WATER BALANCE STUDY OF KCAET CAMPUS FOR SUGGESTING SUITABLE RAINWATER HARVESTING STRUCTURES

Tokyo Metropolitan University Student Member ○Padiyedath Gopalan Saritha
Tokyo Metropolitan University Member Akira Kawamura
Kerala Agricultural University Abdul Hakkim V. M.
Tokyo Metropolitan University Member Hideo Amaguchi
Kerala Agricultural University Amrutha C. A.
Kerala Agricultural University Shajila P.

1. INTRODUCTION

Water is the most precious natural resource. The surface-water scarcity produced by the pressure of economic development will leads to indiscriminate and excessive use of groundwater (GW). To avoid this depletion of GW table, aquifer must be recharged equally. The concept of rain water harvesting (RWH) can be used to achieve this by using structures like storage tanks, ponds, recharge pits, check dams, weirs etc. In RWH system, water can be collected either from roof top or from the ground (storm water harvesting) and diverted through delivery systems to surface/sub surface storage tanks or stored on the ponds or recharged into the GW[1]. RWH helps to replenish the GW, supplement for vagaries of monsoon, serves domestic and agricultural needs during non-rainy seasons. Studies[2] suggests pits dug near wells help in recharging of the wells in agricultural lands.

The primary objective of any RWH system is to arrive at optimal water budgeting in order to sustain crop production and to provide water reserve for domestic and industrial usage. Water budgeting method utilises water balance equations to allocate the available water to various needs based on the demand and thereby estimates whether there is a surplus or deficit. This surplus water either can be stored in storage tanks to utilise during deficit periods or can be recharge to the GW. A sequential water balance study to determine the daily water deficit in Brazil based on daily data of evapotranspiration (ET) and rainfall over a period of approximately 20 years was reported[3]. Based on the light of the above discussion, the present study was undertaken (i) to assess the RWH potential and water demand, both agricultural and non-agricultural within the study area; (ii) to conduct water budgeting; and (iii) to design water storage/recharge structures to collect the rainwater.

2. STUDY AREA

The study area shown in **Fig.1** is an agricultural engineering college (KCAET) in Kerala, India which is situated at 10^0 52’30’’ North Latitude and 76^0 East Longitude with a mean altitude of 914 m above mean sea level. The major seasons in the study area are summer (February-May), monsoon (June-November), and winter (December-January). The campus is spread over an area of 40.07 ha in which 30.66 ha are under agricultural use depending mainly on GW for its varied needs, 9.41 ha under office, residential and hostel buildings and the remaining area covers road,

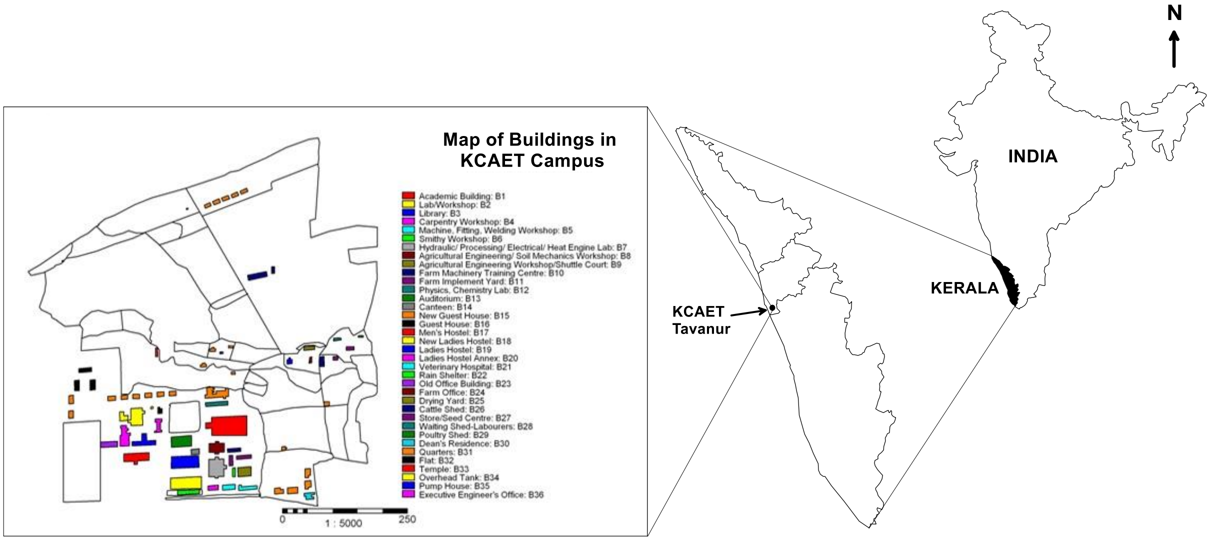

Fig.1 Location map of study area.

Keywords: Water balance, rain water harvesting, roof top water harvesting, ground water recharge

Contact address: 1-1 Minami-Osawa, Hachioji-shi, Tokyo, 192-0397, Japan. Cell phone: +81-80-1193-1183.
E-mail: saritha-gopalan-padiyedath@ed.tmu.ac.jp

playground, fallow land etc. There are 10 open wells, 5 tube wells and 6 ponds. It has been observed that during rains the surface water is wasted as runoff and the GW table is fast declining as years go by. Hence it is important to conduct water budgeting in the study area where the major water source is GW.

3. METHODOLOGY

Water budgeting studies, aimed at equitable distribution of the available water resources was done for the non-agricultural and agricultural areas of KCAET campus. The important parameters in the water balance equation, namely precipitation and ET, are used in the analysis of the supply demand situation. The study aims at finding the extent to which the various demands can be met through RWH. For the water budgeting of non-agricultural areas, a survey was conducted to evaluate the daily water demand for various purposes like drinking, gardening, laboratory use, cooking, bathing, washing etc., of the offices, staff residences and hostels. The data collected were used to calculate the water demands for the various purposes. This demand was compared to the effective runoff potential of the individual rooftops. Surplus/deficit water in each day was worked out with this information. The volume of rainwater that can be collected from the rooftops was calculated by using the formula:

$$V_r = C \cdot A \cdot d \qquad (1)$$

where, V_r= Volume of rainwater harvested from roof per day, m^3; C= Runoff coefficient (0.85)[4]; A= Area of the roof surface, m^2; d = Depth of rainfall, m.

Water budgeting in agricultural areas should be carefully handled. Rainfall and crop ET are the major parameters involved in the estimation of irrigation requirement of a crop. To estimate crop water requirements, the crop ET was related to an estimated reference ET by means of a crop coefficient. The reference ET was estimated using the Penman-Monteith approach[5]. The difference between the crop ET and the rainfall gives the irrigation water requirement (IWR) of the crop. Daily irrigation demand for each crop was got by multiplying the water requirement with total area under each crop. Surplus/deficit water in each day was also estimated.

In order to meet the demands of non-agricultural areas during dry spells, roof top rain water harvesting tanks could be used. The design of roof top water harvesting system includes design of downpipe, gutter and storage tank[6]. At the same time to recharge to the ground water, recharge pits and existing wells can be used. A design of roof top water harvesting structure and recharge pond is proposed in the following sections.

4. RESULTS AND DISCUSSIONS

An accounting of the credits and debits of water for the entire study area for a year (2010) was done on daily basis and is discussed in the following sections. Water is credited by rainfall and the debits include evapotranspiration in agricultural areas and drinking, cooking, sanitary and laboratory demands in the various buildings. The latter is included as water budgeting of non-agricultural areas. **Fig.2** shows the daily rainfall of the study area during 2010, with annual value of 2244 mm. 80% of this rainfall is contributed during south-west monsoon (June-October). The remaining 20 % is contributed by the north-east monsoon (October-November) and summer showers.

(1) Water budgeting of non-agricultural areas

The buildings in KCAET campus were categorized based on the nature of demands as office buildings, residential buildings and student hostels. It was observed from the survey that the average drinking water demand per person per day was 2 litres. Sanitary needs and miscellaneous needs varies with the status of the individual. **Table 1** shows the average values taken for computation.

Monthly cumulative demand and roof top water harvesting for office, residential, hostel buildings and total of non-agricultural areas are shown in **Fig.3**. The total roof area of residential buildings together was found to be 3465 m^2. The survey results show that there are 78 persons occupying these buildings. The annual roof water harvesting potential (RWHP) of the residential building is calculated to be around 6610 m^3 and the water needed to meet the various demand is 4000 m^3 for the year 2010 and is shown in **Fig.3a)**. There is a surplus of 2610 m^3 of water from June to November to satisfy the demands completely from harvested roof water.

The total roof area of hostels was 4728 m^2. The total number of inmates in these hostels were 178. The annual RWHP comes to 9019 m^3 while the total demand is of the order of 9000 m^3. It is seen from

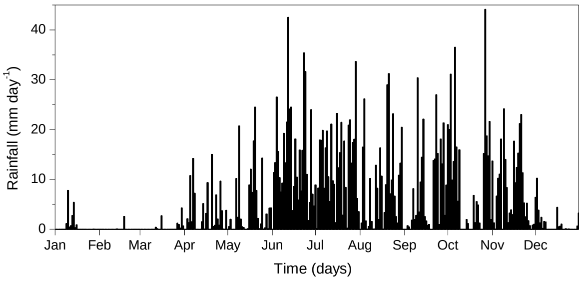

Fig.2 Daily rainfall of the study area during 1st January to 31st December, 2010.

Table 1 Daily water demand.

Demand/person/day		Residences and hostel (L)	Office (L)
Purpose	Drinking	2	2
	Cooking	5	-
	Bathing	40	-
	Sanitary	70	30
	Miscellaneous	25	12
	Total	137	44

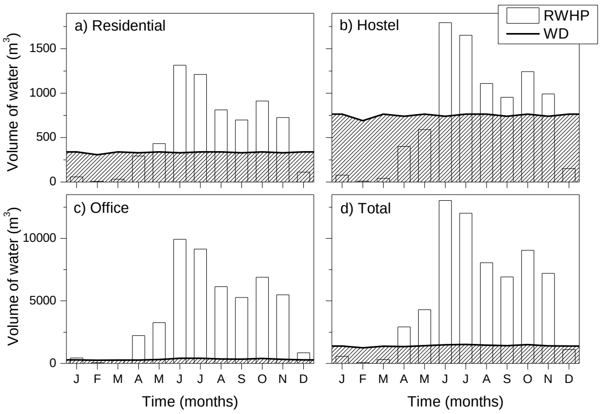

Fig.3 Monthly cumulative rain water harvesting potential (RWHP) and water demands (WD) of (a) residential; (b) hostel; and (c) office buildings; and (d) total of non-agricultural

Fig.3b) that there is a surplus of water from June-November to meet the demands during the following dry spells.

The buildings which accommodate the various departments, laboratories and administrative office are included in office category. The roof area of all such buildings together comes to 26261 m^2. The total number of persons working in these buildings is 144 and the area of lawns in the whole campus is 710 m^2. **Fig.3c)** shows that the annual RWHP is 49900 m^3, whereas the irrigation requirement of the lawns and the water demand for drinking, sanitary, and laboratory purposes are 3940 m^3. This provides an annual surplus of 45960 m^3 during April to November. This shows that the water harvested from roof top is 12.65 times more than the demand.

The total water demand for non-agricultural areas can be met from the rainwater harvested from rooftops alone. **Fig.3d)** shows the annual RWHP is 3.8 times higher than the demand.

(2) Water budgeting of agricultural areas

The major input and output components of this study are rainfall and evapotranspiration respectively. The IWR of the various crops was calculated as the difference between these two parameters. The daily account of these values gives us an idea of how much water is to be extracted from the available GW potential.

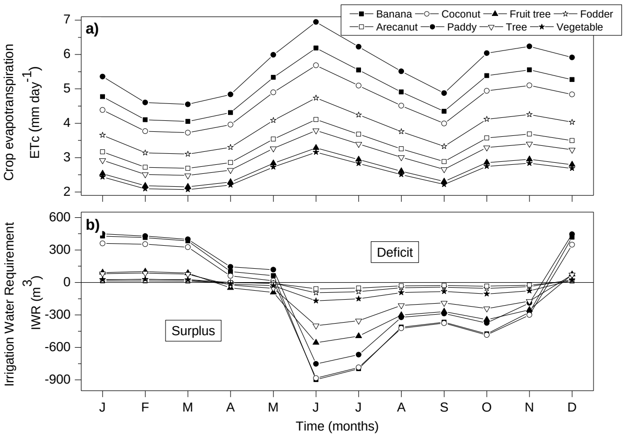

Fig.4 Monthly average ET$_c$ (a) and IWR (b) for different crops.

The entire cultivable area of 30.66 ha is put under paddy, coconut, fruit trees, arecanut, banana, vegetables, other trees and fodder. The area allocated for each crop varies over year. Monthly average ET$_c$ and IWR estimated for different crops are shown in **Fig.4**.

Fig.4a) and **Fig.4b)** shows that paddy, coconut and banana are the crops with high ET$_c$ and IWR respectively. The positive values of IWR shows deficit of water during those periods and the negative values shows surplus of water. Hence we need to irrigate the crops from January to May and in December. During June to November, there is no need of irrigation for the crops and the surplus water can be stored and can use for GW recharge.

Fig.5 shows the water budgeting for all the crops together and it reveals that there is an annual surplus of 252582 m^3 water. Total monthly cumulative surplus/deficit of IWR in agricultural areas shows the same trend of non-agricultural areas. The surplus water during the monsoon (June-November) can be stored in farm ponds to irrigate the crops during dry spells (January-May and December) or can be directed to recharging structures to recharge the GW.

(3) Design of roof top water harvesting structures

In this study, design of the roof top water harvesting system for the Academic building which is having a roof area of 3568 m^2 has been considered. The diameter of the GI sheet gutter with 0.5 percent slope was estimated as 1.67 m. The diameter of the PVC downpipe was estimated as 10 cm provided with a 20 mesh wire screen at the inlet to prevent dust entry. The storage tank was designed to supply sufficient water for the users to meet their demand during the dry periods from February-April (90 days). The Reinforced Cement Concrete (RCC) storage tank with a height of 6 m and radius 1.85 m was proposed and shown in **Fig.6**. The overflow and drainage pipe from the storage tank can be directed to a percolation pond for the GW recharge.

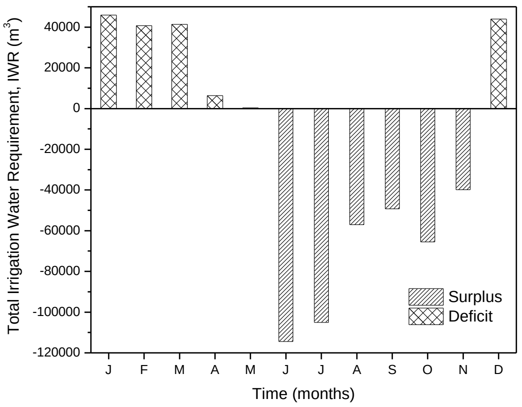

Fig.5 Total monthly cumulative surplus/deficit of IWR in agricultural areas.

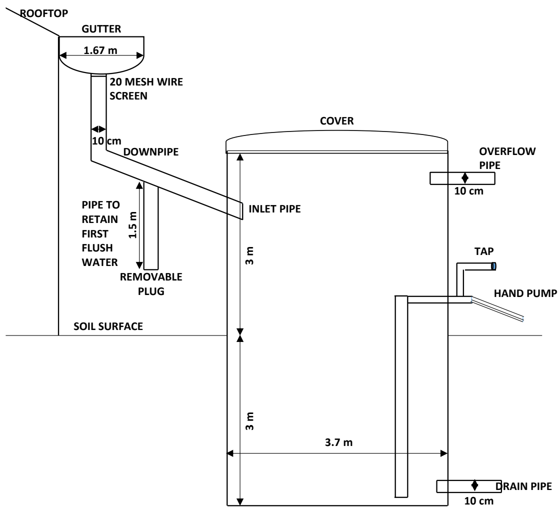

Fig.6 Schematics of rooftop water harvesting.

(4) Design of Recharge pit

The recharge pit was proposed near to two open wells from which the water was abstracted for various purposes. The designed recharge pit$^{7)}$ is having a depth of 2.4m at which the excavation reaches the porous soil. The diameter of the recharge pit was set as 2 m based on the high permeability of the soil. The filling materials used in the recharge pit is shown in **Fig.7** which will allows the rainwater to percolate through and recharges the GW.

5. SUMMARY AND CONCLUSIONS

Vagaries of rainfall, fast depletion of water resources and increasing water demands emphasize the need for implementation of efficient water resource planning. The three essential keys for any successful water resource development project are proper resource assessment, demand estimation and efficient supply management. Water budgeting gives the best solution for this approach.

The KCAET campus depends on groundwater for its various agricultural and non-agricultural uses. Drinking water and other demands are now being met from the tube well and open well in the campus. Almost all the open wells are dry and the aquifers are being tapped heavily to satisfy the water requirements during the summer.

An account of the replenishments and depletions of water for the entire study area was done. The total demand for water of non-agricultural areas in a year is about 16940 m^3 and water harvested from roof tops covers 65529 m^3. This provides a surplus of 48589 m^3. This shows that the water harvested from roof top is 3.8 times more than the demand. This surplus water is sufficient to meet the total water deficit for the remaining dry spells by storing the rain water in roof top water harvesting structures. This will end the dependability on well water supply to meet these demands. The results from agricultural area reveals that there is an annual surplus of 252582 m^3 after meeting the irrigation requirements of all crops. This water can be directed to the recharge pits or abandoned open wells to recharge the ground water. In the same way, water can also be diverted to the existing farm ponds and store for use in summer season.

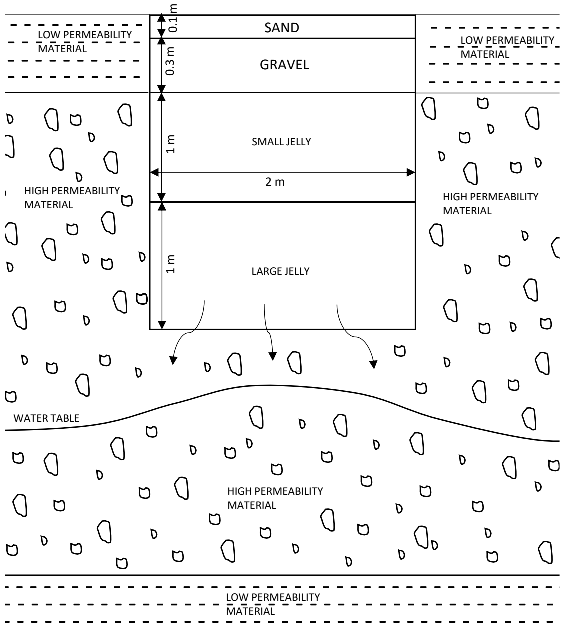

Fig.7 Schematics of recharge pit.

The study reveals that all agricultural and non-agricultural demands can be met from the rainwater harvested only. The surplus water can be use during the summer spells for different needs or to rejuvenate the ground water.

REFERENCES

1) Murthy, D.S.S., Keerthiseelan, K., and Suryanarayana, K.R. (2000). Rainwater harvesting for augmenting ground water resources in Karnataka- an overview. *In: Proc. National seminar on Rainwater Harvesting*. Vigyan Bhawan, New Delhi, 186-199.

2) Gopinath, K.R. (1999). Conservation and harvesting of rainwater. In*: Ground water management,* 103-111.

3) Fietz, C.R., Urchei, M.A., and Frizzone, J.A. (2001). Probability of the occurrence of water deficits in Dourados. *Revista Brasilera de Engenharia Agricola e Ambiental,* 5(3): 558- 562.

4) McCuen, R. (2004). *Hydrologic Analysis and Design*, third ed., Pearson Education Inc., Upper Saddle River, NJ.

5) Allen, R.G. (1986). A Penman for all seasons. *J. Irrigation and Drainage Engineering,* 122 (4): 348-368.

6) BIS (Bureau of Indian Standards). (2008). Rooftop Rainwater Harvesting-Guidelines, Indian Standard, IS 15797, Manak Bhavan, New Delhi.

7) CGWB (Central Ground Water Board). (2007). *Manual on Artificial Recharge of Ground Water*, Ministry of Water Resources, Government of India, 91-92.