Optimization of Land Use for Appropriate Stormwater Harvesting in an Institutional Environment

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Abstract— In recent times and in most places stormwater has been left to runoff uncaught. Much can be achieved if this stormwater is caught and stored, instead of allowing it to wreak havoc to land use in the area. A notable experience of such havoc was the 2012 Nigeria floods that cut across 30 of the 36 states of the country, and caused damage to lives, property and the environment with total worth of 2.6 trillion Naira [1]. This study was aimed at assessing and accessing the potentials in stormwater while seeking a way to curb the menace that can evolve from it.

Field survey and Topographical survey were carried out on the study area, Staff School, University of Ibadan. The results of the survey helped in obtaining the slope and the geographical map of the place, which was used in estimating the average runoff flowrate in the area. To simplify the process, the whole area was divided into six (6) parts, and the runoff for each part was estimated one after the other, using the Rational Method.

From the results obtained, it was seen for a one-hour rainfall and a return period of one year, Part A produces 337.824 metre cube of stormwater, Part B produces 299.808 metre cube, Part C produces 119.232 metre cube, Part D generates 325.728 metre cube, Part E produces 933.120 metre cube, while Part F generates 409.536 metre cube.

With the provision of adequate surface tanks for harvesting and storing of the stormwater, the adverse effect of stormwater on land use can be minimized, and the water harvested can be used for other engineering and agricultural purposes. In the engineering line, it can be used to recharge groundwater, to run turbines, etc. while agriculturally it can be used for irrigation, for feeding animals, etc.

Key Terms— Stormwater, Rainwater, Storage, Environment, Rooftop, Harvesting, Surface tank.

1 Introduction

THERE is an increasing need for water as population raises world-wide. There is therefore a need to maximize the sources of water available to man. One of the sources is stormwater. This source of water has been used most times as a supplementary source to other sources such as, underground water and streams [2][3].

However more can be gotten from precipitation if properly harnessed, and also thereby reducing the adverse effect of the water on land use. Stormwater when left uncaught can minimize land use by its damaging effects on the environment, such as damage to buildings and fences, damage to culverts that they flow through, etc.

In many developing and underdeveloped economies, public water supply to communities evidently provides a shortfall in demand [4]. Coupled with the high level of poverty, particularly in rural and semi-urban communities of Nigeria, rainwater harvest presents a natural alternative that has extensively solved water supply problems of inhabitants of rural, semi-urban and urban communities in Nigeria [4]. Likewise, stormwater will be able to contribute in meeting the water needs of communities lacking water.

The major challenge of rainwater or stormwater harvesting as observed from the literatures reviewed is that emphasis has been on the 'rooftop type' of rainwater harvesting. The works of Oni et al (2008); and Otti and Ezenwaji (2013) [4] [5], both focused on the 'rooftop type' of rainwater harvesting. This limits the catchment area to the rooftop alone, and allows the surrounding land to be flooded after a rain. These floods usually damage the environment.

This study focuses on how to combat the havoc caused by stormwater and optimize land use to achieve greater returns from stormwater.

The study aimed at assessing and accessing the potentials in stormwater while seeking a way to curb the menace posed by it. With objectives:

To investigate the existence of rainwater or stormwater catchment systems in the area, and in relation to land use.

To determine the volume of stormwater runoff in the study area.

To investigate the pattern of flow in the area.

To design surface tanks to catch stormwater runoffs.

The study area considered was Staff School, University of Ibadan, Ibadan. The area is characterised by its uneven terrain. It comprises of some hilly and lowly plains. It has some little outshoot of rocks on some parts of its surface.

It has a total area of about 59 437.25m2, which is covered partly with low grasses, partly with classroom buildings, and partly with road pavement.

2.0 Methodology

2.1 Methods Employed

A field study was done in the study area, and in the city in which it is located, Ibadan. It was aimed at finding out the following:

The existing rainwater or stormwater harvesting systems in place in the area (if any)

The present sources of water being tapped by users in the area, and their level of dependence on them.

The gorges in the area, and in the city in which the study area is located; and the gorges that are being utilized for productive activity.

The study involved the use of a Global Positioning System (GPS) to track locations, the process of observation, and interaction with the people of the community.

A topographical survey was also done using the following instruments:

Measuring tape: to measure distances

Dumpy Level: to ascertain topographical levels

Levelling staff: used together with dumpy-level to obtain various levels.

Pencil and Paper: for recording data obtained.

This helped to come up with a topographical map of the study area. The map showed the dimension of the land mass, both land utilized and land unutilized; it also revealed the elevation of some points on the area; and likewise the drainage system in place in the area. Hence, the topographical map helped in obtaining the following data in this study:

The total area of the place, together with the total paved/covered area and the total unpaved/uncovered area.

The hydraulic gradient (watershed slopes), owing to the differences in elevations.

The precipitation recipient surfaces (that is, showing where is covered with roofs, pavements, lawn, etc)

The Drainage network and flow pattern in the place.

2.2 Estimation of runoffs:

There is first of all a need to know the volume of rainwater that reaches the ground from the sky (precipitation) in the study area; before going on to estimate the volume of runoffs.

The estimation of runoffs was done. The rational method of estimating runoffs was employed.

The study area was divided into six (6) parts to ease investigation work. These are parts A, B, C, D, E, and F. Part A has an area of 8170 metre square, Part B 7500 metre square, part C 4950 metre square, Part D 8827.25 metre square, Part E 26765 metre square, and Part F 59437.25 metre square. The total area of the whole study area is 59 437.25 metre square.

The Rational formula method was used to estimate the amount of rainwater runoffs experienced by each of these parts. The Rational formula method involves three (3) major parameters, these are:

The area of the place in question, A

The intensity of rainfall in the place, I

The runoff coefficient of the area, C

Hence, the runoff flowrate, is given as:

$$Q = 2.78C.I.A \qquad \text{(Equation 1.0)}$$

C… is a dimensionless unit

I… is expressed in inches per hour (or cm/hr); while

A… is expressed in acres (or km square)

The runoff coefficient for each part of the area was determined from the figures obtained from the topographical survey. This also put into consideration paved and unpaved areas of land.

The intensity of rainfall for a 24-hour rainfall with an Average Return Interval (ARI) of one year was employed. The figure for the city of Ibadan, where the study area is located was obtained from the BCC Weather report [6].

3 Result and Discussion

The population of the area was discovered to be about 2076. This comprises of about 2000 pupils and a total staff population of 76; according to the office of the Headmaster.

There exists an appreciable mass some land untouched and unused in the study area.

Also in the course of the field survey observation showed that there exist some gorges in the city where the study area is located, Ibadan. And that these gullies lie fallow. They are not being utilized for anything productive. Whereas, these gorges could be used to accommodate surface catch tanks for catching stormwater in Ibadan, if the city is to employ this stormwater harvesting method.

The study area was divided into six (6) parts to ease investigation work. These are parts A, B, C, D, E, and F. The estimation of stormwater runoff gave the results shown in tables I and II.

From the results obtained, it was seen that Part A produces a runoff of 3.91 litres per second, Part B produces 3.47 litres per second, Part C produces 1.38 litres per second, Part D generates 3.77 litres per second, Part E generates 10.8 litres per second, while Part F produces 4.74 litres per second. These sums up to 28.07 litres per second of stormwater being generated from the study area.

For a one-hour rainfall and a return period of one year, Part A produces 337.824 metre cube of stormwater, Part B produces 299.808 metre cube, Part C produces 119.232 metre cube, Part D generates 325.728 metre cube, Part E produces 933.120 metre cube, while Part F generates 409.536 metre cube of water.

It can be thus seen that a large amount of water is being produced as stormwater from the precipitation in the area.

These stormwater can cause damage to land use in the environment. These stormwater can cause erosion of soils, can cause damage to culverts and drains through which they flow. Therefore, harvesting and storage of these water will lead to optimization of land use in the environment.

Also, the water harvested can be used for other engineering and agricultural purposes. In the engineering line, it can be used to recharge groundwater, to run turbines, etc. while agriculturally it can be used for irrigation, for feeding animals, and all such activities. In general, the stormwater harvested is good for non-potable purposes.

Thus, we can say that while the catch tanks will help us combat the harsh effect of stormwater on land use in the environment, it will also prevent the water from running off, by providing a means by which the water can be stored, and used for other productive purposes. Sizes and volumes of proposed tanks can be seen in table III.

4 Conclusion and Recommendation

From the results obtained it can be seen that more volume of water (2,425.248 m3) can be caught from the use of surface catch tanks to catch water from the entire surface area of the watershed against the Rooftop system for catching water (535.421 m3). This large volume of water can be used for productive purposes, instead of being left alone to wreak havoc in the environment.

Although, the quality of the water harvested from the entire watershed area is low. And, this is because the water caught by the surface catch tanks is the runoffs from the area; which have direct contact with the ground surface. Nevertheless, the water can be used for purposes, such as Irrigation, recharge of ground water, feeding of animals and other non-potable purposes.

The water in the tanks is safeguarded from debris by the placement of filter-screens at the entrance of the water into the tank.

Although the study did not cover the financial costs associated with implementing such system, the establishment of the tanks is a one-time cost, i.e. a capital cost and not a running cost. And the running cost of the project is not high at all. The running cost involves the maintenance cost alone. And these involve activities such as:

Clean up of the tanks, which could be done say once in three years; annual inspection of the tanks for cracks, deflection, and all such serviceability failure signs, which should not cost much, since it is but an inspection.

Thus even though the take-off cost is a bit on the high side, the long term benefit outweighs the cost. The benefit of the tanks lingers on for years.

It is therefore a recommendable system for any community or city.

5 End Sections

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