A STRIDE TOWARDS MICRO-LEVEL WATER MANAGEMENT IN SRI LANKA: RESEARCH AND APPLICATIONS

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ABSTRACT

Management of water resources is becoming more distinct in the art of agriculture, as the intensive use and scarcity issues are more acute. Theoretical base of water management has been broaden and branched into various parts, and micro-level water management has been one of them. The concepts and ideology were originated initially in dry regional agriculture in the world but now need is spreading over countries where water demand is in an increasing trend. In Sri Lanka especially in the dry zone micro-level water management has become an essential element to be researched due to the fact that efficiency of water resource management is expected to reach a level by which the available water must meet the future crop water demand.

Micro-level water management can be grouped mainly into four categories. They are (a) micro-level irrigation (ie. drip irrigation, pitcher irrigation etc.) (b) micro-climate management (lowering evaporative demand) (c) micro-level rainwater harvesting and (d) soil moisture management. Most of these techniques are not new but modifications and adaptations to Sri Lankan conditions are essential to investigate. In the process of investigation emphasis must be made on cost (both initial and running), water quality, soil water dynamics and social acceptance.

In the dry zone of Sri Lanka, an extent of more than one million ha bears the potential for rainfed farming with no expectations for irrigation even in future. Agriculture in this area is severely constrained by water scarcity, therefore, rainwater harvesting at different scales has been identified as a key strategy to exploit the full potential of agricultural production in these lands.

A study on micro-level rainwater harvesting has been already initiated by Field Crops Research and Development Institute, Maha Illuppallama in collaboration with Shared Control of Natural Resources Project (IIMI), Huruluwewa and NWP Participatory Development Project, Kurunegala. The technique was based on a combination of rainwater harvesting and pitcher storage system specifically meant for fruit crop establishment in the dry zone homegardens. Studies were carried out initially on observational basis and feasibility and sustainability of the technology have been assessed. Paper discusses the findings and future research needs of the technique.

INTRODUCTION

The need to regulate supply of water to a plant arises in any form of agriculture due to inadequacy of soil moisture around the plant experienced when and then during its life time. This occurs mainly due to uneven distribution or inadequacy of rainfall and water retention nature of soil base. Management of water has therefore, become the most wanted aspect in the art of agriculture. Now it is becoming more important as the intensive use, deterioration and scarcity issues of physical resources base are more acute in the modern agriculture.

Theoretical base of water management has been broaden due to implications found in the field on its adaptation to various farming environments. The subject has been branched into various parts such as watershed management, reservoir and dam engineering, system management, on-farm water management etc. Micro-level water management is an important element in on-farm water management especially in dry regional agriculture in the world. Although the concepts and ideology were evolved in those part of the world, importance of its adoption is now spreading over countries where the demand for water in agriculture has become a national concern.

In Sri Lanka especially in the dry zone, potential for irrigated agriculture has almost been exploited with the trans-basin diversion of Mahaweli river water. At present, an extent of more than one million hectares bears the potential for rainfed farming with no expectation for irrigation even in future (Abeyratne, 1967). Water conservation in both irrigated and rainfed farming in Sri Lanka is important because a lot of water (rain or irrigated) is now wasted, there will not be enough water for augmentation of all lands in the future when there will be more people to feed. Therefore, micro-level water management has become an essential element to be researched due to the fact that efficiency of water resource management is expected to reach a level by which the only available water must meet the future crop water demand.

Micro-level water management can be broadly divided into four categories. They are: (a) micro-level irrigation (drip irrigation, trickle irrigation, pitcher irrigation etc.); (b) micro-climate management (the manipulation of micro-climate to lower the evaporative demand); (c) micro-level rainwater harvesting; and (d) soil moisture management. Most of these techniques are not new but modifications and adaptations to Sri Lankan conditions are essential to investigate. In such studies, emphasis must be made to understand soil water dynamics, water quality aspects, system economics and social acceptance in practical application.

Micro-level Irrigation

Drip or trickle irrigation is practised in the country at present in isolated locations for crops such as banana, chilli, maize, vegetables etc. However, research on this is essential to identify low head, and low cost methods which could be easily adopted by general farming community in their commercial cultivation. Water quality aspect in these methods needs to be well understood. Pitcher irrigation can successfully be practised in areas where irrigation water quality is questionable, and it is a low cost technology for conserving water, particularly in areas with scarce water resources (Dubey et al, 1988). It is now well established that pitcher irrigation can be utilized for vegetable crops and in establishment of perennial crops with much less quantity of water compared to surface or sprinkler irrigation (Mondal et al, 1987). However, study on water flow pattern and irrigation scheduling has yet to be studied in pitcher irrigation before its extensive adoption for other crops and in field research programmes.

Rainfed Situation

Rainfall exceeds potential evaporation only in April, October, November and December in the dry zone of Sri Lanka. High variability of on-set and distribution of rainfall, causes occurrence of prolonged dry spells even during these months adversely affecting the growth and yields of seasonal rainfed crops. Long dry periods, which usually occur from June to September lead to dry-up the soil profile. This is a constraint in establishment of perennial crops in the homegarden. Despite low annual rainfall, intensity of rains often exceeds the infiltration rate of soil leading to high surface runoff. This is aggravated with the formation of surface crust in the cultivated soils. Therefore, surface runoff of water that should have infiltrated into the soil profile to be used subsequently by crops is lost from the soil profile.

The situation described above can be handled by manipulating the crop micro-climate to minimize the evaporative demand, runoff water harvesting and soil moisture management.

Micro-climate Management

Alley cropping has been introduced to rainfed farming situation with a package of practices expecting various benefits. One of them is a creation of micro-climate in the cropping environment to lower the evaporative demand. The rate of evaporation is determined mainly by vapour pressure and temperature gradients which would occur between soil-air and plant-air interphases. Tree hedge formed in alleys acts as a wind barrier and reduces the vapour pressure gradient. Shade formed by alley tree over the crop strip lowers the temperature gradient. As a result of these two phenomena working in the crop environment, the evaporative demand decreases and effect of dry spells on crop growth would be minimized. Although much research efforts have been diverted towards alley cropping research during last two decades, information gathered on the role of micro-climate management in alley cropping are hardly any.

Research studies were initiated in the latter part of 1980's at Maha Illuppallama to understand the effect of shade trees on fruit crop establishment in homegardens. This study was abandoned but some encouraging observations have been made during the early part showing the possibility of using shade plants for micro-climate management in perennial crop establishment in dry zone homegardens.

Soil Moisture Management

This aspect has been investigated by studying effect of mulching, tillage, organic manuring and soil ridging on retention of soil moisture in rainfed farming. Most of the results have been documented, reviewed and put into practice in this aspect.

Micro-level Rainwater Harvesting

This paper emphasizes more on this aspect as it is a new topic in research as well as in development programmes. In the dry zone of Sri Lanka, homegarden development with perennial tree crops is severely constrained due to shortage of water during the prolonged dry periods which would usually occur from June to September. This annual drought in most cases is tolerable to deep rooted; well established, matured trees but does not permit the survival of fruit plants of less than 5 years old. A rainfall analysis carried out by using records available at Maha Illuppallama from 1945 - 95 shows that during the period from June to September a dry spell longer than 40 days can occur in 2 out of 3 years (Fig. 1). This would be the reason for failing to develop rainfed horticultural farms in the dry zone. However, in homegardens, the establishment of perennial trees could only be possible when planted under the shade of naturally grown tree species (Dharmasena, 1993). Such trees are found in some gardens as left-out trees at the time of chena cultivation. These adopted trees must be managed to provide adequate light to the undergrowth but should not be as high as to increase the temperature of micro-climate. In most of the homegardens formation of such a micro-climate is rare as such natural species are not found and regrowing them would also take a long time span. As an alternative, micro-level rainwater harvesting techniques, can be practised in this situation.

Rainwater harvesting for agriculture is not new to the dry zone of Sri Lanka. Due to uncertainty of seasonal rainfall even the early settlers had realized the importance of man made structures to store rainwater and use during water deficit periods (Dikshit, 1986). Such structures referred to as tanks are still in use collectively forming cascades of different sizes (Madduma Bandara, 1985). Some of these ancient irrigation works date back to the 5th Century BC (Wijayaratna and Widanapathirana, 1995).

Adoption of micro-level rainwater harvesting systems has hardly been reported from Sri Lanka dry zone, but evidence from other countries has been well documented (Laryea, 1992 and Katyal and Das, 1994).

Eye-brow Bund and Pitcher System

A micro-level rainwater harvesting system was designed for fruit crop establishment in the dry zone and named as 'Eye-brow bund and pitcher system'. In this method perennial trees are planted at recommended spacing. Each planting point receives runoff water gathered from eye-brow shaped small earth ridge. These ridges are prepared by using the sub-soil removed from planting pits. Water collected flows freely into a clay pitcher buried close to the plant and spills off if there is any excess water to the other eye-brow bund and so on. The gradient of the eye-brow gradually increases from zero to about 1 % at planting point and decreases to zero back at the spill. The width of eye-brow is directly proportional to the gradient. A row of Citronella is planted at the downstream side to stabilize the ridge and to use subsequently as a mulch source.

Pitcher is painted with lacquer paint leaving a considerable portion unpainted for water movement. It is positioned on a brick placed at the bottom of the pit facing the exposed (unpainted) patch to the plant side. Burying the pitcher and planting are done simultaneously keeping a gap of about 5 cm between the pitcher and the soil pack of the plant. The pitcher is positioned as to have its mouth just above the soil surface with a height difference of 1 - 2 cm. Then the mouth of the pot is covered with a coconut shell filled with sand to act as a filter.

Four Gliricidia plants are planted around the fruit plant to create a shady environment to the plant expecting to lower the soil temperature, by increasing the micro-atmospheric humidity and to cut-off the advection by wind. Schematic ground plan for eye-brow bund and pitcher system and cross-section of the pitcher-plant arrangement are shown in Fig. 2.

Field Research

The eye-brow bund and pitcher micro-scale rainwater harvesting system has been tested in several locations in the North Central and North Western Provinces of Sri Lanka. Observations are still being made on both performance of the system and its effect on plant. The system performance is assessed by an indicator called Rainwater Harvesting

Index (RHI). To describe the index a hypothetical situation is considered below for rainfall-runoff relationship as illustrated in Fig. 3.

If the capacity of pitcher is Cp and volume of rainfall required to generate runoff equivalent to Cp is Rf, then the RHI can be defined as:

$$RHI = \frac{Cp}{Rf} \times 100$$

There can be three phases in the rainfall-storages relationship. Phase A is the initial rainfall amount required to replenish the soil before making any contribution as runoff to the harvesting system. The phase B shows the fraction that would flow into the pitcher after saturation of soil with initial rainfall or due to high intensity of rainfall. This fraction is determined by rainfall intensity, infiltration behaviour of soil, surface roughness and the ground cover. The phase C indicates the possibility of increasing the volume of pitcher if the capacity is found not adequate to provide required amount of water to plant. RHI obtained from this plot can be considered as the efficiency of the water harvesting system and the study of above phases is important for making further improvements in the system.

Observational Study in the NCP

An observational study was conducted during 1996/97 in three farmers' homegardens at Huruluwewa in North Central Province of Sri Lanka. Field sites were selected on the basis of following criteria.

(a) Land is slopy and highly degraded.
(b) Previous attempts to establish perennial trees in the land have failed due to water shortage.
(c) No source of water is found nearby for irrigation (well, tank, pond, canal etc.).
(d) Soil is shallow and can not retain much water.
(e) No trees are found to create a favourable micro-climate for raising new plants.
(f) Farmers are willing to assist for testing a new technology.

Crop species used for the study were mango, jak, lime, orange and coconut giving priority to farmers' selection. Pitchers were calibrated to obtain height-volume relationship for each pitcher as they were of different shapes and sizes. Rainfall, pitcher water levels, plant height and leaf count were recorded.

Average RHI values obtained from three locations are shown in Table 1. Under the conditions prevailed in the field there was a need to receive at least a rainfall of about 30 mm to gain the full capacity (6 - 7 litres) of pitcher. RHI values were different in three locations due to the resultant effect of land slope, ground cover and soil condition. Results suggest that high RHI could be expected from slopy lands with compacted soil under low ground cover.

Rate of water release from pitchers was found very low and would not be adequate for long dry periods (Table 2). The water releasing rate may depend on various factors such as: (a) pitcher size, shape and material; (b) soil-pitcher water interphase; (c) storage of the pitcher; (d) soil moisture status; and (e) plant type and growth stage etc. Observations made on plant wilting indicated that some of the fruit plants tend to wilt although the pitchers still contain water. This means that there is a need to increase the rate of water movement through pitcher wall, to meet the water demand of the plant.

This can be done by using pitchers with larger height or leaving a larger area of pitcher wall unpainted.

Table 1. RHI values in 3 locations at Huruluwewa.

Location	Land slope	Ground cover	Soil	RHI (%)	
				Range	Mean
1	1°50'	High	Gravelly, Compacted	0.13 - 0.73	0.38
2	3°20'	Medium	Gravelly, Compacted	0.29 - 1.15	0.64
3	2°35'	Low	Sandy	0.30 - 0.96	0.50

Table 2. Water releasing rates of pitchers.

Plant Spp.	Rate (litres/day)			
	Location 1	Location 2	Location 3	Mean
Orange	0.09	0.08	0.07	0.08
Mango	0.09	0.06	0.07	0.07
Lime	0.05	0.09	0.10	0.08
Coconut	-	0.07	0.08	0.08

Measurements were taken on various plant growth parameters such as plant height, No. of branches, No. of leaves, leaf area etc. This exercise was done mainly to select some parameters which could reflect the rate of plant growth distinctly in plant species used under study conditions during a short period of time. Experience in the observational study indicates that plant height and leaf count measurements are suitable for assessing the plant growth performance (Table 3 and 4).

Table 3. Increments of plant height in rainwater harvesting system (10.10.96 - 14.04.97).

Location	Plant height increment (cm/month)			
	Mango	Orange	Lime	Coconut
1	6.5	2.6	4.6	8.7
2	1.3	6.1	11.5	3.4
3	6.5	14.9	2.5	13.4
Mean	4.8	7.9	6.2	8.5

Table 4. Leaf forming rates of fruit plants in rainwater harvesting system (10.10.96 - 14.03.97).

Location	Leaf forming rate (No./month)			
	Mango	Orange	Lime	Coconut
1	1.0	1.4	7.6	0.4
2	0.2	2.8	11.0	0.4
3	1.0	4.8	5.6	0.4
Mean	0.7	3.0	8.1	0.4

Study in North Western Province

Three locations were selected from Lokahettigama village in NWP. Crop species used for the study were Mango, Lime and Guava. Five plants from each kind were planted in a location keeping one out of five without the pitcher for comparison.

Data were analysed to determine water releasing rates of pitchers during the dry, spell occurred from 27.07.97 to 09.09.97 (Table 5). Unpainted patch for water movement in pitchers was expanded and as a result larger water releasing rates could be observed compared to that observed in the NCP study.

Table 5. Water releasing rates of pitchers at Lokahettigama (27.07.97 - 09.09.97).

	Water releasing rate (litres/day)			
	Location 1	Location 2	Location 3	Mean
Mango	0.15	0.20	0.14	0.15
Lime	0.12	0.19	0.20	0.17
Guava	0.13	0.25	0.15	0.16
Mean	0.13	0.21	0.16	-

Water releasing rates were generally low in Location 1. Results indicate that the rates vary more with Location and the differences among crops were not considerable. This means that at least during early period of establishment, pitcher water release is mainly determined by soil moisture and soil characteristics of the surrounding of pitchers.

Plant growth performance was assessed by measuring plant height, plant girth and number of leaves in plants grown with and without rainwater collecting pitchers. It was found difficult to maintain a control treatment as plants wilt and die or farmers water the plant once they observe wilting. Therefore, comparison was made with and without water collecting pitchers and all other practices were adopted similarly for all plants. A summary of results is given in Table 6.

Table 6. Plant growth performance in rainwater harvesting system at Lokahettigama.

System		Plant height increment (cm) 06.07.97-01.08.97	Plant girth increment (cm) 06.07.97-25.08.97	Leaf formation (No. of leaves) 15.03.97-17.05.97
Mango	+ Pitcher	3.1	0.47	6.8
	- Pitcher	0.5	0.25	4.7
Lime	+ Pitcher	4.2	0.58	94.8
	- Pitcher	2.5	0.35	105.7
Guava	+ Pitcher	3.4	0.47	2.0
	- Pitcher	-0.4	0.60	-1.3

A vigourous growth was observed in mango plants supported with the rainwater harvesting system. Average plant height has increased by 3 cm during a period of 25 days. The increment was only 0.5 cm in the absence of pitcher. Observation on plant girth showed that the stem development was almost double due to adoption of rainwater harvesting system. About 45 % increase in leaf growth was also observed in mango plants in the presence of rainwater pitcher system.

Average plant height in lime has increased by 4.2 cm in pitcher supported plants but only 2.5 cm in the absence of support. Plant girth also indicated an improvement by about 65 percent due to introduction of water harvesting system. In one location, lime plants without rainwater harvesting system showed large number of tender leaves sprouting due to addition of water by the farmer. In other two locations leaf fall also was observed in lime plants without pitcher and leaf growth was found better in pitcher supported plants compared to others.

Better performance was observed in guava plants supported with rainwater harvesting system compared to control plants. Leaf fall and drying off of some stems also were observed in plants without water supporting systems.

Further Research Needs

In general, plants show better performance when eye-brow bund and pitcher micro-level rainwater harvesting system is adopted. However, improvements need to be made for increasing the efficiency of the system by studying further the following aspects.

(a) Long-term effects of water quality on water movement through pitcher walls.
(b) Arrangement of pitcher-plant system to form a balanced distribution of plant roots.
(c) Controlling device for water releasing process.
(d) Water releasing rates required for different plant-soil environments.
(e) Integration of micro-level irrigation with the plant-pitcher system.

ACKNOWLEDGEMENTS

Authors wish to acknowledge the financial assistance, supporting staff and other facilities provided by Shared Control of Natural Resources (SCOR) Project of IIMI and Participatory Rural Development Project of NWP funded by GTZ.

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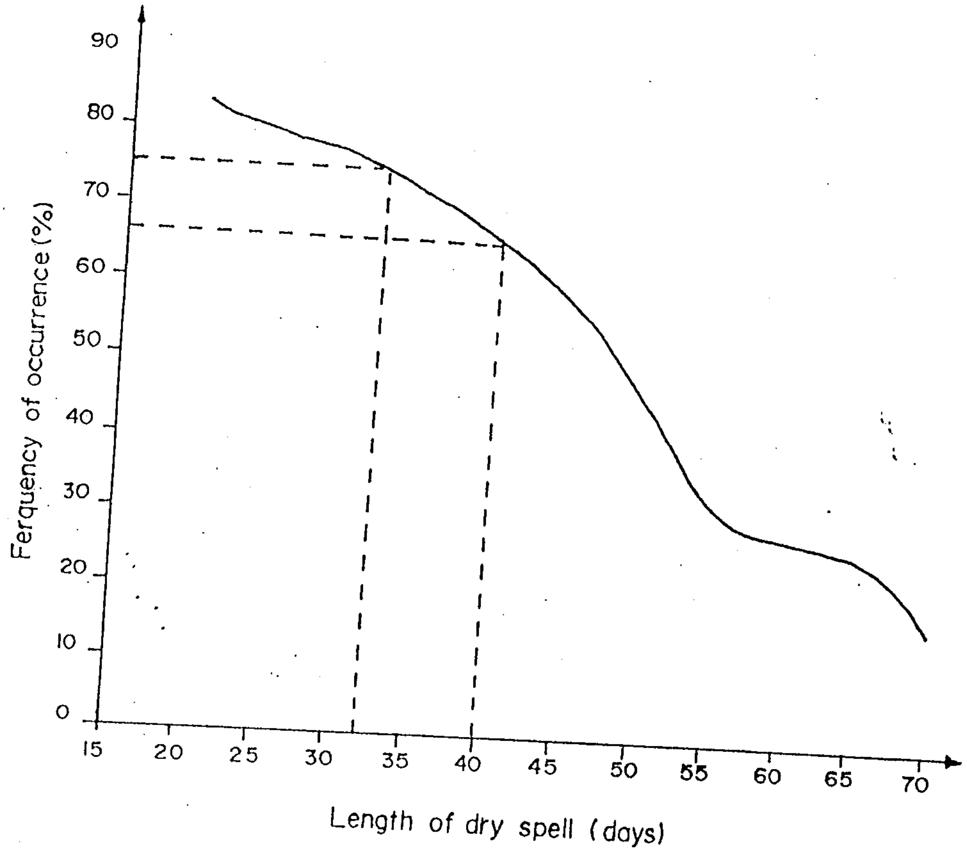

Fig. 1. Occurrence of dry spells from June to September.

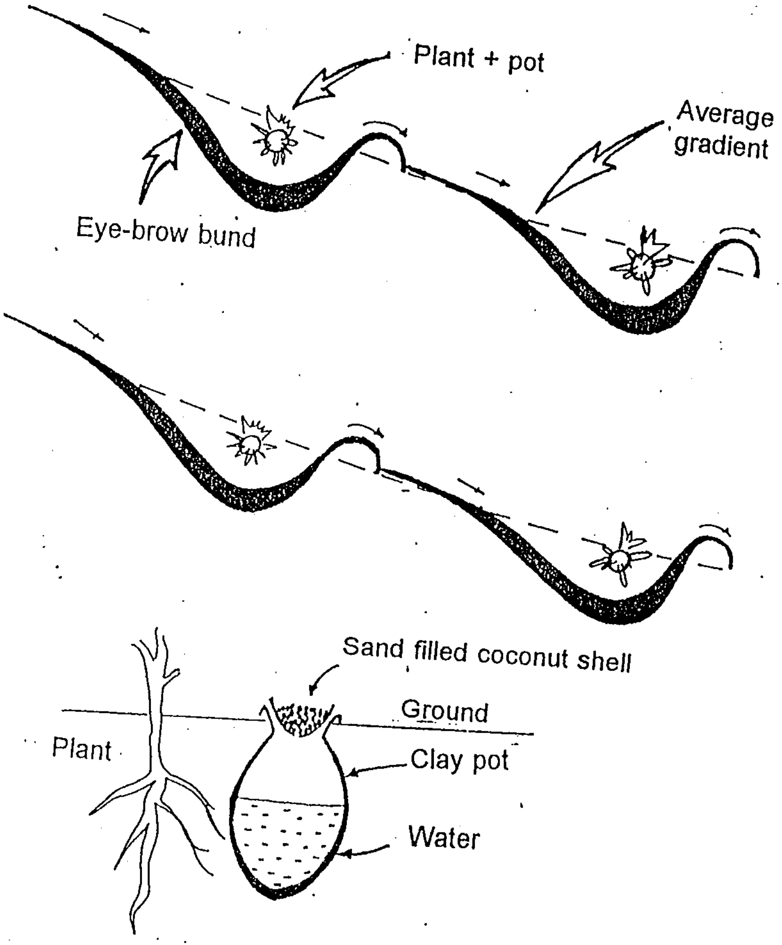

Fig. 2. Eye-brow bund - pitcher rainwater harvesting system.

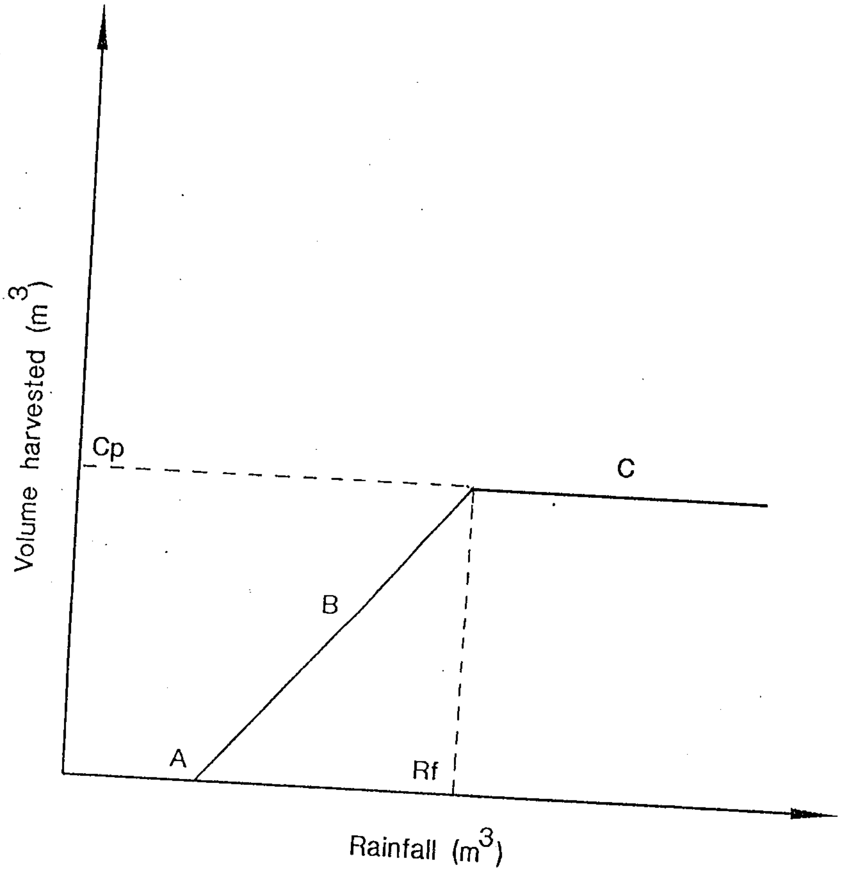

Fig. 3. Expected rainfall-runoff relationship in the rainwater harvesting system