The Interplay between Urban Development Patterns and Vulnerability to Flood Risk in Kisumu City, Kenya

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Abstract
Flooding is becoming a predominantly urban event in recent times. However, the reason why urban areas are becoming places of flood risk has not been clearly understood. Even though past studies had explained the flood risk as a function of the natural and physical environment, more recent studies are now attributing the escalation of urban flood risk to the overall patterns of these areas. Different urban development processes yield dissimilar urban patterns, but how these disparate urban patterns within the same town configure flood risk has not been fully explored. This study attempts to fill this research gap and explores how development processes create urban spatial patterns and further examine how such patterns shape flood risk in Kisumu city.
Keywords: Urban development, spatial patterns, flood risk.

1. Introduction

In the past few decades, Africa has experienced rapid urbanization driven by both natural population increase and the influx of rural population (World Bank, 1978; Bernstein, 1994). This rapid urbanization has in turn led to urban expansion into hitherto rural lands. A development visible in various urban areas around the continent is that the initial core areas of the urban centers could have been placed on sufficiently safe grounds. But due to expansion, the urban areas tend to outgrow their initially safe locations and expand into hazardous zones, thereby generating new patterns of vulnerability that did not exist before. This situation is exacerbated whenever the expansion of the urban area is unregulated (Fekade, 2000; Pelling 2003; Baker, 2012; Dickson, *et al*, 2012).

Against this backdrop of demographic growth and urbanization trends in Africa, flooding is becoming a predominantly urban event (Pelling, 2003). Indeed, the causes of floods are shifting and their impacts accelerating as urban areas increasingly become the locus of flood risk (Pelling, 2003; UN Habitat, 2007; Jha, *et al*, 2012). For example, floods wreaked havoc in Maputo in 2000; Algiers in 2001 as well as the cities of East African countries in 2002. In Kenya, there were flooding events in informal settlements in Nairobi, including Dandora and Mathare (Douglas, *et al,* 2009), as well as other cities in the country such as Mombasa (Awuor, *et al,* 2008). But the reason why urban areas which were once assumed to be places of security from natural hazards are now becoming places of risk has not been clearly understood (Pelling, 2003).

Incidences of floods have become a common feature in Kisumu city particularly in specific residential settlements. For example inundation of households by floods in some residential areas occurred in 1997-1998, 2002 and 2003 (APFM, 2004). With the anticipated effects of climate change, there is likely to be increase in frequency of these flood events as well as the number of persons affected by the floods in the future. This then calls for a better understanding of this phenomenon in order to put in place preventive mitigation measures. Although urban development in Kisumu has been a focal point for some scholars (Anyumba, 1995; Mireri, *et al,* 2007), rarely has it been addressed in the context of vulnerability to flood risk. This then creates a research gap which this study aims to fill and thus the study examines how urban development processes configure flood risk over time and how such risks are spatially distributed among the various settlement types.

2. Location of Kisumu City

Kisumu city is situated between longitudes 00^0 06\` south of the Equator and latitudes $34^0$ 35\` and 34^0 55\`east of Greenwich (Anyumba, 1995; Mireri, *et al*, 2007). It is located on the western part of Kenya in Kisumu County. The city is sited at the eastern extremities of Lake Victoria referred to as Winam Gulf and it is bordered to the north by the Nandi escarpment which rises to over 2000 metres above sea level; Lake Victoria to the southwest with an elevation of about 1140 metres above sea level; and Kano plains to the east (Anyumba, 1995; Mireri, *et al,* 2007). It covers an area of approximately 417 km^2 of which 297 km^2 is dry land and approximately 120 km^2 under water. It receives mean annual rainfall of 1245 mm occurring in two seasons; the long and the short rainy seasons, occurring during March-June and October-November periods respectively (Mireri, *et al*, 2007).

Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.7, No.7, 2017

Fig. 1 Map of Kenya showing location of Kisumu city
Source: Maoulidi, (2011)

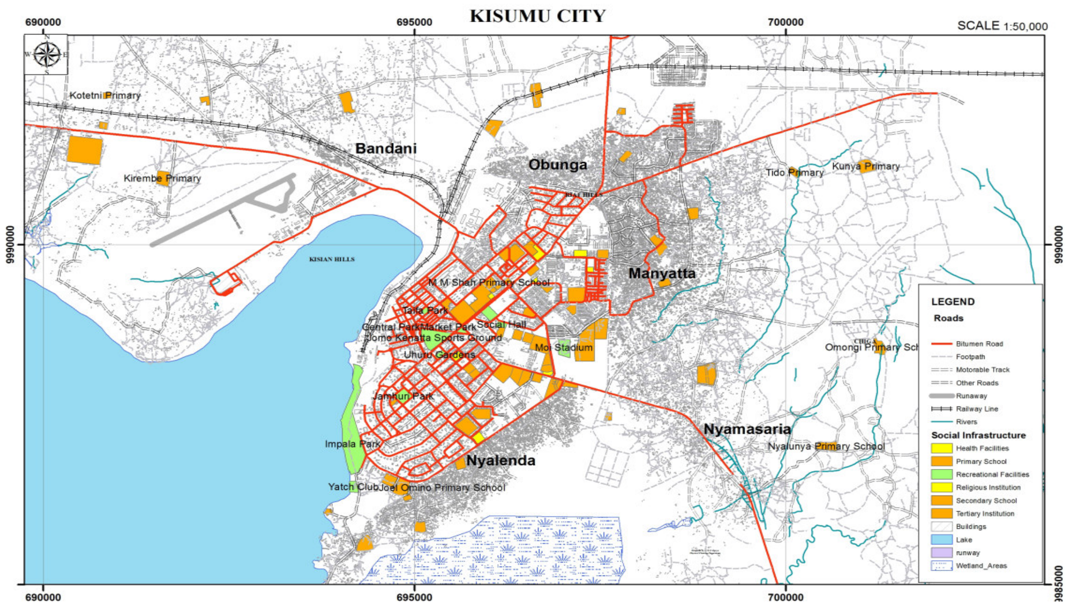


Fig. 1 Map of Kisumu city
Source: Department of Physical Planning, Ministry of Lands, 2014

3. Literature Review

3.1 The formal-informal dichotomy and variations in urban patterns

The coexistence of formality and informality in the same urban area reflects one of the ancient paradigms of the existence of two cities within a city. These two cities were the formal or planned city and the informal, unplanned city (Castro, *et al,* 2015). Past studies show that traditionally, a number of cities in Europe exhibited a continuum from organic (informal) to planned growth (formal), with several of them being formed from elements of both (Batty & Longley, 1994). This led to situations where there were variations in spatial patterns within the same city or urban area. Cases of organic and planned city development are exemplified by the Greek cities that did not follow a single pattern. A common pattern in those cities was for the central district to exhibit planning whereas the outlying areas did not (Batty & Longley, 1994). This means that the precincts devoted to the activities of the elite were often highly planned and regular in form, while the residential areas in the outlying zones often grew by a slow process of accretion, producing complex and irregular patterns that were "organic" in nature (Batty & Longley, 1994). This form of urban development where towns contain elements of the planned within a backcloth of organic growth later found its way into the Kenyan urban development framework during the colonial period.

3.2 The development processes and creation of variation in patterns in Kisumu city

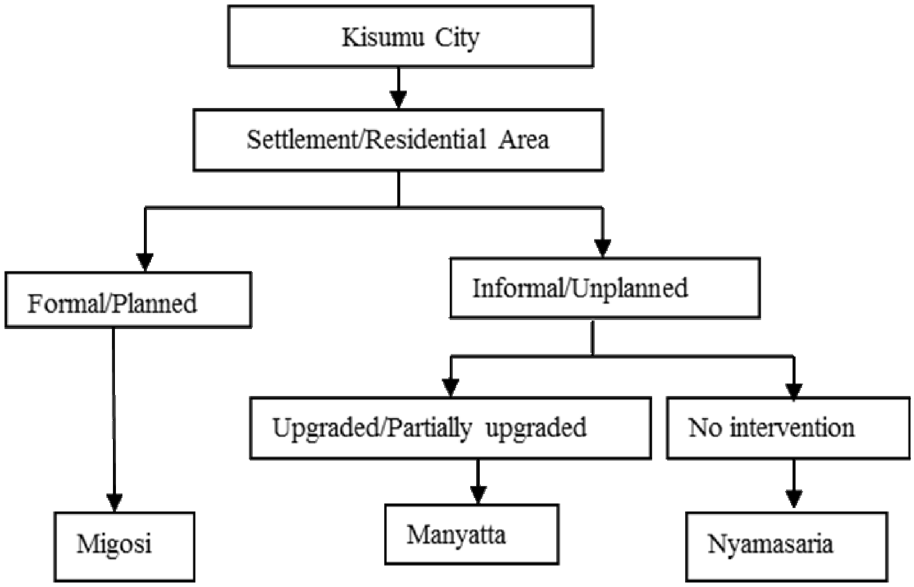
The prevailing development patterns in Kisumu city trace their origin from the exclusion-inclusion colonial urban development policies (Anyumba, 1995). The city became a Township in 1903 and was divided into three areas. These were: area A which was reserved for Europeans; area B reserved for Asians and area C reserved for other immigrant groups living in separate villages. Beyond area C, settlements of African villages mushroomed (Anyumba, 1995; UN Habitat, 2005). Area A formed the urban core in Kisumu Township where urban development was governed by the Town Planning Ordinance 1919, and later the Town Planning and Development Ordinance. Accordingly, the European settlement that emerged in this area strictly adhered to European standards of construction and urban development. As such, all the building activities carried out within the settlement had to be to be verified and approved, through the acquisition and granting of legal permits. In terms of spatial location, high ground was preferable to low ground in siting of the settlement and the colonial government also assumed the responsibility for providing public infrastructure and services in this European settlement alone.

While European settlement benefited from planned development, formal urban planning did not exist in the native settlement (UN Habitat, 2005). Instead, the development of the land in those settlements was done according to the customary practices of the natives. This means that the natives were left to their own initiatives in the development of their settlements. For example, they had to construct their own housing without any form of regulation. The settlements that evolved had very distinct spatial patterns totally different from the European settlements that formed part of the core urban areas. This marked the origin of duality in development processes within the city which continued even after Kenya gained independence from the British. After independence, the areas that formed part of the European settlement like Milimani continued with the planned development, while areas that originally fell under the native settlements like Manyatta, Nyalenda and Nyamasaria among others, continued with the unregulated development. Much later, when these former native settlements were incorporated into the boundaries of Kisumu city, they brought with them the distinct spatial patterns which were typically different from those of the planned former European settlements.

4. Methodology

This study adopted the survey design and employed both quantitative and qualitative research approaches. The study proceeded in three phases. First, desktop survey was conducted to collect secondary data on Kisumu city and the sampled settlements. Secondly, there was the collection of primary data from the households. Third, logistic regression model was developed to enable prediction of occurrence of inundation by floods in each of the three settlements. The sampling technique adopted involved a combination of stratified-sampling and systematic random sampling. The entire city was first stratified into two spatial units which covered both planned and unplanned settlements. The sample included three settlement types all of which are within a low-lying plain land and are adjacent to one another. In the planned (formal) settlements, Migosi was purposively selected. The unplanned (informal) settlements were further categorized into two. These were upgraded informal settlement where Manyatta was selected; and informal settlement without any intervention where Nyamasaria was selected.

In each of these sampling areas, systematic random sampling was used. In Migosi, a random sample was derived from the Kisumu City Plot register. While, in both Manyatta and Nyamasaria, where growth is organic, transect lines were established parallel to the major roads with an interval of about one kilometre. A transect walk was made to determine and mark the households after which simple random sampling was used to sample the households for the study. In Manyatta six transect lines were established in equal interval parallel to the main roads outwards. Similarly, in Nyamasaria, five transect lines were established running parallel to Kisumu–Nairobi road.



Migosi		Manyatta		Nyamasaria	
Total Households	4,795	Total Households	29,227	Total Households	4,880
Sample	150	Sample	160	Sample	150

Fig. 3 Selection of settlements to be studied
Source: Authors

Logistic regression model was used to develop a prediction model. It was used to analyse the relationship between suffering inundation by floods in the past as the categorical dependent variable and the type of settlement typified by different development patterns as the independent variable. The model estimates both the odds of an events occurrence and the effects of independent variables on the odds. The natural log of the odds of an event equal the natural log of the probability of the event occurring divided by the probability of the event not occurring:

ln{odds(event)} = ln{prob(event)}/ prob(nonevent). The equation for can be written as:

odds = $e^{a+b_1X_1+b_2X_2+\ldots}$ …………………………………………………………………………. (1).

The equation for probability therefore is: p = $e^{a+b_1X_1+b_2X_2+\ldots} \div 1+ e^{a+b_1X_1+b_2X_2+\ldots}$ ………... (2).

Where:

p = the probability that a case is in a particular category,
e = the base of natural logarithms (approx 2.72),
a = the constant of the equation and,
b = the coefficient of the predictor variables.

Since the outcome is dichotomous, we model the natural (base e) log of the odds, referred to as the logit of a distribution. The odds express the likelihood of an occurrence relative to the likelihood of non-occurrence. In this case, the odds tell us how likely it is that any resident of the three settlements had suffered inundation by floods in the past in relation to how likely it is that the resident had never suffered inundation by floods in the past in the current place of residence. In developing the model, the absence of the variable inundation by floods in the past in current place of residence (i.e. 'no' response) was used as the reference category. Therefore, the coefficients that were derived were for the presence of the variable (i.e. 'yes' response). Using SPSS, the model was developed with the dependent variable being inundation by floods in the past in the current place of residence (0 = no; 1 = yes). Types of settlements were the independent variables with the different places of residence (PLAOFRES) being used as proxies. These different settlement types were PLAOFRES (0) – formal (Migosi); PLAOFRES (1) - informal upgraded (Manyatta) and PLAOFRES (2) - informal without intervention.

5. Results and Discussion

5.1 Inundation of households by floods in the past in the settlements

The findings of the field survey indicate that Nyamasaria leads with respondents who have suffered inundation by floods in the past. Over 91% of the owner occupiers interviewed indicated that they had suffered inundation by floods in the past in their current place of residence. Similarly, more than 90% of the respondents who were renters had suffered inundation in their current place of residence. The situation is replicated in Manyatta where 88 per cent of the owner occupiers and 57 per cent of renters who were interviewed had suffered inundation by floods in the past in their current place of residence. Majority of the renters in both settlements who had suffered inundation by floods indicated 2008 and 2009 as the years when they suffered what they considered to be the worst inundation. While a number of home-owners in both settlements especially those living on ancestral lands cited the 1997 El-Nino floods as the worst inundation by floods experienced.

Table 1 Households that had suffered inundation in the past in current place of residence

	Home-owners			Renters		
	Frequency	Percentage	N	Frequency	Percentage	N
Nyamasaria	67	91%	74	69	91%	76
Migosi	01	09%	11	09	06%	139
Manyatta	07	88%	08	86	57%	152

Source: Field survey, 2014

In contrast, the findings of the survey indicate that majority (90%) of residents of Migosi settlement had never suffered inundation by floods in their current place of residence. Only 9 per cent of owner occupiers and 6 per cent of renters had ever suffered inundation by floods in their place of residence in Migosi. Out of the renters who had suffered inundation by floods, majority (70%) are those who had stayed in Migosi for more than a decade. Evidently, the suffering of inundation by floods in the past in Migosi is somewhat linked to the length of stay in the settlement with the few reporting to have suffered inundation in the past being those who have stayed longer in the area. This suggests rarity of this phenomenon within this settlement with the occurrence reduced to just occasional inundation linked to extreme weather events like El-Niño.

5.2 Logistic Regression Model

In order to demonstrate variation in flood risk levels amongst the three settlements, binomial logistic regression model was developed. The results of the logistic regression model first gives the test for the model fit. This test for model fit was conducted using Omnibus test and Hosmer-Lemeshow (H-L) goodness-of-fit test. The results of the omnibus test reveal that the model chi-square is 178.280, df = 2, which is statistically significant at $p< 0.01$.

Table 2 Results of the Omnibus tests of model coefficients

	Omnibus Tests of Model Coefficients			
		Chi-square	df	Sig.
Step 1	Step	178.280	2	.000
	Block	178.280	2	.000
	Model	178.280	2	.000

Source: Authors' analysis

The Hosmer-Lemeshow goodness-of-fit test indicate a H-L statistic having a significance of 1.0 which means that it is not statistically significant and therefore our model is quite good. This finding of significance leads us to conclude that there is adequate fit of data to the model.

Table 3 Results of Hosmer and Lemeshow test

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	.000	1	1.000

Source: Authors' analysis

The model summary table provides the -2 Log likelihood and pseudo R^2values for the model. The Cox & Snell R^2value is .385 while Nagelkerke's R^2 value is .515. Therefore, the explained variation in the dependent variable based on our model ranges from 39% to 52%. Most studies often use Nagelkerke's R^2 to estimate the variation. Based on that, our model explains roughly 52% of the variation in the outcome. This therefore suggests that that the settlement type (PLAOFRES) explains about 52 per cent of the variation in suffering of inundation by floods in the past in current place of residence by the households, and only 48% is explained by other factors not included in the model.

Table 4 Results of the model summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	325.900[a]	.385	.515

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Source: Authors' analysis

The model further assessed the effectiveness of the predicted classification against the actual classification.

In this study, 63.7% were correctly classified for not having suffered inundation by floods in the past in current place of residence and 94.5% were correctly classified for having suffered inundation by floods in the past in current place of residence. Overall, the classification was 77.4% correct. Therefore the sensitivity of the model is 94.5% as compared to its specificity which is 63.7%.Conventionally, the higher the sensitivity and specificity, the better the diagnostic test. The classification accuracy in this case therefore, was way above the proportional by chance accuracy criteria and in effect, supporting the utility of this model.

The results in the variables in the equation table shows that there is a significant overall effect {PLAOFRES(1) - Wald = 59.171, df = 1, p< .001; PLAOFRES(2) - Wald = 89.512, df = 1, p< .001}. The B coefficient variable for both PLAOFRES (1) and PLAOFRES (2) are significant and positive. Positive B values indicate that an increase in the independent variable score will result in an increased probability of the case recording a score of 1 (i.e. yes) in the dependent variable.

The odds ratio - Exp(B), represents the change in odds of being in one of the categories of outcome when the value of a predictor increases by one unit. The results of our analysis show that the odds of having suffered inundation by floods in the past in their current place of residence compared to not having suffered inundation by floods for a household increases by a factor of 18.822 when the respondent is living in Manyatta compared to when the respondent is residing in Migosi. Similarly, the odds of having suffered inundation by floods in the past in current place of residence compared to not having suffered inundation by floods in the past for a respondent increases by a factor of 122.778 when he is living in Nyamasaria as compared to when a respondent is living in Migosi, all other factors being equal. In other words, compared to households in formal settlement (Migosi), those living in informal but upgraded settlement (Manyatta) have 18.822 higher odds (95% CI = 8.910 to 39.759) to have suffered inundation by floods in the past within the settlement. Likewise, those living in informal settlement that has not been subjected to any intervention (Nyamasaria) have 122.778 times higher odds (95% CI = 45.325 to 332.585) to have suffered inundation by floods in the past in their current place of residence. The results of this analysis clearly suggest that being a resident in a formal settlement compared to other types of settlements decreases the odds of having experienced inundation by floods in the past within that settlement.

Table 5 Results of the variables in equation

Variables in the Equation									
								95.0% C.I.for EXP(B)	
		B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	PLAOFRES			95.278	2	.000			
	PLAOFRES(1)	2.935	.382	59.171	1	.000	18.822	8.910	39.759
	PLAOFRES(2)	4.810	.508	89.512	1	.000	122.778	45.325	332.585
	Constant	-2.670	.345	60.020	1	.000	.069		

a. Variable(s) entered on step 1: Place of Residence.

Source: Authors' analysis

5.3 Discussion

This study sought to find out the relationship between urban development patterns and vulnerability to flood risk in three settlements that had undergone different development processes. The results show that there are variations in flood risk among the households living in the three settlements. In spite of their proximity as well as being subjected to the same precipitation events, the three settlements show marked variations in the odds of suffering inundation by floods. The two settlements (Nyamasaria and Manyatta) that had undergone informal urban development process emerged as the ones where the odds of having suffered inundation by floods in the past are the highest. It however emerged that the odds are higher in Nyamasaria settlement than in Manyatta settlement. This can be explained by the upgrading that was done in Manyatta which included among other things the improvement of housing structures and the provision of some form of drainage infrastructure. Migosi, which is a formal settlement, has the least odds of any resident having suffered inundation by floods in the past.

Emerging from the foregoing, there are higher probabilities that people residing in the settlements that had undergone unplanned development would suffer inundation by floods. In contrast, there are lower probabilities that the people residing in planned settlement would suffer inundation by floods. This disparity in the odds of having suffered inundation by floods in the past among the residents of the three settlements is attributed to the dissimilarity in urban patterns exhibited by the three settlements. It can therefore be understood that whereas the urban spatial patterns created through informal development are vulnerable to flood risk, those created through pre-planned or formal development process work toward attenuating flood risk potential.

6. Conclusion

The findings of this study clearly point to variation in vulnerability to flood risk among various settlement types that have undergone different development processes. Whereas settlements that developed formally exhibit infrequency of inundation by floods and therefore less vulnerability, those that developed informally show frequent cases of inundation by floods hence indicating high vulnerability. This variation in flood risk profiles can largely be attributed to the variegated spatial patterns that embody the fabric of the different settlements. The spatial patterns are exemplified in locational and site attributes as well as structural factors of the built environment. The variation in vulnerability to flood risk is thus a clear indicator of the role of development-led urban patterns as the primary driver of flood risk in Kisumu city. Although the flood events within the city could be attributed to its spatial location downstream at the lakeshore, this study concludes that the scale of the risk from such flood events is largely configured by spatial patterns characterizing the various settlement types. As such, urban flood risk in Kisumu city is an explainable product of failures in urban development where informal urban development predominate the current expansion of the city into the surrounding areas.

7. Recommendations

Emerging from our conclusion, the most effective action in addressing urban flood risk in Kisumu city is in providing the settlements with features which can limit flood risk. The key elements in the prevention of flood risk are the proper land use planning of the settlements, provision of risk-reducing infrastructure and building control. The following explain in detail how this can be achieved:

1. Introduction of a Plan-Service-Build-Occupy (PSBO) institutional framework: As the extent of urban flood risk in Kisumu city is a direct consequence of how the land is used, efforts to reduce the risk would naturally stem from the proper use of urban land. This can be achieved through institutionalization of the Plan-Service-Build-Occupy framework to guide the formation and development of the settlements within the city. The PSBO framework would provide the opportunity to better plan the formation of any new settlement and new buildings and this is central in mitigating flood risk.
2. In certain parts of Kisumu city, it is impossible to entirely eliminate the risk from flooding. It would therefore require the city authority to determine which areas are highly exposed to flood risk. This could be done through the definition of flood-prone area using a flood hazard map. Accordingly, city authority in liaison with the County government should prepare a flood hazard map for the entire city. Based on those maps, different flood hazard zones could be delineated and placed under land use regulation to limit the flood damage potential. The land use regulations and zoning policy within these areas would completely or partially restrict development in areas deemed to be at certain degrees of risk from floods.

Acknowledgement

This paper is a product of a study conducted in Kisumu city. The study was fully funded through a scholarship from the Deutscher Akademischer Austausch Dienst (DAAD). The authors are immensely grateful for this invaluable support from this organization.

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