E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(9): 178-183
Received: 03-07-2024
Accepted: 08-08-2024

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Determination of field water balance of paddy using drum culture technique

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i9Sc.1449

Abstract

A field experiment was conducted during *rabi* season of 2021-22 and 2022-23 to find the various factors like evaporation, evapotranspiration and deep percolation that are used to evaluate field water balance in paddy field at Indian Institute of Rice Research, Rajendranagar, Hyderabad. Drum culture technique was used to find the above factors. The results revealed that during the first season i.e., during *rabi,* 2021-22 out of total water received by the crop (irrigation and rainfall), only 32 percent is utilized by the crop. The remaining 68 percent of water was lost through percolation and evapotranspiration losses. In the second season i.e., during *rabi,* 2022-23 out of total water received 65 percent water lost through the above losses and only 35 percent of water was utilized by the crop. A positive water balance indicates surplus water was observed during both the years of study.

Keywords: Paddy, drum culture technique, field water balance, percolation, evapotranspiration

Introduction

Soil water balance computation is a must for improving the water use efficiency by reducing the unproductive loss of water *viz.*, evaporation which further improved the sustainable use of irrigation water (Bhatt, 2017) [5]. The sustainable use of water is a critical issue against the backdrop of rising water demand for agricultural use as the world needs about 60% more food to feed the 9.5 billion people in 2050. However, the situations becoming more complicated with shrinking natural resources and climate change impacts on agriculture. Furthermore, improved living standards and changing dietary habits, requiring more water-intakes, make this issue more complicated. About 90% of the global consumptive water use is for irrigation and about 40% of the irrigation water is derived from groundwater which ultimately resulted in declining underground water levels and land-water productivity. Effective strategies for realizing higher productivity along-with mitigating global warming consequences must be verbalized by dissecting wastes and non-productive water uses to where it urgently required. Water budgeting is a procedure for analysing the addition-depletion relationship of water which further helped us to increase water use efficiency. Computation of water budgets provides effective water management strategies, which further helps us to switch onto the effective resource conservation technologies. Water budgets helped us to quantify the adverse effect of anthropogenic activities on water resources. Irrigation and rainfall constitutes the major input side of soil water balance equation. Coming over to the right side of the equation, Evapotranspiration (ET) constitutes a major part of water loss (Chakraborty *et al.*, 2015) [7]. Evaporation is the unproductive loss of water which has to be partitioned to transpiration (whereby inflow of nutrients along with nutrients increased) for finally improving the grain yields. Drainage and seepage losses are the situation when the irrigation water is beyond the reach of the rhizosphere. Soil water balance variables provide a wayout to identify technologies which helped to improve the water use efficiency. Thus, soil water balance studies strengthen the scope of effective, judicious, climate smart, farmer friendly and environmental friendly irrigation water use.

Materials and Methods

A field experiment was conducted during *rabi* season of 2021-22 and 2022-23 at B block, Agronomy unit of Indian Institute of Rice Research, Rajendranagar, Hyderabad to derive various components of field water balance by using drum culture technique.

Field Water Balance or Soil Water Budget

The field water balance is a concept used in hydrology to assess the water availability and usage in a specific area, typically an agricultural field. It involves tracking the inputs and outputs of water to determine the overall water balance within the field. Field water balance is an accounting of the inputs and outputs of water in the field. A positive water balance indicates surplus water, while a negative balance indicates a deficit. The water balance can be expressed on a daily, monthly or annual basis, depending on the purpose and available data. Water inputs is a function of precipitation, irrigation and groundwater charge and water outputs is a function of evapotranspiration, deep drainage and surface runoff (Arthi *et al*., 2018, Arif *et al*., 2012 and Falalakis and Gemitzi, 2020) [4, 3, 9].

Change in Soil Water = Inputs of Water - Losses of Water.
Change in Soil water = (R + I + C) - (ET + D + RO)

Neglect C as water table is not very close to root zone and RO as runoff in the field is very negligible. Rain or irrigation water applied to the land may in some cases infiltrate into the soil as fast as it was received. In other cases, some of the water may get ponded over the surface. Depending on the slope and microrelief, a portion of this water may flow over the area as surface runoff, while the balance will get stored temporarily as puddles in surface depressions.

Therefore, R + I = ET + D

Each component of the water balance was measured as described below.

Irrigation Water Measurement (I)

It was one of the most main input parameter of the soil water balance equation but mostly its measurement was not so accurate. Scientists earlier used area-velocity flow method but provide us a rough estimate and it depends upon several factors. But presently, we have different meters which accurately quantify the irrigation water applied to a particular plot like digital area velocity flow meter. Digital flow meter was irrigation water measuring device based on quantitative basis (Bhatt, 2017) [5]. Before applying irrigation water to a particular plot, pipe with the sensor needs to be installed at the plot. When the irrigation water entered the plot through this pipe from the sensor, then automatically flow meter start showing the reading and one could easily know the amount of irrigation water supplied to a particular plot which was very important to measure the irrigation water productivity (Bhatt, 2017) [5].

Rainfall (R)

Rainfall amount (cm) was determined on the rainy day using rain gauge, which was very important for measuring the rainfall water productivity.

Percolation (D) and Evapotranspiration (ET)

Percolation and Evapotranspiration were calculated by using Drum culture technique in rice (Dastane *et al*., 1967) [8]. Three containers (drums) A, B, and C of about 40 gallons capacity, 50 cm in diameter and 125 cm high) are embedded in a rice field leaving about a quarter of their height above ground level. To container C, outlet pipes are fitted at 0.5 cm intervals. The containers are filled with soil and rice is grown inside, along with the adjoining field crop. Water levels in the drums are maintained at the same level as outside. The amount of water lost is observed and recorded every day in the morning after irrigation or rainfall. Amount of water lost from each drum gives the various components. The difference in the values on two successive days caused by the daily loss of water in container A, represents evapo-transpiration, while in container B, it indicates daily total needs of water. The daily difference between water levels in containers A and B is percolation loss. Container C is intended to assess ineffective rainfall. If there are no rains, the water level in container C will gradually reach the soil surface and the crop will be irrigated according to the intermittent irrigation practice.

Fig 1: Drums arranged in experimental field to measure field water balance components

Results and Discussion

Weather conditions

Meteorological conditions in the first and second cultivation periods are shown in figures 2a-c and 3a-c. In the first cultivation period the meteorological conditions were characterized by low rainfall, high temperature, evapotranspiration and bright sunshine hours compared to the second period. The monthly average air temperature was higher during first cultivation period (*rabi,* 2021-22) with highest value at 30th April to 6th May standard week. As a result, the patterns of water balance components in both periods were different.

Estimated water balance components

The field water balance was computed on seasonal basis (*rabi*, 2021-22 and *rabi*, 2022-23) by using drum culture technique. The results revealed that during both the years of study, positive field water balance was observed i.e., inputs of water (irrigation + rainfall) were more than losses of water (percolation + evapotranspiration). A positive water balance indicates surplus water. Table 1 and table 2 presents the total water balance components for both the years of study. The patterns of changes in water balance components were clearly different between the cultivation periods (Fig. 1-2). In the first cultivation period, total irrigation water given was higher due to lower precipitation recorded (17.4 mm) compared to second period (109.5 mm). On the days when amount of precipitation was large, the amount of irrigation given was small or nil. These results are in accordance with Karnika, 2015 [10]; Santhi, 2004 [11] and Ahmed, 1995 [1].

During the first season *i.e.*, during *rabi*, 2021-22 out of total water received by the crop (irrigation and rainfall), only 32 percent is utilized by the crop for its metabolic activities (Table 1 and Fig 1.) and remaining 68 percent of water was lost through percolation (15.5 %) and evapotranspiration (52.5 %) losses. In the second season i.e., during *rabi*, 2022-23 out of total water received, 65 percent water lost through percolation (17.2 %) and evapotranspiration (47.8 %) losses and only 35 percent of water was utilized by the crop for various metabolic activities (Table 2 and Fig 2). The water lost through evapotranspiration was higher during first year and the percolation losses were higher during second year. Higher ET losses during first year might be due to the higher mean temperature, mean evaporation and mean bright sunshine hours recorded during that year (Fig 2a-c and Fig 3a-c). This shows that plant water requirement was mainly affected by weather conditions (Allen *et al*., 1998) [2]. The lower percolation losses might be due to the clay loam texture of soil and lack of standing water that might reduce water loss by reducing hydrostatic pressure (Bouman and Toung, 2001) [6].

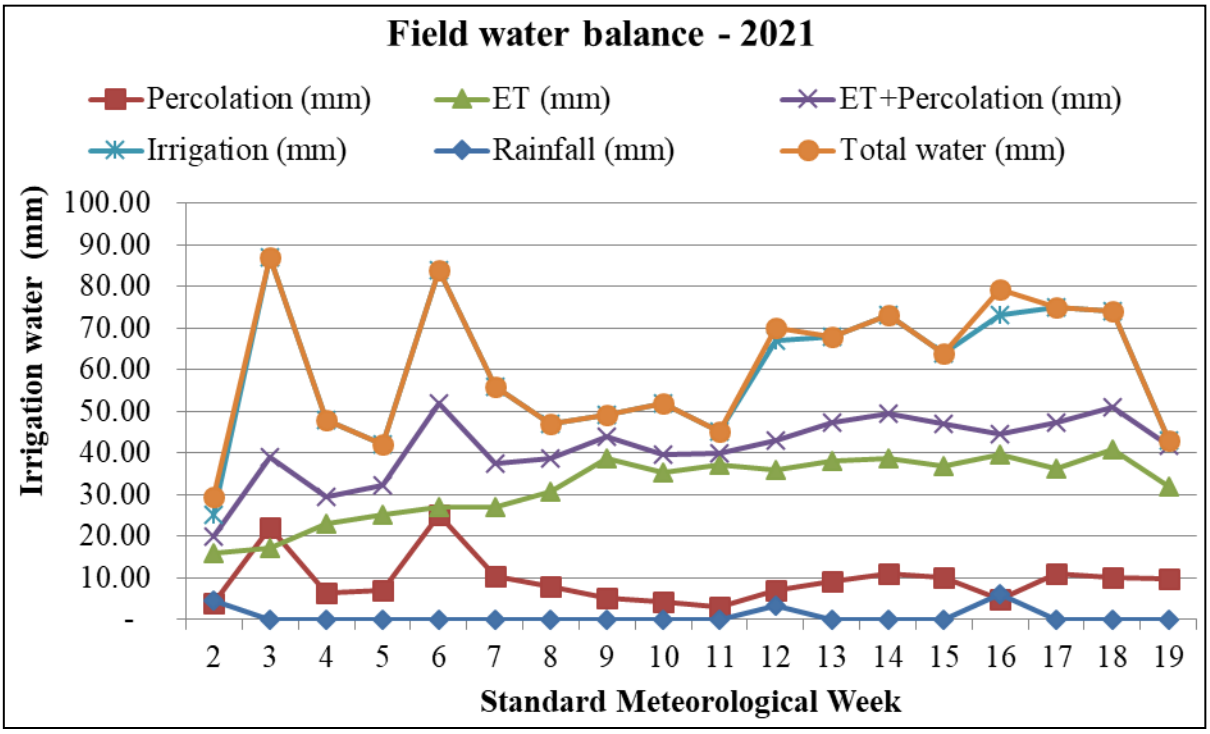

Fig 2: Field water balance components for the *rabi* season, 2021-2022

Table 1: Field water balance components for the *rabi* season, 2021-2022

Standard Meteorological Week (SMW)	INFLOWS			OUTFLOWS			Water balance
	Irrigation (I)	Rainfall (R)	Total inflow (mm)	Percolation (P)	Evapotranspiration (ET)	P+ET	
2	25.00	4.6	29.60	4.00	16.1	20.05	9.55
3	87.00	0	87.00	22.00	17.1	39.05	47.95
4	48.00	0	48.00	6.50	22.9	29.43	18.57
5	42.00	0	42.00	7.00	25.3	32.28	9.72
6	84.00	0	84.00	25.00	27.0	52.05	31.95
7	56.00	0	56.00	10.50	27.0	37.55	18.45
8	47.00	0	47.00	8.00	30.6	38.58	8.42
9	49.00	0	49.00	5.20	38.8	44.01	4.99
10	52.00	0	52.00	4.20	35.3	39.48	12.52
11	45.00	0	45.00	3.00	37.0	40.04	4.96
12	67.00	3.2	70.20	7.00	35.9	42.87	27.33
13	68.00	0	68.00	9.20	38.2	47.42	20.58
14	73.00	0	73.00	11.00	38.5	49.54	23.46
15	64.00	0	64.00	10.00	36.9	46.87	17.13
16	73.00	6.2	79.20	4.90	39.7	44.56	34.64
17	75.00	0	75.00	11.00	36.3	47.31	27.69
18	74.00	0	74.00	10.20	40.8	50.98	23.02
19	43.00	0	43.00	9.80	32.0	41.79	1.21
Total	1,072.00	14.00	1,086.00	168.50	575.36	743.86	9.55

I + R > ET + P indicates positive water balance

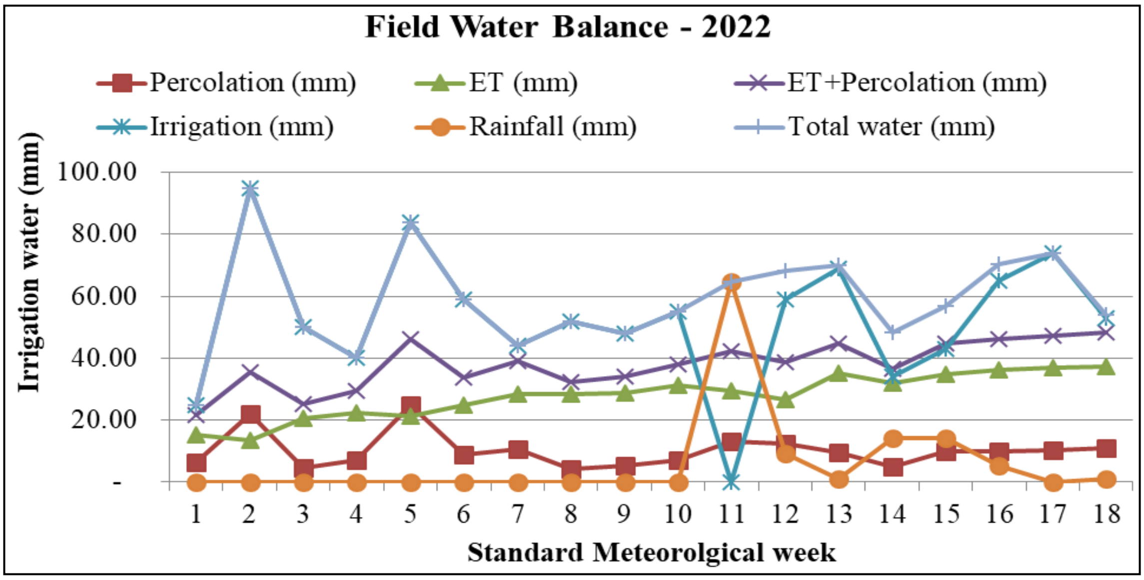

Fig 2: Field water balance components for the *rabi* season, 2022-2023

Table 2: Field water balance components for the *rabi* season, 2022-2023

Standard Week	**INFLOWS**			**OUTFLOWS**			**Water balance**
	Irrigation (I)	**Rainfall (R)**	**Total inflow (mm)**	**Percolation (P)**	**Evapotranspiration (ET)**	**P+ET**	
1	25.00	0	25.00	6.50	15.3	21.79	3.21
2	95.00	0	95.00	22.00	13.5	35.52	59.48
3	50.00	0	50.00	4.60	20.6	25.18	24.82
4	40.00	0	40.00	7.00	22.3	29.34	10.66
5	84.00	0	84.00	25.00	21.2	46.17	37.83
6	59.00	0	59.00	8.90	24.7	33.60	25.4
7	44.00	0	44.00	10.70	28.2	38.92	5.08
8	52.00	0	52.00	4.20	28.2	32.42	19.58
9	48.00	0	48.00	5.20	28.8	34.01	13.99
10	55.00	0	55.00	7.00	31.2	38.16	16.84
11	-	64.8	64.80	13.00	29.4	42.40	22.4
12	59.00	9.3	68.30	12.20	26.5	38.66	29.64
13	69.00	0.9	69.90	9.50	35.3	44.78	25.12
14	34.00	14.2	48.20	4.90	31.8	36.74	11.46
15	43.00	14	57.00	10.00	34.6	44.63	12.37
16	65.00	5.4	70.40	9.80	36.3	46.11	24.29
17	74.00	0	74.00	10.20	36.9	47.07	26.93
18	53.00	0.9	53.90	11.00	37.4	48.43	5.47
Total	949.00	109.5	1,058.50	181.70	502.24	683.94	374.56

I + R > ET + P indicates positive water balance

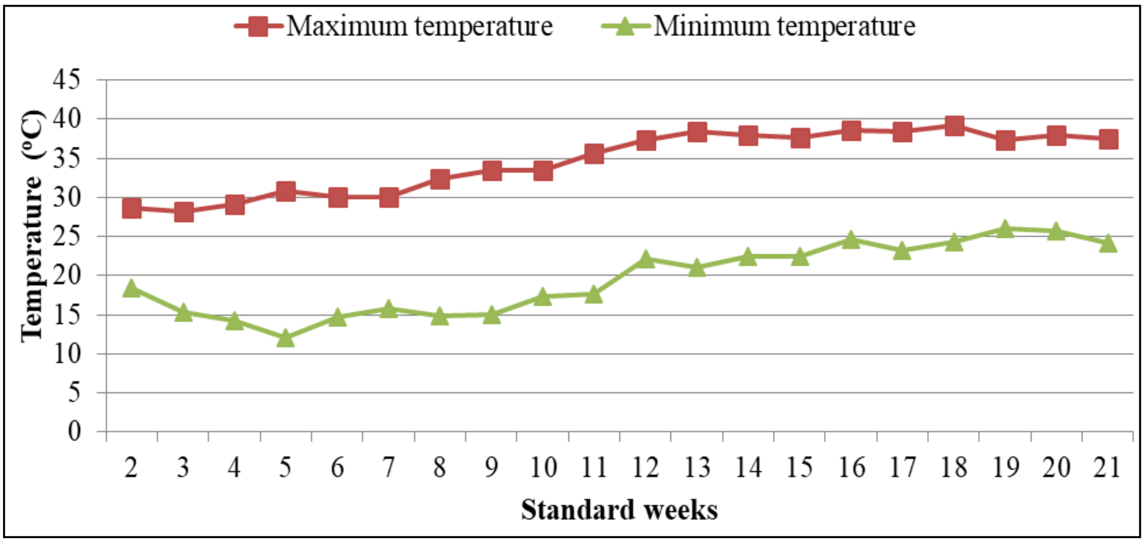

Fig 2a: Standard week wise temperature recorded data during rice growth period (*rabi*, 2021-22)

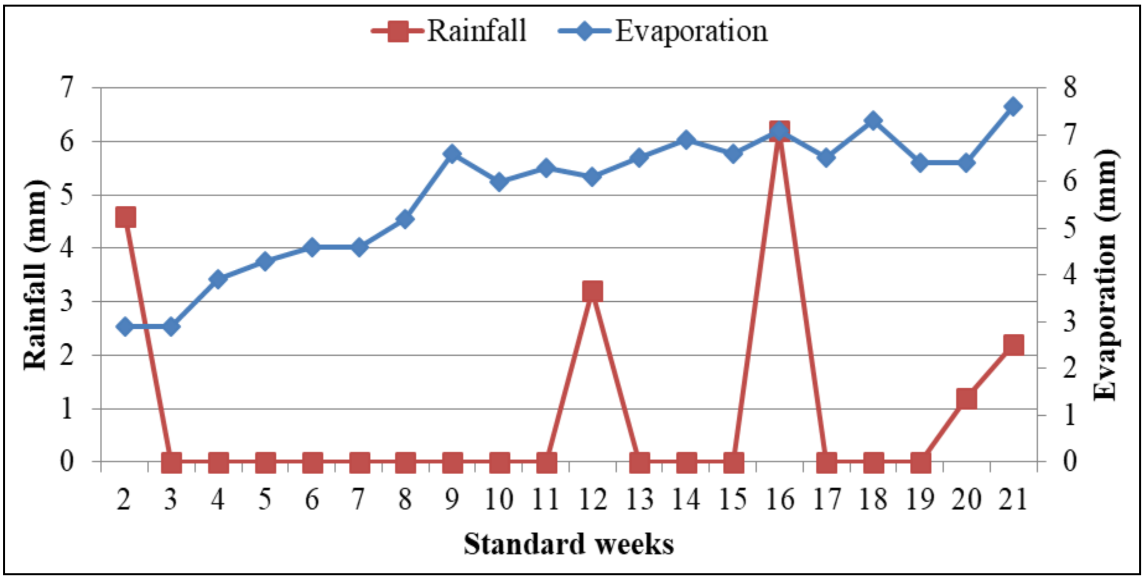

Fig 2b: Standard week wise Rainfall and evaporation recorded data during rice growth period (*rabi*, 2021-22)

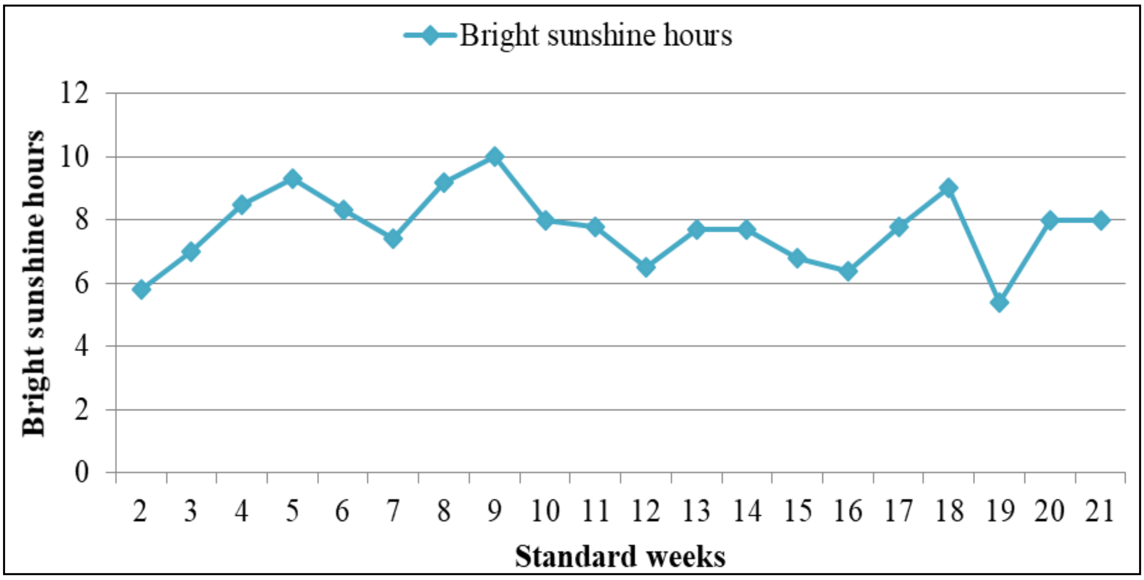

Fig 2c: Standard week wise Rainfall and evaporation recorded data during rice growth period (*rabi*, 2021-22)

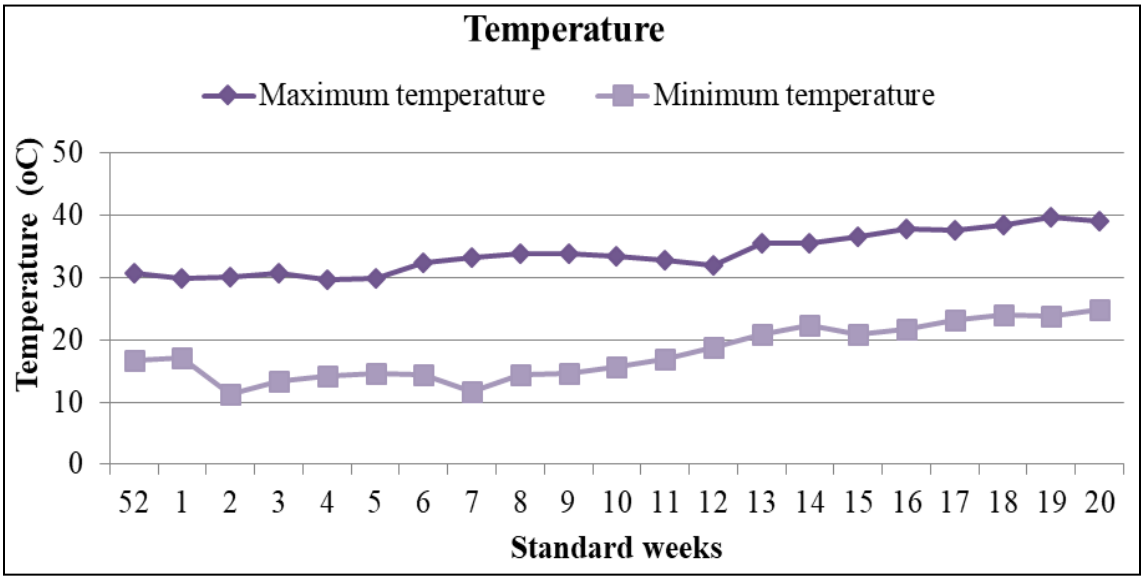

Fig 3a: Standard week wise temperature recorded data during rice growth period (*rabi*, 2021-22)

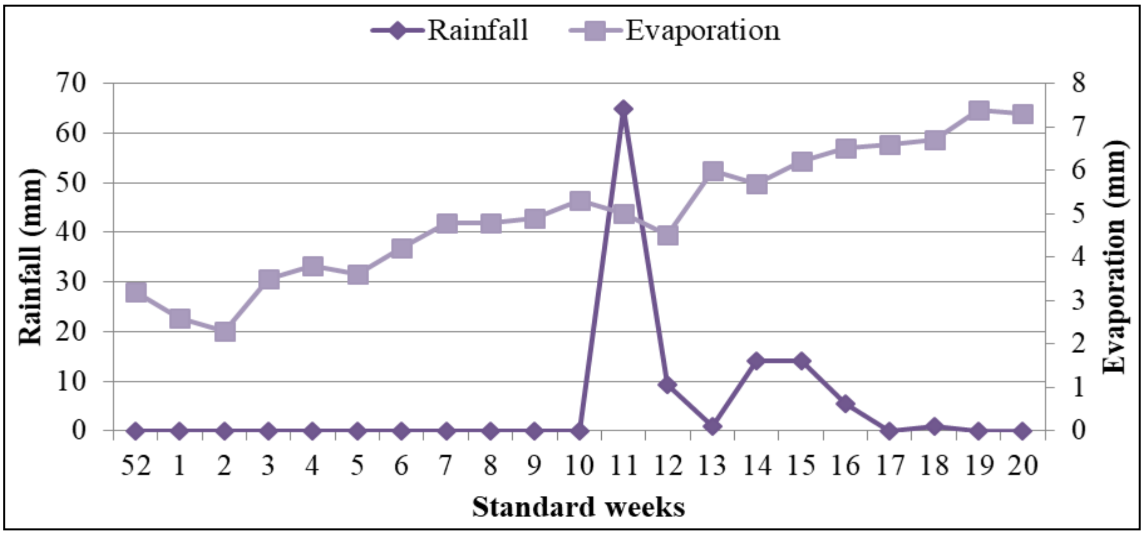

Fig 3b: Standard week wise Rainfall and evaporation recorded data during rice growth period (*rabi,* 2022-23)

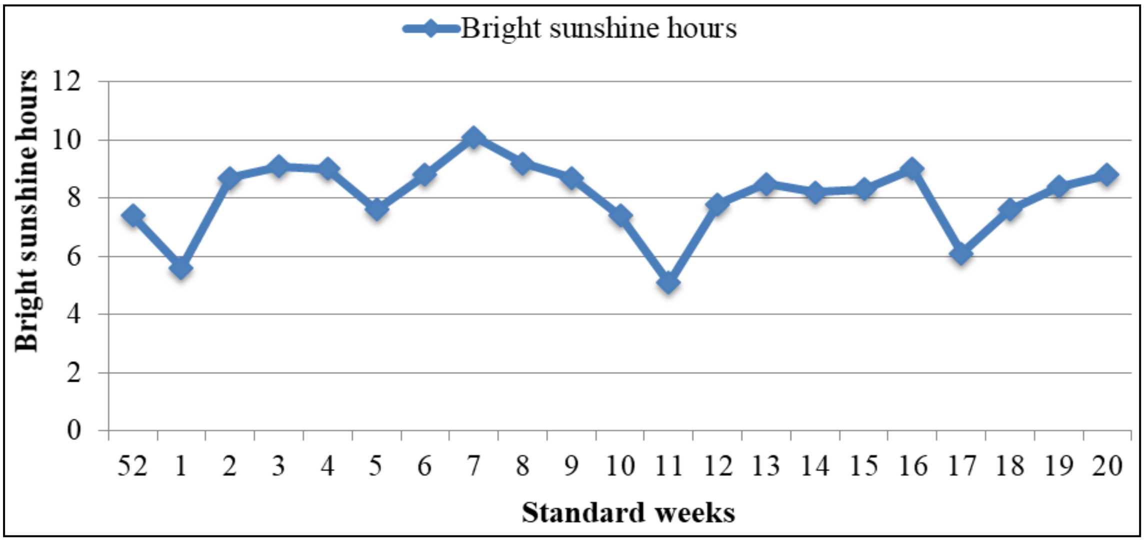

Fig 3c: Standard week wise temperature recorded data during rice growth period (*rabi,* 2021-22)

Conclusion

Drum culture technique was used for estimating the field water balance components consists of irrigation water and rainfall as inputs, crop evapotranspiration and percolation as outputs in a paddy field in two cultivation periods. Positive field water balance was observed during both the years of study indicating surplus water.

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