Influence of Urbanization on Hydrology and Infrastructure in the Kabuga Town, Rwanda

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Abstract

Rapid population growth goes with urbanization, and the formation of impervious cover is the characteristic of the latter. The impervious cover increase can alter the hydrological cycle and hydraulic efficiency of drainage areas thereby influencing urban water management. The paper assesses the influence of urbanization on hydrological cycle and their impact on the performance and design of storm water drainage structures at Kabuga town (4.87 km^2), through the analysis of meteorological data records. Meteorological data have been collected from Rwanda Meteorological Agency for the old time period (1983-1985) and modern time period (2008-2010). The study area has been delineated by using GIS software for a DEM map of 90 m resolution collected from the Center of GIS of University of Rwanda. Data were analyzed using hydrological methods (rational formula method) and empirical equations (formulae of De Chézy and Manning). The results lead to scientific recommendations for sustainable drainage structures design and performance protection, through making efforts in meteorological data collection and analysis, and launch storm water management policy to manage drainage structures generated flows.

***Keywords*:** Drainage structures design, Hydrological cycle, Kabuga town, Kigali city, urbanization

1. INTRODUCTION

In Kigali City and even across the whole Rwanda, human populations are becoming urban with a rapid increasing rate**.** This population increase is associated with the conception and implementation of new dwellings, large infrastructures such as industries, markets and many other institutions. Similarly the Kabuga town, the sub-urban town of Kigali City experiences the same situation. Considerable increasing water related catastrophic dangerous events such as floods, erosion and destruction of drainage structures have been observed in Kigali City including the Kabuga town and surrounding marshlands and even in various regions of the whole Rwanda. On the other hand, Rwanda in 2011 had higher urbanization rates approximately 18.7 % (Gatwaza, 2011). The Government of Rwanda foresees that 30 % of the Rwandan population will live in urban areas by 2020 (UN-Habitat, 2008; Gatwaza, 2011). Generally all these catastrophic events are associated by various problems such as death of people, destruction of some important infrastructures, commercial activities, transport and environmental disturbance. However, some of these problems are expanding rapidly in Kabuga town.

Urbanization can intensely alter the hydrologic response of a watershed. For instance, studies in urban watersheds have documented increased stream flow, reduced time of concentration (Wissmar et al., 2004; Murdock et al., 2004; Zachary et al., 2007). The urbanization is accompanied with an expansion of impervious area, in the form of parking lots, roadways, lawns, and rooftops which results in changes of watershed hydrology including the loss of floodplains, wetlands and even loss of people. This requires the regulation of flows by constructing dams and impoundments. This increase of impervious areas reduces infiltration and surface storage of precipitation and increases surface water runoff (Arnold, 1996). The urban influence upon the precipitation regime is quite strong (Kuprianov, 1973; UNESCO, 1974; Shver, 1976) but the element of the hydrological cycle that undergoes the greatest changes within the urban areas, is runoff in all of its phases (Kuprianov, 1973).

In general there is a more need for research and watershed management efforts in the rapidly urbanizing region. Thus, it experiences some of the predicted effects of urbanization on the hydrological cycle. This research was concerned with the assessment of influence of urbanization

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on hydrological cycle and their effect on the performance and design of drainage structures at Kabuga town. Recommendations on the urban environment and water management are also given in the study.

The assessment of possible influence of urbanization on water cycle and the effects on the performance and the design of drainage structures that may result, can lead to decision making about sustainable urban development and planning.

2. STUDY AREA

Generally, Cities in Rwanda are very recent where the rate of urbanization in 2008 was 18.7 % and the growth rate varied around 9% per annum (MININFRA, 2008) while the urban population increased at an average rate of 5.5% per annum between years (1978 and 1991) while the Rwandan annual population growth rate is 2.6 (NISR, 2012). These increases lead to cities expansion where some people need to settle or to live in suburban's of cities; this is the case of Kigali city. The urban demographic mass is concentrated in the City of Kigali. According to Kicukiro district, the city experienced a massive population loss but relatively minimal damage and destruction of building during the 1994 genocide but up to 1999 the population of Kigali has exceeded its pre-genocide level where currently it has density around 1556 Persons per square kilometer (NISR, 2012).

According to Rwanda Natural Resources Authority (RNRA), Rwanda is divided into nine main catchments (Fig. 1). As hydrological location, the Kabuga town is delineated by using shape files from RNRA and is found to be located in NAKU1 catchment (RNRA, 2012) with approximately 4873014.5 m^2. The delimitation was processed by considering the Kabuga town for different selected two periods of time (The first period –Old time consisting of years 1983-1985 while the second one-Modern time-for years 2008-2010) as it has experiences changes with time. These two periods have been selected based on available data.

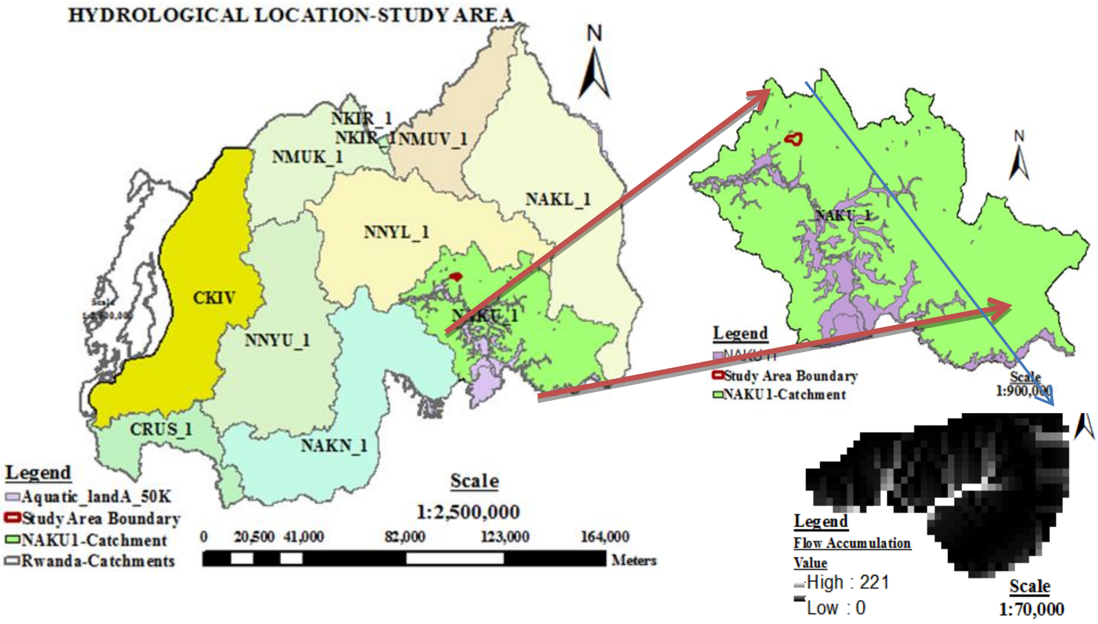


Figure 1: Hydrological location of the study area

The Kabuga town known as Kabuga hill is a populated suburban of Kigali city which is the capital of Rwanda; where some people from the central Kigali City and other far from rural areas come to live in order to approach the City. It is located approximately at 9.5 km from the Kigali International Airport and to approximately 17.6 km away from Kigali City center. The town takes parts from two adjacent districts (Kicukiro at Masaka Sector and Gasabo at Rusororo Sector) in Kigali city and is located between coordinates: Longitude 30°11'30"E and 30°14'0"E and Latitude 1°58'15"S and 1°59'35"S (Fig. 2). Kabuga has high gradient slopes with 9% of average lope.

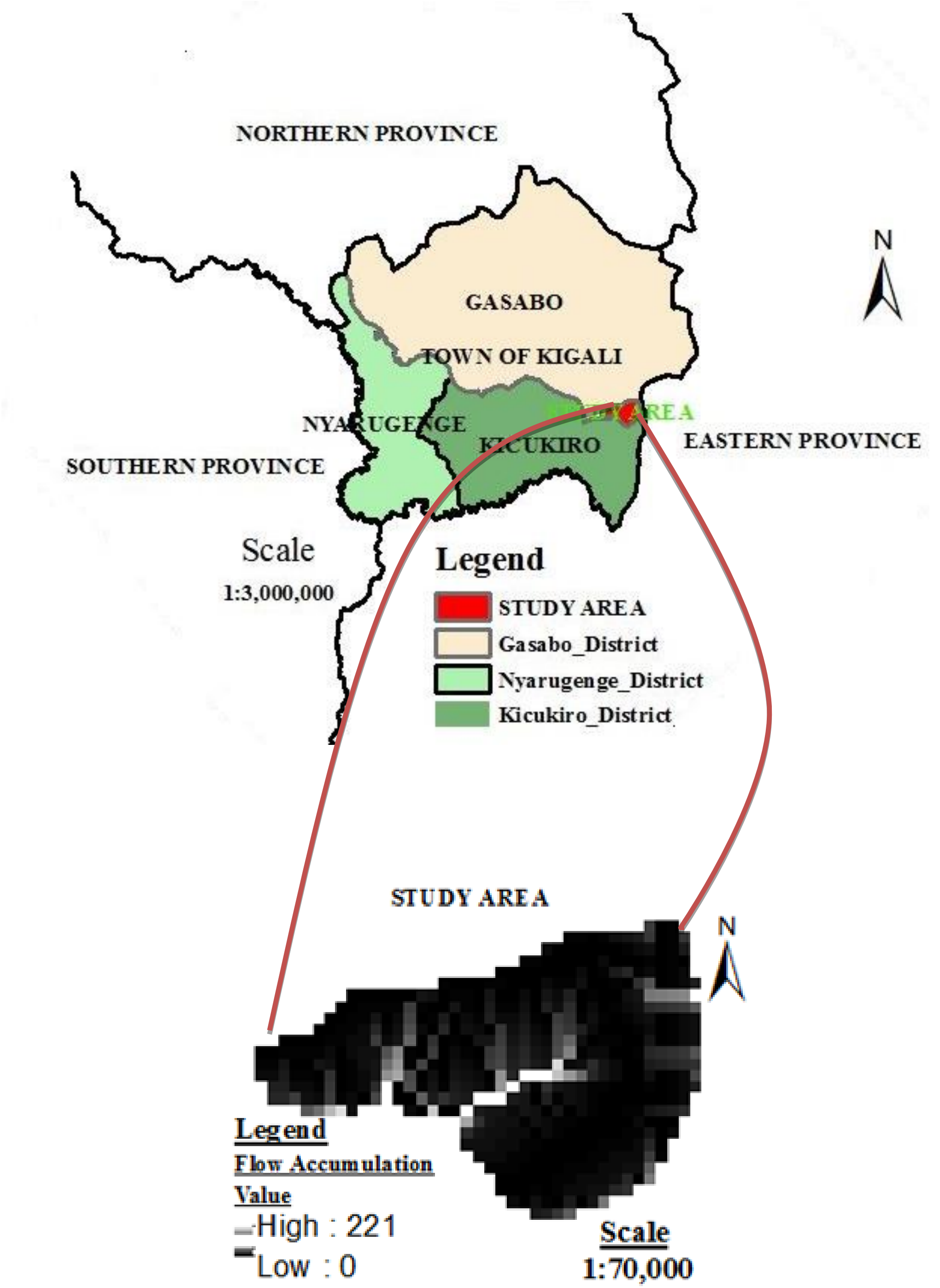


Figure 2: Study area location in administrative map

Study area evolution from the old to modern time

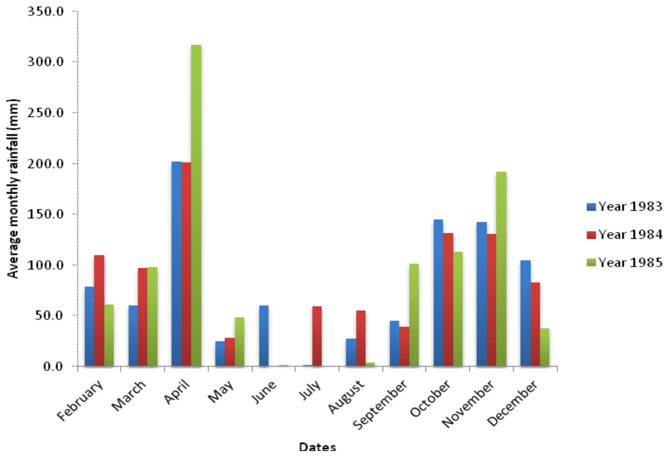
The location of Kabuga town in past years had a little proportion of inhabitants living there (this is according to old local population interview) which reflect the existence of a little proportion of impervious areas. Thus, the region in these years was largely covered by agriculture activities. According to the interview to old inhabitant people in the study area in past years, the remarkable changes have been observed in 1995 after the Rwandan Tutsi genocide, when a large amount of Rwandan refugees who lived outside of the country was coming back in their native country. On the other hand, Kabuga town being the suburb of Kigali city and with respect to the Kigali Master plan, many people wanted to settle down there. Also with the Rwandan government strategy for dwelling people in regrouped settlement (locally known as Imidugudu), a large part is covered by agglomerations. Nowadays the Kabuga town is a highly populated town with increasing population density as part of Kigali city (NISR, 2012). In this area many large institution and infrastructures are being implemented and constructed such as schools, hotels and churches. The land cover today is being dominated by impervious areas with decreasing agriculture activities in contrast to the past time.

3. DATA PROCESSING AND ANALYSIS TECHNIQUES

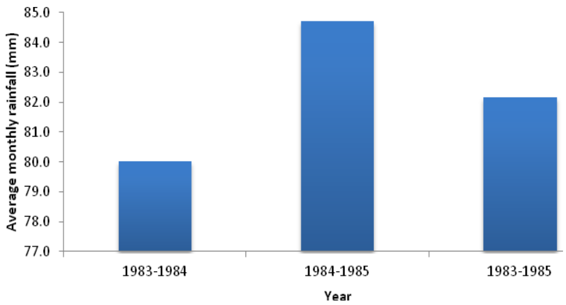
3.1 Input Parameter in Study Area-(Rainfall) During Old Time Period

The rainfall being the quantity of water that enters in the area is very important in the water balance of the latter. For the present project, rainfall data are obtained from Rwanda Meteorological Service (RMS) at KIGALI-Aero meteorological station. These data have been collected for the period of years 1983-1985.

The daily rainfall data for three years (Jan 1983-Dec 1985) as recorded have been transformed into monthly rainfall data and then the annual rainfall and average rainfall has been generated using the Arithmetic Mean Method. This equation has been used for determining average rainfall and the results are shown in Figure 3. The arithmetic mean of the rainfall amounts measured in the area provides a satisfactory estimate for a relatively uniform rain.



a)



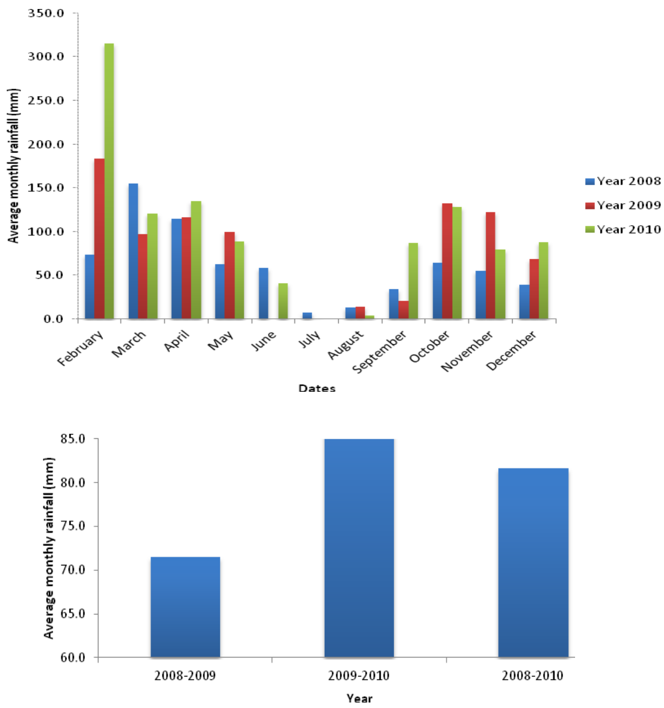
b)

Figure 3: Average monthly rainfall from Kigali Airport meteorological station in old time period based on a) yearly data records and b) yearly averaged basis.

Figure 3 shows that the dry season in the Kabuga within Kigali city lasts 4 months (May; June; July and August), with June and July very critical. This is different from the known dry period in Rwanda which normally lasts 3 months (June; July and August) (see Munyaneza et al., 2012). The explanation of this change is not yet known and more research could be done. The maximum average rainfall was observed in the month of April 1985 (317.1 mm) as shown in Figure 3a. The monthly average rainfall in the city is 82.15 mm (Fig. 3b) and average annual rainfall is equal to 985.8 mm.

3.2 Input Parameter in Study Area-(Rainfall) During Modern Time Period

The rainfall data for the modern time are also obtained from KIGALI-Aero meteorological station. The collected data are for the period of years 2008-2010. The daily rainfall data for three years (Jan 2008-Dec 2010) also as recorded have been transformed into monthly rainfall data and then the annual rainfall and average rainfall have been generated in Figure 4.



a) b)

Figure 4: Average monthly rainfall from Kigali Airport meteorological station in modern time period based on a) yearly data records and b) yearly averaged basis.

Figure 4 shows that the dry season in the Kabuga within Kigali city lasts 3 months (June; July and August), with July and August very critical. The maximum average rainfall was observed in the month of February 2010 (315.7 mm) as shown in Figure 4a. The monthly average rainfall in the city is 81.61 mm (Fig. 4b) and average annual rainfall is equal to 979.3 mm.

3.3. Outflow Of The Study Area

The outflow of the study area is runoff which was estimated using rational method (Haan *et al*., 1982; De Laat and Savenije, 2002) for the return period of 10 years because it is suitable for sizing drainage conveyance systems (storm drains, culverts, and drainage channels), with limited contributing areas (Nyman, 2002). The runoff Q is calculated by rational formula method (Eq. 1) for both old and modern time period. The equation actually used for calculating the peak storm water runoff rate **Q**:

$$Q_p = CIA \tag{1}$$

where: Q_p = Peak runoff rate [m³ s^{-1}], C = Runoff coefficient [-] (dependent on catchment characteristics), I = Intensity of rainfall during time t_c [m s^{-1}], and A = Catchment area [m^2]. The value of I is assumed constant during t_c and the rain uniformly distributed over A. The peak flow Q_p occurs at time t_c).

Using Arc Map and Arc toolbox (ArcGIS software) with orthophoto from CGIS, the study area land use (dominating crops) has been determined for the Old and Modern time periods (see Fig. 5 and Tables 1 and 2). It is considered that the rate of urbanization is proportional to the decrease of crop covers in the study area. As the area was not covered by the same land use type, the composite runoff coefficient is calculated by the Equation 2.

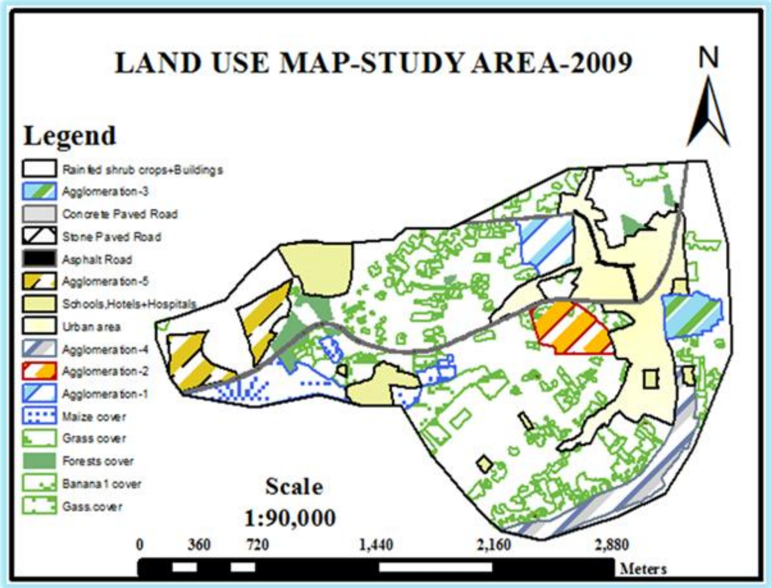


Figure 5 Study area land use map for modern time period

3.4. Estimation of Runoff Coefficient

The runoff coefficient (C) is the least precise variable of the rational method ($0 < C \leq 1$, [-]) (Mihalik, 2007). It is a dimensionless ratio intended to indicate the amount of runoff generated by catchment given an average intensity of precipitation for a storm (Thompson, 2006). Its use in the formula implies a fixed ratio of peak runoff rate to rainfall rate for the drainage basin, which in reality is not the case. However, the runoff coefficient [-] from an individual rainstorm is normally defined (Hawkins, 1975) as runoff divided by the corresponding rainfall, both expressed as depth over catchment area in mm:

$$C = \frac{Q}{P} \tag{2}$$

All catchment losses and water storages are incorporated into the runoff coefficient, which is usually a function of the land use, soils, geology, etc. This means that the magnitude of this coefficient is not constant, but varies with time and in space depending on a number of different factors such as the topography of the catchment, magnitude and intensity of the storm rainfall, vegetation cover and land use, infiltration rate and the initial soil moisture condition, groundwater depths and subsurface flows (e.g. EFM, 1984 in Musoni *et al.*, 2010; Uhlenbrook, 2007). All of these factors influence the hydrological connectivity.

Table 1: Rational method runoff coefficients for modern time period

Category of drainage area	Type of drainage area	Area of occupancy Ai (m^2)	Characteristic runoff coefficient (Ci)	Ci x Ai
Residential	Single family areas	315095.68	0.50	157547.84
	Multi-unity detached: Agglomerations	379581.61	0.60	227748.97
Roof	Roof area	118409.55	0.95	112489.07
Streets	Asphaltic roads	53587.00	0.95	50907.65
	Concrete roads	5388.31	0.95	5118.89
	Stone paved roads	7747.80	0.85	6585.63
Business	Neighborhood: Schools, hotels, hospitals	220007.30	0.70	154005.11
Lawns	Sandy soil, average 2-7%	3110545.24	0.15	466581.79
Urban	Urban area	662651.97	1.00	662651.97
Study area runoff coefficient C = (Σci x Ai)/Σai				**0.38**

Table 2: Rational method runoff coefficients for old time

Category of drainage area	Type of drainage area	Area of occupancy Ai (m^2)	Characteristic runoff coefficient (Ci)	Ci x Ai
Residential	Single family areas	76374.03	0.50	38187.02
Roof	Roof area	27280.69	0.95	25916.66
Streets	Asphaltic roads	5759.75	0.95	5471.76
Lawns	Sandy soil, average 2-7%	4530364.46	0.15	679554.67
Urban	Urban area	233235.55	1.00	233235.55
Study area runoff coefficient C = (Σci x Ai)/Σai				**0.20**

3.5 Estimation Of The Design Rainfall Intensity (i)

Alternatively, rainfall intensity can be computed by the recommended standard IDF equations (Butler and Davies, 2004), and the Equation (3) was selected due to the field investigation on the decade floods occurred in the Kagera River basin as monitored in 2009 by Munyaneza *et al.* (2011). Based on their preliminary results, they have assumed that the flood frequency in the Kagera River basin is 10 years, but they suggested that an advanced study is needed to check or confirm this assumption based on longer rainfall time series available all over the basin. Note, that Migina catchment is a sub-catchment of Kagera River basin.

$$I_{10} = \frac{140}{t_c + 0.7} \qquad (3)$$

where I_{10} is intensity in (mm hr^{-1}) for the return period of 10 years and t_c is time of concentration in mins.

The applied method assumes that the maximum runoff rate in a catchment is reached when all parts of the catchment are contributing to the outflow. This happens when the time of concentration is reached. The Kirpich/Ramser formula (Kirpich, 1940) is mostly used to calculate the time of concentration (De Brouwer, 1997; De Laat and Savenije, 2002; Dawod and Koshak, 2011):

$$t_c = 0.0195 L^{0.77} S^{-0.385} \qquad (4)$$

where: t_c = Time of concentration [min], L = Maximum length of the catchment [m], S = the slope of the catchment over the distance L [m/m]. In cases there are no upstream drains, the inlet time is considered as the time of concentration and is usually obtained by the Kirpich (Kirpich, 1940) or the Lloyd-Davies (not used in this study) formula which include the time of entry $t_e = \frac{58.5L}{A^{0.1}S^{0.2}}$. All the above formulae are very simple empirical equations that are not fully physically based and the units do not add up.

Notes: L and S_{mean} are obtained using ArcGIS software: ArcMap and ArcTool box with Spatial Analyst Tools (Fig. 6).

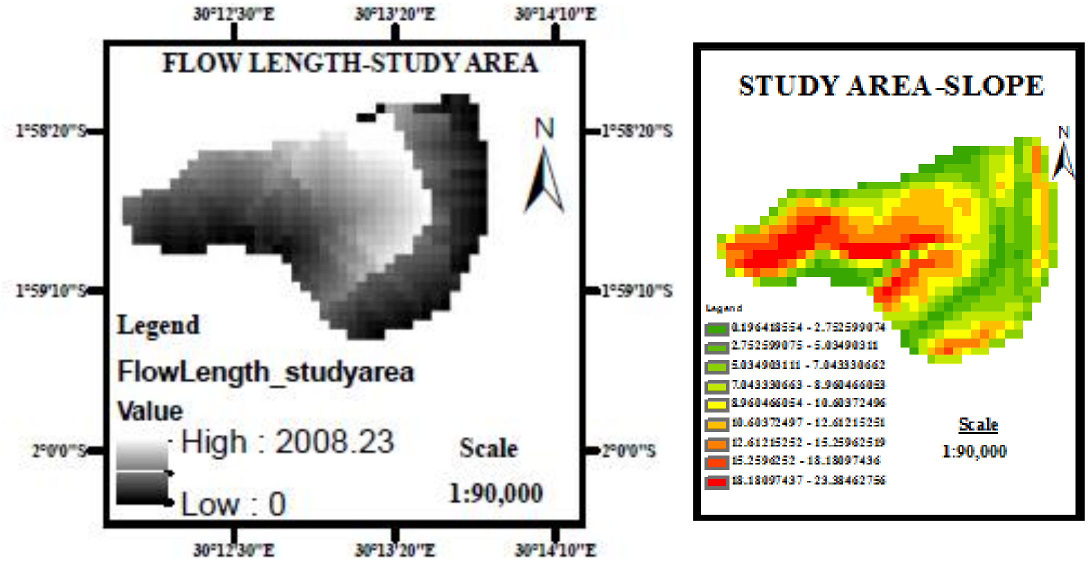


Figure 6: Flow lengths and slope ranges of the study area

3.6. Water Balance of The Study Area

The concept of water balance state that any difference between the inflow and the outflow over a certain time period represents the water that has entered or left storage within the catchment/Watershed (Waterloo *et al.*, 2007).

This is expressed mathematically as follows:

$$Inflow[I] = Outflow[O] \pm Storage[S] \tag{5}$$

All of these components (inputs, outputs, storage) vary over time. Thus, the water budget must be considered in terms of some unit of time, depending on the analysis.

The water balance derived from Equation 5 gives Equation 6 and was used in this study for both Old and Modern time periods (Davie, 2008).

$$Q = P - ET - \Delta S \text{ or } P - Q - ET - \Delta S = 0 \tag{6}$$

Note: The ΔS can be + or – as water can be released from the storage - or absorbed from the storage +.

3.7. Drainage Structures Design

The study area is one of expansion sides of Kigali city, that's why it is becoming more populated with the implementation of new infrastructures including hydraulic structures to control flows for ensuring the safety of inhabitant people. Open channel drainage are one of categories of these structures and must be designed to carry the design discharge in a safe and cost - effective manner especially rainfall flow discharge generated from the drainage area.

For the design of the drainage structure-A rigid boundary Open channel, the common used formula" the Manning's Equation for uniform flow (Eqs. 7 and 8)" has been used. The steps for the design of a rigid-boundary channel presented in Anyemedu (2007) have been used for sizing this kind of channel in the study area for time periods.

The hydraulic discharge Q=VA (7)

The most popular velocity of flow V [m/s] in U.S. for open channels:

$$Q = \frac{A}{n} R_h^{\frac{2}{3}} S_0^{\frac{1}{2}} \tag{8}$$

where n is the Manning roughness coefficient [-], R_h is the hydraulic radius, and S_0 is the slope of the channel (dimensionless).

4 RESULTS AND DISCUSSION

4.1 Input Parameters in The Study Area (Inflow)

The total average rainfall in the study area for the old time period (1983-1985) is equal to 985.8 mm (Fig. 3) whereas the total average rainfall in the study area for the modern time period (2008-2009) is equal to 979.3 mm (Fig. 4).

4.2 Output Parameters in Study Area (Out Flow)

The results of output parameters are summarized in the Table 3 below.

Table 3: Results of output parameters

	Peak runoff – design discharge Q			**Evapotranspiration**	
Parameter	**Old time period**	**Modern time period**	**Parameter**	**Old Time period**	**Modern Time period**
Rational Runoff coefficient C [-]	0.2	0.38	Reference crop evapotranspiration ETo [mm]	1006.85	950.21
Design storm intensity I [mm/h]	7.9	7.9	Actual adjusted crop coefficient Act Kadj [-]	0.52	0.42
Area Reduction factor ARF [-]	0.73	0.73			
Area of the study area A [ha]	487.3	487.3			
Peak Discharge rate **Q [m^3/s]**	**1.57**	**2.99**	Actual evapotranspiration ET act=ETc adj [mm]	**523.56**	**399.09**

4.3 Water Balance of The Study Area

The water balance is assessed by using Equation 5 for both time periods of the study and results are summarized in Table 4 for both old and modern time periods.

Table 4: Results of water balance

Parameter	**Old time period**	**Modern time period**
Rainfall P (m)	0.9858	0.9793
Evapotranspiration ET (m)	0.5236	0.3991
Discharge Q (m^3/year)	52,665,120	94,292,640
Study area A (m^2)	4,873,014.47	4,873,014.47
Change in storage ΔS (m^3/year)	**-50412617.79**	**-91465414.46**

4.4 Design of The Drainage Channel

This section is concerned with the demonstration of possible effects of hydrological changes on the performance and design of drainage structures. The demonstration was performed by carrying the design of a rigid-boundary Channel, by considering both peak discharges generated from the study area for both considered time periods.

4.4.1. Channel design-rigid boundary channel-old time period

Suppose that the channel alignment has been selected by taking into account all requirement stated in chapter II. The channel is to be sized and shaped in the study area by considering the design discharge **Q=1.67m³/s** as has been calculated.

I. Design considerations

- Design flow or design discharge Q=1.67m^3/s.

- Longitudinal slope of the channel S_o, for economic issues is taken to be equal to the mean slope of the terrain (So=0.09), considering flow of low sediment concentration.
- The common channel shape type "Trapezoidal cross section" has been considered.
- Suppose the channel material from preliminary study is selected to be "Concrete bottom float finished with sides of random stone in mortar" the mostly used in Kigali.

II. Design processing and calculations

- For the channel material, the roughness coefficient ***n***=0.020
- The section factor: $AR_h^{\frac{2}{3}} = \frac{nQ}{(C_0 S_0)^{\frac{1}{2}}} = \frac{0.02x1.67}{(1x0.09)^{\frac{1}{2}}} = 0.11$ (i)
- For trapezoidal shape cross section :

  - *Geometrically,*

Considering a hydraulically efficient channel (which will be considered in this calculation) from Figure 7 for a trapezoidal channel section,

The Flow Area $A = \sqrt{3}Y^2$ (ii)

Replacing (ii) in (i) we get, Y=0.4229m≈0.42m=42cm.

For hydraulically efficient trapezoidal channel section, the channel bottom width B_o for wetted perimeter P is given by: $B_0 = \frac{2}{\sqrt{3}} Y = \frac{2}{\sqrt{3}} x0.423$ for which the channel slope s=60°

⇒B_o=0.488m≈0.49m=49cm.

- *Final Channel Geometric dimensions*:

Y=42cm, B_o=49cm, freeboard F_b= 33.6cm. The flow area A=0.31m^2 and the flow velocity V=5.4m/s, thus no silting and vegetation growth, thus the flow velocity is acceptable, no silting of sediments and vegetation growth.

4.4.2. Channel design-rigid boundary channel-modern time period

The process is the same for past time but the channel is to be sized and shaped in the study area by considering the design discharge Q=2.99m^3/s as has been calculated for this time period.

I. ***Design considerations***

- Design consideration are the same, only the difference is about the design flow discharge which is equal to **Q=2.99m^3/s**.

II. ***Design process***

- For the channel material, the roughness coefficient ***n***=0.020
- The section factor: $AR_h^{\frac{2}{3}} = \frac{nQ}{(C_0 S_0)^{\frac{1}{2}}} = \frac{0.02x2.99}{(1x0.09)^{\frac{1}{2}}} = 0.199$ (i)

Also considering hydraulically efficient trapezoidal channel, $R = 0.5Y$ (ii)

Replacing (ii) in (i) we get, $Y = \left(\frac{0.199}{0.5^{\frac{2}{3}} \sqrt{3}} \right)^{\frac{3}{8}} = 0.5282m \approx 0.53m = 53cm$

Also for hydraulically efficient trapezoidal channel section:

$B_0 = \frac{2}{\sqrt{3}} Y = \frac{2}{\sqrt{3}} x0.5282$ for which the channel slope s=60°

⇒ B_o=0.6099m≈0.61m=61cm

Final Channel Geometric dimensions: Y=53cm, B_o=61cm, freeboard F_b=42.4cm. The flow area A=0.485m^2 and the flow velocity V=6.1m/s, thus the flow velocity is acceptable, no silting of sediments and vegetation growth, figure 7.

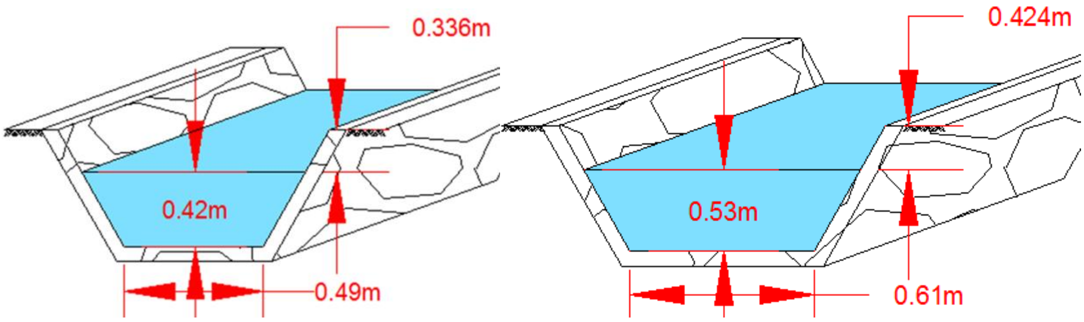


Figure 7: Channel dimensions for old time and modern time respectively to the left and right

4.5 Results Comparison and Discussion

4.5.1. Results- comparison

The Tables 5, 6 & 7 presents the comparisons and summary of results from the data analysis for the considered time periods, Old time (1983-1985) and Modern time (2008-2010).

Table 5: Hydrological cycle parameters comparison

HYDROLOGICAL PARAMETERS		TIME PERIODS		DIRECT DRAINAGE STRUCTURES DESIGN HYDROPARAMETER
Parameter types	**Parameters**	**Old Time period**	**Modern Time**	
Input	Rainfall (mm)	P_1 = 985.8	P_2 = 979.27	
Output	Peak discharge (m3/s)	Q_1 = 1.67	Q_2 = 2.99	
	Evapotranspiration (mm)	ET_{act1} = 523.56	ET_{act2} = 399.09	Peak discharge = Design discharge Q1 and Q2
Study area water balance	Storage change (m3)	-50412617.79	-91465414.46	

Table 6: Population growth rate

t (year)	p_t (year 2012)	p_o (year 2002)	1/t	p_t/p_o	R
10	1135428	765325	0.1	1.483589325	4.02

Table 7: Design parameters and results

DESIGNED CHANNEL DIMENSIONS-SIZE IN THE STUDY AREA	TIME PERIODS	
	Old Time	**Modern Time**
	Design discharge	
	1.67m^3/s	**2.99m^3/s**
Free Board (cm)	36.6	42.4
Flow depth (cm)	42	61
Bottom width (cm)	49	53
Total depth (cm)	78.6	103.4

4.5.2. Discussion of results

4.5.2.1 Results presentation

The minus sign minus (–) (Table 5) for the change in storage means that the water from the storage has been decreased of amount 50412617.79 cubic meters per year and 91465414.46 m^3/a for Old and Modern time, respectivelly.

The direct drainage structures design hydro-parameter in Table 5 is the hydrological parameter directly applied in the design of such structures, the peak discharge Q. (Table 6) is the estimate average annual growth rate of population in the area and Table 7, presents the dimensions of the designed trapezoidal channel for both design discharge Q_1 and Q_2 (Table 5), respectively for Old time and Modern time periods.

4.5.2.2 Influence of urbanization and population increase on hydrological water cycle

Ideas of different researchers presented in Section 3 agree on the fact that "the increase of impervious areas as results of urbanization alters the hydrologic response of a watershed by increasing the hydraulic efficiency of the area and similarly reducing the infiltration and surface storage of rainfall and increases surface water runoff". The results of the present study (Table 5) show the same changes in these parameters as a result of urbanization of the study area. Thus these agreements are true:

About the runoff, from the Old time up to the considered Modern time, it has been increased approximately 79.4%. This is the result of the development of urbanization activities which has increased the impervious areas in the study area. In fact higher peak discharge causes the storm water flows to exceed the capacity of the existing drainage structures and the latter may be damaged and surrounding areas may be flooded.

About the evapotranspiration from the Old time up to the considered Modern time has been reduced approximately 23.8%. This may results from the implementation of urbanization activities which reduces the green crop cover in the study area.

The precipitation between the two time periods of study has been decreased by 0.65%. This maybe result from climate change, the global issue. Note that this climate change is somehow related to the urbanization as the latter is one of sources of Green House Gases (GHG) emission which causes the climate change and carbon development (MINIRENA, 2011).

About the storage change, the results show that the change in storage has increased in magnitude with negative sign between both periods. This implies that water from the storage has been increasingly released ,this also has effect on water resources availability. There have been increase of deficit in water storage batween both time periods.

From Table 6, it is clear that the population in the study area increases with a high rate (6). Comparing these changes with changes related to the runoff and evapotranspiration (Table 5) which result in the increased impervious area percentage resulting from urbanization, it can be concluded that this urbanization is fairly associated with the increased inhabitant population and both influence the hanges on these hydrological cycle parameters.

4.5.2.3 Effects of water cycle change on the performance and design of drainage structures

In previous paragraphs, it has been stated that, in the design of drainage structures or of hydraulic structures in general, the hydrologic discharge (hydrological parameter from Rational Method) is directly applied in the design as the design discharge Q or peak discharge. On the other hand, from results presented previously, it has been found that there have been changes in hydrological cycle parameters including the runoff (peak discharge) Q. This reflects the change of the spatial flow, increase of hydraulic efficiency in the area by increasing the volume and surface water runoff as have been demonstrated in Section 4.5.2.2 of this paper.

The effects of the hydrological cycle change on the performance and the design of drainage structure has been assessed through the results of the drainage channel design in the study area by assessing the effect of changes of the water cycle discharge between both time periods.

In Table 7, it is well demonstrated that the channel dimensions from the design of a rigid boundary channel for the Old time have significantly increased:

- The calculated dimensions of the Modern Freeboard have increased by approximately 15.8% compared to that of Old time.
- About the Flow depth, comparison of the Modern and Old time shows that for Modern Channel, it has significantly increased by approximately 45.2%.
- For the bottom width of the channel, dimension has increased by approximately 8.2%.
- The total channel depth (freeboard + flow depth) has also significantly increased by approximately 31.6%.

On the basis of these changes in dimensions, it can be concluded that by considering the same drainage area (same slope) and the same channel material; for the increased discharge Q_2 for the Modern urbanized area, the design provide bigger channel compared to that of Old non urbanized area for low discharge Q_1 due to the fact that the flow to be conveyed by the channel in the Modern time has been considerably increased due to urbanization. Thus designing without considering future urban development lead to the flooding of drainage structures and finally to environmental disturbance.

4.6 Recommendations for Sustainable Performance and Design of Drainage Structures

With the higher rate of population growth, the study area will continue to become urbanized. The future water cycle parameters fluctuations resulting from urbanization will have dangerous effects on the performance of drainage structures if future development conditions have not been considered during the project design stage. Despite the effects of urbanization, if wise measures are made, the urban generated storm water runoff can be controlled and their negative impacts should be minimized. This section summarizes the engineering and non-engineering alternatives measures for controlling the rainfall surface runoff.

To fight against water related problems, the local governance must hire hydrologists at the lowest levels for dealing with all water related issues. For the purpose of design and from meteorological data analysis, hydrologists must provide data about the intensity-duration-frequency (IDF) curves from which the design storm intensity i can be determined. The design storm intensity should be carefully selected since it can be affected by the climate change. Flows for which structures are designed change over time and the storm drainage channel may be flooded and finally eroded. That’s why the IDF curves and all other relevant approaches should be provided for trend detection.

The government must establish the storm water management policy and regulations for environmental and the wetlands protection against the flow generated from the drainage structures. To protect the surrounding wetlands, well-designed runoff storage on site can be provided and the release of water from the storage facility must be regulated.

Planners and project designers should minimize impervious areas, steep slopes, maximize opportunities for infiltration and overland flow paths by using land use management strategy. The recommended project documents and calculation results (submittals) for any infrastructure project including drainage structures should be submitted to local conservation administrators for sustainable urban development for verification and project approval.

Finally, the local administrators or institutions in charge must provide guidelines for projects development and encourages engineers developing projects fulfilling storm water management policy and related regulations for meeting acceptable engineering storm water management.

5 CONCLUSION

The paramount objectives of this research were to assess the influence of urbanization on hydrological cycle through the analysis of historical and more recent meteorological data records and the effect of the latter on the performance and design of drainage structures at Kabuga town and finally give related scientific recommendations.

In fact, the study area is located in NAKU1 (Akanyaru) catchment (Fig. 1) and is delineated to be 4.87 km^2 with dominantly sand soil. From the data analysis, the study area average input "rainfall" is 985.8 mm and 979.27 mm, respectively for old and modern selected time periods for the research. Also the output has been calculated; for the “runoff discharge”, the runoff coefficient and design storm intensity (by empirical formula) have been determined and by using the rational method the average discharge is found to be $1.57m^3/s$ and $2.99\ m^3/s$, respectively for old and modern period whereas the average evapotranspiration is 523.56mm and 399.09mm respectively after taking into consideration the land cover characteristics. The water balance results indicate the deficit in water budget with change in storage of $50412617.79m^3$/year and $91465414.46m^3$/year (or approximately 10.3mm/year and 18.8mm/year). A rigid boundary drainage channel to convey storm discharge $1.57m^3/s$ and $2.99m^3/s$ for the two time periods have been designed and the channel dimensions have been calculated and found to be 45.2%, 8.2% and 15.8% respectively for flow depth, bottom channel width and freeboard.

To conclude, the analysis of results has been conducted by suitable approaches and the outcomes agree with ideas of researchers as have depicted and finally scientific recommendations about the sustainable design and drainage structures protection have been specified.

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