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Impact of climate change on water footprint of major crops of Chhattisgarh

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Abstract
This study presents the climate change impact on crop water footprint (WF) for the state, Chhattisgarh for all 27 district in three crops mainly rice, wheat and maize. The reference evapotranspiration, crop water requirement and irrigation scheduling has been computed with the help of CROPWAT 8.0 model developed by FAO using the crop, soil and weather data. The blue and green crop water footprints were estimated for 27 districts for present and future climatic scenarios (2030, 2050 &2070) of Chhattisgarh. Results revealed that an increment of evapotranspiration in rice was found 1.45%, 4.13% and 6.3% in the year 2030, 2050 and 2070, respectively as compared to 2018. Similarly in wheat and maize crop, an increment of 1.46, 4.13 & 6.3% and 1.18, 3.32 & 5.11% was recorded in future scenarios when compared to present. The WF of present climatic scenario (2018) comes out to be 3784, 2749 and 1743 m3/t, respectively in rice, wheat and maize crop. However, the highest WF was calculated for district Kabirdham in rice, Sukma in wheat and Bemetara in maize crop. WF of rice increases 2.57% in 2030, followed by 7.27% in 2050 and 11.27% in 2070 as compared to the baseline (2018), respectively. Similarly, for crop wheat and maize, the percentage increment were 2.89%, 8.54% & 14.68% and 2.22%, 7.14% and 11.76%, respectively. In total water footprint, share of green water footprint will decrease and share of blue water footprint will increase in rice and wheat crop in all the districts under future climatic scenarios as compared to present climatic conditions. While green and blue water footprint will be stable in maize crop in all the districts under future climatic scenarios. With increase in temperature extremities and fluctuating rainfall pattern in the upcoming years, fresh water availability and crop production is going to witness a downfall. The result provides a deeper insight into the current and future field water situation in the state. The water footprint hints us regarding use of field water as well as water saving opportunities. Variations in WF is found due to variability in rainfall amount and field management practices adopted in several districts. In rice, district Dhamtari, Janjgir-Champa in wheat, district Narayanpur, Kondagoan; and in maize, district Dhamtari, Kondagoan shows lowest remarkable total water footprint values.

Keywords: Green and blue water footprint, irrigation water requirement, effective rainfall, climate change, Chhattisgarh

1. Introduction

India has an annual precipitation of 1170 mm and about 80% of the total area of nation experience annual rainfall of 750 mm or more. For most parts of India the rainfall occurs under the influence of the south west monsoon between June to September. Southern coastal area near the east coast is influenced by the north east monsoon during October and November. 80% of the river flow occurs during the four to five months of the south west monsoon season (Gopal and Kantha, 2018) [8].

In agriculture, water is used primarily for irrigation purposes. Due to spatial temporal variability in rainfall in the region, irrigation is necessary. The country's large areas are low in precipitation and are vulnerable to drought. It is therefore difficult during the dry season to practice agriculture without guaranteed irrigation. Even in areas of substantial rainfall like Bihar and West Bengal, the monsoon breaks or its failure causes a dry spell, detrimental for agriculture. Water needs of certain crops make irrigation necessary. For instance, the water requirement of sugarcane, jute and rice etc. is very high which can be met only by irrigation (Anon. 2013) [2].

Chhattisgarh state is located in central India. About 80% of population is engaged in agriculture directly or indirectly. As well as 43% of entire arable land is under cultivation. Average rainfall in the state is around 1200 mm and about 90% of the total rainfall is confined in the monsoon season i.e., mid June to September. The precipitation in the state has irregular temporal and spatial distribution.

Because of this variations in rainfall, the output of the state's agriculture is affected. There is always a threat of dry spell or drought which is due to uneven occurrence of rainfall rather than deficient rain. The irrigated area in the state is only 16% of the total cultivable area. State have sufficient water resources and a large untapped potential.

4.3 m ha area can be irrigated if we properly harness the surface water against the trusting irrigation potential of 1.38 m ha. (Anon. 2009) [1].

At the national, regional and local levels, climate change is very likely to affect food security. Climate change can disrupt the food availability, reduce access to food and thereby affecting food quality. For example projected increase in temperature, changes in precipitation patterns, Change in extreme events and reduction in water availability may all result in reduced agricultural productivity. It is anticipated that the future impacts of climate change on the global hydrological cycle will reshape the patterns of demand and water supply for both irrigated and rain-fed agriculture worldwide (Ohmura and Wild, 2002; FAO 2011) [12, 6]. Increased temperature will increase evapotranspiration of crops, variation in crop yield and productivity of water (FAO 2011) [6].

Agricultural processes need to be modified according to the changing environment. It is important to know how climate change affects the process of agricultural production (Hoekstra and Hung, 2002; Hoekstra *et al*. 2011). The water footprint of a product is the amount of water, estimated at the point of production, used to manufacture the specific product. The water footprint of crop production is defined as the amount of freshwater both consumed and allotted by pollution during crop production process. It has three components, 1) green water footprint (the volume of the precipitation consumed during crop production process) 2) blue water footprint (the volume of surface or ground water consumed during crop production process) and 3) grey water footprint (the volume of freshwater that is required to assimilate the load of pollutants during the crop production process) (Chapagain and Hoekstra, 2010) [3]. The water footprint is not only an indicator of water use which looks at both water consumption and pollution, but it can also extend assessment processes for water resources and provide information on water use for decision-making (Ma *et al*. 2006; Ercin *et al*. 2011) [11, 5].

The purpose of this study is to contribute to an understanding of the effect of climate change on water footprints of rice, wheat and maize crop in 27 districts of Chhattisgarh.

2. Methods and Data

2.1 Tudy Area

The study is confined to 27 districts of Chhattisgarh. Chhattisgarh is located between 17°46′ N and 24°5′ N latitudes and 80°15′ E and 84°24′ E longitudes. The state has three agro climatic zones *viz*. Chhattisgarh Plains, Bastar Plateau and Northern Hill regions and 27 districts *viz*. Balod, Baloda bazaar, Bemetara, Bilaspur, Durg, Mungeli, Gariyaband, Dhamtari, Janjgir-Chapa, Rajnandgaon, Kabirdham, Kanker, Raipur, Raigarh, Korba, Mahasamund, Balrampur, Jashpur, Korea, Surajpur and Surguja, Bastar, Bijapur, Dantewada, Narayanpur, Sukma, and Kondagoan spreading over a geographical area of 137.90 lakh ha.

2.2 Data Base

District wise maximum temperature, minimum temperature and rainfall data for the current year (2018) was used as a baseline climatic condition. Future climatic projection data for the year 2030, 2050 and 2070 were estimated through Marksim weather generator by run of RCP 4.5 scenario.

The yield data has been collected from various contingency plans for state, commissioner land resources and several other statistical crop record book.

The crop related data is collected from FAO drainage and irrigation paper no 56, providing general lengths for four growth stages, total growing period of selected crops along with the crop coefficient values, critical depletion and yield response functions.

The soil related data is collected from government yearbook of ground water data (2016-17). Total available moisture content, initial moisture depletion, maximum rain infiltration rate and maximum rooting depth data for various soils has been obtained from inbuilt values on CROPWAT 8.0.

2.3 Cropwat 8.0

The CROPWAT 8.0 model is a decision support program developed by the Food and Agriculture Organisation (FAO) of United States. It is used for the calculation of crop water requirement (CWR) and irrigation water requirement (IWR) based on climate, soil and crop data. Apart from this, the program allows the development of irrigation schedules for different management conditions and calculate the water requirement for crop patterns.

2.5 Crop Water Requirement

Crop water requirement is the amount of water needed to compensate the evapotranspiration loss from the crop field from planting to harvest for a given crop in a specific climatic region. When adequate soil water is maintained by rainfall or by irrigation so that it achieves full product potential under all given condition. The crop water requirement vary mainly with climate and crop factors. The influence of climate on crop needs can be calculated by reference crop evapotranspiration.

The water requirement is calculated by the following equation: $CWR = ETc = ETo * Kc$

Where, Kc = crop coefficient

ETo = reference evapotranspiration (mm/day)

CWR = crop water requirement (mm/day)

When limited water is available, crop water use (CWU) will be less than the total crop water requirement. Hence, CWU will be actual evapotranspiration.

2.6 Calculation of Water Footprint

The water footprints of crops are the volume of water consumed per unit quantity of produce (m3/t or lit/kg) but units depend on what is being studied in the water footprint. Volume of green, blue and grey water are always in the numerator, but it may be time, mass, people or units in the denominator depending upon the category of the product. (e.g. lit./kg or m3/ton for a crop, m3 or lit./person/year for a consumer).

$$\text{WF total} = \frac{\text{green and blue Wateru sed by crop} + \text{Dilution Water Requirement (m3 /ha)}}{\text{Economic Yield of The Crop (ton/ha)}}$$

For crops receive both rainfall and irrigation during its life cycle,

$$\text{Green and blue water footprints for crop production} = \frac{\text{AETc or PETc meet from rainfall and irrigation} + \text{water evaporated during land preparation}}{\text{(m3/ha) economic yield of the crop (ton/ha)}}$$

The green component of the water footprint in crop production (WF green, m3/ton) is calculated as the green component in crop water use (CWU green, m3/ha) divided by the crop yield (Y, ton/ha). The blue component (WF blue, m3/ton) is calculated as the blue component in crop water use (CWU blue m3/ha) divided by crop yield (Y, ton/ha).
WF green= CWU green /Y WF blue = CWU green /Y Where, CWU = crop water use (m3/ha) Y = crop yield (ton/ha)

2.6.1 Green Crop Water Use
It is the amount of rainwater used by crop during evapotranspiration. It is calculated by gathering the daily green evapotranspiration during entire growth period. A factor of 10 is used to change the water depths in mm to water volumes in m3/ha.

CWU green = 10 * ∑ ET green
ET green is either the effective rainfall or the ETc. If effective rainfall is more than CWU, ET green equals to ETc value, because crop never utilises more than required for ideal growth.
ET green = min (ETc, Effective rainfall)

2.6.2 Blue Crop Water Use
It is the amount of crop irrigation water needed for growth that includes irrigation through artificial sources, including ground water and surface water.
CWU blue = 10 * ∑ ET blue
ET blue is the difference between ETc and effective rainfall.
If effective rain > ETc = ET blue = 0
ET blue = max (0, ETc, Effective rainfall)

3. Results and Discussion
3.1 Crop Water Requirement
Table 1 illustrates that the average evapotranspiration value of rice was 554.9 mm in 2018 followed by 552.8 mm in 2030, 567.4 mm in 2050 and 579.3 mm in 2070, respectively. An increment
in evapotranspiration of 1.45%, 4.13% and 6.3% was found in the year 2030, 2050 and 2070, respectively as compared to 2018. The highest evapotranspiration value was found in district Raigarh and the lowest was observed in Jashpur district in all climatic scenarios. However, the average effective rainfall was found to be 551.2, 548.96, 543.36 and 547.11 mm for the year 2018, 2030, 2050 and 2070, respectively. Similarly, the average irrigation water requirement increases as 86.1, 93.43, 104.95 and 107.6 mm, respectively.
In wheat crop, the highest increment in evapotranspiration was found in 2070 (5.92%) followed by 2050 (3.98%) and 2030 (1.46%) as compared to current climatic condition (2018).
Evapotranspiration varies between 367.1 mm to 454.1 mm in 2030, 375.6 mm to 463.9 mm in 2050 and 383.2 mm to 471.3 mm in 2070, respectively. Sukma shows the highest evapotranspiration value of 463.2 mm & 471.3 mm in 2050 & 2070, respectively while Bijapur shows highest evapotranspiration of 454.1 mm in 2030. However, lowest evapotranspiration value of 367.1 mm, 375.6 mm & 383.2 mm in 2030, 2050 & 2070 as compared to 2018 was observed in Koriya district. The average effective rainfall 41.35, 37.36, 35.73 & 42.74 mm and irrigation water requirement 369.95, 380.01, 392.02 & 392.84 mm, respectively was observed for the year 2018, 2030, 2050 and 2070, respectively. (Table 2)

Table 1: Crop evapotranspiration, effective rainfall and irrigation requirement of rice crop for 27 districts of Chhattisgarh for all climatic scenario

	2018			2030			2050			2070		
RICE	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**
Balod	547.1	551.2	89.8	555.7	547.4	97.9	571.5	540.6	111.7	582.2	543.6	113.9
Baloda Bazaar	555.6	532.8	101.8	563.2	529.6	110.7	578.4	522.6	125.6	590.1	523.7	130.9
Balrampur	540.2	535.4	90.7	546.8	532	98.2	560	531.7	107.1	572.1	541.2	106.9
Bastar	533	568.9	60.3	542	565.5	66.3	556.6	561.2	74.1	565.4	562.9	76.6
Bemetara	551.7	521.6	101.1	559.8	518.7	110	574.5	511.4	126.1	586.1	512.7	130.2
Bijapur	554.2	585.8	72.1	563.6	582.4	77.4	578.3	580.5	82.8	587.7	583.8	84.6
Bilaspur	553.9	535	101.2	561.5	532	110.1	576	526.8	124.2	590.3	529.3	129.8
Dantewada	549.6	576.4	61.4	559	573.2	66.7	574	568.6	75.7	582.5	570.3	79.4
Dhamtari	547	551	86.5	554.9	546.4	95.2	570.2	541.1	106.9	583.7	542.7	111.9
Durg	551	543.2	89.5	558.9	540	97.1	574.2	533.9	112	586.5	534.2	118.6
Gariyaband	526.8	555.8	82.8	534.9	553	89.1	549.5	547.5	99.8	559.7	553	96.8
Janjgir	557.1	533.1	108.5	565.1	530.8	116.7	579.7	523.9	133.2	594.2	529.1	136
Jashpur	521.3	553.6	70.6	527.3	552	75.6	539.8	553.1	81	551.1	561.3	80.5
Kabirdham	546.6	524.8	95.6	554.2	521.2	105.6	569.1	515.2	121.2	583.2	517.7	125.2
Kanker	539.5	559.3	75.7	548.9	554.6	84.5	563.8	549.8	93.8	577	552.1	98.3
Kondagaon	530.2	573.3	61.9	538.8	569.2	68.9	553.5	564.9	77.4	563.1	568	78.5
Korba	555.7	554.1	96.9	560.3	551	104	574.5	547.5	116.4	588.7	553.1	119.5
Koriya	525.5	517.4	104.9	532.2	513.5	113.1	545.2	510.3	123.9	557.1	519.5	123.2

Mahasamund	550	558.2	88.2	557.7	555.2	95.5	572.9	549	109	587	551.2	111.5
Mungeli	551.1	522.2	100.3	559.1	518.7	110.1	574.4	512.4	125.9	588.6	516.9	128.4
Narayanpur	530.1	576.4	68.1	539.5	572.4	75.5	557.1	569.8	81.7	566.8	573.7	82
Raigrh	563.9	575.8	92	572	574.2	97.9	585.8	570.1	108.7	600.3	574	112.8
Raipur	550.5	544	94.1	558.9	571.6	96.4	574.3	534.5	116.8	586	534.9	122.6
Rajnandgaon	549.8	564.4	82.8	557.8	560.9	90.6	573.1	554.7	102.7	584.1	555.1	108.2
Sukma	561.7	591.6	53.5	571.1	588.7	58.5	584.9	585.7	65.2	594	587.2	67.8
Surajpur	536.9	529.2	103	543.2	523.8	113	556.6	521.5	123.7	568.4	530.1	124.8
Surguja	534.8	547.6	91.5	541.1	544.1	98.2	554.5	542.5	107.2	566.2	550.9	106.4
Average	545.0	551.2	86.1	552.9	549.0	93.4	567.5	543.4	105.0	579.3	547.1	107.6

Table 2: Crop evapotranspiration, effective rainfall and irrigation requirement of wheat crop for 27 districts of Chhattisgarh for all climatic scenarios

	2018			**2030**			**2050**			**2070**		
Wheat	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**
Balod	424.4	41.1	382.7	430.1	39.8	389.8	441.2	37.8	402.8	449.9	41.3	407.8
Baloda Bazaar	418	34.3	383.2	424.1	30.8	393	435.5	28.2	406.9	443.9	32.7	410.6
Balrampur	361.6	54.8	306.3	368.2	45.3	322.5	378.4	41.6	336.5	386.3	53.1	332.7
Bastar	432.4	31.4	400.1	437.8	29	408	447.7	29.9	417	455.1	39	415.1
Bemetara	414.8	40.2	374	420.9	37.3	383.1	432	34.5	397.1	440.6	39.9	400.1
Bijapur	448.4	25.8	422	454.1	24	429.4	463.9	22.3	441	470.1	25.5	443.9
Bilaspur	410.6	45.1	364.9	416.9	40.3	376.1	427.7	37.1	390.1	436.2	43.8	391.7
Dantewada	444.4	23.6	420.2	449.6	21.4	427.6	459.3	21.7	437	465.5	28.8	436
Dhamtari	422.9	39.1	383.4	429	36.7	391.9	439.9	33.8	405.7	448.5	36.2	411.8
Durg	420.7	46.3	373.9	427	43.1	383.4	438.1	39.4	398.2	446.8	41.9	404.3
Gariyaband	412.2	40.1	371.2	419.6	37.5	381.3	428.5	36.5	391.2	436.3	43.7	391.7
Janjgir	416	40.5	374.8	422	34.4	387.1	433	34.4	398	441.4	45.8	394.9
Jashpur	364.8	59.8	304.2	370.5	51.3	318.6	379.2	51.3	327.3	386.8	64.4	321.7
Kabirdham	407.4	45.4	361.4	413.9	39.1	374.3	424.9	36.5	387.9	433.6	43.5	389.5
Kanker	421.9	38.4	382.6	427.7	36.9	390	438.2	36.8	400.6	446.9	45.9	400.1
Kondagaon	426	35.4	389.7	431.6	33.5	397.1	441.7	35	405.8	447.8	43	403.7
Korba	405.4	42.8	361.8	411.5	37.8	373.1	422.4	37.2	384.6	430.5	47.5	382.3
Koriya	361.7	51.5	309.6	367.1	43.6	323	375.6	41.4	333.7	383.2	52.1	330.4
Mahasamund	420.5	38.9	381	426.8	36.4	389.9	437.9	33.2	404.2	446.7	38	408
Mungeli	409.6	47.5	361.5	415.8	42.3	372.9	426.4	41.4	384.5	434.6	50.4	383.6
Narayanpur	426	45.8	379.1	431.9	42	388.9	442.3	43.4	398	448.5	49.6	397.8
Raigrh	422.3	47.6	374.2	429	44.7	383.9	439.7	44.8	394.5	448	49.8	397.7
Raipur	418.4	43.7	374.1	424.5	45.3	378.7	435.7	37.8	397.4	444.4	41	402.8
Rajnandgaon	422.4	42.7	379.3	428.1	39.7	388.2	439.2	36	402.9	448.4	38.1	409.8
Sukma	448.5	12	436.1	454	10.8	442.8	463.2	9.8	453	471.3	12.1	458.7
Surajpur	369.7	48.7	320.3	374.4	40.5	333.3	384.4	39	344.9	392.4	50.3	341.4
Surguja	371.9	54.1	317.2	378.5	45.3	332.6	388.4	44	343.9	396	56.6	338.7
Average	412.0	41.4	370.0	417.9	37.4	380.0	428.3	35.7	392.0	436.3	42.7	392.8

Table 3: Crop evapotranspiration, effective rainfall and irrigation requirement of maize crop for all 27 districts of Chhattisgarh for all climatic scenario

	2018			**2030**			**2050**			**2070**		
Maize	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**
Balod	322.1	573.6	3.9	325.9	572.9	4	332.7	569	4.2	338	567.2	4.3
Baloda Bazaar	329.1	566.1	4	332.5	566.1	4	339.2	561.9	4.2	345.1	559.9	4.3
Balrampur	322.3	555.7	3.8	325.7	555.4	3.9	332.7	555.3	4	338.8	557.8	4.1
Bastar	309.1	568.2	3.9	313.5	566.7	4	320.6	563.7	4.1	324.3	563.5	4.2
Bemetara	325.5	550.4	3.9	329.2	550.5	4	335.7	545.7	4.2	341	543	4.3
Bijapur	321.4	582.9	4	326.3	581	4.1	333.1	578.3	4.2	337.5	578.7	4.3
Bilaspur	327.7	564.4	3.9	331.2	564.6	4	338.1	561.6	4.2	345.2	560.5	4.3
Dantewada	318.1	564.6	4	323	562.8	4.1	330.2	558.9	4.2	334.2	558.6	4.3
Dhamtari	321	569.4	3.9	324.5	568.6	4	331.5	565	4.2	338.1	563	4.3
Durg	324.2	563.7	3.9	327.8	563.4	4	334.3	559.8	4.2	340.4	557.9	4.3
Gariyaband	308.3	581.1	3.8	312.1	580.6	3.9	318.8	577.7	4	323.1	576.6	4.1
Janjgir	329.5	566.3	4	333.3	566.1	4	340	562.6	4.2	347.4	562.4	4.3
Jashpur	308.5	572.2	3.7	311.7	572.7	3.7	318.2	573.3	3.9	323.9	576.1	4
Kabirdham	322.7	542.8	3.9	326.1	542.3	4	332.7	538	4.1	340.4	536.1	4.2
Kanker	315.4	568.4	3.9	319.9	567.4	4	326	563.6	4.1	333.1	562.3	4.2
Kondagaon	308.1	570.4	3.8	312.4	568.8	3.9	319.2	565.6	4.1	323.5	565.8	4.2
Korba	329.5	582.8	3.9	331.1	582.9	4	337.9	581.5	4.1	345.2	582	4.2

Koriya	312.6	558	3.7	316	557.9	3.8	322.4	556.9	3.9	328.4	559.4	4
Mahasamund	323.1	583.7	3.9	327.2	583.6	4	334.2	580.5	4.2	341.2	578.9	4.3
Mungeli	325.7	550.8	3.9	329.4	550.8	4	336.2	546.9	4.2	343.3	546	4.3
Narayanpur	308.4	579	3.8	312.9	577.7	3.9	321.9	574.4	4.1	325.9	574.2	4.2
Raigarh	331.8	602.2	4	336.1	602.4	4.1	342.7	601	4.2	350.2	601.5	4.3
Raipur	324.2	571.9	3.9	327.8	597.8	4	334.7	568.6	4.2	339.9	566.4	4.3
Rajnandgaon	323.3	580.3	3.9	326.8	579.8	4	333.6	576.3	4.2	338.4	574.2	4.3
Sukma	325.4	573.2	4.1	330.3	571.5	4.1	337.2	569.3	4.3	341.1	569.4	4.4
Surajpur	319.3	567.2	3.8	322.5	566.8	3.8	329.4	566.2	4	335.3	568.8	4.1
Surguja	317.6	577.5	3.8	320.9	577.4	3.8	327.6	577	4	333.5	579.2	4.1
Average	320.5	569.9	3.9	324.3	570.3	4.0	331.1	566.6	4.1	336.9	566.3	4.2

Highest increment in evapotranspiration was found in 2070 (5.11%) followed by 3.32% in 2050 and 1.18% in 2030 as compared to 2018 in maize crop (Table 3). The average evapotranspiration in maize varies between 320.5 mm to 336.9 mm in the year 2018 to 2070. District Raigarh shows the highest evapotranspiration in all the climatic scenario whereas Gariyaband shows the lowest evapotranspiration of 308.3 mm in 2018 & 323.1 mm in 2070 and Jashpur 311.7 mm in 2030 & 318.2 mm in 2050, respectively. The average effective rainfall was observed 569.88 in 2018, followed by 570.3 in 2030, followed by 566.61 in 2050 and 566.27 mm in 2070, respectively. As same the irrigation water requirement increases as 3.88, 3.96, 4.12 and 4.22 mm, respectively.

Similar study was carried out by Sunil *et al.* (2020) [15] showed that the average reference evapotranspiration value increased from 5.41 mm/day to 5.45 mm/day, 5.53 mm/day and 5.57 mm/day for the periods 2020, 2050 and 2080. Saha *et al*. (2018) concluded that an increase in temperature by 0.5, 1.0, 1.5 and 2 °C would increase the evapotranspiration by 0.71, 1.82, 2.91 and 4.01%.

3.2 Water Footprint

Table 4 revealed that the average total water footprint of rice for the year 2018 for the state was 3784 m3/t in which green footprint shares 87.8% while blue water footprint consists 12.19%. Similarly, the total water footprint for the year 2030 is 3880 m3/t consisting of 86.94% green water footprint and 13.05% blue water footprint. For the year 2050, the total water footprint is 4058 m3/t consisting of 85.5% green water footprint and 14.4% blue water footprint and for the year 2070, the total water footprint was 4208 m3/t out of which 85.5% is contributed by green and 14.65% is contributed by blue water footprints. The average water footprint increased as 2.57% in 2030, 7.27% in 2050 and 11.24% in 2070, respectively as compared to present climatic condition.

Highest water footprint of rice was observed in Kabirdham district 5161.28 m3/t, 5487.71 m3/t and 5685.25 m3/t for the year 2018, 2050 & 2070, respectively while Korba district shows 4943.5 m3/t water footprint for the year 2030. Whereas, lowest water footprint was recorded in Dhamtari district 2278.8 m3/t, 2416.9 m3/t and 2503.9 m3/t for the year 2018, 2050 & 2070 while Janjgir district showed 2325.6 m3/t for the year 2030, respectively.

The average total water footprint of wheat crop ranges between 2749 m3/t to 3153 m3/t in 2018 to 2070 for Chhattisgarh state. The average value of total water footprint was found 2749 m3/t for 2018 in which share of green footprint was 18.18% and share of blue water.

Table 4: Comparison of water footprint components of rice crop between present (2018) and future climatic scenarios (2030, 2050 & 2070)

Rice	2018			2030			2050			2070		
Districts	WF green	WF blue	TWF (m3/t)	WF green	WF blue	TWF (m3/t)	WF green	WF blue	TWF (m3/t)	WF green	WF blue	TWF (m3/t)
Balod	3305.6	473.4	3779.0	3344.0	521.8	3865.8	3400.6	612.1	4012.7	3508.2	640.8	4149.0
Baloda Bazaar	3807.0	632.4	4439.4	3829.2	695.4	4524.6	3891.5	811.1	4702.6	4002.6	867.9	4870.5
Balrampur	3376.1	497.6	3873.7	3394.8	544.7	3939.5	3488.4	610.8	4099.1	3637.1	625.9	4263.0
Bastar	3360.8	330.6	3691.4	3448.1	367.5	3815.6	3628.1	422.3	4050.4	3761.7	448.2	4209.9
Bemetara	3522.1	591.9	4114.0	3544.1	651.2	4195.3	3599.2	767.4	4366.6	3703.3	813.5	4516.9
Bijapur	3386.7	385.0	3771.7	3475.1	417.9	3893.0	3654.2	459.6	4113.8	3783.1	482.1	4265.2
Bilaspur	3066.0	504.5	3570.5	3085.0	555.0	3640.0	3144.6	643.6	3788.3	3241.8	690.6	3932.5
Dantewada	3375.1	329.1	3704.3	3413.2	361.5	3774.7	3614.3	421.8	4036.1	3720.5	454.3	4174.7
Dhamtari	2002.6	276.3	2278.8	2022.9	307.4	2330.3	2062.1	354.9	2417.0	2122.5	381.4	2504.0
Durg	3359.1	482.4	3841.5	3379.0	529.2	3908.3	3439.7	627.5	4067.3	3533.2	682.3	4215.5
Gariyaband	3577.5	488.2	4065.6	3665.5	531.1	4196.7	3845.6	611.6	4457.3	3982.8	609.1	4591.9
Janjgir	1938.3	343.0	2281.4	1952.6	373.1	2325.6	1984.7	437.8	2422.4	2055.2	458.9	2514.1
Jashpur	3741.5	439.3	4180.8	3820.9	475.6	4296.5	4009.0	523.9	4532.9	4191.0	534.6	4725.5
Kabirdham	4456.8	704.5	5161.3	4479.5	786.8	5266.4	4559.3	928.4	5487.7	4700.6	984.6	5685.2
Kanker	2319.8	283.5	2603.2	2381.1	319.9	2701.1	2451.5	365.1	2816.6	2526.1	392.8	2918.9
Kondagaon	3165.2	321.1	3486.3	3245.6	361.4	3606.9	3415.9	417.3	3833.3	3560.2	434.6	3994.8
Korba	4218.0	644.6	4862.6	4244.1	699.5	4943.6	4339.0	804.9	5143.8	4494.5	848.4	5342.8
Koriya	3348.5	588.0	3936.5	3363.7	641.0	4004.6	3439.4	721.9	4161.3	3586.2	737.0	4323.2
Mahasamund	3366.4	471.3	3837.7	3431.9	516.0	3947.9	3493.8	605.4	4099.3	3599.6	635.9	4235.4
Mungeli	2967.9	494.3	3462.2	2983.4	548.6	3532.1	3034.9	645.0	3679.9	3139.5	675.4	3814.9
Narayanpur	3446.1	384.7	3830.8	3538.1	431.2	3969.3	3740.8	479.7	4220.5	3899.1	494.3	4393.4
Raigrh	3999.6	571.5	4571.0	4094.9	614.9	4709.8	4197.6	701.9	4899.4	4335.4	747.8	5083.2
Raipur	3084.9	465.2	3550.2	3193.7	481.9	3675.6	3158.0	600.2	3758.2	3244.4	646.9	3891.2
Rajnandgaon	3766.0	495.1	4261.1	3856.2	547.8	4404.0	3945.2	638.4	4583.6	4053.0	690.5	4743.5
Sukma	2888.1	240.8	3128.9	2963.0	266.2	3229.2	3110.7	305.0	3415.8	3204.8	325.7	3530.4

Surajpur	3312.3	560.0	3872.3	3319.4	621.2	3940.7	3399.6	699.1	4098.8	3540.2	724.2	4264.4
Surguja	3489.3	519.3	4008.6	3564.2	563.5	4127.8	3672.5	632.4	4305.0	3821.4	644.5	4465.9
Average	3320	464	3784	3372	509	3880	3471	587	4058	3591	617	4208

Table 5: Comparison of water footprint component of wheat crop between present (2018) and future climatic scenarios (2030, 2050 & 2070)

WHEAT	2018			2030			2050			2070		
District	**WF green**	**WF blue**	**TWF(m3/t)**	**WF green**	**WF blue**	**TWF(m3/t)**	**WF green**	**WF blue**	**TWF(m3/t)**	**WF green**	**WF blue**	**TWF(m3/t)**
Balod	653.7	3084.7	3738.3	653.0	3189.7	3842.7	656.6	3399.7	4056.3	713.1	3576.7	4289.7
Baloda Bazaar	342.8	1768.1	2110.9	331.6	1840.9	2172.6	329.5	1965.9	2295.4	365.0	2061.5	2426.5
Balrampur	655.0	2116.4	2771.4	598.4	2262.2	2860.6	590.4	2434.6	3025.0	700.0	2501.4	3201.4
Bastar	305.7	1712.9	2018.5	299.9	1773.3	2073.2	313.3	1869.3	2182.7	368.0	1933.7	2301.7
Bemetara	808.3	3769.3	4577.6	790.9	3919.8	4710.7	786.2	4190.7	4976.9	876.2	4387.8	5264.0
Bijapur	327.2	2098.5	2425.7	323.1	2167.8	2490.9	324.4	2296.3	2620.7	354.4	2401.9	2756.3
Bilaspur	531.5	2279.1	2810.6	509.2	2384.8	2894.0	504.2	2551.3	3055.6	569.5	2662.1	3231.7
Dantewada	265.0	1750.8	2015.8	259.7	1808.8	2068.5	269.2	1906.6	2175.8	311.9	1976.8	2288.7
Dhamtari	449.6	2179.4	2629.1	442.6	2261.7	2704.3	439.3	2414.9	2854.2	471.3	2547.2	3018.5
Durg	745.5	3229.9	3975.4	728.8	3362.4	4091.2	718.2	3601.9	4320.2	769.9	3800.4	4570.2
Gariyaband	503.2	2332.0	2835.2	494.3	2431.9	2926.2	503.2	2573.5	3076.7	572.2	2677.7	3249.9
Janjgir	471.6	2195.9	2667.5	442.5	2302.5	2745.0	456.4	2441.7	2898.1	547.0	2517.5	3064.5
Jashpur	533.4	1625.9	2159.3	495.4	1728.8	2224.2	511.0	1831.8	2342.7	607.2	1871.0	2478.1
Kabirdham	598.6	2533.2	3131.8	562.9	2663.6	3226.5	561.5	2847.1	3408.6	636.9	2970.8	3607.7
Kanker	336.0	1639.7	1975.7	334.6	1696.9	2031.5	344.7	1797.8	2142.4	400.6	1865.8	2266.4
Kondagaon	322.8	1668.2	1991.0	319.4	1725.8	2045.2	336.2	1819.0	2155.2	386.6	1880.5	2267.1
Korba	583.3	2549.0	3132.3	556.5	2668.6	3225.1	569.5	2837.3	3406.8	670.8	2930.8	3601.6
Koriya	569.6	1927.2	2496.8	528.3	2041.3	2569.6	530.6	2175.1	2705.7	623.9	2238.0	2861.9
Mahasamund	399.8	1930.5	2330.3	393.0	2005.7	2398.7	388.4	2144.6	2532.9	430.1	2249.5	2679.6
Mungeli	584.8	2415.9	3000.7	558.4	2530.1	3088.4	569.6	2690.7	3260.3	657.4	2789.6	3447.0
Narayanpur	367.7	1624.7	1992.4	356.8	1692.1	2048.9	374.3	1786.1	2160.4	417.8	1855.1	2273.0
Raigrh	404.4	1727.3	2131.7	396.9	1799.1	2196.0	409.9	1906.8	2316.7	451.0	1997.6	2448.6
Raipur	409.9	1832.0	2241.9	424.1	1882.8	2306.8	398.9	2037.8	2436.7	431.6	2146.4	2578.0
Rajnandgaon	681.5	3125.5	3807.0	666.7	3247.6	3914.3	655.8	3476.4	4132.2	700.3	3674.5	4374.8
Sukma	520.0	4361.0	4881.0	515.7	4495.4	5011.2	521.5	4743.5	5264.9	566.9	4991.3	5558.2
Surajpur	463.1	1672.2	2135.3	426.7	1766.6	2193.2	431.9	1885.5	2317.3	513.0	1939.4	2452.4
Surguja	513.7	1731.7	2245.4	472.8	1843.4	2316.2	480.2	1965.9	2446.1	573.8	2012.0	2585.9
Average	494	2255	2749	477	2352	2829	481	2503	2984	544	2610	3153

Table 6: Comparison of water footprint components of maize crop between present (2018) and future climatic scenario (2030, 2050 & 2070)

Maize		2018			2030			2050			2070	
Districts	**WF green**	**WF blue**	**TWF**	**WF green**	**WF blue**	**TWF**	**WF green**	**WF blue**	**TWF**	**WF green**	**WF blue**	**TWF**
Balod	2372.8	26.3	2399.1	2425.1	27.3	2452.4	2540.8	29.4	2570.3	2646.7	30.9	2677.7
Baloda Bazaar	2154.6	24.0	2178.6	2199.2	24.3	2223.5	2302.7	26.2	2328.9	2401.9	27.5	2429.5
Balrampur	1235.8	13.3	1249.1	1261.6	13.8	1275.4	1322.5	14.6	1337.1	1380.6	15.3	1396.0
Bastar	1227.1	14.1	1241.2	1256.8	14.6	1271.5	1318.8	15.4	1334.2	1368.3	16.2	1384.5
Bemetara	2555.0	39.0	2594.0	2632.0	40.4	2672.4	2801.5	43.7	2845.1	2959.4	45.9	3005.3
Bijapur	1506.0	17.1	1523.1	1544.0	17.8	1561.8	1617.6	18.7	1636.3	1680.9	19.7	1700.6
Bilaspur	1817.3	19.8	1837.2	1855.5	20.5	1876.1	1944.1	22.2	1966.2	2034.4	23.3	2057.7
Dantewada	1895.0	21.8	1916.8	1943.0	22.6	1965.6	2038.3	23.8	2062.1	2115.9	25.0	2140.9
Dhamtari	1050.6	11.7	1062.2	1072.8	12.1	1085.0	1124.7	13.1	1137.8	1175.8	13.7	1189.6
Durg	1897.5	20.9	1918.4	1938.1	21.7	1959.8	2028.7	23.4	2052.1	2117.7	24.6	2142.3
Gariyaband	1896.3	21.3	1917.6	1938.9	22.1	1961.0	2032.4	23.3	2055.7	2112.3	24.5	2136.9
Janjgir	1899.2	21.1	1920.4	1940.7	21.4	1962.0	2031.9	23.1	2055.0	2127.9	24.2	2152.1
Jashpur	1346.1	14.7	1360.8	1373.9	14.9	1388.8	1439.4	16.1	1455.5	1501.9	17.0	1518.9
Kabirdham	1967.3	21.8	1989.1	2008.4	22.6	2030.9	2103.0	23.8	2126.8	2205.0	25.0	2230.0
Kanker	1434.5	16.2	1450.7	1469.4	16.8	1486.2	1536.9	17.7	1554.6	1609.4	18.6	1628.0
Kondagaon	1157.7	13.0	1170.7	1185.4	13.5	1198.9	1242.9	14.6	1257.5	1291.8	15.3	1307.1
Korba	1678.2	18.2	1696.4	1704.4	18.9	1723.3	1785.3	19.9	1805.2	1869.3	20.9	1890.2
Koriya	1417.3	15.3	1432.6	1447.3	15.9	1463.2	1515.5	16.8	1532.2	1582.4	17.7	1600.0
Mahasamund	2092.4	23.1	2115.6	2140.3	24.0	2164.3	2243.5	25.9	2269.3	2347.6	27.2	2374.8
Mungeli	1778.5	19.5	1798.0	1817.0	20.2	1837.2	1903.3	21.8	1925.2	1992.0	22.9	2014.9
Narayanpur	1192.0	13.4	1205.4	1221.3	13.9	1235.2	1288.5	15.0	1303.5	1337.9	15.8	1353.7
Raigrh	1460.8	16.2	1476.9	1494.6	16.7	1511.3	1564.2	17.6	1581.9	1638.3	18.5	1656.8
Raipur	1840.0	20.3	1860.3	1879.4	21.0	1900.4	1969.4	22.7	1992.1	2050.8	23.8	2074.6
Rajnandgaon	1743.7	19.2	1763.0	1780.6	20.0	1800.5	1865.4	21.5	1887.0	1940.5	22.6	1963.2
Sukma	1820.3	21.0	1841.3	1866.0	21.2	1887.2	1955.1	22.9	1978.0	2028.6	24.1	2052.6
Surajpur	1476.6	16.1	1492.7	1506.7	16.2	1522.9	1579.3	17.6	1596.9	1648.0	18.5	1666.5

Surguja	1624.7	17.8	1642.4	1658.3	18.0	1676.3	1737.4	19.4	1756.8	1813.2	20.5	1833.7
Average	1724	19.1	1743	1762	19.7	1781	1846	21.1	1867	1925	22.2	1947

footprint was 81.81%. Similarly, green water footprint consisted of 17.03% in 2030, 16.3% in 2050 and 17.5% in 2070 of total footprint values. While, blue water footprint consisted of 82.96% in 2030, 83.6% in 2050 and 82.4% in 2070 of total value of total water footprint. Highest total water footprint was found in Sukma district while lowest was observed in Kanker district for present as well as for all future climatic scenario. The average percentage increase was found to be 2.89%, 8.54% & 14.68% in 2030, 2050 and 2070, respectively as compared to 2018 (Table 5).

Table 6 reveal that the water footprint of maize crop was 1743 m3/t in 2018, 1781 m3/t in 2030, 1867 m3/t in 2050 and 1947 m3/t in 2070, respectively for Chhattisgarh state. It varies between 1743 to 1947 m3/t between 2018 to 2070. Higher value of total water footprint was observed in Bemetara district in all the future climatic scenarios. While the lowest was found in Dhamtari district in all future climatic scenarios. The share of green water footprint is 98.8 % and blue water footprint is 1.10% in all climatic scenarios. The average increase was found to be 2.22% in 2030, 7.14% in 2050 and 11.76% in 2070, respectively.

In total water footprint, share of green water footprint will decrease and share of blue water footprint will increase in rice and wheat crop in all the districts under future climatic scenarios as compared to present climatic conditions. Whereas, green and blue water footprint will be stable in maize crop in all the districts under future climatic scenario.

Similarly, Elbeltagi *et al*. (2020) [4] reported a decrease in green water footprint of wheat (24.96% and 37.44%) in western and eastern Nile region, respectively and in maize, it induced a 103.93 % decrease in western and an 8.96% increase in eastern region. Shrestha *et al*. (2017) [14] found an increase in the water footprint of KDML-105 and RD-6 rice varieties ranging from 56.5 to 92.2% and 27.5 to 29.7% respectively for the future period under RCP 4.5, and 71.4 to 76.5% and 27.9 to 37.6%, respectively under RCP 8.5 relative to the simulated baseline water footprint for the period 1976–2005.

3. Conclusion

The result provides a deeper insight into the current and future field water situation in the state. The water footprint hints us regarding use of field water as well as water saving opportunities. Variations in WF is found due to variability in rainfall amount and field management practices adopted in several districts. In rice, district Dhamtari, Janjgir-Champa; in wheat, district Narayanpur, Kondagoan; and in maize, district Dhamtari, Kondagoan shows lowest remarkable total water footprint values.

Improving the productivity of water particularly the green water in cereal production can be accomplished more readily by improving farm management methods such as altering sowing dates or using new cultivars with a more adjusted increasing season for wet spell in each region. This study can be use as a baseline for crop water management for further research in area of sustainability.

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