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Legislative and hydraulic weaknesses in the fight against floods in cities with developing economies: Case study of Yaounde, Cameroon

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ABSTRACT: Floods are natural occurring events that are becoming more and more recurrent, devastating and spectacular in the world. In developing countries this phenomenon is compounded by the lack or absence of specific legislations and poor drainage systems. Regrettably due to the awfully poor sanitation systems, most of the domestic wastes end up in the drainage system and as such reduce the capacities of water conveying structures thus aggravating the effect of the floods. Most countries with developing economies suffer from a lack of adaptation to challenging situations such as floods. Indeed, the absence of legislation on flood control causes the state to spend more on population relief rather than on flood mitigation. Also, the hydraulic structures are cruelly lacking maintenance and due to the fact that these structures are not initially designed to take into consideration the solid domestic waste factor, the subsequent situation is their rapid obstruction and hence flooding during rain events. As a matter of fact during this study carried out in the Mefou drainage basin revealed that almost all the hydraulic structures were found to be blocked by plastic bottles as well as other solid waste materials.Only the bridges kept on being functional.

KEYWORDS: Legislation, Floods, Hydraulic structures, Solid domestic waste, Drainage basin

I. INTRODUCTION

Drainage systems are usually designed to achieve a single objective which is that of flood control during large, infrequent storms. However, drainage systems designed to meet a single flood control objective usually fail to address the environmental effects of increase in runoff volume (due in particular by the presence of solid domestic waste) and velocity caused by development, and consequentlyincrease in peaks flow[1]. Increased runoff from small, frequent storms erodes urban streams and washes eroded sediments and other constituents from the urban landscape into downstream waters, often damaging adjoining properties and impairing their use for people and wildlife.

On the other hand, poor waste management has been observed to be the main cause of floodsin most developing countries in general and Cameroon in particular(in cities such as Douala, Yaounde, Bamenda, Maroua just to name a few). Inhabitants tend to use the drains as evacuation point especially during rainy seasons as well as open areas. Rain water conveys these wastes downstream the drainage basin where their accumulation over time aggravates the impact of floods. When rainwater find their way into the drainage system rapidly they get find obstacles that block their progression and the resultant consequence is their overflow out of these drains into the surrounding environment thus floods[2];[3].

Stormwater systems are engineered to handle specific runoff volumes and flow rates. For flood protection, systems are designed with capacity for the expected peak runoff volumes and flow rates of a given design storm size. This is known as the "peak runoff volume." Unfortunately some realities are not taken into consideration such as the *waste* (solid domestic waste+ soil sediments) when designing the peak factor[2].

In order to fight against floods, most countries with developing economies (Cameroon not being an exception) are heading towards preventive measures, which are either legislative or infrastructural. Yet, it is observed that the legal measures need to be taken regarding the environment and its evolution. Poor waste management and the legislative weakness in addressing such issues, combined with the reoccurrence of floods generate significant economic lost which hinders sustainable development.

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Cameroon is characterized by a dense hydrological system and this implies an efficient drainage system should be designed to evacuate the water within its boundaries so as to minimize the risk of flood.Unfortunately, while the drainage network is lacking or insufficient in some areas; poor town planning and poor waste management encourage frequent flooding.

In Cameroon as well as other countries with developing economies, the legislation as far as flood and waste management are concerned is particularly poor.It's worth mentioning that specific legislations in these areas are even inexistent.

The aim of this paper is to contribute to an efficient management of floods in countries with developing economies and in Cameroon in particular.

More precisely it will be to:

- Carry out a situational analysis of the legislation on floods management.
- Identify and characterise the hydraulic structures in the drainage basin
- Assess the functionality of the existing hydraulic structures

II. METHODOLOGY

A- Presentation of the area of study

The Mefou basin is localised in the political capital of Cameroon, Yaounde, and located between latitudes 3°30' et 3°58'North and longitudes 11°20'et 11°40'East. It has a surface area of 820 km^2(Fig 1).It has an equatorial climate with a bimodal rainfall pattern i.e. two dry seasons and two wet seasons with an average temperature of 24.2 ^oC.The main river crossing this drainage basin is at the origin of its name '***mefou'***. This river is the main tributary of the **Nyong** river which is a river exploited by water distribution companies for domestic supply.

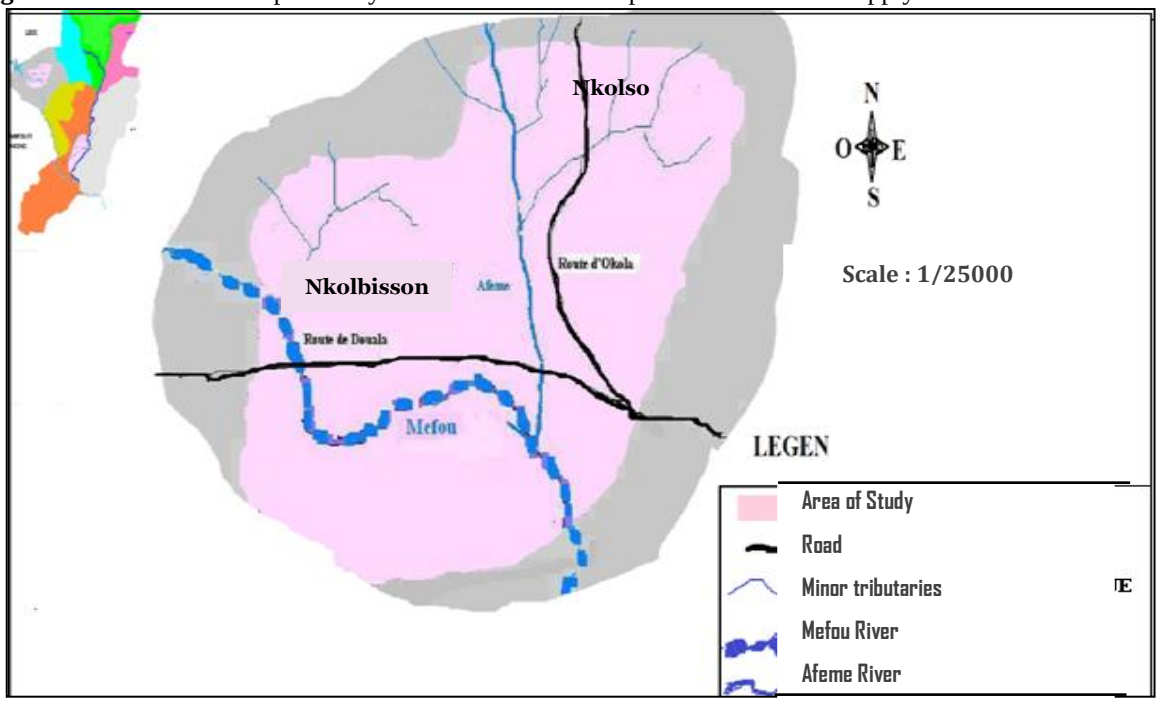

Figure 1: Localization of the area of study

Urban structure

The Nkolbisson district is characterized by structured or planned household configuration though some squatter camps are present. The planned areas comprises mostly of administrative centres including NGO, training and research centres. Most of the constructions carried out in this neighbourhood are done with permanent materials and the road and drainage network are well traced. On the other hand, the spontaneous areas are characterized by low standing constructions with houses belt with temporal material such as plank and mud blocks.

Nkolso is a spontaneous neighbourhoodmostly characterized by haphazard construction of houses, few or no water conveying structures, poor accessibility by road and a relatively high house density.

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B- Floods management: the inexistent legislation

In most developing countries like Cameroon, there are little or no specific legislation on floods management. Many legal measures talk about disaster management broadly, without any categorization, classification of these disasters. In order to intervene in times of disaster, the National Observatory of Risk and the Civil Protection Directorate were created[4]; [5]. The civil protection directorate is a technical structure hosted in the premises of the ministry of Territorial Administration and Decentralization and is in charge of the Rescue Organization Plan (ORSEC) [6].
Similarly, the Urgent Floods Fight Project (Projet d'Urgence de Lutte Contre les Inondations-PULCI), is a project designed to prevent and manage flood in the Far North Region of Cameroon.
Though with addition to international conventions such as that on strategic measures for disaster management from 2005 to 2015 [8]; the Yokohama declaration on natural disaster prevention [9], the convention on Assistance on Civil Protection and the International Strategy of Disaster Management [10], much is still to be done on flood management as a preeminent disaster in Cameroon.
All the above texts have abroad-spectrum and provide common measures which can't solve specific problems with specific causes. In Cameroon as in many other developing countries, several factors are to be taken into consideration in disaster management and particularly in the domain of flooding such as drainage system design, urbanization, sanitation and waste management.
While expecting for specific laws or legal measures in the domain of floods management to be established and implemented in Cameroon, it will be very important to sensitize the population on the origins, causes and factors aggravating floods such as anarchic settlement in inappropriate sites which are classified at risk, on their domestic waste management and the necessity of providing a sanitation system. Also, government should strengthen the urbanization politics and policies.

C- Waste management: the blanks in legislation

Preservation of nature and waste management have always been of major importance in all societies. In developing countries, the topic is crucial; there is an important gap between the generation, the treatment and the recycling of waste. Poor waste management in developing countries has been found to be one of the main causes of flooding as they (waste) invade thedrainage system; impacting on them. Moreover, the most affected areas are found insquatter camps or spontaneousneighbourhoods with poor housing and road conditions.In order to find solution to this situation, many legislative attempts have been carried out.
The law n°96/12 of 5th August 1996 in its 4th chapter, classify some chemical producing industries as dangerous, unhygienic or inconvenient with polluting activities[11]. This part of the law takes into consideration a specific type of waste, which is associated to chemicals management such as fuel and gas installations. The n°2003/006 of 21st April 2003 on safety regulations governing modern bio-technology in Cameroon, puts in place bio-security measures and organizes in its part 7, waste and gas emission treatment[12]. Once more this is related to laboratory security and the manipulation of modified organisms. What is observed in these above stated laws is that there is no appropriate or defined measure on how to manage the produced waste. The laws prescribe storage, treatment and destruction or disposal of waste without defining a procedure, that's leads to various interpretations by the industrials entities; moreover it becomes difficult to express what type and procedure of waste management is secure.
Concerning the solid domestic waste management, there exist no legislation; instead, the National Strategy on Waste Managementamong other types of waste, classifies domestic waste in three categories: solid domestic waste, toxic domestic waste in dispersed quantities, and gas domestic waste. The chain of solid domestic waste management goes from the collection points to the discards points, without any measures on how the waste should be collected and the conditions under which they are supposed to be treated. The main issue is what becomes of the uncollected waste[13].
Actually, in Cameroon, there are blanks in waste management legislation and particularly an absence of legislation on solid domestic waste management. This situation provides a fertile ground for wild dumping for there is neither charges nor sanctions on waste production and their discard.
In a general overview, flood and waste management are obviously related but the absence of a specific legislation has a cost in many domains.

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D- Identification and characterization of the hydraulic structures

Field trips were organised in order to identify and visually characterise the hydraulic structures. The field visit was to appreciate the functionality of these structures, measure their geometric parametersand determine the materials used for their construction. The visual inspection was the only possibility to appreciate these elements. Questionnaires were pre-developed in order to invest on the vulnerability of these structures and to appraise the point of view of the local population with regard to environmental problems. A random sampling technique was used to determine the sample size to be investigated.

E- Evaluation of the hydraulic functionality of major storm waterstructures

The evaluation of the functionality was done from the hydraulic point of view and the main parameter measured wasthe height of overflow of water in conveying structures during flood events. In the course of the work, a hydraulic structure was definedas functional ONLY if it could evacuate flood water efficiently i.e. without outflow of water from the conveying structures into the surrounding environment.In the case of an overflow, the height of the corresponding water blade was deduced from the difference in altitude between the upper edge of the conveying structures and the maximum altitude of overflow water.A GPS (Global Positioning System) was used as well as a measuring tape to collect these data. With less than one meter of water blade, the precision of the GPS could not appreciate the variation of the water level in conveying structures. This is why a measuring tape was used in certain cases.
At each flood event, the date, the duration of overflow and the level of flood water on walls of houses were recorded. The limits of flood water was identified either by a point materialized on the ground or by a horizontal line left on the wall by water of flood. Field agents were used for various identification points.

F- Environmental functionality of the storm water structures

As far as the environmental functionality of the hydraulic structures in the fight against floods is concerned, two aspects were considered: the frequency of the floods per season in a year and the potential causes of the floods in the drainage basins.

G- Environmental impacts analysis of the malfunction of flood mitigation hydraulic structures.

In this drainage basin, the environmental impact analysis of these hydraulic structureswas done through the study of the frequency of the floods, the incidents due to floods at household and drainage basin level, the immersion of the roadway systems and agricultural lands. These various aspects were analysed for the period preceding the installation of some hydraulic structures of fight against floods and the period of service of these structures. The various visit on the field at the time of certain downpours enabled us to observe the various damage which floods caused on the environment.
With each field visit, the observation was guided by the following points: the type of impact, the duration, the importance (if the impact is average or high), the spatial distribution, the quality (positive or negative), the probability of occurrence, the reversibility (durable or not durable), the occurrence which can be short-term, medium-term or long-term and intensity or extent of the impact

III. RESULTS

A- The cost of inexistent legislations both in flood and waste management in Cameroon

The insufficiencyor absence of legal framework on flood management, the blanks in waste management legislation and the non-efficient application of existing laws on waste management are causes of significant economic lost to a country and damages to the environment.
To these abstentions, result crimes such as non-authorisedwaste dumping, and improper waste treatment. This can be observed in many industrial installations, garages, where generally there is no adequate evacuation, storage or treatment of the waste generated. Also, the medical wastes (surgery waste, chemicals and materials) end up at times in the nature. These two examples explicitly showthe threat on the environment.

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With about 80% of water extraction from surface water sources for consumption, Cameroon faces the problem of high water treatment cost. The additional cost of water treatment generated by pollution is high and is reflected on households. Moreover under-structured and underprivileged neighbourhoods and households are exposed to water diseases all year long. When flooding occurs, polluting elements are conveyed byrunoff from one part of the city to another, generating health crisis and this causes the state to invest more on assisting the local population which in return hampers the economic growth.

Wild waste dumping and floods affect also the agricultural sector; the soil pollution resulting leads to the reduction of productivity and crops contamination and therefore increase the risk of rare diseases manifestation.

The economic consequences of what can be call a legislation paralysis is of a great threat to the development. During every flood event, homes, jobs, commerce and others belongings are lost; creating a type of permanent starting allover with a psychological effect on population-this favours precariousness and poverty.

A general observation carried out in Cameroon to appreciate waste and flood impacts on economy showed there is no data base on the economic cost of the poor management of waste and floods. Nevertheless it is spotted that, water cost is high because of treatment charges generated by increasing pollution; government inputs in first aid assistance and diseases treatment when flooding is difficult to estimate because of financial and materials aids from international organizations and other governments; damaged infrastructure are generally not repaired or replaced; activities and commerce paralysis caused important financial lost and agricultural (crops and cattle) lost. A very huge lost for a developing economy.

B- Identification and characterization of hydraulic structures

In the drainage basin, 20 hydraulic structures were identified among which: circular culverts (C. Culvert), bridges, trenches and rectangular culverts (R.Culvert). Fig2 illustrates the spatial distribution of these hydraulic structures.

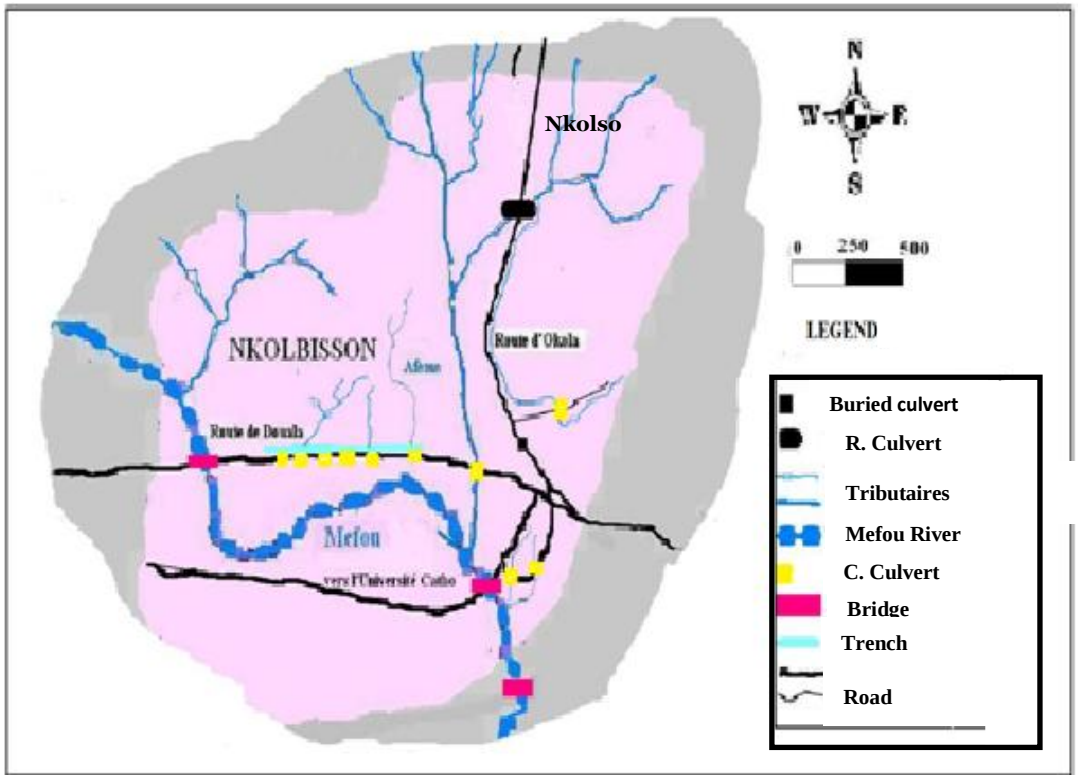

Figure 2: Localization of hydraulic structures

From the various hydraulic structure identified, 13 of them are natural outlets, 03 on the Mefou river and 01 on the Afeme river. These structures are made out of Aluminium, concrete and wood.

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C- Hydraulic and environmental functionality of water conveying structures

The study revealed that most of the hydraulic structures (storm drains) in the area of study are not maintained at all. Among the varioushydraulic structured identified in the drainage basin, onlyfewcircular culvertsespecially those around the Afeme Riverwere maintained. TABLE 1 presents the various hydraulic structures and their functional capacities. The presence of solid domestic waste in water constitute the main cause of floods in the drainage basin. According to [13]solid domestic wastes are not taken into consideration during the design of drainage networks and this result in situations observed on daily basis i.e. rapid blockage of water conveying structures (trenches, culverts), flood generations, and breeding ground of disease carrying organisms.

Table 1: Limits in the functional capacities of water conveying structures

Days with rainfall registered	Height of overflow (m)	Duration of overflow (minutes)	Hydraulic structure	Observation
31/05/2012	2	180	Culvert	Waste around the structure
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	Nothing
01/06/2012	1	90	Culvert	Waste blocking the structure
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	Nothing
02/06/2012	2	120	Culvert	Waste around the structure
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	Nothing
25/09/2012	4	360	Culvert	Presence of suspended house furniture on water
	1	4 320	Trench	Flooded house
	0.3	2 880	Bridge	Dumping of waste on the bridge
30/09/2012	1	60	Culvert	Structured blocked by debris
	0 .5	2 880	Trench	Flooded houses
	0	0	Bridge	Nothing
09/10/2012	6	600	Culvert	All the area completely flooded
	0.20	2 160	Trench	Flooded houses
	0	0	Bridge	Nothing
15/10/2012	3	5 760	Culvert	Waste around the structure
	0.60	4 320	Trench	Houses flooded
	0	0	Bridge	Nothing
19/10/2012	1	75	Culvert	Structured blocked by debris
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	Nothing
24/10/2012	1	2 880	Culvert	
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	
28/10/2012	2	2 880	Culvert	Structured blocked by debris
	0.5	2 880	Trench	Flooded houses
	0	0	Bridge	

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08/11/2012	2	4 320	Culvert	Waste around the structure
	0.5	2 880	Trench	Flooded houses
			Bridge	Nothing

D- Frequency of floods in the drainage basin

TABLE 2 illustrates the variation of the impact of floods with respect to the season, and its occurrence. It was observed that the parameter that brought about these variation were mostly the distance from storm drains and their dysfunctionalities.

Table 2: Frequency of floods

Frequencyof flood	**Proportion of household**	
	First rainy season	Second rainy season
Once per month	8.61%	11.92%
Twice per month	2.65%	1.99%
Trice per month	9.27%	7.28%
Once per year	1.32%	1.99%
Twice per year	5.96%	3.97%
Trice per year	5.96%	5.96%
Twice per week	1.32%	9.27%
After each rain effect	3.31%	9.27%

E- Potential causes of floods in the basin

Among the feedback given by the 157 household interviewed, poor waste management was observed to be the major reason of the increase in the frequency of floods followed by little or no maintenance of these structures. Details are provided on TABLE 3.

Table 3: Causes of floods in the drainage basin

Causes of floods	**Responses (proportion)**
Spontaneous habitat	10.13%
Poor construction of hydraulic structures	8.86%
Poor maintenance	17.72%
Degradation of structures	3.85%
Urbanisation	23.08%
Long duration rainfall	46.15%
High intensity rainfall	7.69%
Blockages of storm drains by solid waste	53.85%

IV. CONCLUSION

This study reveals the weaknesses in the fight against flood mitigation carried out by developing countries both on the legislative and hydraulic point of view.Based on the methodology used and the results obtained, it can be concluded that:

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The little or no regulationson floods and solid domestic waste management is one of the main problems faced by developing countries. Moreover, there is a link between poor waste management and flood occurrence in urban and semi-urban areas. It would be appropriate to create a legal institution in charge of floods survey, in order to control or mitigate floods and sanctions should be developed and implement efficiently to manage solid domestic waste.

Four major types of hydraulic structures for the evacuation of rain water are present in urban and semi-urban areas: circular culverts, trenches, bridges and rectangular culverts. These structures are mostly made out of wood, concrete and aluminum materials. Among these various hydraulic structures identified in the drainage basin, bridges are the only ones found to be functional underboth environmental and climatic hazard.

Also, though floods aggravates because of a combination of factors, the main cause of this hazard remains the presence of solid domestic wastes which are dumped profusely in nature and conveyed by runoff into the drainage basin reducing the carrying or discharge capacities of water bodies and hydraulic structures. As such in addition to a regular maintenance of hydraulic structures, an update of these structures has to be made to incorporate these elements.

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