Performance-Assessment of Existing Drainage Facilities for The Purpose of Stormwater Management

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Abstract

The study assesses the performance of the existing drainage facilities in some selected areas in Ilorin Metropolis of Kwara State, Nigeria. The rapid increase in urbanization, increase in population without corresponding infrastructures in the city of Ilorin have led to the increased incidence of flood as the available drainage channel cannot convey the volume of water. The study focuses on the household demograph, flooding, drainage maintenance and solid waste management strategies employed in the study areas. The methodology involves the use of questionnaires and interview method to gather information from the respondents of the study areas. The study was carried out with 200 copies of well-designed questionnaire through systematic random sampling technique in the administration. The research questions were answered using tables of frequencies and percentages, bar chart, pie chart and regression analysis for flood modelling and prediction of flood occurrence. The analysis revealed that frequent flood events in the city of Ilorin can be traced to dumping of solid waste in the drainage system, inadequate drainage channels, poor solid waste management strategy and variables such frequency of drainage maintenance, predominant waste material and duration of drainage maintenance, made statistically significant contributions to the prediction of Flood occurrence. A model for prediction of effect of stormwater management on flood was formulated. All the variables used in the model were evaluated and it has been established that frequency of drainage maintenance makes the strongest contribution to the causes of flood (Y dependent variable) among all other significant variables, other significant variables included availability of drainage system, waste disposal mechanism, distance of available dumpsite, frequency of waste collection, agency responsible for drainage maintenance and predominant waste materials.

Keywords: Assessment, Drainage facilities, Stormwater, Flood, Management.

Introduction

Stormwater is the water that originates during precipitation events and snow/ice melts. Storm water can soak into the soil (infiltrate), be held on the surface and evaporate, or runoff and end up in nearby streams, rivers, or other water bodies (surface water). In natural landscapes such as forests, the soil absorbs much of the stormwater and plants help hold storm water close to where it falls. In developed environments, unmanaged stormwater can create two major issues: one related to the volume and timing of runoff water (flooding) and the other related to potential contaminants that the water is carrying (water pollution). Stormwater is also an important resource as the world's human population demand exceeds the availability of readily available water. Techniques of stormwater urban runoff entering a storm drain harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water. (Alex and Robert, 2005) Drainage is the natural or artificial removal of surface and sub-surface water from an area. The term is commonly applied to the removal of excess water by canals, drains, ditches, culverts and other structure designed to collect and transport water earlier by gravity or by pumping (Sulaimon, 2015).

Storm drain is that portion of the storm drainage system that receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel, water body or piped system in

response to precipitation and snowmelt. Such systems include: ditches, culverts subsurface interceptor drains, roadways, curb and gutters, catch basins, manholes, pipes, attenuation ponds and service lateral lines. A storm drain may be close conduit, open-conduit, or some combination of the two. The purpose of storm drain is to collect storm water runoff from the roadway and convey it to an outfall. (Taiwo, 2014)

Stormwater Management is managing the quantity and quality of storm water. The term Best Management Practice (BMP) or stormwater control measure (SCM) is often used to refer to both structural or engineered control devices and systems (e.g. retention ponds) to treat or store polluted stormwater, as well as operational or procedural practices (e.g. street sweeping) (NRC,2009). The poor disposal of waste frequently leads to blockages in drainage and watercourses (Muñoz-Cadena et al, 2009), this effectively reduces their capacity of storage and conveyance and leads to flooding (Marfai, 2011). During flooding, waste and other debris collected by floodwaters can cause increased damage to property and lead to higher flood losses (Nicholas et al, 2002) after flooding the deposition of waste can block access and be a source of toxins and breeding ground for disease. Over the years, the impacts of flooding have increasingly assumed from significant to threatening proportions, resulting in losses sustained by the urban dwellers and flood victims, it is obvious that irreparable havocs have been sustained by the citizen of Nigeria due to what has become perennial natural disaster. As the inundation continues unchecked, challenges such as environmental degradation (erosion and biodiversity loss), public health issues (pollution and contamination of surface and underground water) and socio-economic issues (loss of lives, distortion of livelihoods chain and properties and displacement of people) will be exacerbated. Therefore, there is an urgent need to address this urban menace.

The subsequent series of flood and its negative effects in Ilorin, it can be concluded that flood has affected the Metropolis significantly. It has reduced agricultural production, render people homeless, loss of properties and lives and to a large extent increased poverty level. Base on these, this study is to provide solution to flood problem resulting from improper waste management, poor drainage system, inadequate drainage planning and maintenance by providing alternative storm water management strategies.

Material and Methods

The methodological approach adopted in this study involves both field and desk works. The desk work involves analysis to develop the drainage topographical map and questionnaires analysis while the field work entails; study area observation (reconnaissance survey) and questionnaire administration on the designated study areas.

The questionnaires were designed to respect the rights and anonymity of the respondents thereby ensuring confidentiality of the respondents. A total number of 200 copies of a well-designed questionnaire were administered to the residence based on the three local governments in Ilorin metropolis (see table 1).

The questionnaire was drafted to provide required responses from target population to obtain data in areas that are more susceptible to flooding at the selected drainage. Systematic random sampling technique was used in the administration of questionnaire on household heads per housing units, selected along the streets of the sampled residential districts.

Table 1: Distribution of sample size

Name of Area	Sample size	Percentage
<i>Ilorin South</i>		
Sanrab	20	10
Tipper garage	20	10
GRA	20	10
Pipeline	20	10
<i>Ilorin East</i>		
Fate road	30	15
Basin road	30	15
<i>Ilorin West</i>		
Unity	30	15
Asa dam road	30	15
Total	200	100

Source: Field Survey, 2019.

Results and Discussion

Analysis of Questionnaire

Residential distribution of the respondent: The data gotten from the field is shown in the table 2. From the table, 89% of the respondents were residents of the area while 11% of the respondents did not reside in the area of study. This showed that the majority (89%) of the respondents reside in the areas of study. Hence, could provide necessary information concerning the drainage system for the study. Respondents at Fate have the least frequency because 60% of the respondents are resident of the area while the remaining 40% are non-resident.

Table 2: Resident Distribution of the Respondent

Area	Resident	Non-resident	Total
Sanrab	19	1	20
Tipper garage	17	3	20
GRA	20	0	20
Pipeline	19	1	20
Unity	29	1	30
Asa road	27	3	30
Fate road	18	12	30
Basin road	29	1	30
Total	178	22	200
Percentage %	89	11	100

Duration distribution of the Respondent

From table 3, 4.5% of the respondents have been living for less than 6months duration in the study areas while 29.5%, 42.5% and 12.5% have been living for 6months-2years, 3years-10 years and more than 10 years respectively. This showed that the majority of the respondent have been living for 3years-10 years and 4.4% of the respondents have been living in the area for less than 6 months. With that, the total of 89% of the respondents were able to provide valid information the condition of the drainages in the areas of study.

Table 3: Duration of Settlement of Respondents

Area	<6mnth	6mnth-2yrs	3yrs-10yrs	>10yrs	Total
Sanrab	3	7	5	4	19
Tipper garage	1	4	7	5	17
GRA	2	14	4	0	20
Pipeline	1	7	8	3	19
Unity	0	12	15	2	29
Asa road	1	8	17	1	27
Fate road	0	1	9	8	18
Basin road	1	6	20	2	29
Total	9	59	85	25	178
Percentage	4.5	29.5	42.5	12.5	89

Dumpsites in the study Area

Figure 1 shows the presence of dumpsites in the study areas by the respondents. From the figure, 50.5% of the respondents had dump sites in their vicinity while 49.5% of the respondent said there were no dumpsite in their environs. This showed that 50.5% of the respondents had an accessible dumpsite in their residence where they would be able to dump their solid waste generated on daily basis. The other percentage of the respondents 49.5% had no accessible dumpsites in their residence, this would make them find alternative method of solid waste disposal which could be burning, use of RORO bin for waste collector, waste burial or dump it on the ground will later find its way into the drainages.

Figure 1: Pie chart showing the presence of dumpsites

Distance of dumpsites to the Residents in the study area

Figure 2 shows the distance of dumpsite to the residence in the study area. From the figure, 55.5% of the respondents in all the local government of the study area have dumpsites that ranges from 0 to 50m distance while 19%, 23.7% and 1.8% of the respondents have dumpsites of 50m-100m, >100m and other ranges of distance respectively. This showed that a high percentage (55%) of the respondents have dumpsite in the range of 0-50m distance. At this range, the dumpsites can still be easily accessible. Ilorin East has the highest percentage in the range which is 32% followed by Ilorin South of 25.5%. Distance greater than 50m cannot be easily accessible except for People who are mobile and hygiene conscious. With that, residents in the area will find alternative solid waste disposal methods or dump their waste on the ground which later find its way into the drainage during heavy downpour.

Figure 2: Bar chart showing the distance of dumpsite to the Residence

Flooding

Experience with Solid Waste in the Study Area

The figure 3 shows the experience of respondents with solid waste in the study areas. From the analysis, it was observed that 56% of the solid waste end up in the drainages while 33%, 8.5%, 2.5% were scattered on the road, remain where it is, end up in the drain and scattered on the road respectively. This means that most solid waste finally ends up in the drainages which affect the conveyance capacity of the stormwater drainages leading to flooding. The other 33% which scattered on the road and 8.5% that remained where they dumped will later be washed or find their way into the drainages as shown in figure 4 which after will lead to flooding. The presence of waste being littered on the ground after rainfall or a windy period will make the environment unhealthy.

Figure 3: Pie chart showing the experience with solid waste in the study areas

Figure 4: Solid waste that end up in drainage system

Presence of drains in the study areas: Figure 5 show the presence of drainages in the study areas. From the analysis, it was observed that 63.5% of the respondents has drainage system while 36.5% of the respondents has no drainage system. This shows that there are no sufficient drainage systems in the area of study and this prevent the efficient disposal of surface runoff from paved and built up environment. Places such as Sanrab, GRA, Unity, Fate and Asa have no sufficient drainage system which in turn increase flood rate in these areas.

Figure 5: Bar chart showing the presence of drainages in the study areas

Consequences of lack of enough drains: Figure 6 shows the consequences of lack of enough drainage systems in the study area. From the analysis, it was shown that 42.5% of the consequences lead to flooding while 10%, 6.5% and 3.5% of the consequences lead to restriction of movement and business activities, destruction of properties and infrastructure facilities and the combination of flooding with restriction of movement. This implies that the major consequence of lack of enough drainage system is flooding due to inadequate sufficient and efficient storage and conveyance capacity of resulting runoff from built up and paved environment in the study areas.

Figure 6: Bar chart showing the consequences of lack of enough drainage systems

Flood occurrence in the study area: Figure 7 depicts the rate of flood occurrence in the study areas. From the table, 76% of the respondents in all the study areas experienced flood in their areas of residence while 24% of the respondents did not experience flood in their areas. This showed that there is high rate of flood in the selected areas of Ilorin South, East and West. From the analysis, flood occurrence is high in Ilorin East followed by Ilorin West and South respectively.

Figure 7: Bar chart showing rate of flood occurrence in the study areas

Causes of flood in the study area: Figure 8 shows the results of the causes of flood in the study areas. From the analysis, it showed that 47% of flood occurrence was due to dumping of refuse in the drainage system while 19.5%, 5.5% and 5% were due to improper or insufficient drainage, no drainage and the combination of improper design and dumping of refuse in the drainage facilities. This shows that the major causes of flooding in these areas of study is the dumping of solid waste in drainages and water ways followed by improper drainage design and lack of drainages or insufficient drainage facilities in the Ilorin Metropolis of Kwara state.

Figure 8: Causes of Flood in the Study Areas

Drainage Maintenance

Construction of drainage

Figure 9 shows the construction of drainages in the study areas. It showed that 83% of the drainage systems in the study areas were constructed by the government while 14%, 2.5% and 0.5% were constructed by the community or residents, donated and by the combined efforts of the governments and community respectively. The analysis showed that the majority of the drainage systems under study were constructed by the government. Hence, most constructed drains are usually expected to be maintained by the government, individual usually do not take responsibilities for government infrastructures. This explains why these drainage systems are not properly maintained.

Figure 9: Pie Chart Showing the Construction of Drainages in the Study Areas

Duration of the drains

Figure 10 shows the duration of the drainages in the study areas. From the table, 38.5% of the respondent reported that drainages in the study areas have lasted for more than 10years while 30.5%, 26% and 5% have lasted for 5 to 10 years, 1 to 5 years and less than 1 year respectively. This shows that most of the drainage has exceeded 10 years in the study areas without proper maintenance and that can affect their present situation of efficient storm water conveyance.

Figure 10: Bar chart showing the duration of the Drainages in the Study Areas

Maintenance of Drainage Systems

Table 4 shows the various set of people responsible for drainage maintenance in the study areas. From the analysis, 8% of the respondent reported that the drainage systems were maintained by the government while 73% were maintained by the Residents usually during environmental sanitation which is not constantly observed of the area and by nobody respectively. This shows that only few people engage in the maintenance of drainage system, the negligence of the government and people have aggravated the degree of drainages blockage in the study areas.

Table 4: Maintenance of Drainage Systems

Area	Government	Community	Individual	Nobody	Total
Sanrab	0	8	1	11	20
Tipper garage	0	13	7	0	20
GRA	5	11	4	0	20
Pipeline	1	2	16	1	20
Unity	0	7	23	0	30
Asa dam road	9	14	1	6	30
Fate road	1	7	4	18	30
Basin road	0	10	18	2	30
Total	16	72	74	38	200
Percentage %	8	36	37	19	100

Duration of Drains Maintenance

The table 5 shows the period or duration at which the drainages are maintained in the study areas. From the table, 3.5% of the respondents engaged on daily maintenance of the drainage, 19.5% of the respondents maintained the drains weekly, 42.5% of the respondents maintained the drains monthly while 34.5% of the respondents never maintained the drains at all. This result shows that the highest percentage (42.5%) of the respondent maintained the drains on monthly basis during environmental sanitation exercise that takes place monthly followed by 34.5% of the respondents who never maintained the drainages and very few engaged on daily and weekly maintenance basis. This result shows to a large extent that these drainage systems under study are not properly maintained.

Table 5: Duration of Drainage Maintenance Systems

Area	Daily	Weekly	Monthly	Never	Total
Sanrab	1	2	4	13	20
Tipper garage	0	3	14	3	20
GRA	1	12	7	0	20
Pipeline	4	10	5	1	20
Unity	0	5	22	3	30
Asa dam road	0	1	8	21	30
Fate road	0	1	6	23	30
Basin road	1	5	19	5	30
Total	7	39	85	69	200
Percentage %	3.5	19.5	42.5	34.5	100

Source: Field Survey, 2019.

Solid Waste Management

Solid waste management strategy employed in the study areas

From Figure 11 the major domestic waste management strategies employed in the study area is burning. An average 55.8% of the respondents burn their wastes while others dispose openly at dumpsites, bury their waste or make use of waste collectors respectively. This is an indication that most residents' burn their domestic solid waste and the burning activities are not done by incineration rather they are open air burning which releases toxic chemicals that pollute air. Inhaling the smoke from burning activities causes respiratory infections and aggravate existing respiratory diseases such as asthma. While some dump their domestic solid wastes on the streets, gutters or any available open space. Open dumping poses a lot of health hazards to the residents and can make roads inaccessible by obstructing the free flow of traffic. It can also lead to flooding due to blockage of drainages and other water channels during the rainy season.

Figure 11: Method of Waste Disposal

Predominant solid waste generated in the study areas: Figure 12 shows the predominant solidwaste generated in the study areas. The analysis revealed that about 57% of all the domestic solid waste generated in the study area were mainly nylon and plastic, while 15%, 11.5% and 1.5% were from food waste, paper and bottle and other wastes respectively. The nylon, plastic, paper and bottle waste can be attributed to the presence of students from higher institution in the study Area, as students tend to generate waste from daily consumption of sachet water, bottled drinks, disposable from eateries, photocopied materials and other sources. This means that a very large percentage of the domestic solid wastes generated in the study area are non-biodegradable (about 85%) compared to the biodegradable wastes generated in the study area (about 15%), this implies that the non-biodegradable wastes later find their ways into drainage system which affect the conveyance capacity of the storm drainage.

Figure 12: Bar Chart Showing the Predominant Waste Material in the Study Areas

Duration of solid wastes evacuation: From Table 6, 3.5% of the respondents reported that solid wastes were evacuated daily while 25.5%, 33% and 41% were evacuated weekly, intermediately and not at all respectively. This showed that most of the solid wastes were not evacuated from the source at all while few disposed their waste on daily and weekly basis. This result shows to a large extent that the waste are not evacuated regularly in the study areas. Only few engage in waste disposal on daily

and weekly basis while others never evacuate the wastes which later find its way into the drainage during heavy rainfall.

Table 6: Duration of Solid Waste Evacuation

Area	Daily	Weekly	Intermediately	Not at all	Total
Sanrab	2	6	3	9	20
Tipper garage	0	7	9	4	20
GRA	3	16	1	0	20
Pipeline	0	3	5	12	20
Unity	0	0	22	8	30
Asa road	0	16	17	7	30
Fate road	0	7	5	18	30
Basin road	2	0	4	24	30
Total	7	45	66	82	200
Percentage %	3.5	22.5	33	41	100

Modelling of Flood Occurrence

Table 7 shows the mean and standard deviation of the variables used for obtaining the regression equation while Table reveals the summary of the model predictor statistics. From Table 8, the probability value for F-test statistics is (0.000) which is less than 0.05 (5% level of significance), hence, it reveals that the combination of the predictors significantly joined together to predict average flood occurrence which establishes the fact that the model is adequate. The multiple correlation coefficients, (R) are the linear correlation between the observed and the model predicted values of the dependent variable (average flood occurrence). The value of R obtained was 0.753 and R square obtained was 0.567 which reveals that 56.7% of the variation in average flood occurrence is explained by the model.

Table 7: Mean and Standard Deviation of Flooding and its Predictors

Variable	Mean	Std. Deviation
Average Flood Occurrence	1.25	0.435
<i>Predictors Variables</i>		
Availability of Drainage System	1.61	0.490
Waste disposal mechanism	1.78	1.074
Frequency of drain maintenance	3.13	0.826
Distance of available dumpsite	2.68	1.274
Frequency of waste collection	3.12	0.875
Agency responsible for drainage maintenance	2.72	0.887
Predominant waste materials	1.92	1.242

Table 8: ANOVA Table

R	R-Squared	Std. Error	F Change	Prob. (F- statistic)	Durbin-Watson
0.753	0.567	0.293	28.526	0.000	1.617

To further test the strength of the model fit, the standard error of regression 0.295 (Table 9) was compared with the standard deviation of average flood occurrence. The mean Average Flood occurrence was 1.25 with standard deviation of 0.435. with this multiple regression model, the error of the estimate was considerably lower, about 0.295. For K = 9 (Number of predictors including the intercept) and N = 200 (No of Respondents), dL = 1.682, dU = 1.768. where dL = Durbin lower limit and dU = Durbin upper limit. The Durbin Watson statistics of 1.617 falls below the upper Durbin Watson Limit (1.768) and is above the Durbin Watson Lower Limit (1.582) which signifies that there are probably some elements of serial correlation.

Table 9: Table of coefficients for predictors of Average Flood Occurrence

Model	B(Coefficient)	Std. Error	β	t-value	Sig(p-value)
(Constant)	1.173	0.175		6.690	0.000
Availability of enough drainage system	0.027	0.048	0.030	0.552	0.582
Waste disposal mechanism	0.015	0.023	0.038	0.648	0.518
Frequency of drainage maintenance	0.075	0.032	0.143	2.380	0.018
Distance of available dumpsite	0.032	0.018	0.094	1.751	0.082
Frequency of waste collection	0.054	0.029	0.108	1.827	0.069
Agency responsible for drainage maintenance	0.009	0.028	0.018	0.323	0.747
Predominant waste material	0.039	0.018	0.110	2.146	0.033

The linear regression model formulated from Table 9 is

$$Y = 1.173 + 0.027X_1 + 0.015X_2 - 0.0075X_3 - 0.032X_4 - 0.054X_5 + 0.009X_6 - 0.039X_7$$

Where Y (dependent variable) = What Causes flood?

X_1 = Availability of Drainage system.

X_2 = Waste disposal mechanism.

X_3 = Frequency of drain maintenance

X_4 = Distance of available dumpsite

X_5 = Frequency of waste collection

X_6 = Agency responsible for drainage maintenance

X_7 = Predominant waste materials

Prediction of flood occurrence

From table 9, the β values were used in comparing the contribution of each predictor (independent variables). The largest β coefficient is 0.143 which is frequency of drainage maintenance. This means that this variable makes the strongest contribution to the explanation of the dependent variable, while the variance explained by all other variables in the model is controlled for. The β

value for agency responsible for drainage system maintenance was 0.018 which made the least contribution.

As shown in table 9, the significant p-value was checked for each variable, this showed whether the predictor made a statistically significant contribution to the average flood occurrence which is dependent on which variable is included in the equation. When p-values are less than 0.05, the variables made significant contribution to the prediction of average flood occurrence. For values greater than 0.05, variables did not make significant contribution to the prediction of the causes of flood occurrence. In this scenario, availability of enough drain system, frequency of drainage maintenance and predominant waste material made statistically significant contributions to the prediction of causes of flood occurrence.

Conclusion

Flood remains a very serious environmental problem in Ilorin Metropolis. Frequent flood events in the city of Ilorin have been traced to dumping of solid waste in the drainage system, inadequate drainage channels, and poor solid waste management strategy.

The results gotten from the field showed that

- i. The causes of flood in the study area were majorly dumping of solid waste in the drainage system, improper design of drainage systems and lack of drainage systems. About 47% of flood cases were due to dumping of solid waste in the drainage system, 19.5% cases of improper drainage design and 5.5% were lack of drainage system.
- ii. A model for prediction of effect of stormwater management on flood was formulated. All the variables used in the model were evaluated and it has been established that blockage of drainage system has the highest effect among all other significant variables, other significant variables included availability of drainage system, waste disposal mechanism, frequency of drain maintenance, distance of available dumpsite, frequency of waste collection, agency responsible for drainage maintenance and predominant waste materials.

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