

INFLUENCE OF LAND USE ON CATCHMENT RUNOFF AND ITS IMPACT ON THE VILLAGE TANK WATER SUPPLY IN THE DRY ZONE

T.M.J.BANDARA and S. SOMASIRI

Land and Water Management Research Centre, Peradeniya

ABSTRACT

Village tank systems which are the basis for settlement and stability of agriculture in the dry zone, derive their water supply mainly from their own catchments. Catchment land use, however, exerts a major influence on the runoff yield. This study evaluates the impact of land use types, chena, mono-culture teak and forest, on runoff generation. The forest-dominant catchments yielded the least runoff, which was about 6-7% of the rainfall; runoff from teak lands was more than twice that of forest land; and the chena lands yield the highest runoff, which was about 48% in maha and 22% in yala with a total of 39% for the year. The results of this study indicate the need for water conservation on chena (rainfed agriculture), enhancement of runoff yield from forested catchments to improve the water supply of tanks and the need to further evaluate the usefulness of teak mono-culture as a catchment protection measure against soil erosion.

KEY WORDS: Catchment, Land use, Runoff, Village tank

INTRODUCTION

Small scale reservoirs constructed across first, second or sometimes even third order valleys referred to as village tanks are a distinct feature in the dry zone of Sri Lanka. From early times, this tank system (or minor irrigation system), has been the most important single factor responsible for the establishment of human settlements in the dry zone and it occupies a central place in the life of the dry zone villager. The village tank is a community-owned water resource managed by the community for irrigation of rice fields and for variety of other uses such as bathing, washing, fishing and as a source of water for animals.

The distribution of village tanks, specially their spacing in a valley, seems to be related to social factors rather than the hydrological relationships of catchments (Somasiri, 1979). Therefore, their locations may not be hydrologically the best that would ensure a good water supply for the command areas. It is widely known that most minor tanks in the dry zone do not receive adequate water supplies on a regular basis. This is because the water supplies to these tanks are derived primarily from their own catchments, while catchment runoff varies due to a number of factors. At least partly, the catchment runoff is determined by the catchment characteristics;

therefore the catchment land use and its changes should have a major influence on the catchment yield.

In the recent past, tank water management primarily emphasized water distribution and improving the crop water use in the command area, but not much efforts had been given for the management or improvement of water supplies to the village tanks. In other words there had been no attempts to develop strategies to improve and stabilize the water supply to village tanks through the management of catchment areas. This applies to both major and minor tank catchments in the dry zone. There is now an urgent need to develop good management practices in the tank catchments, because of the population pressure on catchment lands, unplanned development of tank catchments and extreme fluctuations of water supply to tanks. To develop agriculture in the dry zone outside the major irrigation areas, it is necessary to optimize the use of total incident rainfall both in uplands and in command areas of village tanks. Abeyratne (1956) reported that the village tank is an essential factor to stabilize dry zone agriculture. Therefore, it is very necessary to know the hydrologic behaviour of catchments as influenced by different land uses to ensure the functioning of the tank system. This study was carried out with the specific objective of evaluating the impact of catchment land use on the rainfall/runoff relationship.

MATERIALS AND METHODS

Description of the study area

The study areas are micro-catchments located within the large catchment of Nachchaduwa tank, lying entirely in the North Central Province. This large catchment has a total land area of about 55,000 ha and it is entirely in the DL1 agro-ecological region, (Agroecological Map of Sri Lanka, Land and Water Use Division, Peradeniya, 1976) which is characterized by a bimodal rainfall distribution pattern. The main rainy season maha, is from September to January and minor rainfall season, yala is from March to May. For the purpose of this study, maha season is defined as the period between 36th standard week of 1987 to 12th standard week of 1988, while rest of the year 1988 is considered as yala season. In the Nachchaduwa catchment there are about 300 village tanks, covering a surface area of about 1600 ha. A large majority of these tanks do not reach the full supply level in most years.

The landscape of the study area is gently undulating to rolling with rock knob plains and erosional remnants occurring in some crest areas. Reddish Brown Earths (RBE) and Low Humic Gley (LHG) soils occur in a catenary sequence in the undulating landscape.

INFLUENCE OF LAND USE ON CATCHMENT RUNOFF

Selection of micro-catchments

To evaluate the catchment runoff variability arising from the influence of different land uses, three micro-catchments with different land use compositions were selected for monitoring of runoff. The micro-catchments selected were namely, Siyambalagaswewa, Kolongaswewa and Tammannagala located respectively in the south, north and western corners of the Nachchaduwa catchment. These micro-catchments were so selected to evaluate the influence of chena, forest and teak monoculture. The other catchment conditions, such as topography, soils distribution etc. were kept similar, as far as possible, in all micro-catchments.

Land use in micro-catchments

The land use composition of the three tank catchments is given in Table 1. The demarcation of land uses in the micro-catchment is based on aerial photo interpretation and field verification. Estimation of areas under each land use was made using a planimeter. Nearly 80% of the land area of Kolongaswewa is under chena; 73% of the area of Siyambalagaswewa is under teak; and 89% of the area of Tammannagala is under forest. Home gardens and Rock Knob Plain (RKP) areas assumed to have similar hydrologic behaviour were found to have comparable proportions in Kolongaswewa and Tammannagala. Compared to the above two catchments, Siyambalagaswewa catchment has less of high runoff generating surface areas, such as RKP and home gardens, and more of low runoff generating surfaces such as paddy lands. The runoff generating potential of forest, secondary forest and scrub jungle are shown to be very similar in this region (Sumanaratne and Somasiri, 1992; and Unpublished data from Land and Water Management Research Centre). Thus any differences in rainfall/runoff relationship observed in the three micro-catchments can be attributed to the differences in the major land uses, namely chena, teak monoculture and forest.

Estimation of runoff

The runoff from each micro-catchment was estimated by making use of the village tank water balance model (Somasiri, 1979). The model includes all the inflow and outflow components and the tank storage in a given time duration. The rain directly falling on the tank bed and the runoff from the tank catchment are the most important inflow components. The outflow components of the water balance model are flow from the spill, irrigation issues from the sluice, evaporation from the tank water surface, bund leakages and deep percolation losses.

Table 1. Land use patterns in selected micro-catchments

Land Use	Kolongaswewa		Siyambalangaswewa		Thammannagala	
	Extent (ha)	% total	Extent (ha)	% total	Extent (ha)	% total
Forest	-	-	-	-	32.8	48.8
Secondary Forest	-	-	-	-	27.4	40.8
Chena	31.5	79.2	2.9	2.9	-	-
Scrub Jungle (Abandoned Chena)	4.0	10.1	17.9	17.7	-	-
Gardens (Homestead)	0.7	1.7	3.5	3.5	-	-
Paddy	1.0	2.4	3.5	3.0	-	-
Rock Knob Plain	2.6	6.6	-	-	7.0	10.4
Teak	-	-	73.7	72.9	-	-
Total	39.8	100.0	101.2	100.0	67.1	100.0

In order to work out the water balance for each selected micro-catchment, rainfall, irrigation issues and spill discharges were directly measured in the field. The losses due to evaporation, percolation and seepage are estimates based on the decreases in the storage during short periods of 4 to 5 days at which period no visible inflow occurred or irrigation issues made. The daily changes of tank water levels recorded on gauge posts were converted into tank storage using area capacity curves of the selected tanks. As indicated below, components of inflow and outflow have been equated to estimate the water balance of the three micro-catchments.

$$S = (R_i + R_o + I_n) - (I + D_o + D_m + ET)$$

where S = change in storage; R_i = rainfall on the tank surface; R_o = runoff from the catchment; I_n = sub-surface flow; D_o = overflow drainage (spill discharge); D_m = deep percolation and bund leakage; I = irrigation issues; and ET = evapotranspiration from the tank.

INFLUENCE OF LAND USE ON CATCHMENT RUNOFF

RESULTS AND DISCUSSION

Table 2 shows the rainfall, runoff percentage of the rainfall and major land use types of the three micro-catchments, Kolongaswewa, Siyambalagaswewa and Tammannagala, for maha and yala seasons as well as for the whole year. The runoff fraction was computed by estimating runoff volume from the catchments and the total incident volume of rainfall on the catchment.

Table 2. Rainfall and runoff in selected micro-catchments during maha 1987/88 and yala 1988

Micro-catchment	Dominant land use	Rainfall (mm)	Runoff (%)
Maha 1987/88			
Kolongaswewa	Chena	1000	48.5
Siyambalagaswewa	Teak	792	11.1
Tammannagala	Forest	918	6.1
Yala 1988			
Kolongaswewa	Chena	511	22.0
Siyambalagaswewa	Teak	742	20.4
Tammannagala	Forest	688	6.9
Full year			
Kolongaswewa	Chena	1511	39.2
Siyambalagaswewa	Teak	1534	15.7
Tammannagala	Forest	1606	6.7

The measured rainfall values in the three catchments are not widely different and they are comparable; therefore these rainfalls should produce similar runoff values in different micro-catchments, if the catchment conditions are similar. In maha 87/88 the highest rainfall (1000 mm) was in Kolongaswewa catchment where chena is the dominant land use. The catchment with mono-culture teak received 792 mm, nearly 80% of the rainfall of the former catchment, while Tammannagala catchment, which is dominant in forest cover received 918 mm, an amount close to 92% of the rainfall of Kolongaswewa catchment.

Regression analysis indicated that daily or weekly runoff quantity in the catchment is only partially related to rainfall. This is because, runoff is dependent not only on catchment conditions and quantity of rainfall per event, but also on

rainfall intensity and antecedent soil moisture levels. However, in the absence of rainfall intensity data, a season's or a full year's runoff was assumed to give a better expression of the relationship between rainfall and runoff. Furthermore, unlike the daily or weekly rainfall, there was very little place to place variation of seasonal and yearly rainfall in the study area. Therefore seasonal and annual runoff differences would reflect more of the impacts of catchment conditions rather than the rainfall characteristics.

The percentages of rainfall that were converted to the catchment runoff yields are shown in the Table 2. In maha 1987/88 the runoff yield in Kolongaswewa was about 48% of the rainfall, while Siyambalagaswewa with teak plantation has generated about 11%; the least runoff was from the catchment under primary and secondary forest (6%). The comparison of runoff yield in Siyambalagaswewa and Tammannagala catchments shows that catchment of Siyambalagaswewa with teak as the dominant land use, has generated nearly twice the runoff yield of the forested catchment of Tammannagala, in spite of a lower rainfall in Siyambalagaswewa. The catchment of Siyambalagaswewa may have produced even higher runoff, if the area under teak had been comparable to forested area fraction of Tammannagala and had no paddy lands and scrub jungle in the catchment. About 20% of the Siyambalagaswewa catchment consists of very low runoff-yielding land uses, the scrub and paddy lands and it is therefore possible that much rainfall was retained in the catchment. In yala 1988, although rainfall in the above two catchments were comparable, the runoff yield of Siyambalagaswewa teak-dominant catchment appears to be again much higher than the forested catchment. The runoff yield from Kolongaswewa catchment, with chena as the dominant land use, was about 48% of the maha 1987/88 rainfall, more than four times the runoff of the teak-dominant catchment. In yala 1988, in spite of the low rainfall, of the three catchments Kolongaswewa yielded the highest runoff. Although total rainfall (maha plus yala) in Kolongaswewa and Siyambalagaswewa were nearly the same, runoff yield of teak-dominant catchment had been less than half of the chena-dominant catchment (Table 2). On the other hand, though rainfall in Tammannagala was slightly higher than that of Siyambalagaswewa catchment the total runoff yield of teak-dominant catchment had been more than twice that of forest-dominant catchment. In the case of Siyambalagaswewa, in spite of very similar seasonal rainfall, runoff in yala season increased in total amount as well as in the proportion that ended as runoff. This is probably related to the less canopy cover due to leaf fall in the yala season, which may result in less protected soil surface.

The higher runoff discharges also enhance soil erosion and therefore soil erosion under teak mono-culture can be expected to be higher than under forest cover. Further studies are required to assess the degree of protection under different land uses.

INFLUENCE OF LAND USE ON CATCHMENT RUNOFF

CONCLUSIONS

The study shows that teak mono-culture generates higher runoff yield in village tank micro-catchments when compared to that of forested catchments in the dry zone. Chena lands generate the highest runoff under similar rainfall, soil and topographic conditions. In micro-catchments under natural vegetation, the runoff yield is lowest compared to that of other types of land uses. In order to rationalize the use of incident rainfall in catchments for balanced agricultural development in the village tank environment, several strategies are necessary. They are, the generation of sufficient catchment runoff yield for an adequate water supply, *in situ* moisture conservation in chena lands to enhance and ensure chena crop production, and maintenance of adequate soil moisture in forest lands and in areas with other vegetation types to ensure their productivity. The results of this study also indicate that if soil moisture conservation is improved on chena lands, it will affect the village tank water supply. However, if the runoff from other areas such as forest, scrub or teak could be improved without affecting their productivity or causing moisture stress on these land use types, then tank water supply can be improved. It has been observed that under similar rainfall conditions water availability in teak land was less than that in the forest land. Despite this, teak grows very well indicating its ability to grow well under low moisture conditions. Therefore if similar tree species with low water requirement could be identified and introduced into the natural forests then its runoff yield can be increased resulting in the improvement of tank water supply. The result of this study stresses the need for a total micro-catchment management plan to address all different issues related to agriculture development in the dry zone.

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