribution of relief items to flood victims by flood management organisations (Appiah 2015), while political leaders demonstrate their weaknesses by making unfulfilled promises towards addressing the problem (Ghana News 2015; Star Fm 2015). Unfortunately, the impact of flooding is often perilous with the poor being the worst affected (Okyere et al. 2012). Aside the lost of human lives, important infrastructure such as roads and utility services are often destroyed.

Effective urban planning that responds and coordinates land use development within the urban environment is necessary in flood risk management (Jha et al. 2011) and the management of rapid urbanisation (Cobbinah and Korah 2015). Regrettably, urban planning particularly land use planning in Ghana and many African countries lacks the capacity, in terms of logistical support and personnel, to keep pace with urbanisation (Cobbinah and Korah 2015; Nwaka 2005). This situation, coupled with the lack of an integrated flood risk management plan in Ghanaian cities (Ahadzie and Proverbs 2011), makes the problem of flooding atrocious. This study, as a first step in understanding flood hazard mapping in Ghanaian cities, by spatially analysing flood prone zones in Kumasi. This is critical in an integrated flood risk management, and provides the basis for understanding the extent of exposure of urban residents to flood events.

Study area and research methods

Study area

The city of Kumasi is located in the transitional forest zone of Ghana and lies about 270 km north of Accra, the national capital (see Fig. 4). It has a population of 2,035,064 and covers an area of about 230 km^2, approximately 10 km in radius (Kumasi Metropolitan Assembly 2014). The city lies between latitudes 6.35° and 6.40° and longitudes 1.30° and 1.35°, and on an elevation of between 200 and 300 m above sea level. The topography is generally undulating and drained by a number of

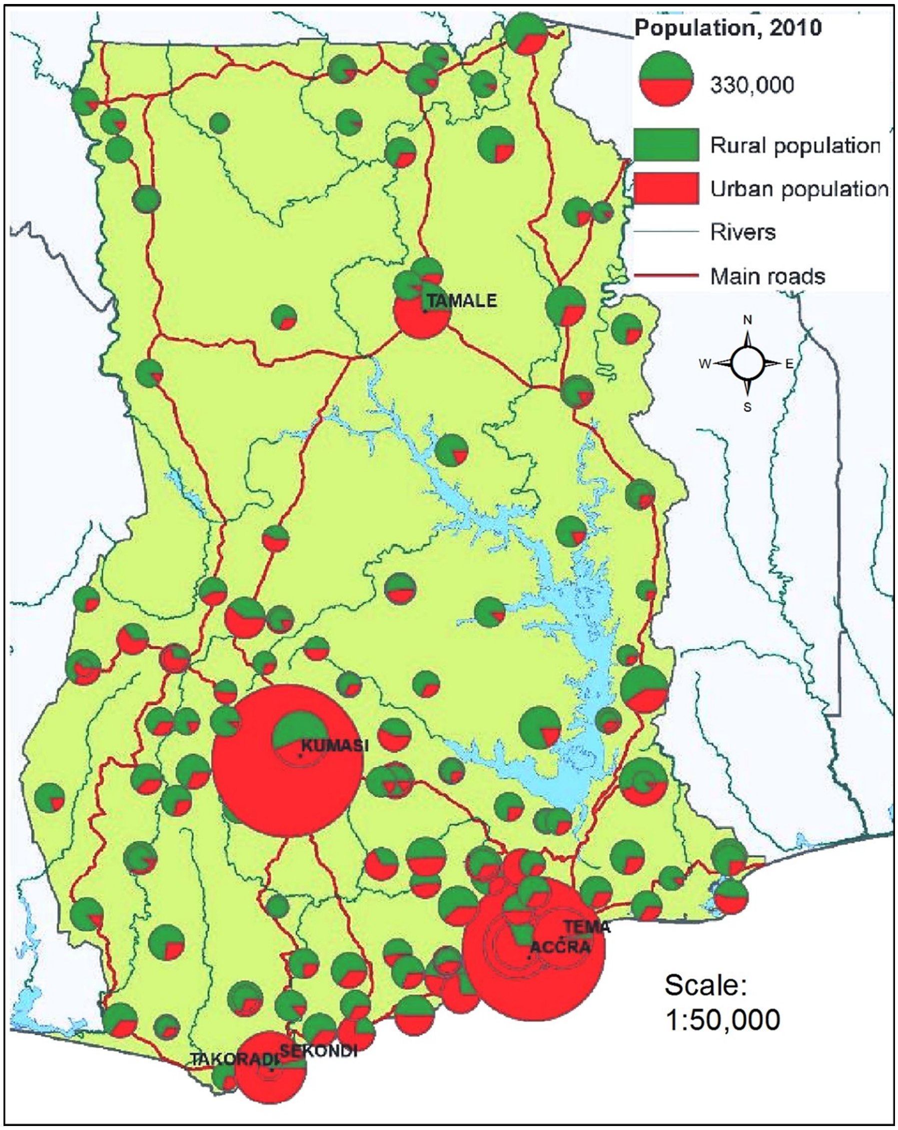


Fig. 1 Level of Ghanaian urbanisation (2010) *Source*: World Bank (2015)

streams, making it highly prone to flooding. However, the incidence of flooding in Kumasi is largely due to haphazard physical development along riparian zones of streams (e.g., Subin and Aboabo). According to Oppong (2011), residential neighbourhoods have sprung up so close to these streams such that people living in those neighbourhoods are in constant danger of being inundated in an event of heavy downpour. Recent research (e.g., Campion and Venzke 2013; Owusu-Ansah 2015) further emphasises the contribution of poor physical development on and near riparian zones of streams to flooding in Kumasi. Asokore Mampong Municipality (see Fig. 4) was carved out of Kumasi in 2012 for political expediency. However, communities like Aboabo and Asawase, which are located in Asokore Mampong Municipality experience flooding in recent years (see Campion and Venzke 2013). This, coupled with their close proximity to Kumasi central, makes it appropriate for the inclusion of these communities in the study.

Research methods

The study reviewed relevant and related literature on urbanisation characteristics and flood dynamics. The review was based on recent literature (2000–2015)

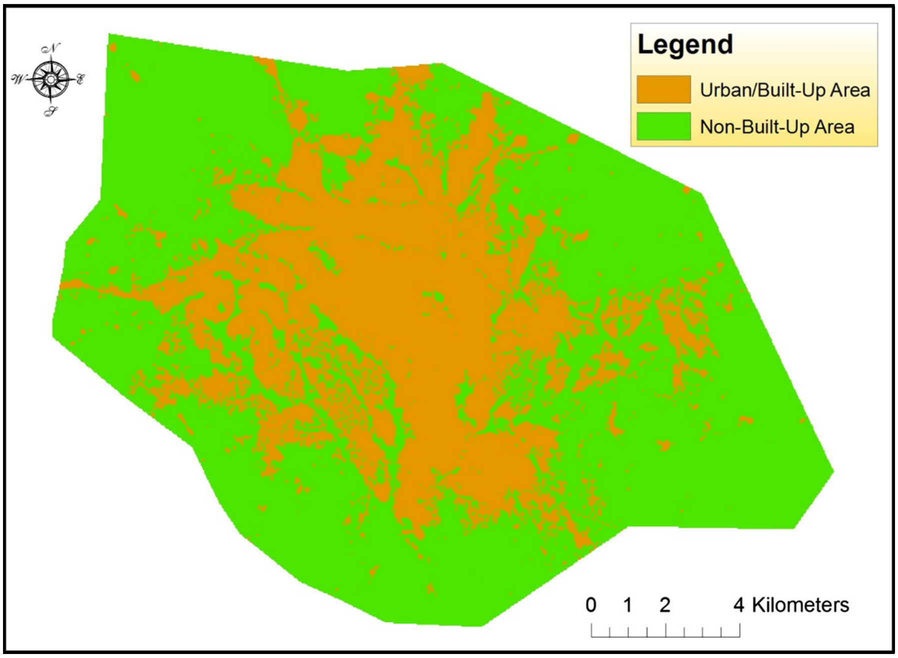


Fig. 2 Land cover of Kumasi in 1986

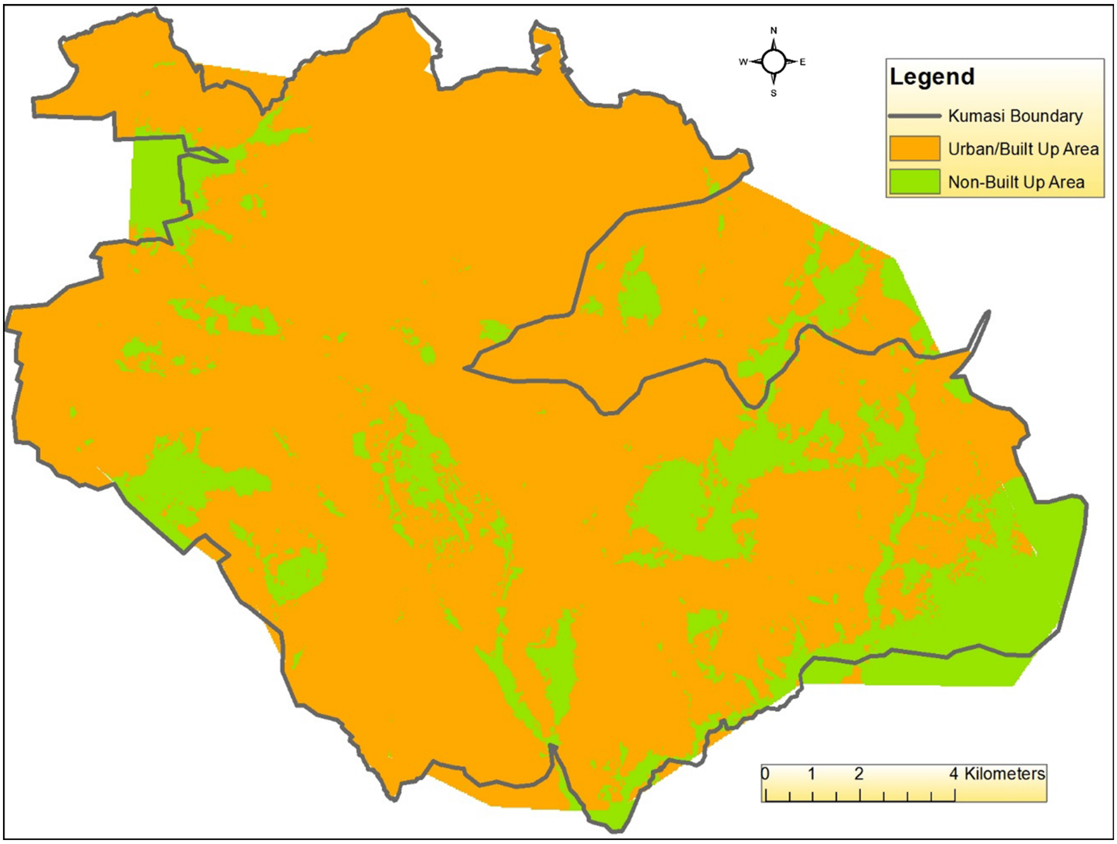


Fig. 3 Land cover of Kumasi in 2015

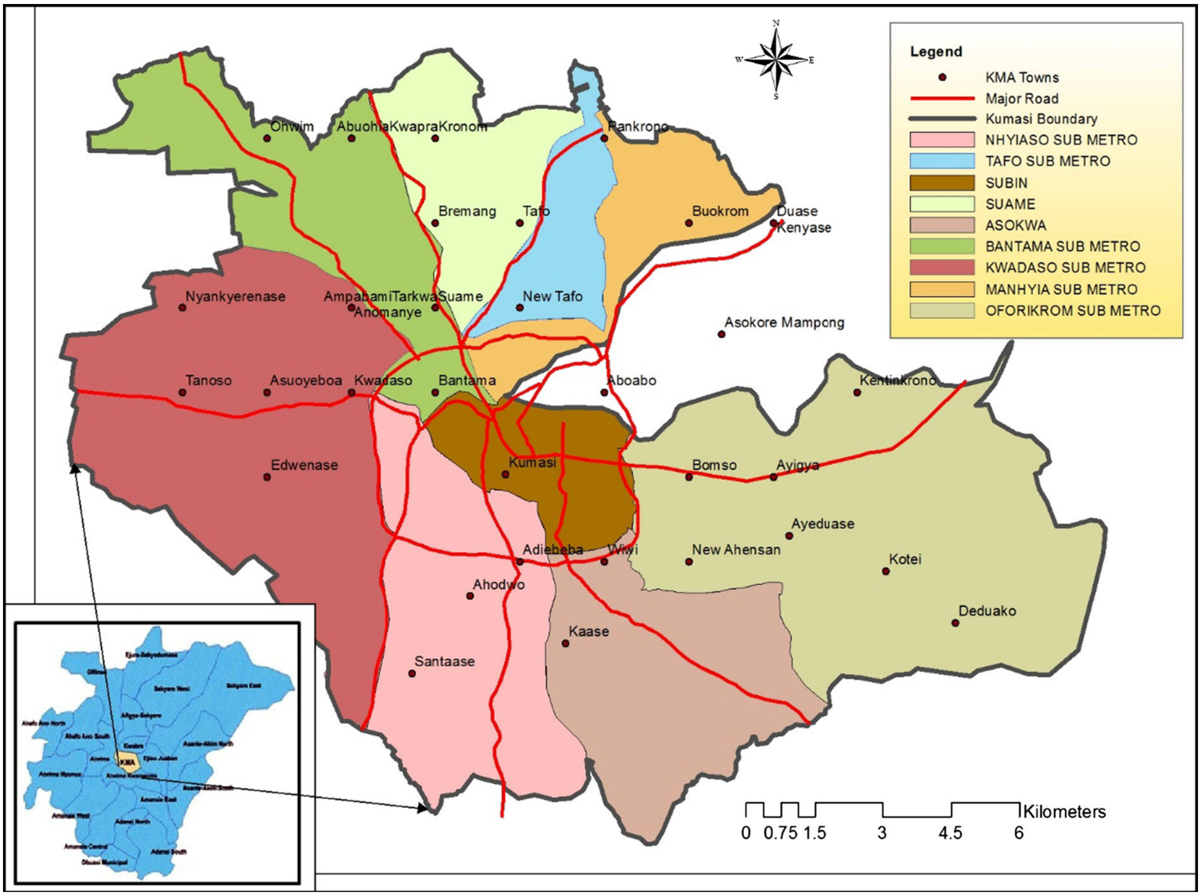
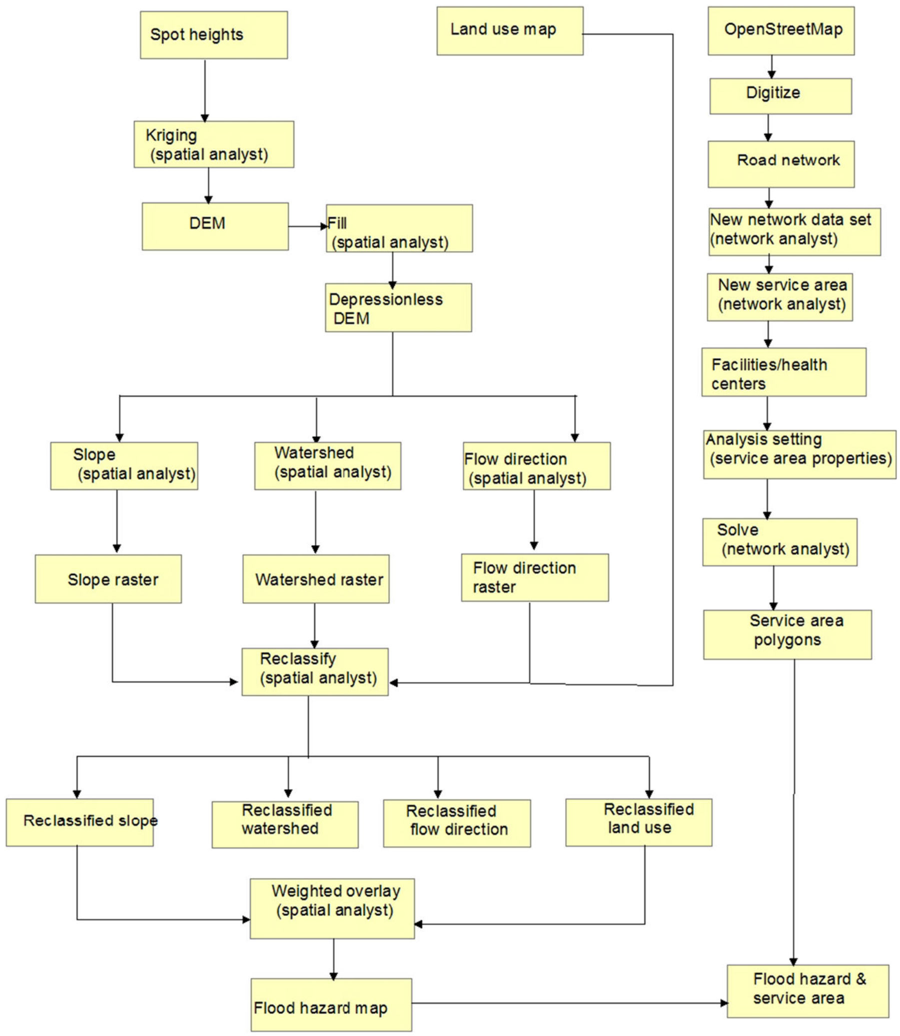


Fig. 4 Geographical location of Kumasi

on urban planning, urbanisation and urban flooding focusing on Africa particularly Ghana. Two main approaches were used for the review: (1) analysis of peer-reviewed and edited literature from published sources such as books and journal articles on urbanisation, urban planning and urban flooding. Various terms relating to these concepts were used in undertaking the web search in major electronic databases such as Scopus, Academic search complete, SAGE Journals online, JSTOR, and CABI, as well as catalogues from the Australian Library. (2) Furthermore, there was an assessment of published documents (reports) from major international and local organisations which are into urban planning, urbanisation and urban flooding issues. Published documents were obtained from organisations such as the World Bank, United Nations (UN), United Nations Development Programme (UNDP), and the United Nations Human Settlement Programme (UNHABITAT). Other local documents such as district development plans and news paper articles were reviewed to address the dearth of official reports and research on the subject. Literature obtained from these two sources/approaches was mainstreamed to focus on research or cases that provided relevant evidence to the subject being reviewed. About 50 published documents including peer reviewed articles and books were reviewed for this study. The literature review was important in determining the patterns of urbanisation and flooding in Ghanaian cities, and also formed the basis for using Kumasi as a case study area. Preferably, the study intended to focus on two cities. However, due to resource constraints and the unique characteristics of Kumasi: land ownership problems, slum proliferation, urban sprawl, high population growth rate,

Fig. 5 Methodological flow chart for GIS based analysis



frequent cases of flooding and weak planning institutions, the study was limited to Kumasi.

In addition, remote sensing was used to generate contour map of Kumasi, by creating various spots (locations) using Google Earth Application (GEA). A total of 13,611 spots (locations) were generated using the *add path* tool in GEA. The spots were saved as kml file and imported into a TCX Converter application, where the height/altitude data of the spots were updated. The resultant output was saved as a CSV file (excel) and loaded into ArcGIS 10.2 environment as spot heights for further analysis, focusing on multi-criteria analysis and weighted overlay, as well as a spatial network analysis. As illustrated in Fig. 5, the kriging tool (spatial analyst) was used to convert the spot heights into a Digital Elevation Model (DEM), which formed the basis for slope, watershed, flow direction and flow accumulation rasters generation.

Multi-criteria analysis

Multi-criteria analysis (MCA) is a technique for analysing complex decision problems, that involve large data (Fenandez and Lutz 2010). Applying GIS in MCA is fundamental in spatial decision making. For example, many (e.g., Estoque and Murayama 2010; Joerin et al. 2001; Mendas and Delali 2012) have used GIS in MCA to map and assess land suitability across different landscapes and to support urban planning and agriculture decisions. In flood hazard studies, Fernandez and Lutz (2010) applied GIS in MCA in flood risk area delineation and mapping in Tucumán

Table 2 Weight and rank of layers/classes of Kumasi

Layers	Weights (%)	Classes	Rank	Interpretation
Watershed	30	217–246	4	High hazard
		246–261	3	Moderate hazard
		261–276	2	Low hazard
		276–309	1	No hazard
Flow direction	25	1–8	4	High hazard
		8–32	3	Moderate hazard
		32–64	2	Low hazard
		64–128	1	No hazard
Land use	30	High density residential	3	Moderate hazard
		Low density residential	2	Low hazard
		Nature reserve	4	High hazard
		Open space	1	No hazard
Slope	15	0–34	4	High hazard
		34–77	3	Moderate hazard
		77–88	2	Low hazard
		88–90	1	No hazard

province, Argentina. In this research, GIS was used to develop a weighted flood hazard model showing flood prone zones in Kumasi within the context of MCA. The flood hazard model allowed for the application of a common measure scale to multiple data sets to produce an integrated analysis (Riad et al. 2011). In this research, four layers were generated and used: DEM, slope, land use map, and flow direction. A reclassification of the layers into a common measurement scale with values between 1 and 4 (see Table 2) depending on the degree of susceptibility to flooding was done. Based on the reclassification, each layer was multiplied by a weight (level of influence on flooding) and put together for the final weight to determine flood prone zones in Kumasi (see Riad et al. 2011) using Eq. 1.

$$\mathrm{FH} = \sum_{\mathrm{W_i X_i}} \quad (1)$$

where $\mathrm{W_i}$ = the weight of ith layer; $\mathrm{X_i}$ = criteria score of class of layer I; FH = flood hazard level of each pixel on the map. All layers were combined in ArcGIS 10.2 platform to produce a map depicting flood prone zones. The total weight of each pixel of the final flood hazard map was obtained using Eq. 2.

$$\mathrm{FH} = \left(\mathrm{WS_y WS_c + FD_y FD_c + LU_y LU_c + S_y S_c}\right) \quad (2)$$

where WS = watershed; FD = flow Direction; LU = land use; and S = slope. The subscript letters ‘y’ and ‘c’ represent the weight of each layer and the weight of each class of the individual layer respectively (see Table 2).

Spatial network analysis

A spatial network analysis with GIS is essential in determining equity and accessibility to facilities and services within a particular geographical enclave. The spatial network analysis is useful in providing answers to variety of queries related to accessibility to roads, railways, rivers, and facilities (Comber et al. 2008), and remains central in route planning, route finding, calculation of service areas, identifying the closest facility by travel time or distance (Environmental Systems Research Institute (ESRI) 2006). In this research, the spatial network analysis was used to determine access to emergency services in flood prone zones in an event of flood. Using the road network in Kumasi, a new network data set was created and used to determine accessibility to health facilities, which helped determine the level of accessibility of flood prone zones to emergency services.

Results and discussion

With the preceding overview in mind, this section analyses flood hazard zones and access to emergency services in Kumasi by applying a GIS-based methodology. The GIS MCA shows two distinct factors influencing flooding in Kumasi: natural and anthropogenic factors. The complex interaction between these two factors is generating multiple flood prone zones in Kumasi. The following sections examine these two factors using GIS MCA, which set the context for the analysis on flood hazard mapping and emergency services facilities in Kumasi.

Natural characteristics and flooding in Kumasi

The geography of Kumasi—the undulating topography interspersed with streams—is a potential for flooding resulting from a heavy downpour. The GIS MCA shows that Kumasi's topography is an important indicator of the dynamics of flood events. The analysis shows that a number of areas in Kumasi are below 260 m above sea level (see Fig. 6). However, there is a projected minimum tolerable flood height of 260 m above sea level (see Owusu-Ansah 2015). Thus, all areas in Kumasi below 260 m above sea level are naturally prone to flooding, as they always receive much of the water in an event of runoff. For example, topographical features such as higher elevation (slope) influence the direction, velocity and amount of surface runoff (Korah and Lopez 2015). In Kumasi, although most areas are on higher elevation, others are on low elevation (see Fig. 6).

This advanced elevation of Kumasi further combines with poor attitude towards watersheds, water resources and other natural areas to create intense flooding. The analysis shows that lack of recognition of

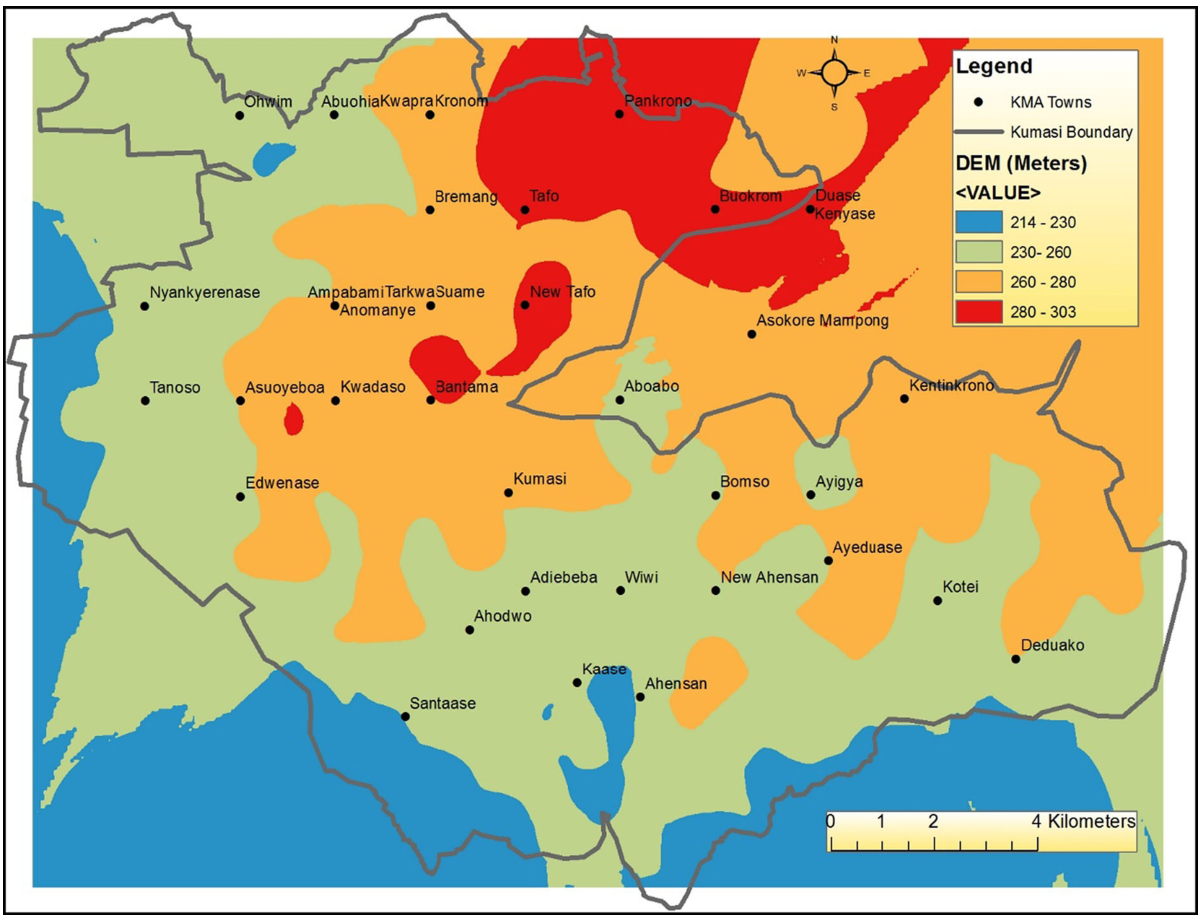


Fig. 6 Natural elevation of Kumasi

watersheds and water resources in Kumasi as natural areas and potentially floodable zones by urbanites and urban planning authorities is influencing the flood dynamics. In many developed countries, such as the Netherlands, management mechanisms are in place to protect watersheds, which are regarded as an important urban ecological resource and necessary channels for free flow of runoffs (see van der Brugge et al. 2005). However, in Kumasi, it is not uncommon to find watersheds, water resources and flood plains serving as dumping grounds for solid and liquid waste, and places of human habitation, despite their vulnerability to flooding. Several studies (e.g., Ahmed and Dinye 2012; Campion and Venzke 2013; Cobbinah and Korah 2015; Owusu-Ansah 2015) have reported poor management of watersheds, water resources and natural areas in Kumasi. It is somewhat unsurprising, therefore that watersheds, water resources and other natural areas in Kumasi overflow their boundaries and cause flooding whenever there is a downpour. What this means is that certain areas in Kumasi by virtue of their location and function, are naturally susceptible to flooding and require protection. Unfortunately in Kumasi, such areas are increasingly under pressure due to rapid urbanisation (see Ahmed and Dinye 2012). The next section examines how rapid urbanisation is impacting on urban flooding in Kumasi.

Anthropogenic characteristics (urbanisation) and flooding in Kumasi

Anthropogenic occurrences such as rapid urbanisation are inextricably linked to the removal of natural vegetation cover and the creation of impervious surfaces (Fernandez and Lutz 2010). A simple indication, for Wu et al. (2002), of a place's susceptibility to flooding is to relate its land use and flood prone zones. Changing land use is associated with increasing pressures on the environment in terms of pollution and destruction of environmental resources. The natural vegetation cover determines the rate at which water flows and accumulates in an area (Korah and Lopez 2015; Ouma and Tateishi 2014). Whereas natural vegetation cover aids in water infiltration, impervious surfaces do not support water infiltration. In many cases, rapid urbanisation is linked with the process that brings about reduced infiltration which affects the hydrological cycle by redirecting the natural courses of water. This situation was ominous in Kumasi where urbanisation is equated to population growth (see GSS 2012). However, the consequences are often disastrous, as high density development zones with less or no vegetation cover frequently experience increase run-off. In their reflections, Wu et al. (2002) argue that a flood event will not constitute a hazard except when it puts at risk lives and properties, and other areas of value including wildlife habitat.

Kumasi's current urbanisation and land use conversion from open spaces and nature reserves to commercial, residential and other uses are shown in Table 3 and Fig. 7 respectively. From 1960 when Kumasi's population was slightly above two hundred thousand (200,000), this figure had by the year 2000 jumped to over 1 million. By the 2010 population and housing census, the population of Kumasi was over 2 million. The rapid urbanisation of Kumasi is accompanied by significant changes in land uses, particularly conversion of natural and green areas into residential and related development (see Figs. 3 and 7). Today, Kumasi is virtually a built-up city with limited vegetation cover or green areas, a situation which appears to have contributed to the rate of flooding. Compounding the issues of rapid urbanisation and land use changes are the poor attitudes of urbanites towards sanitation. As reported by Owusu-Ansah (2015), indiscriminate disposal of waste particularly in water resources and drains system have constricted the free flow of water and generating avoidable flooding in Kumasi. Thus, rapid urbanisation and its associated land use changes would put more of the city's natural areas and ecological systems at risk of flooding.

Mapping flood hazard zones and emergency services in Kumasi: urban planning limitations

In order to produce a flood vulnerability map of Kumasi, both the natural and anthropogenic factors

Table 3 Urban growth of Kumasi (1960–2010)
Source: Base on Kumasi Metropolitan Assembly, 2014

Year	Total population
1960	218,172
1970	346,336
1984	487,504
2000	1,170,270
2007	1,625,180
2010	2,035,064

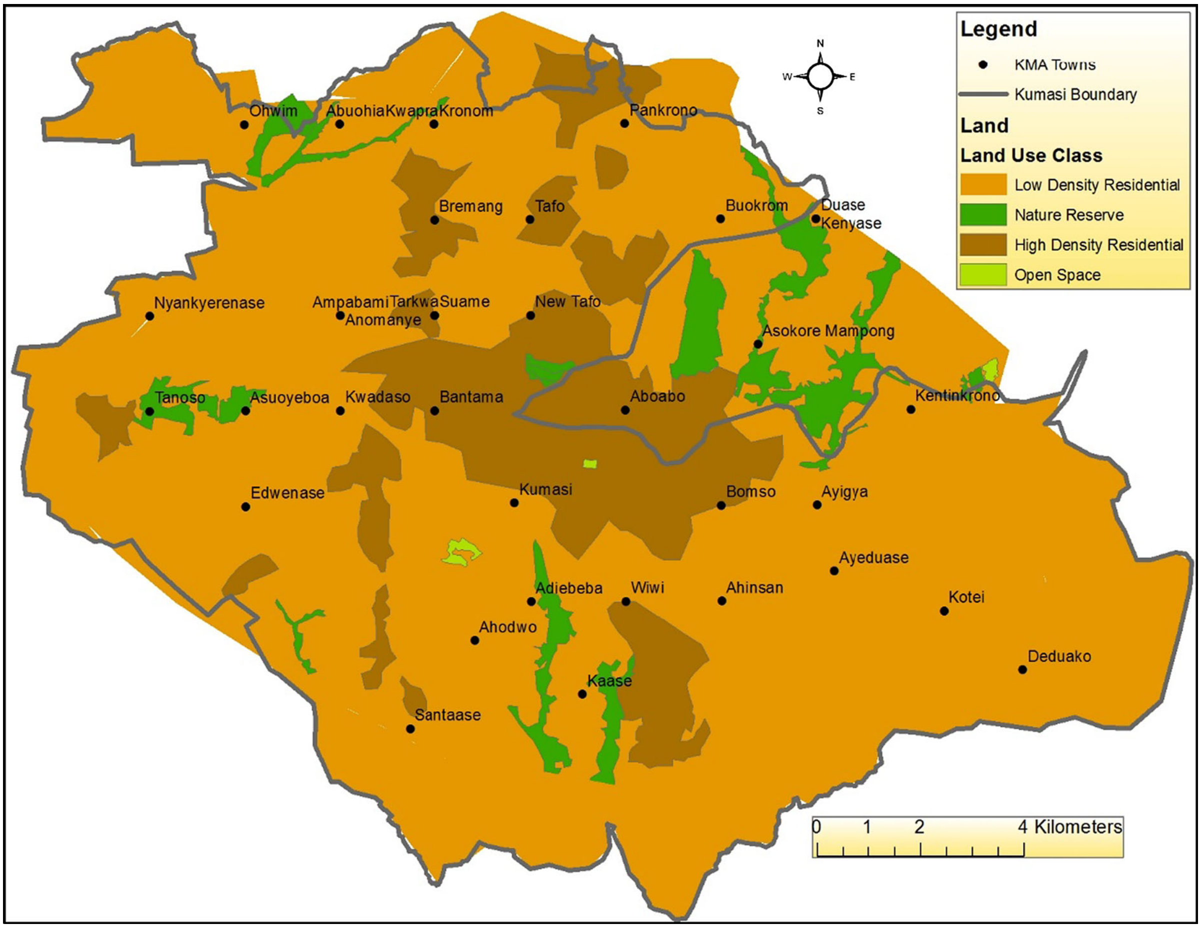


Fig. 7 Land use density in Kumasi

were considered and combined. The factors included land use characteristics induced by rapid urbanisation, flow direction, slope and watersheds. Given that previous studies on flooding in Kumasi found rainfall to be inconsequential in flood analysis (see Owusu-Ansah, 2015; Campion and Venzke, 2013), rainfall was not considered as a determinant factor in the flood hazard mapping. The weighted overlay (spatial analysis) in ArcGIS superimposes several raster layers based on a common scale and their level of influence to produce an integrated output. In this research, four layers which directly impact flooding in the Kumasi were used (see Table 2). Equations 1 and 2 were used as the basis for arriving at the flood hazard map (refer to Sect. 3 for detailed explanation). Figure 8 shows the flood hazard map of Kumasi that integrates natural and anthropogenic forces.

Based on Fig. 8, Kumasi can be categorised into four classes of risk to flooding: high hazard zones, moderate hazard zones, low hazard zones and areas with no risk to flooding. High and moderate hazard zones, mostly at the southern part of Kumasi, are areas with low topography, close to natural areas and water resources, and with increased human concentration. The analysis further shows that these areas are experiencing rapid land use/cover changes. As illustrated in Fig. 9, increased and unregulated human activities such as haphazard physical development abound in the high and moderate hazard zones in the city. This finding corroborates those of Owusu-Ansah (2015) who identified the high and moderate hazard zones as areas that experience the most frequent overflows of streams in the city. As a result, neighborhoods in the high hazard zone (e.g.,

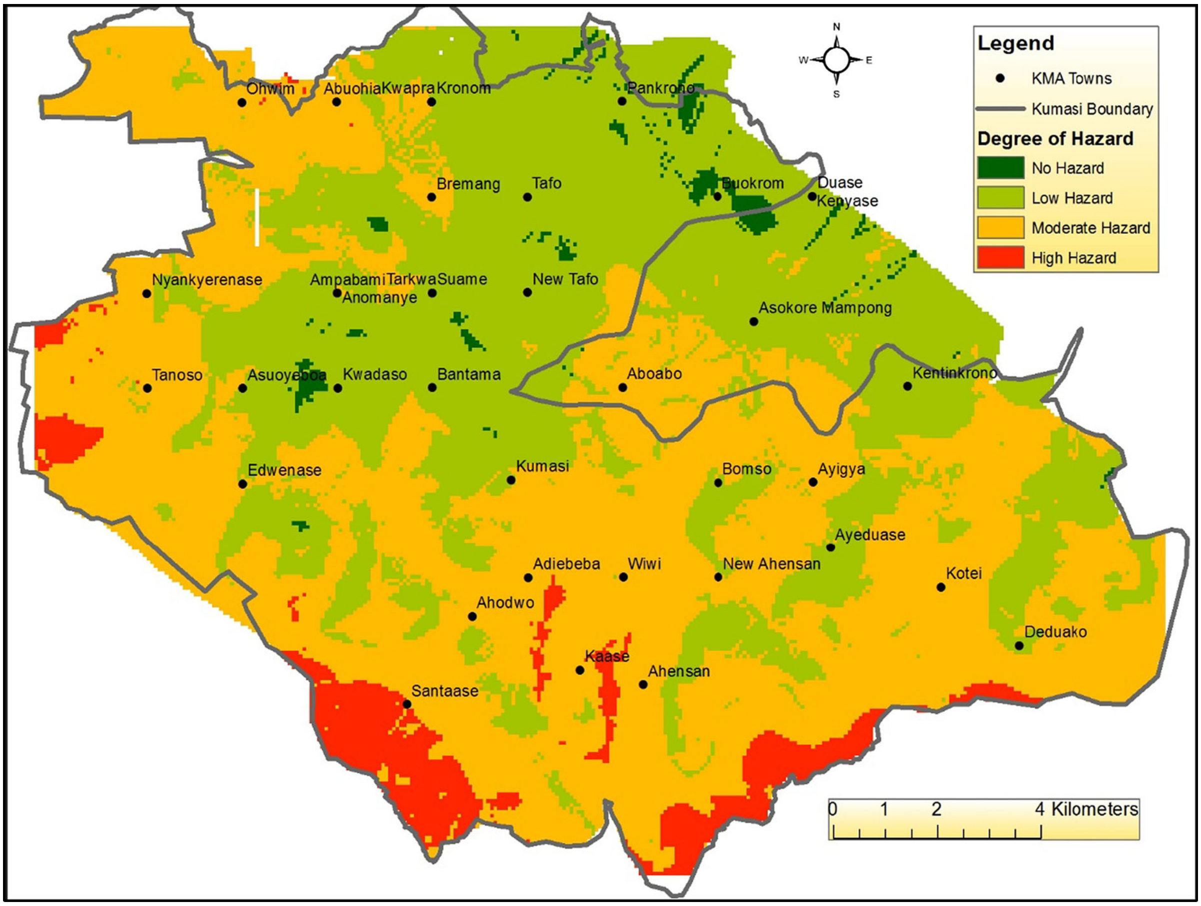


Fig. 8 Flood vulnerability map of Kumasi

Kaase) and those within the moderate hazard zone (Ahensan, Aboabo and Ayigya) are frequently reported to be experiencing severe flooding in recent times (see Campion and Venzke 2013; Oppong 2011).

To reduce the risk of flooding in the high and moderate hazard zones, urban planning and management remains a necessary precondition, especially for preventing and managing the effects of flooding in areas that are naturally susceptible. Several planning instruments are available to ensure sustainable development of Kumasi and prevent avoidable flooding. For example, the Kumasi Metropolitan Assembly (KMA)—the official institution responsible for the socio-economic and physical development of Kumasi—is mandated, by law, to:

> "prohibit, abate, remove, pull down or alter so as to bring into conformity with the approved plan, a physical development which does not conform to the approved plan, or the abatement, removal, demolition or alteration of which is necessary for the implementation of an approved plan" (Local Government Act, 1993 (Act 462), section 53).

Also, Ghana's zoning guidelines and planning standards allow for a riparian zone of 30 m around natural areas especially those liable to flooding. The zoning guidelines further ensure that no physical development occurs within 30 m zones from natural areas. Among others, this preposition in the zoning guidelines is to ensure sustainable management of natural resources particularly water resources, avoid flooding and safeguard the lives of urban residents. Regrettably, urban development in Kumasi, like many cities in Africa is dominated by individuals (See Roy 2005; Yeboah and Shaw 2013). As a result, despite the growing emergence of physical development and

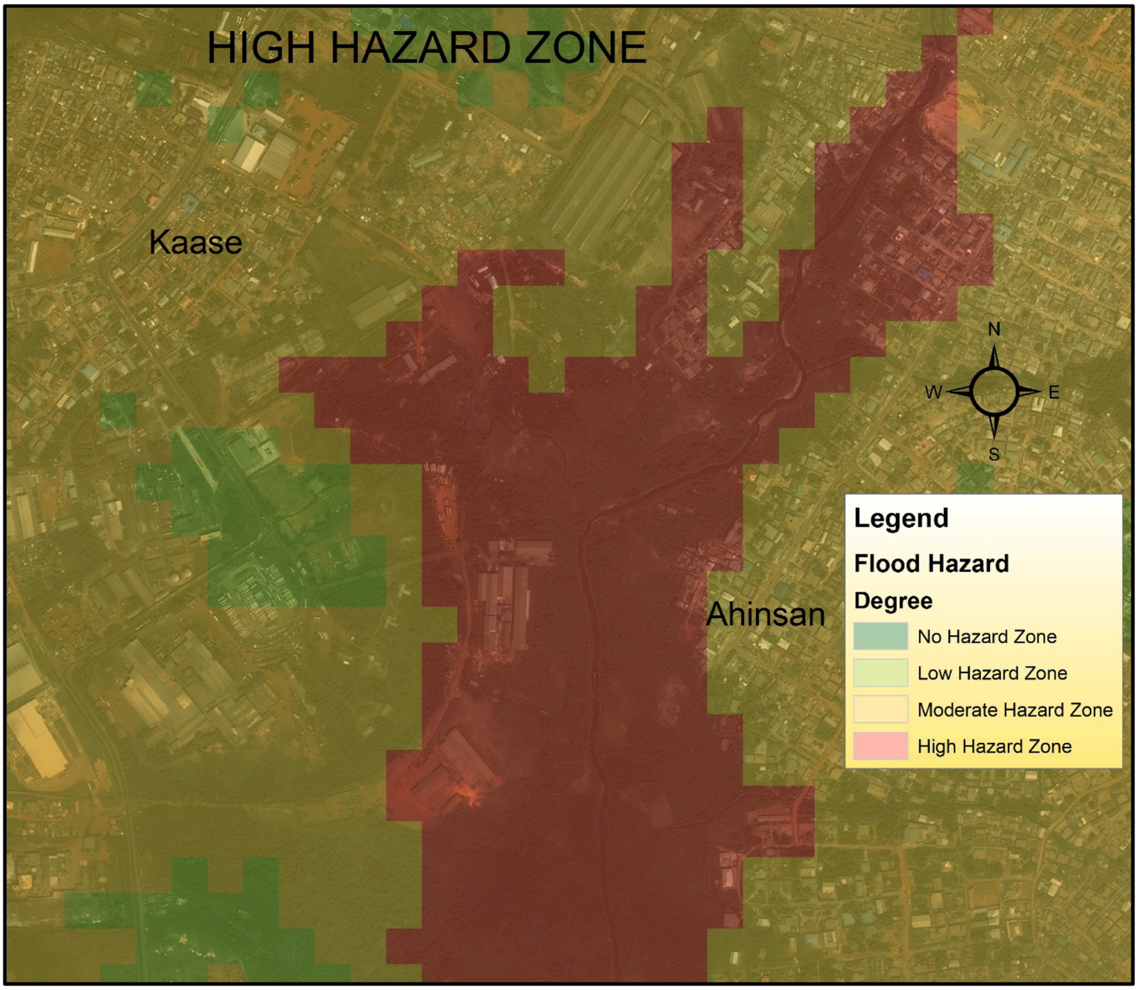


Fig. 9 Overlay of flood hazard map on satellite imagery of Southern Kumasi

human habitation in natural areas in Kumasi, there is limited action in terms of development control by the state. As presented in Fig. 9, areas south of Kumasi are dominated with buildings located in a watercourse, exposing residents to flood hazard.

City authorities often seem to lack policy direction in an event of flooding (see Nwaka 2005). The need for building resilience to flooding is evermore becoming pressing. However, this process requires an integration of flood risk zones into spatial planning and a considerable understanding of the natural functioning of the city, in terms of flood prone areas and regions of human habitation. The results from this research can be an important step towards the creation of a strategic metropolitan-wide plan to deal with flood issue. Flood risk management is also about preparedness, prevention and response.

While the GIS MCA analysis may perhaps assist city authorities and urbanites to prepare and avert negative impacts of future flood events, the emergency response strategy is equally important. The spatial network analysis however shows that high and moderate hazard zones are also spatially disadvantaged in terms of access to emergency services. It is true that the Ghana’s Town Planning Standards indicate that the maximum radius of a health facility should be between 8 and 16 km. It is also true that the Standards classify neighborhoods within less than 8 or 16 km radius of a health facility as being within the sphere of influence in terms of access to health facility. Yet, the spatial network analysis shows that in Kumasi, despite the availability of a number of health facilities, neighbourhoods located in high and moderate hazard zones have limited access to health facilities, as ambulance services travel between 10 and 13 min before reaching these areas, using Ghana's ambulance maximum driving speed limit of 50 km per h (Derry et al. 2007). As illustrated in Fig. 10, five closest health facilities to the moderate and high risk flood zones were identified in Kumasi. Some of the high and moderate hazard neighbourhoods (e.g., Owhim, Santase and Ayigya) are located relatively farther away from these emergency services.

Conclusion and recommendations

The main findings of this research are simple but strong and consistent: urban land development across Ghanaian cities is largely unregulated, haphazard and unauthorised; rapid urbanisation is becoming a commonplace in Ghana; and urban flooding is frequently becoming a perennial occurrence in Ghanaian cities with devastating consequences. Unfortunately, urban areas will continue to be threatened by floods due to rapid and demographic driven urbanisation and climate change. Today, cities are regarded as hubs of modern risks (White 2008). Acknowledging urbanisation and flood dynamics in Kumasi, the GIS analysis shows that Kumasi is no exception as there are several flood hazard zones. These flood hazard zones are also areas with high population densities, and mostly unsafe for human habitation.

Flood hazard zones in Kumasi result from natural and anthropogenic factors, and the interaction thereof. While one would have expected the natural factors to guide, direct and steer the patterns of urban development from flood hazard zones, the GIS analysis shows that anthropogenic factors particularly urbanisation are increasingly concentrating population in areas liable to flooding in the urban environment. This situation is compounded by land cover/use changes

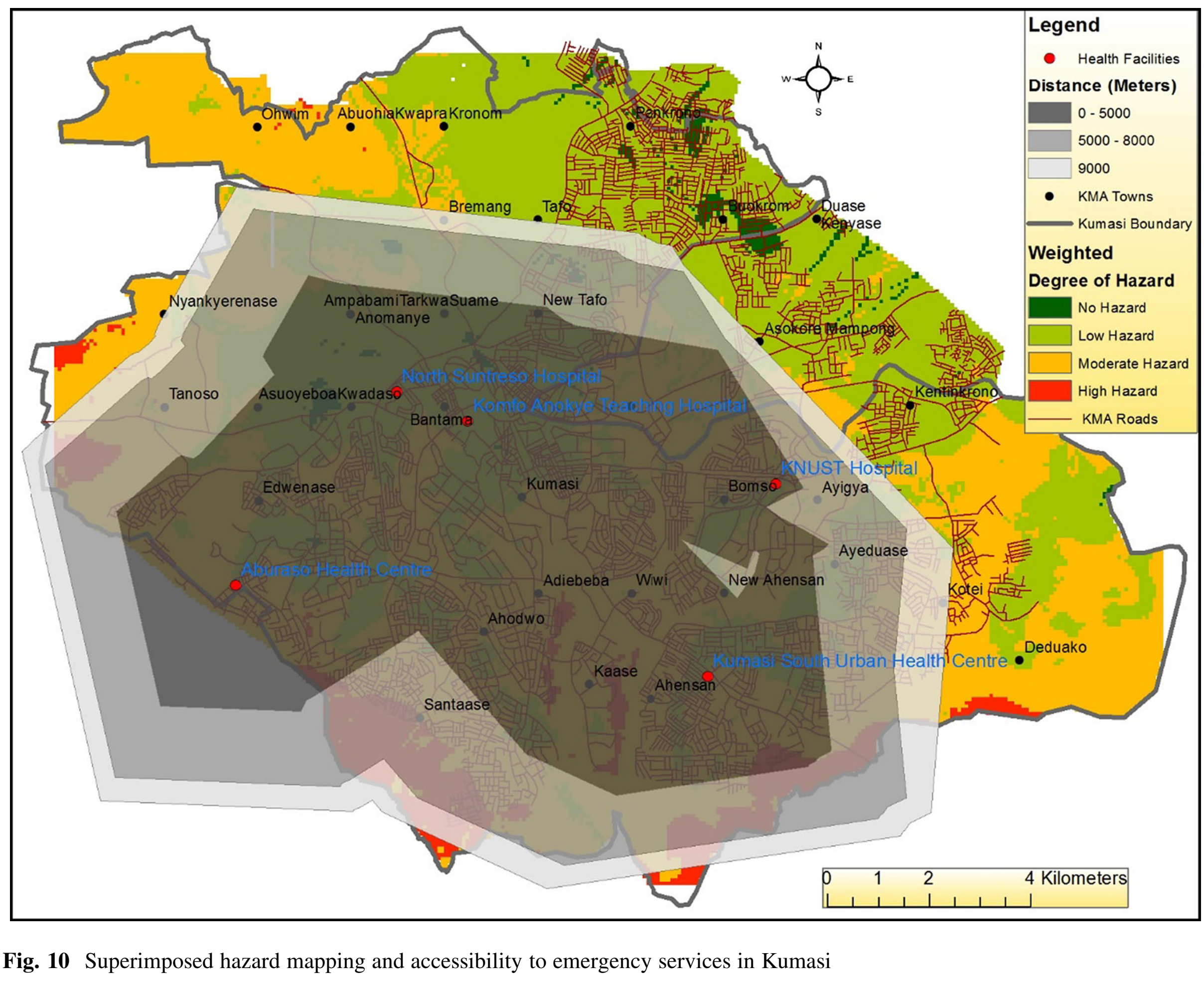


Fig. 10 Superimposed hazard mapping and accessibility to emergency services in Kumasi

and the reported general haphazard development across the city (Ahmed and Dinye 2012; Cobbinah and Amoako 2012). Unfortunately, flood hazard zones are also low service areas in terms of emergency relief services. In this case, the survival of urban residents within flood hazard zones is increasingly threatened especially when there is a heavy downpour.

The paper also shows that GIS is an effective tool in determining and monitoring flood hazard zones and population concentration in urban areas. The interpretation and classification of GIS data could help estimate the extent of accessibility to emergency services from flood hazard zones. In so doing, it becomes possible to detect the extent of susceptibility of urban residents inhabiting flood hazard zones without emergency relief services, and to enforce urban development regulations for reasonable and sustainable development of urban environment as well as integrating emergency relief services into urban planning process, especially in spatial planning. Given that the form of spatial development in an urban environment has implications for managing risk (see Oyesiku 1997), urban planning is necessary to cope with these inevitable uncertainties (Davoudi et al. 2012). It is in this direction that, this research recommends that urban planning authorities in Kumasi should consider integrating spatial planning, which has long been ignored, into flood risk management strategies. The flood hazard mapping can be a relevant input towards delineating buildable and non-buildable areas within the city depending on the degree of flood risk. This may perhaps reduce, if not put an end to, the occupation of high flood hazard zones by urban residents.

Compliance with ethical standards

Conflict of interest The authors declare that there is no actual or potential conflict of interest in terms of financial, personal or other relationships with other people or organisations that could inappropriately influence, or be perceived to influence this work. Moreover, this work has solely been submitted to GeoJournal, and it is not under consideration/review in another journal. Also, this work has not been previously published in anywhere or in any language. The authors claim full responsibility for the content of the work.

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