A STUDY ON THE INTERCEPTION PROCESS AND ITS HYDROLOGICAL IMPACT

Dr. SHAHANE DE COSTA
Dept of Civil Engineering, Open University of Sri Lanka.
Nawala, Nugegoda, Sri Lanka
Costas@Civil.ou.ac.Lk

ABSTRACT

The catchment has been modelled in the laboratory and artificial rainfall is induced using a pipe net work system. A series of experiments have been carried out using tropical vegetation (Rubber and Mango) of varying densities and thereby an attempt has been made to understand the interception process. It has been found that Rubber retards the rainfall runoff transformation more than Mango and it also has a greater storage capacity. It has also been found that the interception process could be separated into two segments. One, when the vegetation actively retards the rainfall runoff transformation process and stores water resulting in loss of rain water, and the other is when the vegetation has absolutely no effect on the rainfall runoff transformation process.

Key Words : Interception, Effect of vegetation, Plant storage, Canopy flow

1. INTRODUCTION

The basic hydrological aspects of a catchment in relation to rainfall runoff transformation are its interception due to vegetation, infiltration and its conducting capabilities. Nevertheless generally these aspects (the process of input of water into the streams due to rainfall) are lumped into runoff coefficients and the subject of runoff routing is concentrated on routing of stream network systems [1]. However it has been found that, even though the use of runoff coefficients for long term analysis yields satisfactory results, when considering short term analysis this tends to give rise to appreciable deviations for the rising limb, recession period and the peak discharge [2],[3]. Therefore, for detail rainfall runoff transformation calculations with appreciable degree of accuracy, the interception characteristics, the infiltration characteristics and the conducting capabilities must be taken into consideration.

Vegetation intercepts the rainfall, and initially accumulates a certain proportion of it at the canopy and thereafter accumulates a good part of it both in the canopy and the stem. This not only brings about a loss of water but also retards the rainfall runoff transformation process. Taking this into consideration there is a conceptual framework [4] which attempts to quantify the effect of interception on the rainfall runoff transformation. Nevertheless since there has been no studies on the practical aspect of the effect on interception / vegetation [5], this study endeavours to understand the effect of interception on the rainfall runoff transformation process specially for Sri Lankan conditions.

Here, the catchment has been modelled in the laboratory and a series of experiments have been conducted using tropical vegetation. Artificial rainfall has been induced and thereafter analysing the temporal variation of the discharge, the effect of vegetation (tropical) on the rainfall runoff transformation process has been obtained.

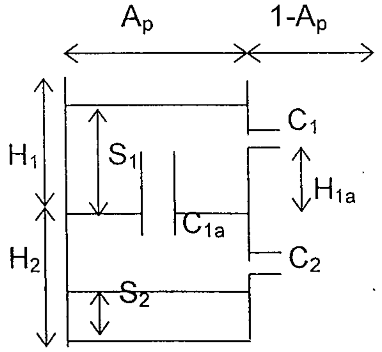
2. THEORETICAL VIEW

Interception of rainfall could be assumed as a function of the growth (largeness of trees) and density (closeness of trees) of vegetation and thereby expressed as canopy flow and stem flow. It is physically observable that, larger trees intercept and store more water than smaller trees and as the density of trees increase interception increases. Therefore this could be expressed as follows.

$$I \propto G$$
$$I \propto C$$

I : Interception
G : Growth of trees
C : Density of trees

Taking these two factors into consideration a conceptual model has been developed as follows.



A_p : Influence ratio
H : Characteristic heights of tanks
S : Storage heights of tanks
C : Coefficients of tanks
Subscript 1 indicates canopy while 2 the stem.

Fig.1 Interception model

Here $1-A_p$ is the proportion of rainfall that falls on the catchment without being intercepted by rainfall. A_p is the proportion that is being intercepted. A_p is the ratio of the sum area of canopy of all the vegetation to the total catchment area. Here it could be seen that the intercepted water would be initially stored in the canopy (S_1) and once it passes its characteristic storage (H_{1a}) the water will flow to the catchment surface through C_1. The intercepted water will also flow to the stem through C_{1a}. Once the stem storage (S_2) is also full (H_2) the water will flow to the catchment surface through C_2. C_1,

C_2, C_{1a}, S_1, S_2 etc., are characteristics of the catchment and vary according to the growth and density of vegetation. H_1, H_2, S_1 and S_2 are parameters related to canopy and stem storage while C_1, C_2 and C_{1a} are parameters related to the ability of the vegetation to release water to the catchment surface. Therefore if C_1, C_2, C_{1a}, H_1, H_2, S_1 and S_2 are known it is possible to quantify the interception process. Nevertheless this necessitates a prior in-depth experimental study of the catchment.

It could be noticed that once S_1 and S_2 are full vegetation will have no affect on the rainfall runoff transformation process. Since these conceptual characteristics needs an experimental study for its validation and also for further investigation for the interception process the following experiments have been performed.

3. EXPERIMENTAL APPARATUS AND DATA

In order to model a real catchment in the laboratory a scale down version of a catchment has been constructed and artificial rainfall has been induced by a series of pipe net works connected to a water tank. The model catchment is of 1.5m in length and 1.33m in width giving a total catchment area of 2 m^2. Small plants of commonly found vegetation in Sri Lanka namely, Rubber and Mango have been used to simulate the vegetation of the catchment.

Since the whole catchment has been scaled down it is assumed that a plant of the real tree will represent the true catchment condition. However, since the average plant height is of 0.6m to 0.8m it could be said that there has been a scaling affect of 1 : 10. The pipe network used for the artificial rainfall also has been connected with due consideration to rain drop distances and to simulate the above scaling down affect. Since in total 1500 ml of water fell as rain fall over this catchment of 2 m^2 considering scaling affects it could be said that this simulates a 7.5mm rainfall ($1500 \times 10 \times 10^{-6} / 2 = 7.5$ mm) falling over a catchment. Fig. 2 indicates the model catchment with the pipe network for artificial rainfall.

The discharge occurring on this catchment due to the rainfall has been measured. Numerous experiments have been conducted for each type of plant with varying densities. The density has been increased by increasing the number of plants in the model catchment. Fig. 3 indicates the discharge occurring over the catchment.

A series of experiments with 2 Mango plants, 4 Mango plants, 2 Rubber plants, 4 Rubber plants and mixed plants (2 Rubber and 2 Mango) have been performed. In order to keep the initial conditions uniform experiments were conducted on a 4 hourly basis. First rainfall was induced on the catchment without the vegetation and the temporal variation of discharge was measured. Thereafter the vegetation was introduced, rainfall induced and the temporal variation of discharge was measured. Using these values it is possible to obtain the actual effect of interception on the rainfall runoff transformation phenomena. A series of experiments have been carried out for each category. The following table indicates the average values obtained. It must be noted that after 1200ml it took a longer time to collect the balance and the maximum collected was below 1,300ml. This meant that there was a average loss of 250ml, 1/6th of the total supplied. In rainfall terms, 1.25mm of the 7.5mm rainfall was lost due to interception.

Fig. 2 Model catchment & artificial rainfall

Fig. 3 Catchment discharge & measurement

Table -1 Effect of vegetation

Discharge	Time in seconds for 100 ml to collect					
(ml)	No Vegetation	Mango 2 plants	Mango 4 plants	Rubber 2 plants	Rubber 4 plants	Man. & Rub. 2 plants each
100	49	56 (7)	63 (14)	60 (11)	67 (18)	65 (16)
200	66	77 (11)	87 (21)	82 (16)	94 (24)	90 (24)
300	76	88 (12)	99 (23)	94 (18)	109 (33)	104 (28)
400	83	97 (14)	109 (26)	103 (20)	121 (38)	115 (32)
500	88	103 (15)	117 (29)	110 (22)	131 (43)	124 (36)
600	92	108 (16)	124 (32)	116 (24)	139 (47)	131 (39)
700	96	112 (16)	130 (34)	121 (25)	145 (49)	137 (41)
800	100	116 (16)	135 (35)	125 (25)	150 (50)	142 (42)
900	104	120 (16)	139 (35)	129 (25)	154 (50)	146 (42)
1,000	108	124 (16)	143 (35)	133 (25)	158 (50)	150 (42)
1,100	112	128 (16)	147 (35)	137 (25)	162 (50)	154 (42)
1,200	116	132 (16)	151 (35)	141 (25)	166 (50)	158 (42)

Figures in parenthesis indicate actual effect of vegetation.

4. DATA ANALYSIS

It could be seen from Table - 1 that for 100ml and 200ml to collect in the case of no vegetation it has taken 49 and 66 seconds respectively. This is due to the model catchment characteristics such as gradient etc. However when Mango (2 plants) are introduced for 100ml to collect it has taken 56 seconds while for 200 ml to collect it has taken 77 seconds. This means the effect of Mango (2 plants) for the first 100ml is a delay of 7 seconds (56 - 49 = 7). Like wise for 200 ml it is a delay of 11 seconds (77 - 66 = 11). It could be seen that for 500 ml to collect it has caused a delay of 15 seconds

(103 - 88 = 15). Similarly for 600 ml to collect the delay is 16 seconds, however thereafter the delay remains constant which means that the vegetation has no effect on the rainfall runoff transformation process. Therefore it could be said that the impact of interception on the rainfall runoff transformation process decreases with time. Similar results could be seen for the other categories too. Fig. 4 indicates the effect of vegetation in the rainfall runoff transformation process.

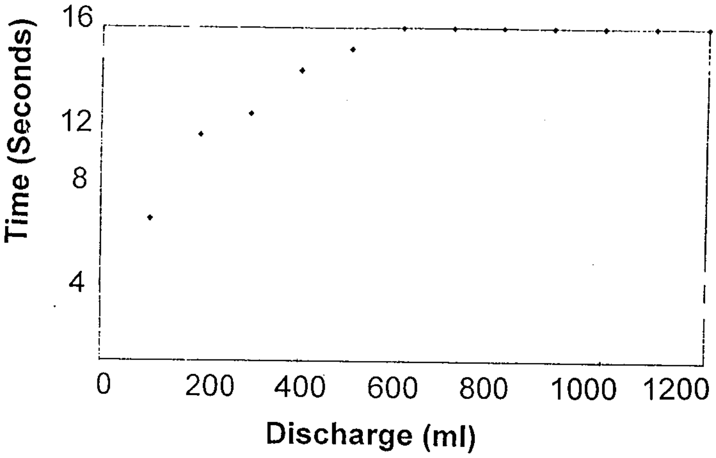


Fig. 4 Effect of Mango (2 plants)

From the above it could be seen that the interception process (effect of vegetation on rainfall runoff transformation) could be basically divided into two segments. One the initial stage, the stage in which the vegetation absorbs or begins to collect (stores) the water. This results in retardation of the rainfall runoff transformation as well as brings about a loss of rain water volume. The second stage commences after a time threshold. Beyond this threshold the vegetation has absolutely no effect on the rainfall runoff transformation phenomena. It could be seen from the above experiments that once 600ml for Mango (2 plants), 800ml for Mango (4 plants), 700ml for Rubber (2 plants) and 800ml for Rubber (4 plants) were collected they all reached a uniform state. Probably as it has reached maximum storage capacity. During this stage the transformation process would be identical to the condition of no vegetation. The results obtained here are in perfect agreement with the previously mentioned conceptual framework.

Therefore it could be said that vegetal growth effects rainfall only during the initial stages of rainfall. This means that for longer duration high intensity rainfall vegetation does not appreciably effect the rainfall runoff transformation. However for the low intensity short duration case vegetation has an appreciable influence on rainfall runoff transformation.

The time threshold the vegetal growth influences the rain fall runoff transformation is characteristic to the type of vegetation, the growth of vegetation and the density of vegetation. As either growth or density, or both increases the time threshold extends. The type of vegetation also impacts the interception process. It was found that Rubber has a higher time threshold than Mango as it took 700 ml to pass for the case of Rubber

(2 plants) while for Mango (2 plants) it took only 600 ml to pass before no effect condition was reached. It was also found that Rubber retards the rainfall runoff transformation more than Mango as for 100 ml to collect Rubber (2 plants) took 121 seconds while Mango (2 plants) it took only 108 seconds. Therefore it could be said that for catchments with typical shorter duration rainfalls the rainfall - runoff transformation process could be controlled by the type, growth and density of vegetation, but not for catchments with typical long duration high intensity rainfalls. Nevertheless if it is required to retard the rainfall runoff transformation of a catchment prone to floods (for example to reduce flood damage (reduce flood peak) or to delay the occurrence of flood peak in order to enhance the flood warning time) it is better to grow Rubber trees on such catchments than Mango.

5. CONCLUSION

From the above experimental analysis the following conclusions could be made.

1. The results of the experimental analysis agrees well with the conceptual framework.
2. The interception process basically consists of two area. The first is when it actively retards the rainfall runoff process and brings about a loss of rain water. During this stage interception has a decreasing impact on the rainfall runoff transformation process. The second is the stage beyond a characteristic time threshold, where the vegetation has absolutely no effect on the rainfall runoff transformation. This time threshold could be varied as it is characteristic to the type of vegetation, growth and density of vegetation.
3. For longer duration high intensity rainfalls vegetation has no significant effect on the rainfall runoff transformation, however for short time duration low intensity rainfalls vegetation has an appreciable effect on the rainfall runoff transformation process.
4. Rubber retards the rainfall runoff transformation more than Mango. Rubber also possesses a greater storage capacity comparative to Mango. Therefore for catchments that are subject to flooding even for short duration rainfalls Rubber would be more suited than Mango and could be used to retard the peak occurrence as well as reduce the peak flow.

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