Assessment of Weekly Water Surplus/Deficit in the Ahmednagar District of Maharashtra, India

ABSTRACT

Climate change and its impact on water resources is one of the most important issues affecting the world agriculture at the beginning of the twenty-first century. The last four decades have witnessed extensive research concerning climatic variability and trends of climatic parameters in different regions and for different time scale. Climatic water supply as well as demand was changed in different regions of the world affect the food and nutritional security of the region. Crop water requirement was also affected by the variation of meteorological parameters under the conditions of climate change. The present study was under taken to evaluate tehsil-wise weekly water surplus/deficit availability during rainy season (June to October) in the Ahmdnagar district for a period of 2001 to 2016. Water surplus and deficit was estimated by weekly rainfall and reference crop evapotranspiration. Results of the study revealed that weekly water availability was very meager during rainy season in the Panrner nd Kopargaon tehsil. Number of surplus weeks in these two tehsil were only four weeks which is less than 20 per cent weeks. It was observed that in the Akole tehsil highest 12 (50%) weeks were surplus followed by 9 weeks in Jamkhed tehsil. Remaining tehsils had exist water surplus only during 6 to 8 number of weeks in the district. In the Ahmdnagar district rainfall is not sufficient to fulfill crop water requirement and needs supplemental irrigation facility to get maximum returns. Some of the week's showing water surplus in the many tehsils of the district but it probability is less than 50 percent which is not assured.

Keywords: Rainfall, water surplus, water deficit, crop water requirement

INTRODUCTION

Climatic variability increased the extreme event frequency, such as drought event are projected to rise throughout the 21st century on the tropical regions that are likely to experience less rainfall (Kruger, 2006), which is due to the water continuity that requires increased vertical moisture transfer and resulted increase in rainfall at some place should be balanced by reduced vertical motion in another place (Kumar *et al.*, 2004; Bosilovich *et al.*, 2005). On the basis of the climatic water balance approach it is possible to make a quantitative evaluation of water resources and their change under the influence of anthropogenic activities. Natural availability of

water for crop production gets influenced and it results very low and highly unstable crop yields due to soil moisture stress during active growth period of the crops. The most important aspect is proper distribution of rainfall, in order to meet the crop water requirement. The crop production is very closely related to moisture availability and soil characteristics. The rainfall distribution is highly erratic and uncertain both in time and space and thereby the moisture availability also becomes very uncertain. In the changing climate era planning and better management of natural water resources to curb environmental hazard and to give impetus to the agricultural production and productivity for food and nutritional security to ever increasing population. Estimation of magnitude and duration of rainfall excess and deficit plays vital role in crop planning and water resource management practices. Knowledge of rainfall and evaporation pattern is very useful for estimating water availability period for deciding the cropping pattern, water harvesting practice. Water balance conceptualized as balancing in surplus and deficit quantity of water in hydrological cycle. Whereas, water balance was first enunciated by Thornthwaite (1948) and later modified by Thornthwaite and Mather (1955). They computed water surplus, water deficit and actual evapotranspiration by utilizing the precipitation and potential evapotranspiration data (Salam and Mazrooe, 2006). This method is widely accepted due to involved major climatic parameters of concern with water resources. To minimize ambiguities in the interpretation of potential evapotranspiration, the term reference evapotranspiration (ET_0) is used in the present study (Allen *et al*., 1998). Ahmadnagar district having diverse cropping system which is difficult to prepare the planning for every crop therefore a commonly used water requirement for every crop is close to the reference crop evapotranspiration which is considered in this study as climatic water demand. In the present study weekly water requirement and availability in the respective week was balanced to know its temporal availability. Rainfall in the district is not assured which fulfill the crop water requirement even during rainy season due to which the potential yield of crops is reduced significantly and ultimately its loss of economic returns to the farmer. To prevent this huge loss it is very important to assess the weekly water availability and its demand.

Study Area

Ahmadnagar is the largest district of Maharashtra State in respect of area. It is situated in the central part of the State and lies between north latitudes 18°19’ and 19°59’ and east longitudes 73°37’ and 75°32’. The district being situated in “Rain Shadow” zone of Western

Ghats, it often suffers the drought conditions. The district comprises of 14 talukas (an administrative district for taxation purposes, typically comprising a number of villages), namely Ahmednagar, Parner, Pathardi, Shewgaon, Karjat, Shrigonda, Jamkhed, Shrirampur, Newasa, Akole, Sangamner, Kopergaon, Rahuri, Rahta. The whole district lies on the elevated table land of the Deccan which has a general slope from west to east. The western sub-division of Akola, which abuts on the Sahyadris, is the highest part of the district, and indeed of the Deccan, averaging 2500 feet above the sea-level. The plain of Shevgaon which lies to the extreme east of the district is not more than 1500 feet above the sea. The average rainfall of this zone ranges from 500 to 700 mm received in 40 to 45 days. About 70-80% of annual rainfall is received during monsoon period (June to September). It was noted earlier that about 70 percent of the workforce is engaged in the agricultural sector. However, the contribution of this sector to the District income is only 24.83 percent which is very low as compared to other sectors. This indicates that productivity in the primary sector is very low.

Table 1 Geographical location details of study stations:

Sr. No..	Name	Latitude	Longitude	Elevation (m)	Average Rainfall (mm)
1	Ahemadnagar	19.0952° N	74.7496°E	649	554.86
2	Parner	19.0001° N	74.4394°E	790	505.55
3	Shrigonda	18.6175° N	74.6981°E	561	519.03
4	Karjat	18.5522° N	75.0101°E	-	591.14
5	Jamkhed	18.7380° N	75.3121°E	590	658.19
6	Shevgaon	19.3504° N	75.2194°E	544	605.87
7	Pathardi	19.1761° N	75.1750°E	533	645.05
8	Nevasa	19.5512° N	74.9281°E	508	543.88
9	Rahuri	19.3927° N	74.6488°E	511	591.08
10	Sangamner	19.5771° N	74.2080°E	549	482.48
11	Akole	19.5406° N	74.0054°E	593	835.59
12	Kopargaon	19.8917° N	74.4791°E	493	448.84
13	Shrirampur	19.6222° N	74.6576°E	540	564.14

Data Collection

Daily rainfall data of (June to October) of 2001 to 2016 was collected from Department of Agriculture, Government of Maharashtra and daily meteorological data in respect of minimum/maximum temperature, minimum/maximum relative humidity, wind speed, sunshine

duration, pan evaporation and rainfall of Rahuri station was collected from Department of Agronomy, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri.

METHODOLOGY

Estimation of Surplus/Deficit of Water availability

Annual and seasonal water surplus or deficit was evaluated by using climatic water balance approach which is difference between rainfall (P) and reference crop evapotranspiration (ET_o) (Prasad and Sinha, 1999; Dabral, 2000; Gregory and David, 2002; Singh and Prasad, 2004; Dabral *et al*., 2009; Choudhury *et al*., 2012; Bhagat and Patil, 2014). A positive value of difference indicates that climatic water supply (rainfall) is greater than the climatic demand (reference crop evapotranspiration) i.e. water surplus and negative value indicates climatic water demand is more than the climatic supply i.e. water deficit. In the present study climatic water balance study was worked out for the Konkan region by using following equation and water deficit or water surplus were calculated as.

$$SUR\ /DEF = \pm (P - PET) \quad ...(1)$$

Where,

SUR = Amount of water surplus (mm);

DEF= Amount of water deficit (mm);

P = Precipitation (mm); and

ET_0 = Reference crop evapotranspiration (mm).

Estimation of reference crop evapotranspiration (ET_o)

In the present study daily reference crop evapotranspiration (ET_o) of Rahuri tehsil was calculated by FAO-56 PM model to be the most accurate method under various climatic conditions (Allen *et al*., 1998; Irmak *et al*., 2003; Hargreaves and Allen, 2003; Jabloun and Sahli, 2008; Martinez and Thepadia, 2010; Azhar and Perera, 2011; Tabari *et al*., 2011; Xystrakis and Matzarakis, 2011). DSS_ET software was used for estimation of daily reference crop evapotranspiration.

Penman-Monteith equation

A brief description of Penman-Monteith equation used for ET_0 using the daily weather data is discussed below:

...(2) .....

Where,

ET_o = Reference crop evapotranspiration (mm/day);

R_n = Net radiation at the crop surface (MJ/m^2day);

Δ = Slope of the saturation vapor pressure function (kPa / ^oC);

G = Soil heat flux density (MJ/m/day);

γ = Psychometric constant (kPa/^oC);

T = Mean daily air temperature at 2 m height (^oC);

e_a = Actual vapour pressure at temperature T (kPa);

e_s = Saturation vapour pressure at dew point Temperature (kPa); and

u_2 = Average daily wind speed at 2 m height (m/s).

RESULTS

Weekly water surplus/deficit availability in Ahmdnagar taluka.

Weekly water availability during rainy season in the Ahmdnagar taluka is presented in Table 2. From Table 2 it is revealed that amount of rainfall in the 4th week was assured and highest in the Ahmadnagar taluka followed by 3rd, 15th, 17th, 13th, 16th and 10th week whereas remaining week exist water deficit in which crop water requirement is more than rainfall available. Water deficit in the Ahamdnagar taluka was less than 20 mm during most of the weeks except 1st, 11th, 19th, 20th and 21st weeks. For the considered period dry weeks were more than 50 per cent in the Ahamdnagar taluka which revealed the need of supplemental irrigation facility in the taluka.

Table 2 weekly water surplus/deficit availability in the Ahmadnagar taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET_0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	20.1	40	20.0	-	81.3	18.8
2	08-14 Jun	16.4	36	19.6	-	87.5	12.5
3	15-21 Jun	49.2	33	-	16.2	62.5	37.5
4	22-28 Jun	69.8	32	-	37.8	56.3	43.8
5	29 Jun-05Jul	18.9	30	11.1	-	75.0	25.0
6	06-12 Jul	13.4	30	16.6	-	87.5	12.5

7	13-19 Jul	12.5	30	17.5	-	81.3	18.8
8	20-27 Jul	14.8	28	13.2	-	81.3	18.8
9	28 Jul-03 Aug	24.5	28	3.5	-	56.3	43.8
10	04-10 Aug	32.7	27	-	5.7	62.5	37.5
11	11-17 Aug	6.0	30	24.0	-	93.8	6.3
12	18-24 Aug	22.5	32	9.5	-	75.0	25.0
13	25-31 Aug	41.8	31	-	10.8	62.5	37.5
14	01-07 Sept	25.6	32	6.4	-	68.8	31.3
15	08-14 Sept	46.0	33	-	13.0	50.0	50.0
16	15-21 Sept	36.2	33	-	3.2	56.3	43.8
17	22-28 Sept	42.5	34	-	8.5	56.3	43.8
18	29 Sept-05 Oct	22.6	35	12.4	-	81.3	18.8
19	06-12 Oct	24.8	37	12.3	-	75.0	25.0
20	13-19 Oct	13.5	38	24.6	-	93.8	6.3
21	20-26 Oct	0.8	40	39.2	-	100.0	0.0
22	27-31Oct	0.4	34	33.6	-	100.0	0.0

Weekly water surplus/deficit availability in Parner taluka.

Parner taluka is one of the most dry taluka of the Ahamdnagar district. Weekly water availability in the Parner taluka is presented inTable 3 which revealed that amount of rainfall during most of the weeks are less than 30 mm except 3rd, 4th and 15th weeks whereas weekly climatic water demand was more than 30 mm during almost all months except 8th, 9th and 10th week. Out of total 22 weeks only 4 (3rd, 4th, 10th and 15th) weeks were showed surplus water availability than the requirement and remaining all weeks exist water deficit in the Parner taluka. During last fifteen years all the weeks were showed more that 60 per cent water deficit weeks which also indicated need of irrigation facility in the taluka. The weeks showing surplus water availability are also have more than 60 per cent water deficit weeks.

Table 3 weekly water surplus/deficit availability in the Parner taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET_0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	22.5	40	17.5	-	81.3	18.8
2	08-14 Jun	21.4	36	14.7	-	75.0	25.0
3	15-21 Jun	46.2	33	-	13.2	68.8	31.3
4	22-28 Jun	63.1	32	-	31.1	75.0	25.0
5	29 Jun-05Jul	21.7	30	8.3	-	68.8	31.3
6	06-12 Jul	12.0	30	18.0	-	81.3	18.8
7	13-19 Jul	14.1	30	15.9	-	93.8	6.3
8	20-27 Jul	14.1	28	13.9	-	81.3	18.8

9	28 Jul-03 Aug	20.0	28	8.0	-	75.0	25.0
10	04-10 Aug	29.6	27	-	2.6	68.8	31.3
11	11-17 Aug	12.9	30	17.1	-	87.5	12.5
12	18-24 Aug	14.7	32	17.3	-	87.5	12.5
13	25-31 Aug	26.5	31	4.5	-	62.5	37.5
14	01-07 Sept	29.2	32	2.8	-	62.5	37.5
15	08-14 Sept	37.0	33	-	4.0	62.5	37.5
16	15-21 Sept	26.0	33	7.0	-	68.8	31.3
17	22-28 Sept	32.1	34	1.9	-	62.5	37.5
18	29 Sept-05 Oct	23.4	35	11.6	-	75.0	25.0
19	06-12 Oct	24.6	37	12.4	-	75.0	25.0
20	13-19 Oct	9.8	38	28.2	-	100.0	0.0
21	20-26 Oct	4.5	40	35.5	-	93.8	6.3
22	27-31Oct	0.5	34	33.5	-	100.0	0.0

Weekly water surplus/deficit availability in Parner taluka.

Shrigonda tehsil of Ahamdnagar district is the southern-most part of the district and its weekly water balance is presented in the Table 4. From Table 4 it is observed that climatic water supply was less than its demand during most of the weeks except 3rd, 4th, 13th, 15th, 16th and 17th. Average water deficit was more than 15 mm during most of the weeks except 5th, 9th, 14th and 18th week.

Table 4 weekly water surplus/deficit availability in the Shrigonda taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	23.9	40	16.1	-	75.0	25.0
2	08-14 Jun	20.2	36	15.9	-	81.3	18.8
3	15-21 Jun	33.9	33	-	0.9	68.8	31.3
4	22-28 Jun	74.4	32	-	42.4	75.0	25.0
5	29 Jun-05Jul	22.8	30	7.2	-	56.3	43.8
6	06-12 Jul	14.6	30	15.4	-	87.5	12.5
7	13-19 Jul	11.6	30	18.4	-	81.3	18.8
8	20-27 Jul	10.9	28	17.1	-	81.3	18.8
9	28 Jul-03 Aug	18.3	28	9.8	-	62.5	37.5
10	04-10 Aug	21.2	27	5.8	-	81.3	18.8
11	11-17 Aug	5.3	30	24.7	-	93.8	6.3
12	18-24 Aug	7.9	32	24.1	-	100.0	0.0
13	25-31 Aug	42.8	31	-	11.8	56.3	43.8
14	01-07 Sept	22.8	32	9.2	-	87.5	12.5
15	08-14 Sept	39.9	33	-	6.9	62.5	37.5
16	15-21 Sept	37.1	33	-	4.1	62.5	37.5
17	22-28 Sept	35.1	34	-	1.1	68.8	31.3

18	29 Sept-05 Oct	30.2	35	4.8	-	68.8	31.3
19	06-12 Oct	17.1	37	19.9	-	87.5	12.5
20	13-19 Oct	22.1	38	15.9	-	75.0	25.0
21	20-26 Oct	3.1	40	36.9	-	100.0	0.0
22	27-31Oct	3.8	34	30.2	-	100.0	0.0

Weekly water surplus/deficit availability in Karjat taluka.

Weekly water availability and its demand in the Karjat tehsil is presented in Table 4a. From Table 4a it is found that weekly rainfall was less than 25 mm during most of the weeks except 3rd, 4th and 13th to 17th week whereas weekly water demand was more than 30 mm during most of the weeks except 8th to 10th weeks. During last fifteen year every week exist more than 50 per cent water deficit whereas every week showed less than 40 per cent surplus weeks. Average weekly water availability was more than the demand was observed in the week number 3rd, 4th, 13th to 17th in the Karjat taluka.

Table 4a weekly water surplus/deficit availability in the Karjat taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	29.0	40	11.0	-	68.8	31.3
2	08-14 Jun	20.0	36	16.0	-	68.8	31.3
3	15-21 Jun	46.1	33	-	13.1	68.8	31.3
4	22-28 Jun	76.3	32	-	44.3	75.0	25.0
5	29 Jun-05Jul	22.7	30	7.3	-	62.5	37.5
6	06-12 Jul	20.5	30	9.5	-	75.0	25.0
7	13-19 Jul	14.5	30	15.5	-	75.0	25.0
8	20-27 Jul	18.3	28	9.7	-	62.5	37.5
9	28 Jul-03 Aug	18.4	28	9.6	-	68.8	31.3
10	04-10 Aug	25.9	27	1.1	-	75.0	25.0
11	11-17 Aug	8.4	30	21.6	-	87.5	12.5
12	18-24 Aug	22.1	32	9.9	-	68.8	31.3
13	25-31 Aug	40.7	31	-	9.7	56.3	43.8
14	01-07 Sept	34.4	32	-	2.4	68.8	31.3
15	08-14 Sept	45.6	33	-	12.6	68.8	31.3
16	15-21 Sept	43.8	33	-	10.8	50.0	50.0
17	22-28 Sept	34.3	34	-	0.3	56.3	43.8
18	29 Sept-05 Oct	30.5	35	4.5	-	62.5	37.5
19	06-12 Oct	21.8	37	15.2	-	81.3	18.8
20	13-19 Oct	15.6	38	22.4	-	87.5	12.5
21	20-26 Oct	1.9	40	38.1	-	100.0	0.0
22	27-31Oct	0.5	34	33.5	-	100.0	0.0

Weekly water surplus/deficit availability in Jamkhed taluka.

Jamkhed tehsil is situated in the south-eastern part of the Ahamdnagar district it weekly climatic water balance is presented in Table 5. From Table 5 it is observed that water availability is less than the water requirement during most of the weeks except 3rd, 4th, 10th and 13th to 18th. In the Jamkhed tehsil around 40 per cent weeks are water surplus whereas remaining weeks exist water deficit. Amount of water deficit was less than 20 mm during most of the weeks except 1st and 20th to 22nd.

Table 5 weekly water surplus/deficit availability in the Jamkhed taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	19.6	40	20.4	-	75.0	25.0
2	08-14 Jun	23.4	36	12.6	-	62.5	37.5
3	15-21 Jun	56.4	33	-	23.4	56.3	43.8
4	22-28 Jun	70.6	32	-	38.6	56.3	43.8
5	29 Jun-05Jul	29.1	30	0.9	-	62.5	37.5
6	06-12 Jul	23.1	30	6.9	-	81.3	18.8
7	13-19 Jul	26.9	30	3.1	-	62.5	37.5
8	20-27 Jul	23.6	28	4.4	-	75.0	25.0
9	28 Jul-03 Aug	27.7	28	0.3	-	62.5	37.5
10	04-10 Aug	28.6	27	-	1.6	75.0	25.0
11	11-17 Aug	12.1	30	17.9	-	87.5	12.5
12	18-24 Aug	24.4	32	7.6	-	75.0	25.0
13	25-31 Aug	51.3	31	-	20.3	37.5	62.5
14	01-07 Sept	44.0	32	-	12.0	56.3	43.8
15	08-14 Sept	45.3	33	-	12.3	50.0	50.0
16	15-21 Sept	40.0	33	-	7.0	68.8	31.3
17	22-28 Sept	41.0	34	-	7.0	62.5	37.5
18	29 Sept-05 Oct	35.7	35	-	0.7	56.3	43.8
19	06-12 Oct	22.5	37	14.5	-	81.3	18.8
20	13-19 Oct	7.5	38	30.5	-	93.8	6.3
21	20-26 Oct	4.7	40	35.3	-	93.8	6.3
22	27-31Oct	0.6	34	33.5	-	100.0	0.0

Weekly water surplus/deficit availability in Pathardi taluka.

In the Pathardi tehsil climatic water balance is presented in Table 6 which revealed that about 66 per cent weeks exhibited water deficit condition whereas remaining 33 per cent weeks are water surplus. Week number 3rd, 4th, 10th, 13th to 15th and 17th showed water surplus but its

probability was less than 50 per cent during last fifteen years. During considered study period every weeks exist more than 50 per cent weeks were water deficit.

Table 6 weekly water surplus/deficit availability in the Pathardi taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Deficit weeks	% Surplus weeks
1	01-07 Jun	18.9	40	21.1	-	81.3	18.8
2	08-14 Jun	24.8	36	11.2	-	68.8	31.3
3	15-21 Jun	52.5	33	-	19.5	62.5	37.5
4	22-28 Jun	98.3	32	-	66.3	50.0	50.0
5	29 Jun-05Jul	18.2	30	11.8	-	75.0	25.0
6	06-12 Jul	16.0	30	14.1	-	87.5	12.5
7	13-19 Jul	15.3	30	14.7	-	81.3	18.8
8	20-27 Jul	20.4	28	7.6	-	75.0	25.0
9	28 Jul-03 Aug	15.1	28	12.9	-	81.3	18.8
10	04-10 Aug	31.1	27	-	4.1	62.5	37.5
11	11-17 Aug	10.6	30	19.4	-	93.8	6.3
12	18-24 Aug	23.7	32	8.3	-	68.8	31.3
13	25-31 Aug	52.1	31	-	21.1	50.0	50.0
14	01-07 Sept	36.3	32	-	4.3	56.3	43.8
15	08-14 Sept	46.7	33	-	13.7	56.3	43.8
16	15-21 Sept	23.8	33	9.2	-	75.0	25.0
17	22-28 Sept	47.5	34	-	13.5	50.0	50.0
18	29 Sept-05 Oct	31.3	35	3.7	-	68.8	31.3
19	06-12 Oct	25.6	37	11.4	-	68.8	31.3
20	13-19 Oct	29.7	38	8.3	-	75.0	25.0
21	20-26 Oct	2.8	40	37.3	-	93.8	6.3
22	27-31Oct	4.5	34	29.5	-	93.8	6.3

Weekly water surplus/deficit availability in Shevgaon taluka.

Weekly water condition of Shevgaon tehsil is presented in Table 7 which revealed that weekly water availability was more than weekly water demand during 3rd, 4th, 10th, 12th to 15th and 17th week whereas week number 1st, 11th and 19th to 22nd exist water deficit more than 20 mm in the Shevgaon tehsil.

Table 7 weekly water surplus/deficit availability in the Shevgaon taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	17.9	40	22.1	-	87.5	12.5
2	08-14 Jun	16.6	36	19.4	-	81.3	18.8
3	15-21 Jun	50.5	33	-	17.5	62.5	37.5
4	22-28 Jun	79.6	32	-	47.6	43.8	56.3

5	29 Jun-05Jul	23.5	30	6.5	-	81.3	18.8
6	06-12 Jul	19.0	30	11.1	-	81.3	18.8
7	13-19 Jul	20.5	30	9.6	-	75.0	25.0
8	20-27 Jul	20.9	28	7.1	-	68.8	31.3
9	28 Jul-03 Aug	23.4	28	4.6	-	75.0	25.0
10	04-10 Aug	27.1	27		0.1	81.3	18.8
11	11-17 Aug	7.7	30	22.3	-	93.8	6.3
12	18-24 Aug	34.8	32	-	2.8	81.3	18.8
13	25-31 Aug	51.2	31	-	20.2	43.8	56.3
14	01-07 Sept	41.0	32	-	9.0	62.5	37.5
15	08-14 Sept	39.0	33	-	6.0	62.5	37.5
16	15-21 Sept	25.4	33	7.6	-	75.0	25.0
17	22-28 Sept	39.0	34	-	5.0	56.3	43.8
18	29 Sept-05 Oct	33.3	35	1.7	-	56.3	43.8
19	06-12 Oct	16.9	37	20.1	-	81.3	18.8
20	13-19 Oct	16.6	38	21.4	-	81.3	18.8
21	20-26 Oct	1.4	40	38.6	-	100.0	0.0
22	27-31Oct	0.7	34	33.4	-	100.0	0.0

Weekly water surplus/deficit availability in Nevasa *taluka.*

Weekly climatic water balance of Nevasas tehsil is presented in Table 8 which showed that weekly water supply was less than 30 mm during most of the weeks except 3rd to 5th, 13th, 16th and 17th on the other hand weekly water demand was more than 30 mm during most of the weeks except 8th to 10th. Water availability during week number 3rd to 5th, 10th, 13th, 16th and 17th are sufficient to fulfill the climatic demand in the respective weeks.

Table 8 weekly water surplus/deficit availability in the Nevasa taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	8.2	40	31.8	-	100.0	0.0
2	08-14 Jun	18.7	36	17.3	-	81.3	18.8
3	15-21 Jun	43.2	33	-	10.2	75.0	25.0
4	22-28 Jun	60.8	32	-	28.8	56.3	43.8
5	29 Jun-05Jul	34.4	30	-	4.4	62.5	37.5
6	06-12 Jul	19.5	30	10.5	-	68.8	31.3
7	13-19 Jul	18.5	30	11.5	-	87.5	12.5
8	20-27 Jul	21.1	28	6.9	-	68.8	31.3
9	28 Jul-03 Aug	22.7	28	5.3	-	62.5	37.5
10	04-10 Aug	29.0	27	-	2.0	62.5	37.5
11	11-17 Aug	10.8	30	19.2	-	87.5	12.5

12	18-24 Aug	21.7	32	10.3	-	68.8	31.3
13	25-31 Aug	44.2	31	-	13.2	56.3	43.8
14	01-07 Sept	28.7	32	3.3	-	62.5	37.5
15	08-14 Sept	27.2	33	5.8	-	68.8	31.3
16	15-21 Sept	34.4	33	-	1.4	68.8	31.3
17	22-28 Sept	40.4	34	-	6.4	56.3	43.8
18	29 Sept-05 Oct	29.3	35	5.7	-	68.8	31.3
19	06-12 Oct	14.5	37	22.5	-	87.5	12.5
20	13-19 Oct	9.5	38	28.5	-	93.8	6.3
21	20-26 Oct	3.7	40	36.3	-	100.0	0.0
22	27-31Oct	3.4	34	30.6	-	100.0	0.0

Weekly water surplus/deficit availability in Rahuri *taluka.*

Rahuri tehsil is situated in the central part of the Ahamdnagar district and its weekly climatic water balance is presented in Table 9. From Table 9 it is observed that rainfall during most of the weeks is not sufficient to fulfill the climatic water demand in the Rahuri tehsil except 3rd, 4th and 13th to 18th weeks. During this weeks also average water availability was surplus but it was not assured because more than 50 per cent respective week are water deficit was observed during study period.

Table 9 weekly water surplus/deficit availability in the Rahuri taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	23.5	40	16.5	-	87.5	12.5
2	08-14 Jun	23.9	36	12.1	-	75.0	25.0
3	15-21 Jun	44.6	33	-	11.6	68.8	31.3
4	22-28 Jun	69.8	32	-	37.8	68.8	31.3
5	29 Jun-05Jul	25.1	30	4.9	-	68.8	31.3
6	06-12 Jul	16.4	30	13.6	-	81.3	18.8
7	13-19 Jul	16.1	30	14.0	-	81.3	18.8
8	20-27 Jul	18.9	28	9.1	-	81.3	18.8
9	28 Jul-03 Aug	18.3	28	9.7	-	75.0	25.0
10	04-10 Aug	23.7	27	3.3	-	62.5	37.5
11	11-17 Aug	9.1	30	20.9	-	93.8	6.3
12	18-24 Aug	26.1	32	5.9	-	75.0	25.0
13	25-31 Aug	43.2	31	-	12.2	56.3	43.8
14	01-07 Sept	34.5	32	-	2.5	56.3	43.8
15	08-14 Sept	41.2	33	-	8.2	62.5	37.5
16	15-21 Sept	44.7	33	-	11.7	62.5	37.5
17	22-28 Sept	38.1	34	-	4.1	50.0	50.0

18	29 Sept-05 Oct	39.9	35	-	4.9	50.0	50.0
19	06-12 Oct	22.7	37	14.3	-	81.3	18.8
20	13-19 Oct	9.7	38	28.3	-	93.8	6.3
21	20-26 Oct	0.8	40	39.2	-	100.0	0.0
22	27-31Oct	0.9	34	33.1	-	100.0	0.0

Weekly water surplus/deficit availability in Sangamner *taluka.*

Sangamner tehsil is situated in the north part of the Ahamdnagar district and its weekly water surplus/deficit is presented in Table 10. From Table 10 it is observed that weekly rainfall was varied from 10.9 mm during 11th week to 63.6 mm during 4th week whereas it climatic water demand varied between 27 mm during 10th week to 40 mm during 1st week. Average weekly water surplus was observed during 3rd to 5th, 10th, 16th and 17th weeks and remaining weeks are water deficit.

Table 10 weekly water surplus/deficit availability in the Sangamner taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	16.3	40	23.7	-	87.5	12.5
2	08-14 Jun	13.3	36	22.7	-	93.8	6.3
3	15-21 Jun	40.6	33	-	7.6	68.8	31.3
4	22-28 Jun	63.6	32	-	31.6	68.8	31.3
5	29 Jun-05Jul	33.3	30	-	3.3	56.3	43.8
6	06-12 Jul	12.4	30	17.6	-	87.5	12.5
7	13-19 Jul	12.0	30	18.0	-	87.5	12.5
8	20-27 Jul	13.3	28	14.7	-	93.8	6.3
9	28 Jul-03 Aug	22.3	28	5.7	-	75.0	25.0
10	04-10 Aug	27.9	27	-	0.9	62.5	37.5
11	11-17 Aug	10.9	30	19.2	-	87.5	12.5
12	18-24 Aug	13.3	32	18.7	-	87.5	12.5
13	25-31 Aug	26.3	31	4.7	-	62.5	37.5
14	01-07 Sept	24.3	32	7.7	-	81.3	18.8
15	08-14 Sept	27.0	33	6.0	-	68.8	31.3
16	15-21 Sept	37.7	33	-	4.7	62.5	37.5
17	22-28 Sept	38.4	34	-	4.4	56.3	43.8
18	29 Sept-05 Oct	19.9	35	15.1	-	75.0	25.0
19	06-12 Oct	13.0	37	24.0	-	87.5	12.5
20	13-19 Oct	12.4	38	25.6	-	81.3	18.8
21	20-26 Oct	3.2	40	36.8	-	100.0	0.0
22	27-31Oct	1.1	34	32.9	-	100.0	0.0

Weekly water surplus/deficit availability in Akole *taluka.*

Akole tehsil is situated in the Sahyadri ranges and receives more rainfall compared to the other tehsils of the Ahamdnagar district. Weekly water surplus/deficit in the tehsil is presented in Table 11 which revealed that weekly surplus water was observed during 3rd to 6th, 8th to 11th and 15th to 18th weeks whereas remaining weeks are water deficit. Surplus water was more than 20 mm during 3rd to 5th, 9th and 10th weeks.

Table 11 weekly water surplus/deficit availability in the Akole taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	14.9	40	25.1	-	87.5	12.5
2	08-14 Jun	24.3	36	11.7	-	75.0	25.0
3	15-21 Jun	71.0	33	-	38.0	50.0	50.0
4	22-28 Jun	89.5	32	-	57.5	56.3	43.8
5	29 Jun-05Jul	60.0	30	-	30.0	43.8	56.3
6	06-12 Jul	32.8	30	-	2.8	68.8	31.3
7	13-19 Jul	24.6	30	5.4	-	68.8	31.3
8	20-27 Jul	46.4	28	-	18.4	56.3	43.8
9	28 Jul-03 Aug	78.7	28	-	50.7	31.3	68.8
10	04-10 Aug	82.3	27	-	55.3	37.5	62.5
11	11-17 Aug	39.7	30	-	9.7	50.0	50.0
12	18-24 Aug	11.5	32	20.5	-	87.5	12.5
13	25-31 Aug	29.2	31	1.8	-	68.8	31.3
14	01-07 Sept	28.6	32	3.4	-	68.8	31.3
15	08-14 Sept	39.5	33	-	6.5	62.5	37.5
16	15-21 Sept	48.5	33	-	15.5	56.3	43.8
17	22-28 Sept	35.3	34	-	1.3	62.5	37.5
18	29 Sept-05 Oct	37.5	35	-	2.5	68.8	31.3
19	06-12 Oct	26.7	37	10.3	-	75.0	25.0
20	13-19 Oct	7.2	38	30.8	-	100.0	0.0
21	20-26 Oct	6.5	40	33.5	-	93.8	6.3
22	27-31Oct	1.1	34	32.9	-	100.0	0.0

Weekly water surplus/deficit availability in Kopargaon *taluka.*

Kopargaon is the northern-most part of the the Ahamdnagar district and its weekly water balance is presented in Table 12. Average weekly water availability was less than the weekly water requirement in the tehsilduring most of the months except 3rd, 4th, 10th and 13th week.

Amount of water deficit weeks was more than 20 mm during most of the water deficit weeks except 5th to 9th and 14th to 18th weeks.

Table 12 weekly water surplus/deficit availability in the Kopargaon taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	11.7	40	28.3	-	87.5	12.5
2	08-14 Jun	13.0	36	23.0	-	87.5	12.5
3	15-21 Jun	42.7	33	-	9.7	81.3	18.8
4	22-28 Jun	50.1	32	-	18.1	62.5	37.5
5	29 Jun-05Jul	29.1	30	0.9	-	56.3	43.8
6	06-12 Jul	17.7	30	12.3	-	87.5	12.5
7	13-19 Jul	10.4	30	19.6	-	87.5	12.5
8	20-27 Jul	19.5	28	8.6	-	68.8	31.3
9	28 Jul-03 Aug	21.4	28	6.6	-	68.8	31.3
10	04-10 Aug	28.7	27	-	1.7	62.5	37.5
11	11-17 Aug	9.5	30	20.6	-	93.8	6.3
12	18-24 Aug	9.0	32	23.0	-	93.8	6.3
13	25-31 Aug	32.6	31	-	1.6	68.8	31.3
14	01-07 Sept	25.2	32	6.8	-	68.8	31.3
15	08-14 Sept	23.5	33	9.6	-	81.3	18.8
16	15-21 Sept	25.5	33	7.5	-	68.8	31.3
17	22-28 Sept	32.8	34	1.2	-	43.8	56.3
18	29 Sept-05 Oct	26.6	35	8.5	-	75.0	25.0
19	06-12 Oct	9.6	37	27.4	-	87.5	12.5
20	13-19 Oct	4.0	38	34.0	-	93.8	6.3
21	20-26 Oct	6.5	40	33.5	-	93.8	6.3
22	27-31Oct	0.0	34	34.0	-	100.0	0.0

Weekly water surplus/deficit availability in Shrirampur *taluka.*

Shrirampur tehsil is also situated in the north part of the Ahhamdnagar district and its weekly climatic water balance is presented in Table 13. From Table 13 it is observed that weekly water supply was mostly less than 30 mm during most of the weeks except 3rd to 5th, 13th and 15th to 18th weeks while weekly water demand was more than 30 mm during almost all the weeks except 8th to 10th. Weekly waster surplus was exist only during 3rd to 5th,13th, 16th and 17th weeks.

Table 13 weekly water surplus/deficit availability in the Shrirampur taluka

Week No.	Period	Avg. Rainfall (mm)	Avg. ET0 (mm)	Avg. Deficit water (mm)	Avg. surplus water (mm)	% Dry weeks	% Wet weeks
1	01-07 Jun	10.1	40	29.9	-	93.8	6.3

2	08-14 Jun	20.0	36	16.0	-	75.0	25.0
3	15-21 Jun	44.3	33	-	11.3	75.0	25.0
4	22-28 Jun	71.3	32	-	39.3	62.5	37.5
5	29 Jun-05Jul	31.1	30	-	1.1	56.3	43.8
6	06-12 Jul	27.2	30	2.8	-	75.0	25.0
7	13-19 Jul	9.5	30	20.5	-	87.5	12.5
8	20-27 Jul	19.8	28	8.2	-	68.8	31.3
9	28 Jul-03 Aug	22.9	28	5.1	-	62.5	37.5
10	04-10 Aug	26.5	27	0.5	-	62.5	37.5
11	11-17 Aug	9.7	30	20.3	-	87.5	12.5
12	18-24 Aug	12.8	32	19.2	-	81.3	18.8
13	25-31 Aug	59.0	31	-	28.0	43.8	56.3
14	01-07 Sept	20.8	32	11.2	-	68.8	31.3
15	08-14 Sept	32.3	33	0.7	-	68.8	31.3
16	15-21 Sept	37.7	33	-	4.7	68.8	31.3
17	22-28 Sept	35.3	34	-	1.3	50.0	50.0
18	29 Sept-05 Oct	31.7	35	3.3	-	56.3	43.8
19	06-12 Oct	27.9	37	9.1	-	81.3	18.8
20	13-19 Oct	8.0	38	30.0	-	93.8	6.3
21	20-26 Oct	4.2	40	35.8	-	93.8	6.3
22	27-31Oct	2.1	34	32.0	-	100.0	0.0

Conclussion

From the study it is concluded that rainfall as well as surplus water availability in the district varied significantly spatially as well as temporally. most of the weeks during rainy season are water deficit which varied between 10 weeks at Akole to 18 weeks at Parner and Kopargaon. In the district 60 per cent weeks are water deficit in the 9 tehsils and water surplus weeks are not assured. From the study it is concluded that supplemental irrigation facility is key to get maximum return from the agriculture during rainy season and rainfed agriculture in the district is more vulnerable due to lower and erratic rainfall.

REFERENCES

Allen, R. G., L. S. Pereinra, D. Raes and M. Smith. 1998. Crop evapotranspiration guidelines for computing crop water requirement. FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization, Rome, Italy.

Azhar, A. H., and B. J. C. Perera. 2011. Evaluation of reference evapotranspiration estimation methods under Southeast Australian conditions. *Journal of Irrigation and Drainage Engineering.* 137(5):268–279.

240 Bhagat, A. and M. Patil. 2014. Water excess/deficit studies at different seasons (bahars) of
241 pomegranate (*Punicagranatum* L.) cultivation. *International Journal of Agricultural*
242 *Engineering*. 7(2): 323-327.
243 Bosilovich, M.G., Schubert, S., Walker, G., 2005. Global changes of the water cycle intensity.
244 *Journal of Climate*. 18: 1591-1607.

245 Choudhury, B. U., D. Anup, S. V. Ngachan, A. Slong, L. J. Bordoloi and P. Chowdhury. 2012.
246 Trend analysis of long term weather variables in mid altitude Meghalaya, North-East
247 India. *Journal of Agricultural Physics.*12 (1): 12-22.

248 Dabral, P. P. 2000. Excess-deficit analysis of rainfall for water management planning in Terai
249 region of West Bengal. *Indian Journal of Soil Conservation*. 28(2): 175-177.

250 Dabral, P. P., P. Pandey, S. Debnath1, S. Tado and R. P. Singh. 2009. Excess-deficit analysis of
251 rainfall for Umaiam (Barapani), Meghalaya. *Journal of Indian Water Resources Society*.
252 29(3): 15-22.

253 David, M. M. W. and. J. Gregory. 2002. Trends and temperature sensitivity of moisture
254 conditions in the conterminous United States. *Climate Research.* 20: 19-29.

255 Hargreaves, G. H. and R. G. Allen. 2003. History and evaluation of Hargreaves
256 evapotranspiration equation. *Journal of Irrigation and Drainage Engineering.* 129 (1):
257 53-63.

258 Irmak, S., A. Irmak, R. G. Allen and J. W. Jones. 2003 Solar and net radiation-based equations to
259 estimate reference evapotranspiration in humid climates. *Journal of Irrigation and*
260 *Drainage Engineering.* 129 (5): 336-347.

261 Jabloun, M. and A. Sahli. 2008. Evaluation of FAO-56 methodology for estimating reference
262 evapotranspiration using limited climatic data application to Tunisia. *Agriculture and*
263 *Water Management*. 95: 707-715.
264 Kruger, A.C. 2006. Observed trends in daily precipitation indices in South Africa: 1910–2004.
265 *International Journal of Climatology*. 26: 2275–2285.

266 Kumar, K,, V. Joshi, S. Joshi, K. S. Supyal, J. Roy and A. Ghosh. (2004) Global change impact
267 assessment for Himalayan mountain regions-India report. Final Technical Report, 158 p.

268 Martinez, C. J. and M. Thepadia. 2010. Estimating reference evapotranspiration with minimum
269 data in Florida, USA. *Journal of Irrigation and Drainage Engineering*. 136 (7): 494-501.

270 Prasad, B. N. and A. K. Sinha. 1999. Rainfall excess and deficit analysis of crop planning and
271 drought proneness. *Journal of Research.* 11(1): 53-57.

272 Salam, M. A. and S. A. Mazrooe. 2006. Evapotranspiration estimates and water balance of
273 Kuwait. *Journal of Agrometeorology*. 8: 243-247.

274 Singh, R. K. and V. H. Prasad. 2004. Remote sensing and GIS approach for assessment of the
275 water balance of a watershed. *Hydrological Science Journal.* 49 (1): 131-141.

Tabari, H., M. Grismer and S. Trajkovic. 2011. Comparative analysis of 31 reference evapotranspiration methods under humid conditions. *Irrigation Science.* 31(2): 107-117.

Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. *Geographical Revolution.* 38:55-94.

Xystrakis, F. and A. Matzarakis. 2011. Evaluation of 13 empirical reference potential evapotranspiration equations on the island of Crete in Southern Greece. *Journal of Irrigation and Drainage Engineering.*137: 211-222.