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EFFECTS OF LANDUSE AND LANDCOVER CHANGE ON FLOODING IN KANO METROPOLIS, KANO STATE, NIGERIA

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ABSTRACT

This paper looked at the change in land use land cover (LULC) of Kano metropolis from 2001 to 2012; projected to 2035 and thereby assessing the response of these different land covers to rainfall event using the Hydrologic Engineering Corps- Hydrologic Modelling System (HEC-HMS) model. The outcome of the LULC revealed that the built-up areas increased from 19.7% to 34.4% and then to 54.4% in 2001, 2012 and 2035, respectively. The discharge of Jakara basin indicated a rise from 2001, 2012 to 2035 in the order of 443, 585.2 to 609.7 cm^3/sec respectively. However, that of Chalawa shows increase between 2001 and 2012 and a decrease in 2035 as a result of canalization within the basin. The paper recommended adherence to the city masterplan and construction of canals within each sub-drainage basin for proper conveyance of run-off discharge.

Keywords: Landuse and Landcover (LULC), HEC-HMS model, Chalawa basin, Jakara basin and sub- drainage basins.

INTRODUCTION

Urbanization aggravates run-off by restricting where flood waters can go. In an urban area, large parts of the ground are covered with roofs, tarred roads and pavements. These obstruct sections of natural channels, infiltration and built drains that ensure water movement to rivers faster than it could under the natural conditions. Another factor in an urban setting is the population density. As more people crowd into cities like Kano Metropolis, so does the floods effect intensify because of the tendency to create more impervious surfaces. Consequently even quite moderate storms could produce high flows within a drainage basin because there are more hard surfaces than drains (Action Aid International, 2006). In extreme cases urban floods can result in disasters that setback urban development by years or even decades. Given the high spatial concentration of people and values in cities, even small scale floods may lead to considerable damages. Statistics clearly indicate that economic damages caused by urban floods are rising (MunichRe, 2005).

It is displeasing to note that, urban areas in Nigeria are particularly vulnerable to flooding due to inadequate drainage system; changes in ecosystem through the replacement of natural and absorptive soil cover with concrete; and deforestation of hillsides, which has the effect of increasing the quantity and rate of runoff. In the developed countries, flood forecasting and prediction, flood control and mitigation, early warning systems, disaster response and management have been in the forefront, however in most developing countries (including Nigeria), these responses are mostly inadequate. Flood early warning, prediction, and mitigation would have rather been better programmes than search and rescue, relief and rehabilitation programmes found in developing countries (Jeb, 2013).

Assessing flood hazard and related vulnerabilities often require knowledge of land use and land cover, run-off rate as well as human and environmental attributes of the communities. Land use and land cover (LULC) models such as the Markov model is a class of probability model used to study the evolution of a system over time. Transition probabilities are used to identify how a system evolves from one time period to the next. A Markov chain is the behavior of the system over time, as described by the transition probabilities and the probability of the system being in various states (www.jatit.org, 2017).

Hydrological models are regarded as powerful tools for predicting drainage basin response to rainfall events and assessment of impacts of parameters such as land-use and cover change on drainage basin hydrology (Whitehead and Robinson, 1993). The complexities of global flood disasters need a much technical approach than the conventional methods used, this will lead to a more effective management, reduction and forecasting of flood events. Alghmand, Abdullah, Abustan and Vosoogh (2010) reiterated that information on drainage basin characteristics and response to rainfall help reduce risk and vulnerability levels within the basins and mitigate future occurrence of flood events.

MATERIALS AND METHODS

Study Area

Kano Metropolis is located within latitudes 11^0 52'30" N to 12^0 7'30" N and Longitudes $8^0$25'30" E to $8^0$40' E. The boundary of the Metropolis keeps changing with time (Mortimore, 1989) as a result of urban sprawl. The Metropolis is made up of eight Local Government Areas namely: Municipal, Gwale, Dala, Fagge, Tarauni, Nassarawa, Kumbotso, and Ungoggo (Fig.1). The study area comprises of two drainage basins: the Challawa river basin in the south with an area of 109.8km^2, 17 sub-basins, 8 junctions and Jakara river basin in the north with an area of 104.9km^2, 15 sub-basins and 7 junctions (Fig.2).

Land use Classification

The first step was to download the satellite image, and then the image was georeferenced to the coordinate system of the study area from World Geodic System 1984 Projection to Universal Transverse Mercator (WGS84 to UTM, Zone 32N). Visual image by colour compositing of three band 3, 2, and 1 for red, green and blue respectively.

The next step is to define spectral characteristics of different classes by identifying sample areas. Samples of a specific class include a number of training pixels into groups (classes) according to their spectral characteristics to see how it relates to the sample classes.

After defining the training sample, the method of maximum likelihood classification was applied in order to obtain the land use land cover classification.

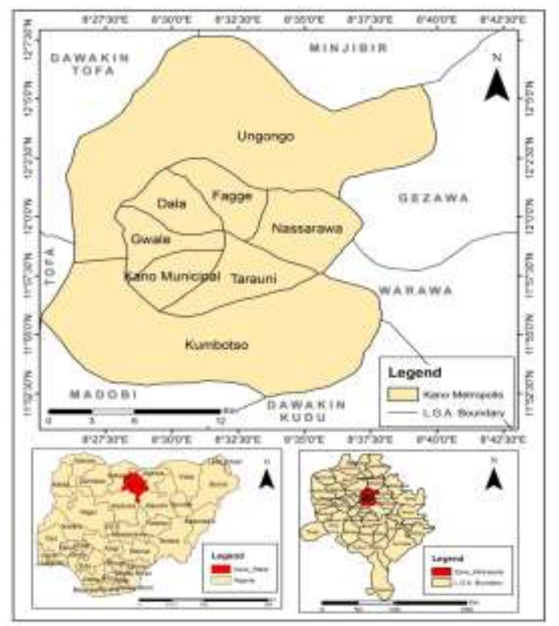

Figure 1: Map of the Study Area
Source:Adapted from the Administrative map of Kano State

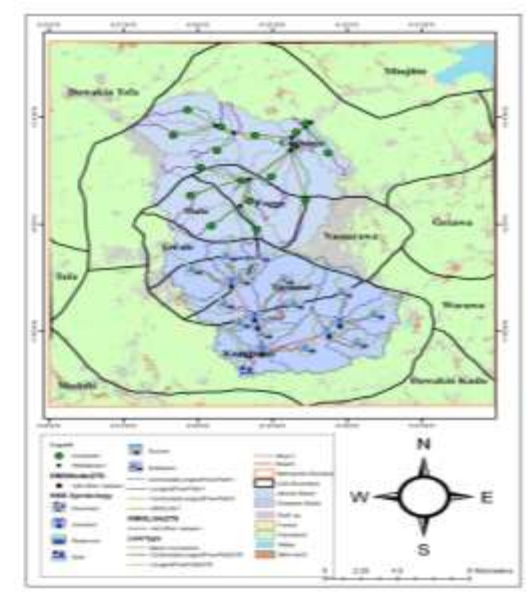

Figure2: Map of Kano Metropolis
Source: Modified Kano State Topographic Map (Ministry of Land and Survey)

Digital Elevation Model (DEM) Pre-processing

Digital Elevation Model defines the topography of the area by describing the elevation of any point at given location and specific spatial resolution as a digital file. It is one of essential spatial input for HEC-HMS to delineate watershed into a number of sub-watershed or sub-basins based on elevation. Drainage pattern, slope, channel width and stream length within the watershed was processed using the DEM. The raw DEM was downloaded from United States geographic Survey (USGS), Shuttle Radar Topography Mission (SRTM) with 90m resolution and projected using ArcGIS 10.3 software package.DEM was used to access several potential catchments within the study area. The catchment for the study area was chosen for further investigation and processing. The extracted DEM for the catchment was further examined to visualize the drainage system and was compared with existing stream network on existing topo maps of the study area.

Figure 3 shows the steps involved in terrain processing using HEC-Geo HMS and ArcHydro in ArcGIS software.

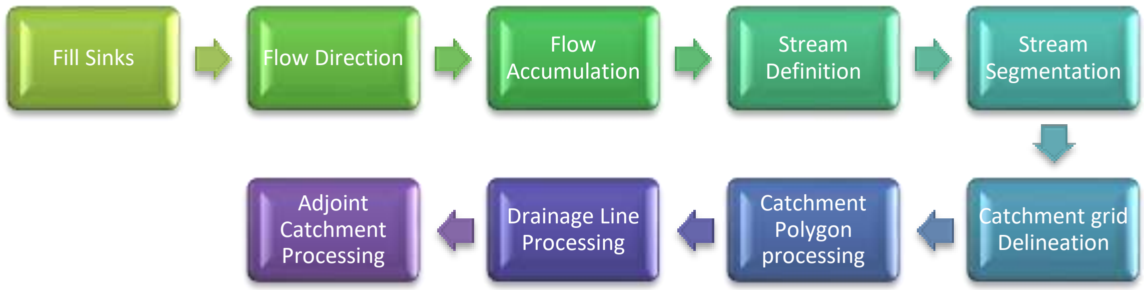

Figure 3: Physiographic Data Extraction Using HEC-Geo HMS and ArcHydro
Source: Fieldwork, 2016

RESULTS AND DISCUSSIONS

Nature of Land Use and Land Cover Change in Kano Metropolis

The study area was categorized into five (5) thematic classes under supervised classification which are; built-up areas, Forest, farmland, water and bare land. The analysis was carried out for 2001, 2012 and 2035. The Jakara Basin occupies the northern part of the metropolis comprising of 17 sub-basins within Gwale, Dala, Fagge, Ungoggo and Nassarawa while the Chalawa basins occupy the southern part of the metropolis comprising of 15 sub-basins within Kumbotso, Tarauni, Kano Municipal part of Gwale, Dala and Fagge, the entire study area covers an area of 767.23km^2.

Kano Metropolis 2001 Land Use and Land Cover

In 2001 over 60% of the metropolis was occupied by farmland and 19.7% by built-up areas. The sub-basins that made up most part of the built-up areas are W310, W280, W330 and W250 in Jakara basin and W170, W180, W210 and W200 in the Chalawa basin. This is believed to influence the peak discharge of the basins (see figures 4, 5 and 6), but as a result of the high percentage of open pervious surfaces, there is a possibility of high infiltration which results in low run- off. This depicts the findings of Balaid (2003) Ismail et.al. (2010), where it was observed that open spaces, forests, and farmlands increased the amount of infiltration or delayed time of peak discharge.

Kano metropolis 2012 land Use Land Cover Change

The LULC in 2012 shows a different trend with the pervious surfaces (farmland, forest, bare land and water bodies) constituting less than 66% of the entire metropolis. The built-up areas increased from 150.9km^2 in 2001 to 263.4km^2 in 2012 almost a 50% increase. This signifies the increase in impervious surface and hence increased in runoff. These findings are in tune with the results of Ejao and Abdullahi (2013) and Mishra*et.al* (2012) where changes are skewed towards built-up areas as a result of rapid urban development. Figure 4, 5 and 6 indicates that sub-basins W160, W170, W180, W190 and W230 have had over 20% increase in built up areas in the Chalawa basin, while the Jakara basin had a 30% increase in built up areas in sub-basins W340, W330, W310, W280, and W270, which indicates a possible increase in run-off accumulation.

Kano Metropolis 2035 Land use Land Cover Change Projection

The percentage of built-up areas in 2035 jumps to over 50% (Figure 4, 5 and 6) of the entire metropolis leaving the pervious surfaces with less than 45%. This sharp rise in impervious surfaces leads to increase in runoff. Balogun *et.al* (2011), Mashere and Malthus (2013) reported similar findings and attributed it to a rise in flash flood incidences in their study areas. Kano metropolis have experienced a drastic change in land use and land cover mostly from pervious to impervious surfaces which could be attributed to the rise in flood incidences as a result of run-off accumulation. Studies by Ishaya *et.al* (2009), Ogba *et al.,*(2009) and Cummings *et.al* (2012) further reiterated the influence of rapid urbanization on flood occurrences.

Run- Off Discharge of Jakara Drainage Basin

The Jakara basin has an area of 109.7km^2 and 17 sub-basins. The results presented below are simulations for rainfall events of 2001, 2012 and 2035 that resulted in massive flooding. The rainfall event of 2001 that occurred on the 25thof August had a total volume of 163mm^3 while that of 2012 had a volume of 143mm^3 on the 7th of August which was also replicated for 2035 forecast.

Jakara Run off Discharge Simulation 2001

Sub –basins W310 has an area of 13.35200km^2 and a peak discharge of 70.2cm^3/sec. the total depth of run-off is 0.65mm^3, a total loss of 0.25mm^3 at the beginning of the storm event and reached field capacity within 3hrs 30mins. The basin covers a large part of Dala Local Government Area which is known to be a highly urbanized area with most part of it impervious. Sub-basin W280 covers part of Nasarawa, Fagge and drains into Ungoggo LGA. It covers an area of 20.274km^2 and a peak discharge of 114.2cm^3/sec. The basin had a flow depth of 0.6mm^3 and a loss 0.2mm^3 over a period of 4hrs before reaching field capacity. This basin is also highly urbanized and large, thus the reason for the high flow rate.

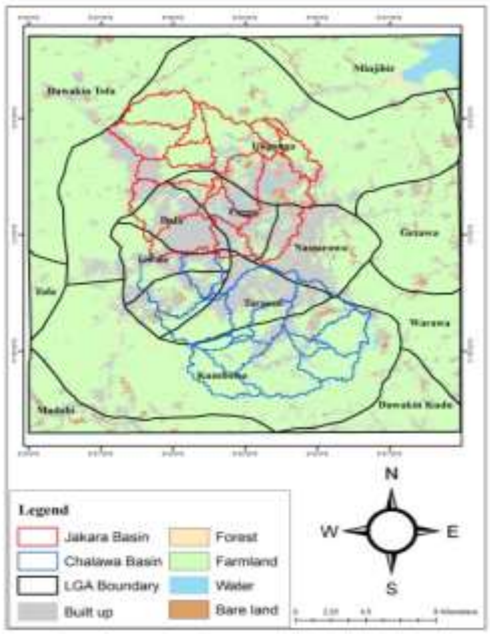

Figure 4: Jakara and Chalawa Land Use Land Cover 2001
Source: Authors Analysis (2017)

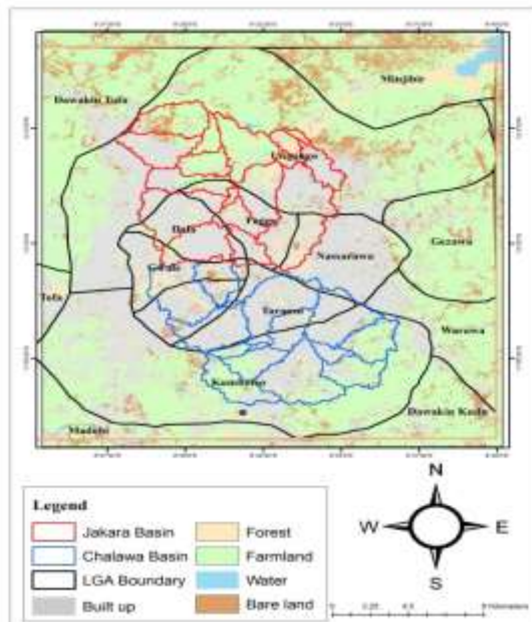

Figure 5: Jakara and Chalawa Land Use Land Cover 2012
Source: Authors Analysis (2017)

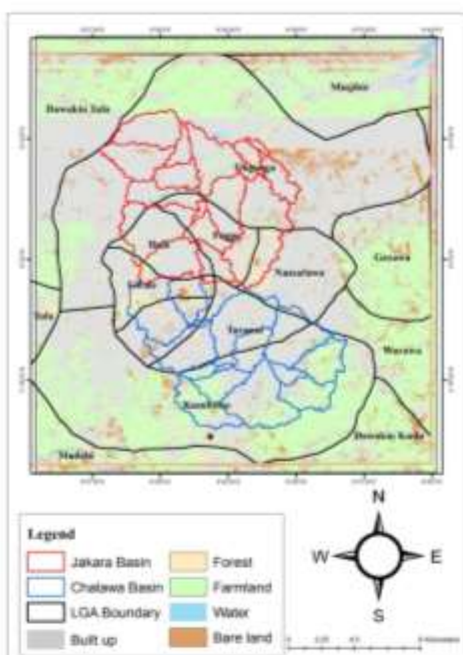

Figure 6: Jakara and Chalawa Land Use Land Cover 2035
Source: Authors Analysis (2017)

Sub-basins W190 and W300 are the smallest in size with 0.70592 and 0.68870km^2 respectively. Even though W190 is slightly larger than W300 the peak discharge is less due to higher impervious surfaces. W300 had a peak discharge of 3.6cm^3/sec whileW190 has 3.4cm^3/sec with a loss of 0.4mm^3 and 0.62mm^3 over 6hrs respectively. This indicates less inundation for W190 as a result of being within the Ungoggo axis with more pervious surface and high discharge for W300 which is situated within Fagge area and highly developed. The Outlet of the entire basin has a peak discharge of 446.2cm^3/sec (Figure 7). The findings is in agreement with that of Ishman (2014) that increased development of impervious layers increases flow discharge of a basin.

Figure 7: Jakara BasinTotal Run-Off 2001

Jakara Run off Discharge Simulation 2012

The trend of peak discharge of the various sub-basins resembles that of 2001 but with an increase in the number of sub-basins with higher peak discharge of above 55cm^3/sec. The highest was also observed in W280 with 137.2cm^3/sec., this is as result of an increase in impervious layers in the sub-basins that had lower peak discharge in 2001. Sub-basins W310, W250, and W330 had peaks of 84.2, 61.0 and 59.8cm^3/sec which is quite higher than that of 2001 both in quantity and number of basins with such discharges, the outlet's peak discharge is 585.2cm^3/sec,(Figure 8) this shows an increase in discharge of 130cm3/sec although with a lower observed rainfall intensity. W300 and W190 had peaks of 4.7 and 4.2cm^3/sec which shows a slight increase in volume compared to 2001. The outcome coincides with that of Screenivasulu and Bhaskar (2010) where the study noticed a sharp increase in discharge of developed small basins and high incidences of flash floods.

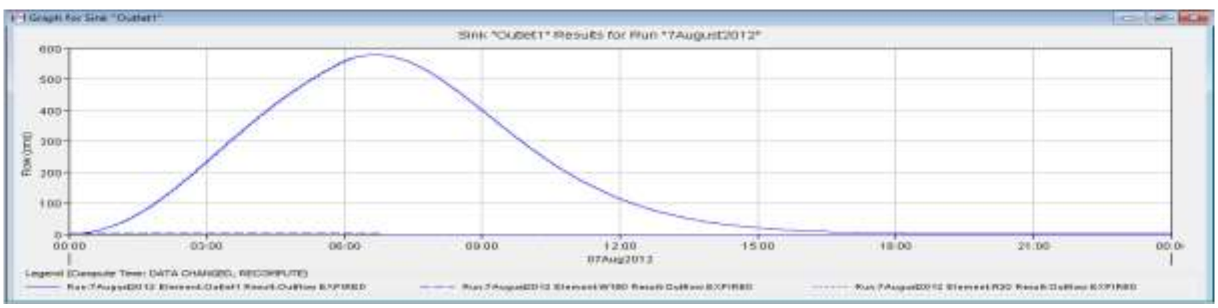

Figure 8: Jakara Total Run-Off 2012

Jakara Run off Discharge Simulation 2035 Forecast

In 2035, using the same rainfall amount of 2012 but projected land use and land cover values, gave a slight rise in peak discharge for few sub-basins especially the less urbanized areas in 2012. There was an increase in peak discharge in sub-basins W310, W340, W180, the outlet W190, W250 and W210 with 88.3, 30.7, 56.4, 609.7, and 4.7 cm^3/sec. (see Figure 9), likewise the loss was also low, (see Figure 4.) these reflects the influence of increased imperviousness of the surface. This was also observed in the study of Samarasingh et.al. (2010), Alghamand et.al. (2010) and Garcia-Pintado (2013), where an increase in impervious surfaces raised the amount of run-off, reduced the time of peak discharge and increased the extent and velocity of flood waters. As revealed, flooding will increase in extent and depth within sub-basins that were not affected in 2012 due to an increase in the extent of built up areas (see Figure 4, 5 and 6).

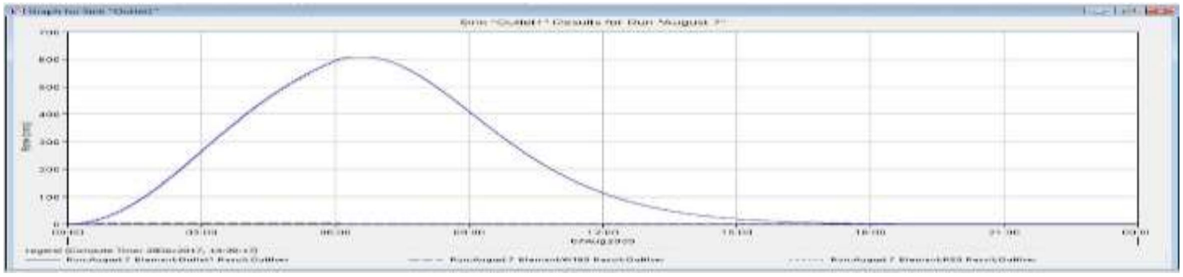

Figure 9:Jakara Total Run-Off 2035 projection

Chalawa Run off Discharge Simulation 2001

This presents the result and discussion of the amount of runoff in Chalawa drainage basin of 2001, 2012 and 2035. The basin has an area of 104.9km^2 and 15 sub-basins, the rainfall event of 2001 that occurred on the 25th of July had a peak discharge of 163mm^3/sec while that of 7th August 2012 was 143mm^3/sec, which was also replicated for 2035(see Figure 11).

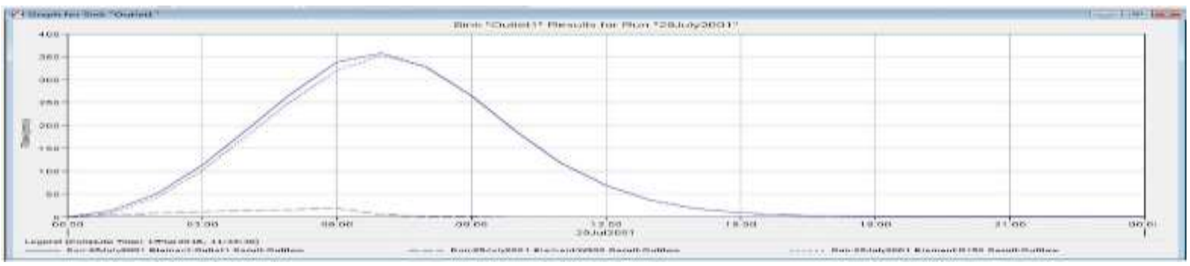

Figure10:Chalawa Total Run-Off 2001

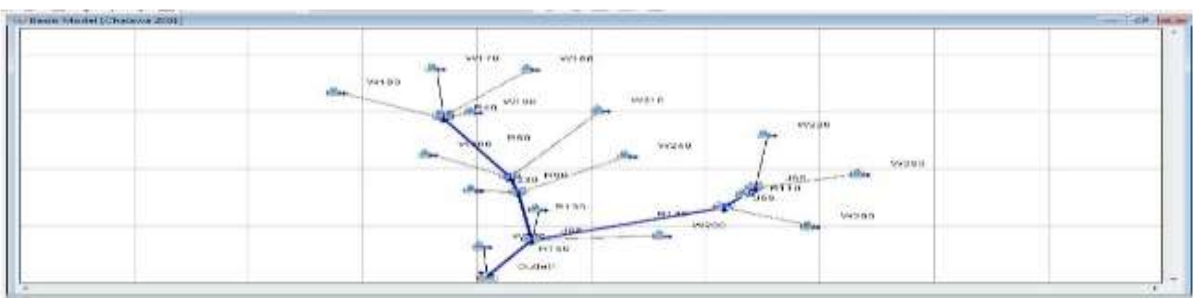

Figure 11: Chalawa Drainage Basin model

Sub-basin W210 has an area of 12.7km^2 and a peak discharge of 93.2cm^3/sec and a 25mm^{3}depth of runoff with a loss of 5mm^3 within 2hrs from onset of the rainfall likewise W160 had a peak discharge of 72.2cm^3/sec within 3hrs with an area of 11.9km^2 this basin had a loss of 11mm^3 over a span of 6hrs. The sub-basins with the lowest discharge are W190 and W250 with a peak discharge of 3.1 and 3.7cm^3/sec respectively (see Figure 10). Theses sub-basins are also highly urbanized but with small area coverages thus the reason for lower discharge. It was also observed that large sub-basins with extensive impervious surface generated more run-offs and flooding than the smaller basins. This results disputes that of Bhatt (2012) which observed that smaller basins had higher peak discharge than the larger basin, but this agrees with the findings of Ojigi and Shaba (2013) which revealed that larger basins have higher peakdischarge and run-off loss.

Chalawa Run off Discharge Simulation 2012

On the 7th of August 2012 the basin observed a rainfall event with a peak discharge of 143mm^{3}which is less than that of 2001. The increase in discharge was mostly observed in areas that had changes in land use and land cover. Sub- basin W160, W200, W220, W230, and W280 increased in the amount and depth of run-off compared to 2001 with (80, 61, 60, 11, and 81) cm^3/sec respectively. The amount of run-off loss also increased as a result of change in LULC (see figure 4), W160, W220,W200 and W210 had losses of 0.1mm^3 within the first 2hrs rainfall event before reaching field capacity. A similar result was observed by Bandaragoda (2008) in a study on prediction of run-off of ungauged basins.

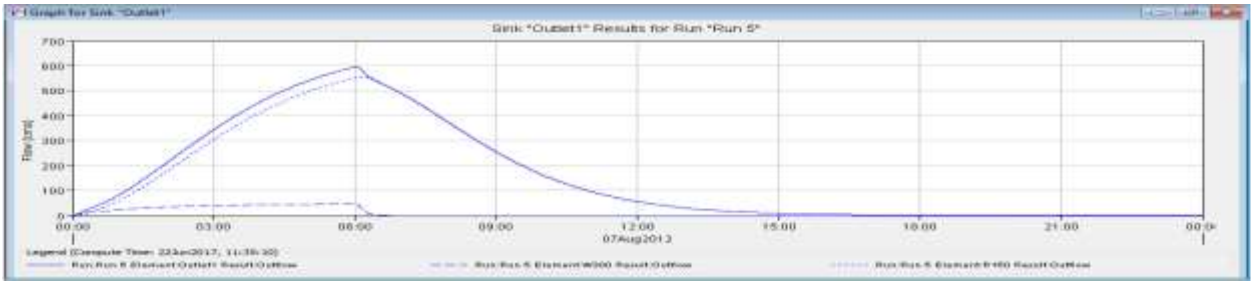

Figure 12: Chalawa Basin Total Run-Off 2012

The findings coincide with that of Alghamand *et.al* (2010) where changes in land use land cover increased the peak discharge of run- off. Generally, the outlet of the basin discharged 600cm^3/sec (see Figure 12) which is much higher than that of 2001 even though with less rainfall amount (143cm^3) indicates a 47% increase in run-off and thus more flood waters.

Chalawa Run off Discharge Simulation 2035 Forecast

The Chalawa basin shows a slight decline in peak discharge of the outlet in 2035(from 600 to 539.7 cm^3/sec) (see Figure 13) due to considerations of the ongoing canalization of the kwarin Gogaw, Kwanar Madobi and Sabuwar Gandu. This is believed to reduce the amount of discharge within the basin and channel it to a more accommodating stream. The increase in peak discharge was observed in sub-basin W220 and W200 (72cm^3/sec and 64cm^3/sec) which were much lower in 2012. This is in harmony with the findings of Smith (2012) where canalization of the Wanalta Creek County reduced the run-off discharge. It was also revealed in the study of Johnson (1997) that changes in the infiltration rate through paving increases the run-off proportionally to the amount of paving. Sub-basins W 270, W240, W190, W180, W170, and W160 had no run-off loss which indicates an almost 98% accumulation of run-off.

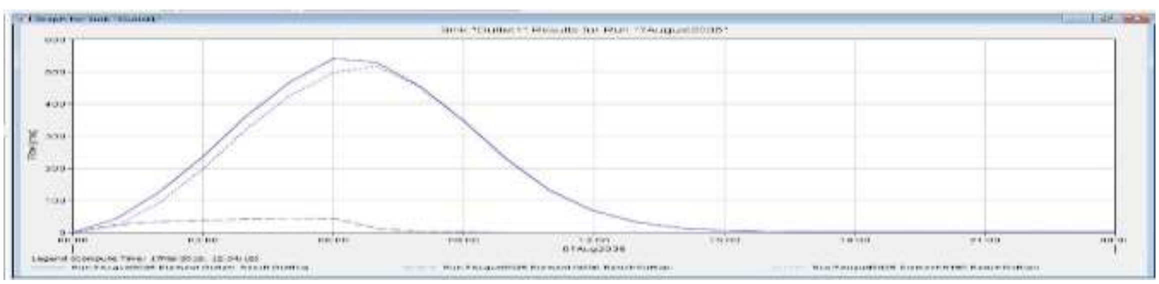

Figure 13: Chalawa Basin Total Run-Off 2035 projection

CONCLUSION

Generally, Change in land use and land cover have had a significant impact on the amount of run-off especially in the Chalawa basin in 2012 and the Jakara basin in 2035. The research revealed that a change in the landscape with impervious surfaces increased the amount of run-off and reduced the time to peak discharge thereby increasing flood occurrences. Therefore LULC have tremendous effect on flooding in the study area. The study recommended adherence to the city masterplan and construction of canals within each sub-basin for proper conveyance of run- off discharge.

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