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Crop Water Requirement of Major Crops of Srinagar, Kashmir (J&K)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

Precise estimation of crop water requirement is essential for efficient water management of crops. Reference evapotranspiration plays a vital role in determining the water requirements of crops as well as planning of irrigation. The present study has been undertaken to determine the water requirement of major crops cultivated in the Srinagar District of Kashmir Valley on the basis of reference evapotranspiration and pan evaporation measurements. The crops used for the study are paddy, wheat, maize and pulses. Reference evapotranspiration was estimated by Penmen-Monteith method using standard meteorological data for a period of four years (2012-2015). The results showed that the total water requirement is maximum for paddy crop being 573.8 mm by Penmen-Monteith method and 721.4 mm by pan evaporation method. Wheat crop requires minimum water being 343 mm by Penmen-Monteith method and 134.3 mm by pan evaporation method. The water requirement for maize and pulses was in between paddy and wheat being 485.7 mm and 644.1 mm for maize by Penmen-Monteith method and pan evaporation method respectively. For pulses the water requirement was 370 mm by Penmen-Monteith method and 510.8 mm by pan evaporation method.

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Keywords: Reference evapotranspiration; crop evapotranspiration; pan evaporation and crop water requirement.

1. INTRODUCTION

Climate, water and soil are fundamental resources for crop production. For efficient crop production, it is essential to utilize these resources efficiently. The maximum potential yield of a crop is determined primarily by the climate and the genetic potential of the crop. However, the availability of water in quantity and time at different stages of growth has a profound effect on the upper limit of a crop's productivity. A judicious assessment of the water requirement of the crops is crucial for irrigation scheduling and planning of farm irrigation systems.

Irrigation is the largest consumptive use of water globally involving 75-80% of the water use [1]. Irrigation scheduling necessitates careful estimation of crop water requirement. The crop water requirement plays a crucial role in the yield of a crop. Crop water requirement is the optimum amount of water required by the crop for full-fledged nourishment of the plants and to obtain maximum yield. It is defined as "the depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment" [2].

Crop water requirement is estimated in terms of evapotranspiration. Field measurement of evapotranspiration is arduous and costly. Direct measurement of evapotranspiration is also impractical for permanent and large scale use [3]. Empirical methods are thus commonly used for estimation of evapotranspiration. These methods have been developed using the relation of evapotranspiration with parameters of climate and atmosphere. Evapotranspiration is determined by these models by the combination of energy balance and mass transfer methods with parameters describing the crop. A number of models for estimation of reference evapotranspiration exist. Penman-Monteith method however gives acceptable results under most of the global climatic conditions and thus is applied extensively for reference ET calculations [4]. Actual or crop evapotranspiration is then calculated from reference ET by multiplying it with a crop coefficient.

Another common method of estimating crop ET is by using the measured evaporation from the standard Class A pan. Empirical coefficients are used to adjust pan evaporation values to ET values [5]. These coefficients may be determined by calibration but acceptable results are also obtained using representative values from other studies [6].

The present study has been undertaken to ascertain the water requirement of major crops cultivated in the Srinagar region of Kashmir Valley on the basis of reference evapotranspiration and pan evaporation measurements. The crops used for the study are wheat, maize, paddy and pulses. The problem with agriculture in the Kashmir Valley is that cultivation of crops is carried out by the farmer's skill and experience but not by the use of proven scientific methods for maximizing the yield of the crop. If proper scientific methods are adopted and used the yield of the crops can be increased substantially which can boost the economic growth of the famers and revenue income of the state. The rationale behind the study and assessing the water requirements of various crops that are cultivated in the Srinagar District of the valley is to boost the agricultural yield to improve the economic condition of the state. From the ascertained value of water requirement of crops, the value of discharge of the channel can be calculated by using the efficiency of application of water in the cultivated land and efficiency of conveyance of water through the channel for the design of channels to irrigate cultivable area. The Crop water requirement of the crops can be useful in selecting a suitable crop in a particular place of the region depending upon the availability of water, soil texture, water holding capacity of the soil and land slope.

1.1 Study Area

The area considered for the present study is the Srinagar district of Kashmir Valley. Srinagar has average latitude of 34° 44' N and 74° 54' E longitude. Himalayas surround the Kashmir Valley on all sides. The high elevation and northerly position of the valley bestows it with a humid subtropical climate. The SKUAST-K station is located within the Srinagar district at an elevation of 1605 m above mean sea level and latitude and longitude of 34°05'N and 74°50'E respectively. Winters are cool, with daytime a January average of 2.5°C (36.5°F), and temperatures below freezing at night. Moderate to heavy snowfall occurs in winter. Summers are warm with a July daytime average of 24.1°C (75.4°F). The average annual rainfall is around 720 millimeters (28 in).

2. METHODOLOGY

2.1 Data Used

Daily meteorological data of maximum temperature (°C), minimum temperature (ºC), relative humidity (%), wind velocity at 2 m height (m/s) sunshine hours (hrs.) and daily pan evaporation (mm) were obtained from Agro-meteorological observatory of SKUAST-K, Shalimar, (J&K) for the time period from January, 2012 to December, 2015. The average monthly values of weather data over this period are given in Table 1. The values of crop coefficients for the crops at different stages of growth are given in Table 2.

2.2 Penman-Monteith Method

Penman [7] derived an equation for computing evaporation from open water surfaces using temperature, humidity, sunshine hours and wind speed data. Many researchers then introduced resistance factors in the equation in order to apply it to cropped surfaces as well. The Penman model was modified by Monteith with the inclusion of an aerodynamic and a physiological resistance [8]. The Penman-Monteith method, also known as FAO-56 Penman-Monteith method is considered as a standard method for estimating evapotranspiration because of relatively accurate calculations for a range of climatic conditions. The equation is given as,

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_{mean}+273} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}$$

Where,

ET_0 = reference evapotranspiration [mm day^{-1}],

R_n = net radiation at the crop surface [MJ m-2 day^{-1}],

G = soil heat flux density [MJ m-2 day^{-1}],

T_{mean} = mean daily air temperature at 2 m height [°C],

U_2 = wind speed at 2 m height [m s^{-1}],

e_s = saturation vapor pressure [kPa],

e_a = actual vapor pressure [kPa],

$e_s - e_a$ = saturation vapor pressure deficit [kPa],

Δ = slope vapor pressure curve [kPa °C^{-1}],

γ = psychrometric constant [kPa °C^{-1}].

Table 1. Monthly values of various meteorological parameters for the time period 2012-2015

Year	Month	MAXT(C)	MINT(C)	RH1(%)	RH2(%)	WS (KMPH)	SS(HR)	EVP(MM)	RF(MM)
2012	1	4.4	-3.3	94	80	1.6	1.8	2.2	67.5
2012	2	8.6	-0.1	91	66	2.8	3.1	10.9	78.9
2012	3	15.7	3.5	80	44	3.6	3.9	61.6	38.6
2012	4	19.3	7	83	54	2.9	4.9	82.4	130.5
2012	5	23.1	8.7	81	57	2.7	7	95.8	43.6
2012	6	27.7	12.5	77	49	2.2	7.7	122.2	24.2
2012	7	31.3	16.7	81	48	1.7	7.9	122.9	32.2
2012	8	30.1	17.8	82	54	1.3	5.9	109.4	60.2
2012	9	26.3	13.5	90	64	1.2	5.9	72.2	86.4
2012	10	20.8	4.3	87	55	1.4	6.4	48.6	8.9
2012	11	16.3	0.1	83	54	1.6	5.1	33.9	12.8
2012	12	8.2	-0.6	89	73	1.6	2.2	11	44.6
2013	1	7.2	-2.8	92	71	2	3.8	6.5	89.4
2013	2	9.6	0.1	87	63	2.4	3.3	15.5	137
2013	3	17.1	3.8	80	48	2.9	5.6	66.5	51.6
2013	4	19	6.6	80	59	2.7	5.2	77.3	135.6
2013	5	24	9.2	80	49	2.5	7.1	114	59
2013	6	29.4	14.9	79	50	2.1	8.9	147.5	107.2
2013	7	30.9	17.8	77	48	1.8	8.7	162.4	73.6
2013	8	28.6	17.7	81	62	1.4	5.7	138.8	178.4
2013	9	27.7	12.1	83	58	1.2	7.3	107.5	31.2
2013	10	24.1	8.1	85	59	1.4	6.1	80.3	21

Year	Month	MAXT(C)	MINT(C)	RH1(%)	RH2(%)	WS (KMPH)	SS(HR)	EVP(MM)	RF(MM)
2013	11	15.3	-0.4	86	66	1.1	4.1	30.9	17
2013	12	10.1	-2.2	90	70	1.1	2.6	17.1	25.2
2014	1	4.7	-1.7	89	79	0.5	1	7.1	165.6
2014	2	9.2	0	88	61	2.1	3.4	21.3	68.5
2014	3	11.1	3.1	85	66	1.9	2.2	40	278.2
2014	4	17.8	6.2	78	61	1.4	4.8	79.6	124.8
2014	5	23.1	8.9	81	56	1.2	5.8	102.7	68.9
2014	6	29.3	11.4	72	44	1.8	9.2	157.5	24.1
2014	7	30.5	16.8	79	49	1	7.7	148.7	72.8
2014	8	29.1	14.8	80	53	1.5	7.4	141.7	80
2014	9	24.8	10.1	88	66	1.7	6.3	75.8	211.1
2014	10	21.2	6.5	92	67	1.7	5.7	75.5	23.4
2014	11	13.7	0.2	90	72	1.3	2.7	28.7	19.6
2014	12	10.1	-4.2	91	64	1.5	2	13.6	0
2015	1	10.4	-2.9	90	56	2.1	4.3	16.6	14.8
2015	2	9.3	-0.2	90	67	2.4	2.7	20.3	249.5
2015	3	11.7	1.8	89	66	2.7	3.4	42.1	440.3
2015	4	19.4	6.6	80	52	2.9	6	102.6	186.6
2015	5	23.8	9	77	59	3.1	7	134.7	64.2
2015	6	25.2	12.1	77	58	2.5	7.1	136.3	125.6
2015	7	29	17.5	84	63	1.8	6.5	133.9	268.6
2015	8	29.9	16.3	83	55	1.4	7.2	142.1	174.6
2015	9	26.3	10	82	53	1.7	7.7	115.3	75.4
2015	10	21	5.7	88	59	1.4	5.9	76.7	92.3
2015	11	13.6	2.2	88	69	1.3	2	36.7	39
2015	12	9.1	-2.4	89	70	1.5	2.2	23.2	23

MAXT = Maximum temperature; WS = Wind speed
MINT = Minimum temperature; SS = Sunshine hours
RH1 = Morning relative humidity; EVP = Evaporation
RH2 = Evening relative humidity; RF = Rainfall

Table 2. Crop coefficient values at different stages of development

Crop	Crop development stage			
	Initial	Crop development	Mid-season	Late season
Paddy	1.1-1.15	1.1-1.5	1.1-1.3	0.95-1.05
Wheat	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75
Maize	0.3-0.5	0.7-0.85	1.05-1.2	0.8-0.95
Pulses	0.3-0.4	0.7-0.8	1.05-1.2	0.65-075

(Source: Hargreaves et al., 1985)

2.3 Pan Evaporation Method

Evaporation pans combine the effect of different meteorological parameters, namely radiation, wind, temperature and humidity on evaporation from a particular exposed water surface. Plants also react to these climatic variables in a similar manner [6]. In order to take the climate and pan environment into consideration, empirical coefficients are used to relate pan evaporation and reference crop evapotranspiration. One of these relations is given as:

$$ET_0 = K_p \times E_{pan}$$

Where,

ET_0 = Reference evapotranspiration [mm day-1],

E_{pan} = Pan evaporation [mm day-1],

K_p = Pan coefficient (0.70 for the present study).

2.4 Crops

2.4.1 Paddy

It is the staple cereal crop of Kashmir Region and is cultivated in Kharif (summer) Season. Optimum growth of paddy requires diurnal temperatures of 25-33°C and nocturnal temperatures of 15-20°C. Maturity period is 130-150 days.

2.4.2 Wheat

It is a rabi (winter season) crop and its plant requires a cool and somewhat moist climate in the beginning and warm and dry weather at the harvest time. It is sown in August and harvested in March-April. It is largely a rain-fed crop particularly in foothills and hilly areas of the valley.

2.4.3 Maize

In terms of acreage, maize is a chief crop of J&K state. It is a kharif crop and grown mostly in warmer parts of temperate regions and areas of humid sub-tropical climate. Nearly 85% of the cropped area in the state is rain-fed and thus prone to vagaries of rainfall distribution.

2.4.4 Pulses

Hot and dry climate suit their cultivation. They are largely grown on small patches of land and the pulses of Kashmir Valley are well known for their quality.

2.5 Crop Coefficients

The idea of crop coefficient(Kc) was made known by Jensen [9]. The idea was further advanced by some more researchers [6,10,11]. The value of Kc is influenced by the crop characteristics and the stage of growth. To some extent climate also influences the value of Kc. Kc is an integrated representation of four chief factors; crop height, albedo, canopy resistance and evaporation from the soil.

3. RESULTS AND DISCUSSION

The water requirement of some major crops of Kashmir valley, namely wheat, maize, paddy and pulses was estimated using Penman-Monteith Method and Pan evaporation method. The results showed that the crops require maximum water during mid-season stage and final stages of development. Paddy crop requires maximum water for growth while least water requirement is for wheat crop. The yearly water requirement of these crops during 2012-2015 during different stages of growth by Penman-Monteith Method is given in Table 3 and Pan evaporation method is given in Table 4.

Table 3. Annual water requirement by penman-monteith method

Crop	Year	Crop water requirement (mm)				
		Initial stage	Crop development stage	MID-season stage	Final stage	Total
Paddy	2012	98.0	118.5	210.2	128.9	555.6
	2013	102.7	130.3	228.0	140.0	601.0
	2014	59.2	105.1	205.5	157.8	527.5
	2015	113.4	136.8	196.4	164.6	611.2
Wheat	2012	18.8	72.3	48.9	280.2	420.3
	2013	17.1	65.2	50.0	88.0	220.3
	2014	16.1	53.1	56.3	295.0	420.5
	2015	16.4	44.9	53.7	195.7	310.7
Maize	2012	11.2	50.8	152.1	320.9	535.0
	2013	10.9	56.3	166.7	267.7	501.6
	2014	6.4	31.9	153.2	252.8	444.3
	2015	11.2	65.0	144.4	241.5	462.0
Pulses	2012	13.2	32.0	86.6	247.0	378.9
	2013	12.9	35.5	95.4	269.1	412.9
	2014	7.6	20.1	81.4	278.6	387.7
	2015	13.3	41.0	98.2	255.9	408.3

Table 4. Annual water requirement by pan evaporation method

Crop	Year	Crop water requirement (mm)				
		Initial stage	Crop development stage	Mid-season stage	Final stage	Total
Paddy	2012	97.3	130.0	250.6	134.5	612.4
	2013	105.2	157.0	320.8	184.6	767.7
	2014	100.3	156.3	313.2	163.0	732.7
	2015	130.5	162.7	286.8	192.9	772.9
Wheat	2012	8.7	31.7	13.2	34.3	88.0
	2013	14.5	28.9	20.5	37.5	101.4
	2014	13.6	26.9	16.3	87.6	144.4
	2015	13.8	34.4	27.8	127.2	203.2
Maize	2012	11.2	50.1	180.0	303.3	544.5
	2013	10.4	60.6	224.1	393.2	688.4
	2014	10.7	54.6	227.2	379.1	671.7
	2015	13.9	71.6	225.9	360.3	671.7
Pulses	2012	13.2	31.6	97.2	296.4	438.4
	2013	12.4	48.2	127.8	357.7	546.2
	2014	12.7	34.4	118.6	382.0	547.7
	2015	16.4	45.1	118.7	330.6	510.8

The water required by the crops during different stages are shown in Fig. 1. The charts are based on 4-year average of water required in different stages of growth. For wheat, maize and pulses maximum water is required during final stage of growth. The maximum water requirement for paddy is however during mid-season stage.

The comparison of water requirement during different stages for each crop by Penmen-Monteith Method is shown in Fig. 2 and by Pan Evaporation Method is shown in Fig. 3. The results show that paddy requires more water as compared to other crops in initial, crop development and mid-season stages of growth. The water requirement of paddy is however less in the final stage of growth as compared to other crops. The results obtained by Penmen-Monteith Method are analogous to those obtained by Pan Evaporation Method.

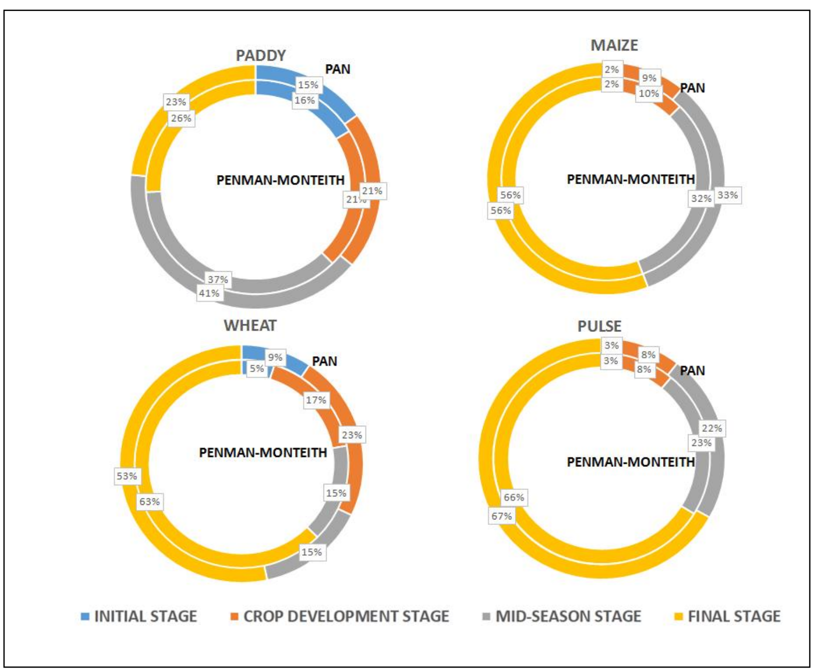

Fig. 1. Relative water requirement during different growth stages

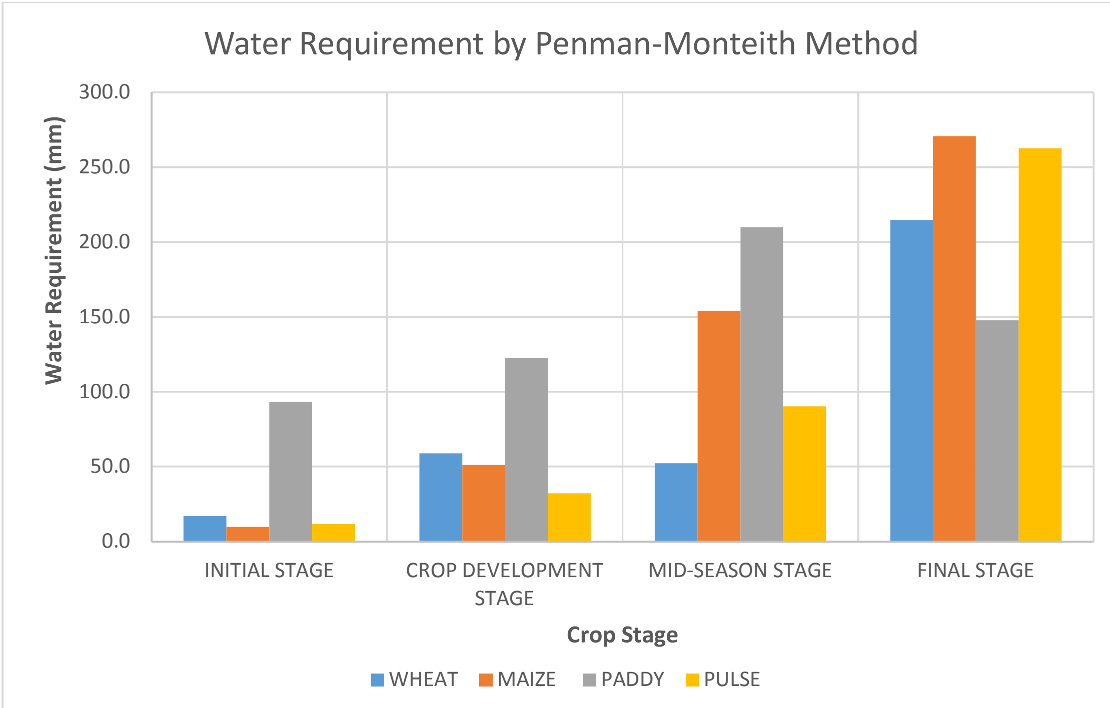

Fig. 2. Stage-wise water requirement by penman-monteith method

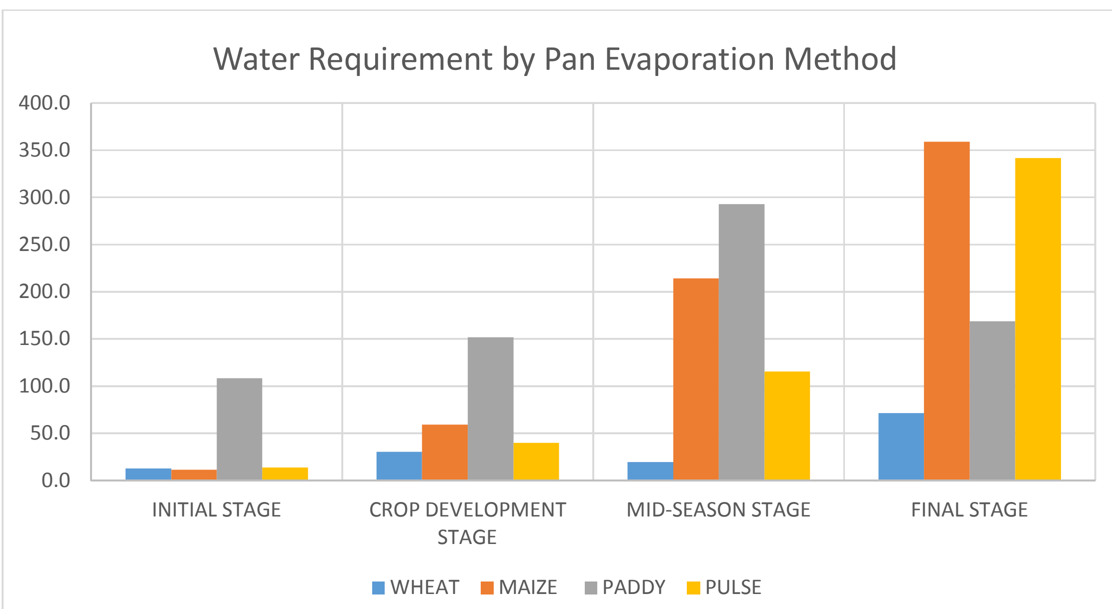

Fig. 3. Stage-wise water requirement by pan evaporation method

The estimated water requirement by Penman-Monteith Method is more than estimated water requirement for maize, paddy and pulses crops. However, for wheat crop, the estimated water requirement by Pan Evaporation Method is lower than that by Penman-Monteith Method as shown in Fig. 4.

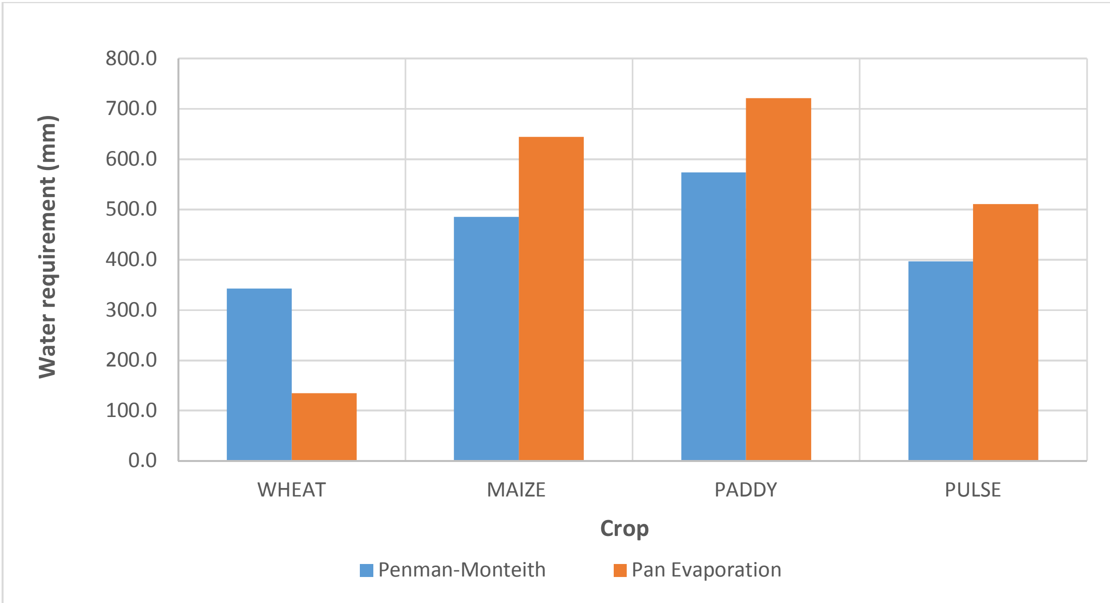

Fig. 4. Comparison of estimated water requirements of different crops by penman-monteith method and pan evaporation method

4. CONCLUSIONS

The crop water requirement for various crops was analyzed by using Penman-Monteith and Pan Evaporation method. The results were consistent and the graphical plot of the water requirements followed similar trends in both methods. The Penman-Monteith method is one of the most suitable methods of estimating crop water requirement in crops. The method is suitable for sub-humid and sub-tropic climate regions also [12]. The Crop water requirement of the crops can be useful in selecting a suitable crop in a particular place of the region depending upon the availability of water, soil texture, water holding capacity of the soil, land slope etc. The PET calculated by Penman method and Pan Evaporation method can used for assessing the water losses in the Srinagar region. When the rainfall-runoff relations of the area are known, evapotranspiration measurements can be used to ascertain the water balance of the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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