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The Water Footprint Assessment of Agriculture in Banjar River Watershed

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Abstract

The water footprint (WF) is a spatially explicit character of water use in terms of consumption or pollution for producing a product, commodity or service. The WF of a crop may be defined as the amount of water required for producing the crop over the complete growing season. The present study was carried out to assess the WF of agriculture in Banjar river watershed (BRW) over the period 2000 - 2013. The WF of crops were evaluated and their further multiplication with production (ton/yr) in the watershed yielded the water footprint of crop production (WF_{CP}) in Banjar river watershed whose further summation gave WF of agriculture in BRW. The findings depicted that the water footprint of rice was maximum (7848 m^3/ton) followed by gram (5782 m^3/ton) and wheat (5417 m^3/ton). The crop with least WF was maize (2886 m^3/ton). These values of WF are much higher than the national average WF for different crops grown in India. Lower crop yields due to improper irrigation practices, low fertilizer application rates and improper on farm water management practices are the primary reasons of such high values of WF of crops in BRW. The water footprint of agriculture in BRW was 690.37 million m^3/yr with 59.74 % WF_{green}, 39.69 % WF_{blue} and 0.56 % WF_{grey}. Rice was having maximum share in water footprint of agriculture in BRW with 87.38 % of total water footprint followed by gram (4.97 %), wheat (4.33 %) and maize (1.31%).

Article History

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Keywords

Crop Evapotranspiration, Leaching Runoff Fraction. Water Footprint, Watershed.

Introduction

Water is an essential natural resource for human survival. It is one of the most crucial physical entity responsible for survival of human beings on earth. Water is principally used for drinking purposes and for providing sanitation. The other uses of water includes its involvement in agriculture, livestock rearing and management, domestic supplies

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and industrial operations. The water is greatly endangered by human activities.[1,2,3,4]

Freshwater scarcity is a major concern.[5,6] Increasing populations, socioeconomic growths, worldwide freshwater withdrawal, drying rivers and high population levels are all signs of rising water scarcity.[7,8,9,10] Water scarcity has been aggregating in more and more countries all over the world.[11] Agriculture is the major consumer of freshwater with 85% of global surface and ground water consumption.[12,13]

To manage the global concern of freshwater scarcity, water footprint (WF) has emerged as an interactive tool for exploring the water use among the policy makers to encourage effective, justifiable and sustainable water use. The concept of WF, was initially introduced by Hoekstra[14] and consequently elaborated by Hoekstra and Chapagain.[15] WF is a consumption or pollution based indicator of water use allocated for producing a product, commodity or a service. Knowledge of how allocated surface and groundwater resources are consumed over the production process is highly valuable for effective planning, management and sustenance of water resources by policy makers.[16,17]

The WF of a product refers to the amount of water required for producing the product over the complete production chain. WF assessment is an analytical tool that can describe the relationship between human activities and water scarcity, and offers an innovative approach to integrated water resources management.[18] The WF is further classified into three components, based on the consumption or degradation of freshwater use.[18] The first and second components are the WF_{green} and WF_{blue} whereas the third component is the WF_{grey}.

The green WF (WF_{green}) refers to the consumption of rainwater, and blue WF (WF_{blue}) denotes the consumption of surface or groundwater required for producing the product. The degradative component of WF i.e. grey WF (WF_{grey}), measures the volume of water requisite to integrate the load of pollutants flowing towards freshwater bodies based on the acceptable and ambient water quality standards.

Former WF studies primarily concentrated on six distinct areas: product, sector, river basin, administrative boundary, country and global level. At the product level, Van Oel and Hoekstra[19] quantified the WF of paper products and Chapagain and Hoekstra[20] quantified it for tea and coffee consumption in the Netherlands. Mekonnen and Hoekstra[21] made a global assessment of WF of farm animal products.

At a river basin, Miguel *et al.,*[22] evaluated the WF of agriculture sector in Duero river basin, Dumont *et al.,*[23] analyzed the WF of Guadalquivir river basin with special focus on groundwater and Zeng *et al.,*[24] assessed it for Heihe river basin. D'Ambrosio *et al.,*[25] assessed the sustainability in water use for Canale d'Aiedda Basin using water footprint as an indicator, Martínez-Paz *et al.,*[26] evaluated the water footprint of irrigated agriculture sector of Segura river basin through simulation of anthropised water cycle combining a hydrological model and a decision support system. At provincial level Zhao *et al.,*[27] estimated the regional water footprint of Leshan city in China. At country level, Kampman,[28] Ahmed and Ribbe,[29] Ge *et al.,*[30], Arabi *et al.,*[31] quantified the WF of India, rainfed and irrigated areas of Sudan, China and Iran. Chapagain and Hoekstra[32] quantified the water footprint of rice at global level from production and consumption perspectives.

Using a 5 × 5 arc minute grid, Mekonnen and Hoekstra[33] quantified the WF_{green}, WF_{blue} and WF_{grey} of crops and derived crop products for global production. By adopting an interregional input output framework, Zhang *et al.,*[34], analyzed the water footprint of Beijing, China.

The WF within a geographically delineated area (e.g. a province, nation, catchment area or river basin) is the sum of all the processes taking place in that area.[18] Although the literature on WF assessment studies is increasing rapidly, there are still very few studies focusing on specific river basins.[35] The assessment of WF at a watershed level is an essential step in integrated water resource management and sustainable water use as it helps to understand how human activities influence natural water cycles.[24]

In India, very few studies has been executed to assess the WF at a basin level. Sambhaji *et al.,*[6] assessed the WF of selected sub basins of river

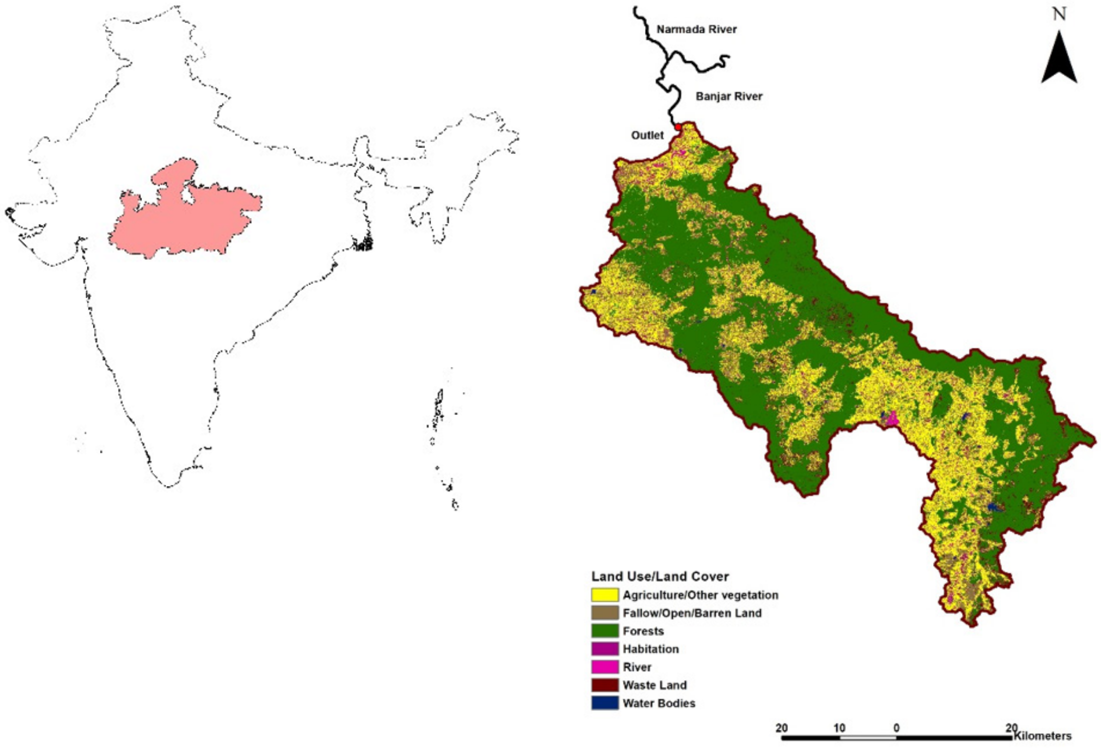
Ganga (i.e. Gomti and Betwa) whereas Kumar[36] determined the WF of major crops in rainfed and irrigated areas of Kinnerasani basin. Banjar river watershed lies in a tribal area with meagre literacy, poor socio-economic condition, lack of proper water management practices which leads to agriculture as only source of income for livelihood. The objective of this study is to quantify the WF_{green}, WF_{blue} and WF_{grey} of crops grown in Banjar river watershed (BRW) so as to make a comparison with other water footprint studies executed at global and basin or catchment level. Such comparison would help policy makers and corresponding government agencies to achieve highest crop yields with optimal surface and groundwater resources. It will also prove to be advantageous to have an analysis on the WFgrey values and its changing trend if yields increases substantially.

Study Area

Banjar River Watershed (BRW)

Banjar river is one of the primary tributary of river Narmada. The watershed predominantly exists in Balaghat and Mandla district of Madhya Pradesh with higher altitude areas of watershed lying in Kabirdham (Kawardha) and Rajnandgaon district of Chhattisgarh. It is geographically located in between $21^{0}41'00''$N - $23^{0}30'00''$N latitudes and $80^{0}20'00''$E - $81^{0}15'00''$E longitudes and covering a total geographical area of 2503 km^2 up to the gauging station. The general elevation of the watershed varies from 442 m to 905 m. The study was carried out in between 2000 to 2013. The climate of the area is tropical with moderate winter and severe summers and it generally receives rainfall from southwest monsoon. However due to high general elevation and abundance of forests in the watershed,[37] summer temperature does not rise as much as in other areas which generally ranges from 7^{0}C in winter to 48^{0}C in summer in between 2000 to 2013 with average annual rainfall ranging from 1000 to 1400 mm for the watershed.

A key portion of watershed is covered with forests followed by open land/fallow land/Barren land and agriculture.[37] The underlying soils in the watershed are Clay loam, Loam and Clay soil. The Fig. 1 shows the location of BRW and land use pattern of BRW.



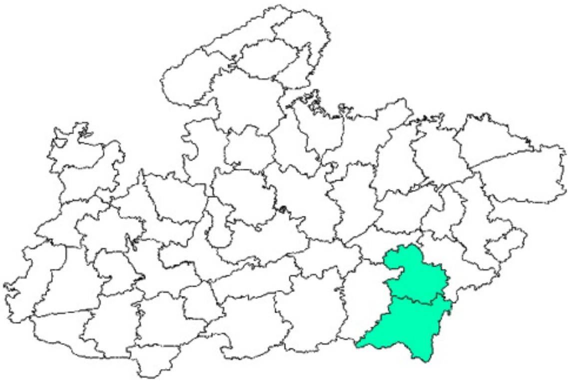


Fig. 1: Location map of BRW with land use pattern of the watershed

Materials and Method

The WF of crops grown in BRW were computed following the calculation framework as suggested by Hoekstra *et al.,*[18] by considering the WF_{green}, WF_{blue} and WF_{grey} for the study. At preliminary stages, snap pour point technique was followed so as to delineate the watershed in GIS environment using Arc Map 10.3 and consecutively the shape file of watershed was allowed to coincide with the administrative boundaries of the developmental blocks of districts for identifying the blocks that are lying completely or partially within the boundaries of the watershed.

WF Assessment of Crops

The WF_{green} and WF_{blue} of crops were computed using the CROPWAT model using the Crop Water Requirement option of the model, whereas the WFgrey was calculated based on the data available on the fertilizer application rates obtained from the local survey and the data obtained from the Farmer's welfare website of Government of Madhya Pradesh. The CROPWAT model developed by the FAO Land and Water Development Division[38] includes a simple water balance model that allows the simulation of crop water stress conditions and estimations of yield reductions based on well-established methodologies for determination of crop evapotranspiration.[39] CROPWAT model estimates the crop evapotranspiration of a given crop by using reference evapotranspiration (ET_0). The reference evapotranspiration may be defined as the evapotranspiration rate from a hypothetical grass reference crop with specific characteristics, which has an abundance of water. CROPWAT model requires meteorological data including maximum temperature, minimum temperature, relative humidity, sunshine hours and rainfall. The lack of available meteorological data at the watershed scale lead to the adoption of data acquired from Global weather data for SWAT for a period of 14 years (2000 – 2013). The unavailability of crop classification maps of BRW lead to the appropriation of an assumption that the crop production statistics for the developmental blocks lying in the watershed was based on the proportionate area. The crop yield statistics of districts underlying in the watershed were obtained from the Agriculture Production Statistics portal of Government of India.

Beside meteorological data, CROPWAT model also requires soil data and crop data for computing the ET_0 and ET_C The soil map of the watershed was adopted from Tiwari,[38] however the soil parameters for each soil type i.e. total available soil moisture content, maximum infiltration rate, initial soil moisture depletion and maximum rooting depth were used based on the preset values of the model. The crop data which includes certain crop parameters such as crop coefficients, length of crop development stages, rooting depth, critical depletion fraction, yield response function and crop height were acquired from FAO Irrigation and Drainage paper no. 56.[37]

The WF_{green} (m^3/ton) of crops was determined by dividing green crop water use (CWU_{green}, m^3/ha) with crop yield. In the similar manner the WF_{blue} of crops was determined by dividing the blue crop water use (CWUblue, m^3/ha) with crop yields (Yc, ton/ha).

$$WF_{green}[c] = (CWU_{green}[c])/(Y_C[c])$$

$$WF_{blue}[c] = (CWU_{blue}[c])/(Y_C[c])$$

The CWU_{green} and CWU_{blue} were computed by multiplying a factor of 10 with green and blue evapotranspiration.

$$CWU_{green}\,[c] = 10 \times \sum_{t=1}^{lgp} ET_{green}\ [c,t]$$

$$ET_{green}[c] = Min\ (ET_C[c], P_{eff}[c])$$

where, t refers to the time step of 10 days, lgp and c stands length of growing period and crop, ET_{green} is the green evapotranspiration. The multiplication of a factor of 10 with ET_{green} (mm) gave the values of CWU_{green} and CWU_{blue} in terms of m^3/ha. The values of crop evapotranspiration (ETC, mm) and effective rainfall (P_{eff}, mm) were acquired from the CROPWAT model. The effective rainfall in the current context denotes the amount of total precipitation that can be used for evapotranspiration by the crop and soil surface. The effective rainfall was calculated using the USDA SCS method. The assessment of WF of agriculture in BRW was the first attempt to quantify the WF_{green}, WF_{blue} and WF_{grey}. The CWU_{blue} was calculated in the similar manner as that of CWU_{green} whose formulas are depicted as

$$CWU_{blue}[c] = 10 \times \sum_{t=1}^{lgp} ET_{blue}\ [c,t]$$

$$ET_{blue}[c] = Max\ (ET_C[c] - P_{eff}\ [c], 0)$$

where ET_{blue} is the blue evapotranspiration (mm). The ET_{green} is the depth of rainfall supplied to a crop so as to compensate the water losses through crop evapotranspiration whereas the ET_{blue} may be defined as the depth of irrigation water (surface or groundwater) required to compensate the water losses through crop evapotranspiration.[27]

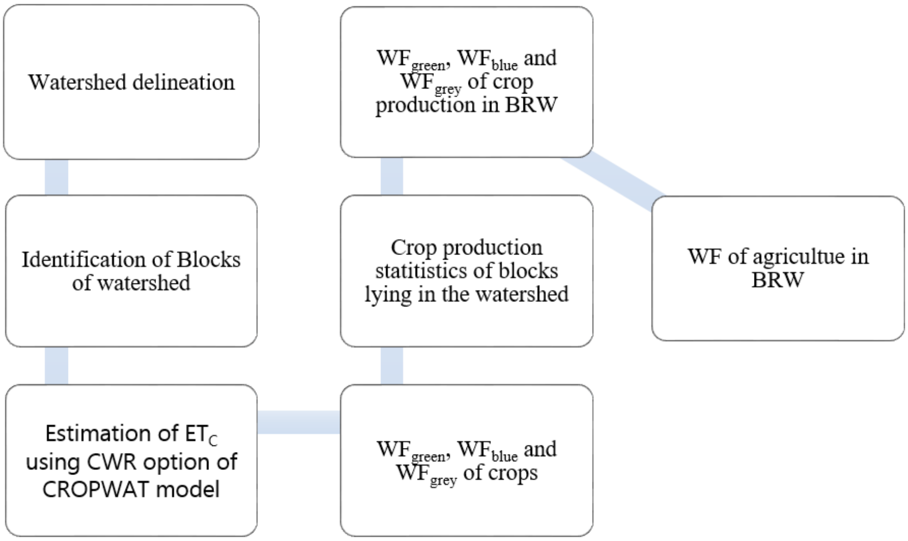


Fig. 2: Flowchart of steps involved in WF assessment of crops, crop production and WF assessment of agriculture

The WF_{grey} (m^3/ton) was assessed using the mathematical structure as suggested by Hoekstra *et al.,*[18] The chemical application rate to the field per hectare (AR[c], kg/ha) times the leaching-run-off fraction (α, %) is divided by the difference of maximum acceptable concentration (c_{max}, kg/m^3) and natural concentration for the pollutant considered (c_{nat}, kg.m^3) and then divided by the crop yield (Y_C, ton/ha) gives WF_{grey} (m^3/ton). In computing WF_{grey}, it should be noted that only those pollutants which have higher chemical application rates are taken into consideration for WF_{grey} accounting as it will present significant value of WF_{grey}.[18] The consumption of chemicals in BRW for agriculture production was only in the form of fertilizer and thus here the chemical application rate is referring to the fertilizer consumed for a decent production. The equation used for assessing the WFgrey is depicted as follows

$$WF_{grey}[c] = ((\alpha \times AR[c])/(c_{max} - c_{nat}))/(Y_C[c])$$

The inadequacy of mathematical model for calculating the leaching runoff fraction (α, %) lead to assumption of adopting α as 10% for assessing the WFgrey as suggested by Hoekstra *et al.,*[18].

WF Assessment of Agriculture (WF_A)

The WF of agriculture denotes the entire amount of water required for producing all the crops grown within the boundaries of the watershed. The WF_A in BRW (million m^3/yr) was calculated by summing up the water footprint of crop production (WFCP) for different crops grown in BRW. It was assessed using the following formula

$$WF_A[ws] = \sum_{c=1}^{n} WF_{CP}\ [c,ws]$$

where, c refers to the crop grown in BRW, n represents number of crops and ws denotes BRW. The WF_{CP} for crops grown in the watershed was obtained using the following formula

$$WF_{CP}[c,ws] = WF_{green(CP)}[c,ws] + WF_{blue(CP)}[c,ws] + WF_{grey(CP)}[c,ws]$$

where, ws has its usual meaning, $WF_{green(CP)}$ [c,ws], $WF_{blue(CP)}$ [c,ws], $WF_{grey(CP)}$ [c,ws] are the green, blue and grey water footprint of crop production for crops grown in BRW expressed in million m^3/yr. The WFCP crops grown in BRW were evaluated using the following formulas

$$WF_{green(CP)}\,[c,ws] = \sum_{b=1}^{N} WF_{green}\,[c] \times Prod\,[c,b]$$

$$WF_{blue(CP)}\,[c,ws] = \sum_{b=1}^{N} WF_{blue}\,[c] \times Prod\,[c,b]$$

$$WF_{grey(CP)}\,[c,ws] = \sum_{b=1}^{N} WF_{grey}\,[c] \times Prod\,[c,b]$$

where, b is the blocks of BRW, N shows number of blocks in BRW, and Prod [c, b] refers to production of crop (ton/ha) of a crop c in block b.

Results

Water Footprint of Crops

The table 1 shows the WF of crops grown in BRW for the mean of 2000 to 2013. Among all the crops taken into consideration, the WF of rice (7848 m^3/ton) was maximum followed by gram (5782 m^3/ton) and wheat (5417 m^3/ton). The higher values of WF for gram was due to lower crop yield of gram over the entire watershed. As gram is a *rabi* crop, the WF_{blue} was maximum in between the other two components. The WF_{green} was highest for rice.

The practice of organic farming in the watershed lead to the value of WF_{grey} as low for all the crops. The WF_{grey} was highest for *arhar* (81 m^3/ton) and was lowest for groundnut (38 m^3/ton). The figure 3 and 4 portrays the WF_{green}, WF_{blue} WF_{grey} and WF_{total} of crops grown in BRW.

Table 1: Water footprint of crops grown in BRW

Crop	Blue WFP	Green WFP	Grey WFP	Total WFP
	m^3/ton			
Arhar	109	4719	81	4909
Gram	5150	569	63	5782
Groundnut	997	3051	38	4086
Jowar	212	3481	45	3739
Maize	116	2734	36	2886
Rice	2884	4925	39	7848
Soybean	100	2916	45	3060
Wheat	5000	369	49	5417

Water Footprint of Agriculture (WF_A)

The WF of agriculture was 690.37 million m^3/yr over the mean of 2000 to 2013 in BRW. The table 2 shows the WFCP for crops grown in BRW. Rice was the major contributor to the water footprint of agriculture in BRW having 87.38 % contribution with 63.81 % of $WF_{green(CP)}$ of $WF_{total(CP)}$. This was due to the predominant practice of taking rice as a *kharif* crop in BRW. Availability of surplus water and favourable soil type also plays a prominent role in adopting rice as a principal *Kharif* crop in the BRW. Rice was followed by gram with 4.97 % of $WF_{total(CP)}$, wheat with 4.33 % of $WF_{total(CP)}$ and maize with 1.31% of $WF_{total(CP)}$ to the WFA.

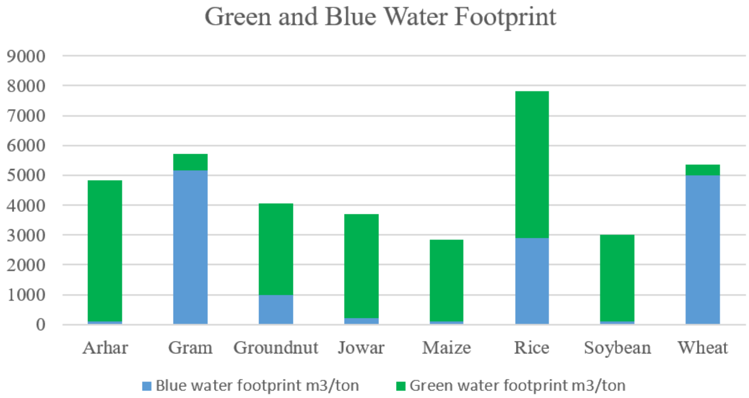


Fig. 3: WF_{green} and WF_{blue} of crops grown in BRW

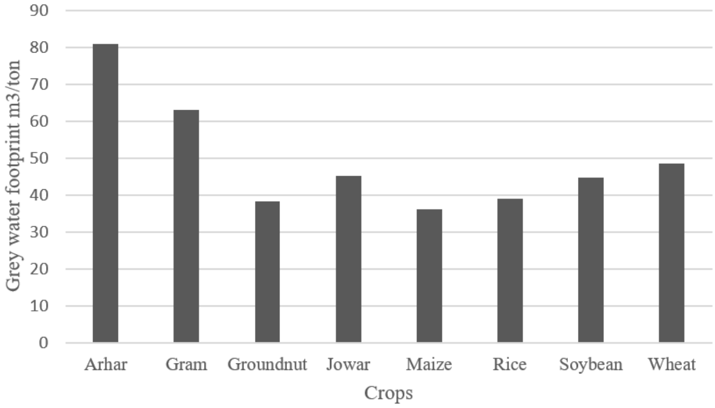


Fig. 4: WF_{grey} of crops grown in BRW

Table 2: WF_{CP} of different crops grown in BRW

Crop	Blue WFP	Green WFP	Grey WFP	Total WFP
	Million m³/yr			
Arhar	0.11	4.76	0.08	4.96
Gram	29.88	4.02	0.45	34.35
Groundnut	0.11	0.39	0.01	0.50
Jowar	0.01	0.18	0.00	0.20
Maize	0.41	8.54	0.10	9.05
Rice	215.42	385.00	2.87	603.29
Soybean	0.31	7.64	0.14	8.09
Wheat	27.79	1.91	0.25	29.94
TOTAL	274.03	412.44	3.90	690.37

The acquisition of good rainfall in BRW is due to the chief occupancy of forests in the watershed which lead to higher $WF_{green(CP)}$ for rainfed (*Kharif*) crops of BRW. As discussed earlier, the WF_{grey} of crops was minimal and hence the $WF_{grey(CP)}$ crops grown in BRW was negligible as compared to the WF_{green} and WF_{blue}. The Fig. 5 shows the percentage share of each crop in WF_{green}, WF_{blue} and WF_{grey}.

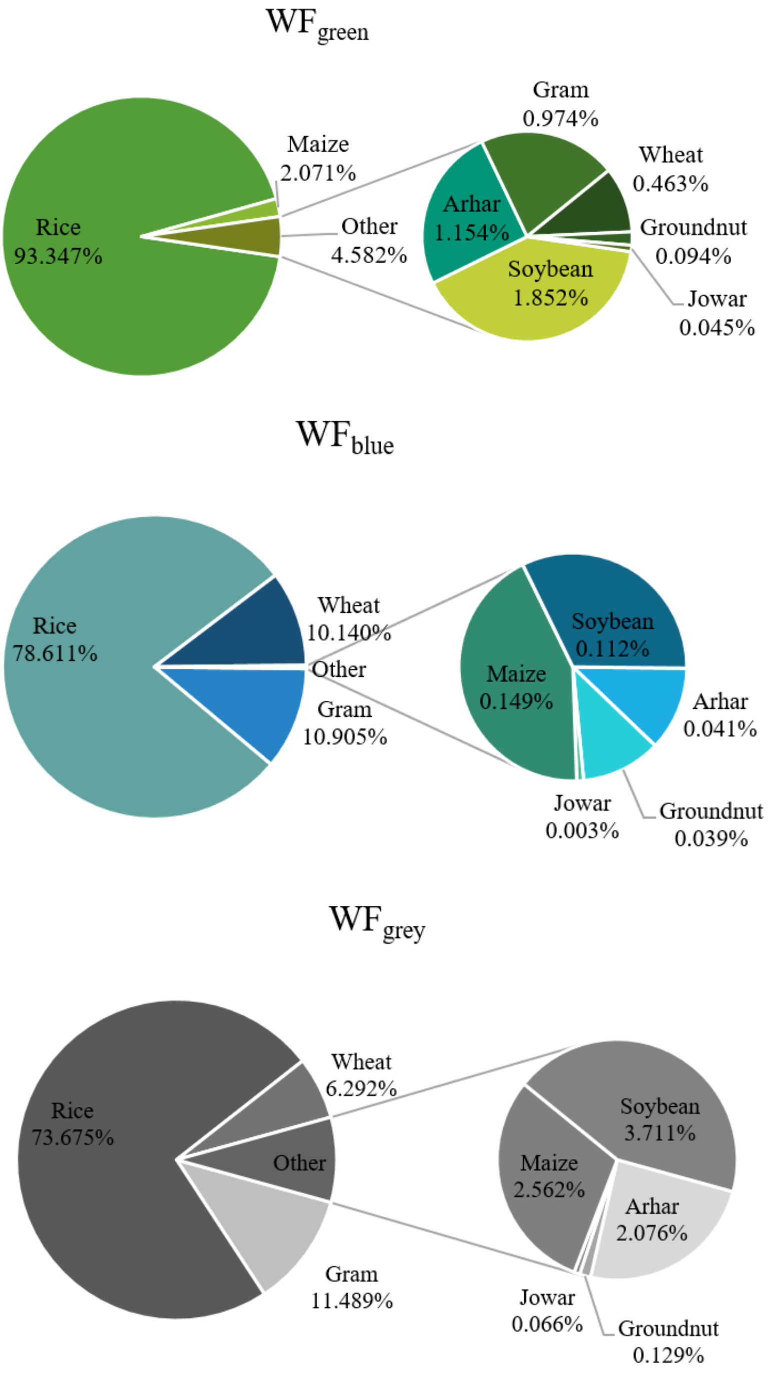


Fig. 5: WF_{green}, WF_{blue} and WF_{grey} of crop production in BRW for the mean of 2000 to 2013

Spatial Distribution of WF$_{CP}$ in BRW

The Fig. 6 shows the spatial distribution of WF$_{(green)CP}$, WF$_{(blue)CP}$ WF$_{(grey)CP}$ WF$_{(total)CP}$ of crops grown in BRW. Both the components i.e. green and blue water footprint indicated a similar pattern of spatial extent of WF$_{CP}$. It revealed that Baihar block of the watershed was having maximum share of the WF$_{(green)CP}$ (123.96 million m^3/yr) and WF$_{(blue)CP}$ (75.80 million m^3/yr). It was due to high cropped areas of the crops. The Baihar was followed by Paraswada having high share of WF$_{(green)CP}$ (112.90 million m^3/yr) and WF$_{(blue)CP}$ (75.24 million m^3/yr) WF.

The least values of WF$_{(green)CP}$ and WF$_{(blue)CP}$ was preoccupied by Chhuikhadan (WF$_{(green)CP}$– 8.70 million m^3/yr, WF$_{(blue)CP}$ – 8.43 million m/yr and Mandla block (WF$_{(green)CP}$ – 0.91 million m^3/yr, WF$_{(blue)CP}$ – 0.89 million m^3/yr). In case of WF$_{grey(CP)}$, Bodla possessed highest values (1.16 million m^3/yr) because of the higher chemical application rates of nitrogenous fertilizer. It was followed by Baihar (0.84 million m^3/yr) and Paraswada (0.79 million m^3 /yr).

The spatial distribution of WF$_{total(CP)}$ showed a similar pattern to the WF$_{(green)CP}$ and WF$_{(blue)CP}$, having maximum WF$_{(total)CP}$ in Baihar (200.59 million m^3/yr)

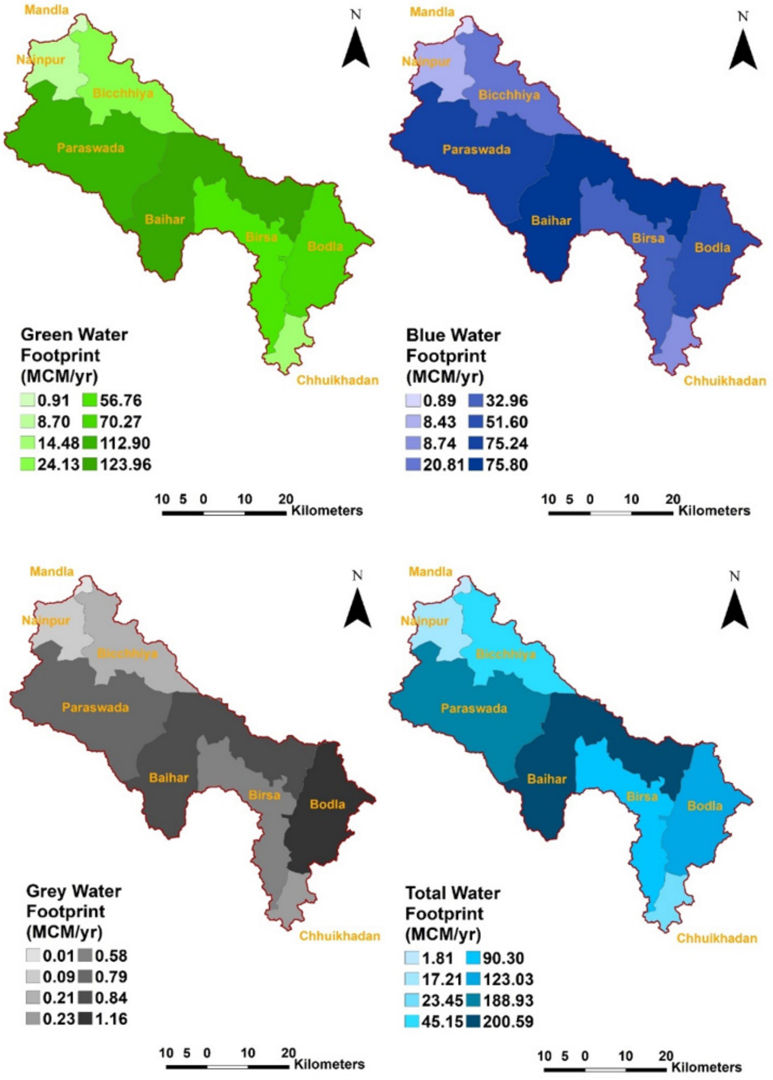


Fig. 6: Spatial distribution of WF$_{green(CP)}$, WF$_{blue(CP)}$, WF$_{grey(CP)}$ and WF$_{total(CP)}$ in BRW

followed by Paraswada (188.93 million m^3/yr) and Bodla (123.03 million m^3/yr). The block with least WF$_{(total)CP}$ was Mandla (1.81 million m^3/yr).

Discussion

The WF of the crops of BRW was different from the national average WF of crops as portrayed by Kampman.[27] The WF of rice was 82 % more than national average WF whereas for wheat it was 283% higher.[27] The WF of maize showed least deviation from national average WF of maize with 11.55% increment. The WF of soybean was 13.2% lower than the average WF of soybean for India.

The values of WF$_{green}$, WF$_{blue}$ and WF$_{grey}$ of crops grown in BRW when compared with a global study as revealed by Mekonnen and Hoekstra[32] gave a good correlation coefficient for rice (0.89). However moderate and poor negative correlation coefficient was obtained for wheat (-.034), maize (-.057) and soybean (-.047). The negative correlation coefficient were due to the high WF values for the crops of BRW. The WF of agriculture in BRW (690.37 million m^3/yr) was much lower than the other studies undertaken at basin or catchment level as evaluated by Miguel *et al.,*[21] for Duero river basin (9473 million m^3/yr), Mekonnen and Hoekstra[32] for Ganges (408 Gm^3/yr), Indus (253 Gm^3/yr), Krishna (118 Gm^3/yr), Zhuo *et al.,*[40] for Yellow river basin (12.4 billion m^3/yr), Martinez-Paz *et al.,*[25] for Segura river basin (4403 million m^3/yr, 2874 million m^3/yr), Zeng *et al.,*[23] for Heihe river basin (1768 million m^3/yr).

Indian study as conducted by Sambhaji *et al.,*[6] gave a moderate negative correlation coefficient (-0.54) for WF of maize, rice and wheat in BRW when compared with Gomti river basin whereas it gave a moderate positive correlation coefficient (0.51) for WF when compared with Betwa river basin. However the WF for Gomti (12196 million m^3/yr) and Betwa (8855 million m^3/yr) river basin was very much higher due to larger cropped area under each crop.

The WF of rice in BRW (7848 m^3/ton) was noticeably higher than the WF of rice (3018 m^3/ton) as computed in Gomti river basin whereas the WF of rice for BRW was lower in contrast to WF of rice as calculated for Betwa (8209 m^3/ton) river basin. For maize, the WF (2886 m^3/ton) in BRW was in the middle of the WF of maize as calculated for both the river basins (Gomti – 4555 m^3/ton and Betwa – 3430 m^3/ton). A similar trend was represented by groundnut (4086 m^3/ton) for BRW which was midst of the WF values of the two river basins (Gomti - 6399 m^3/ton, Betwa – 5718 m^3/ton).

The WF of wheat in BRW (5417 m^3/ton) was much greater than the values of WF for Gomti (1586 m^3/ton) and Betwa (3252 m^3/ton) river basin. The WF of soybean for BRW (3060 m^3/ton) was less than half of the WF of soybean as mathematically obtained for Betwa (6493 m^3/ton) river basin.

Large variations of WF of crops in BRW with the WF of crops for Gomti and Betwa river basin was due to lower crop yields in BRW. Farmers residing in BRW are small and marginal farmers owing very small and fragmented farm lands. They generally practice farming as a source of livelihood. BRW being a tribal area triggers lack of awareness, risk bearing capacities, farmer's voluntary participation in upgraded and efficient agriculture practices with poor soil fertility due to soil erosion in the watershed which often leads to lower crop yields. Adequate rainfall due to abundant forests[37] in BRW indicates high values of WF$_{green}$ and WF$_{green(CP)}$ in BRW. Though crop yields can be increased by assimilation of improved agriculture practices such as crop residue mulching, plastic mulching for good agriculture production in the watershed. Beside management practices, proper irrigation practices can be advantageous for getting higher crop yields. By enhancing crop yields, the WF of crops can be reduced to a much great extent.

It is observed that using drip or subsurface irrigation systems with synthetic mulching, with the inclusion of different environments for crops can help in consumptive WF reduction of 28% with full irrigation and 29% for deficit irrigation.[41] There are numerous uncertainties in WF assessment of agriculture in BRW. At introductory stage, it is due to the input data available for the models. Various numeral assumptions were made in the study which can be discussed as follows:

- The meteorological data was obtained from global weather data for SWAT, which gave best estimated values of meteorological parameters. Although meteorological parameters database was on daily basis with no lack of data, these data could have a significant effect on WF assessment.

- Due to lack of local available data, the crop parameters adopted for the study was consulted from FAO Irrigation and Drainage paper no. 5638 which gave the values of crop coefficients strictly based on nation level.
- The assumption of taking leaching runoff fraction as 10% was adopted as no framework model was available to suit the local conditions of BRW for assessing WF_{grey}.
- The developmental blocks lying in the watershed was a part of administrative boundary of the district. Lack of crop classification map of the watershed lead to the assumption of adopting second proportionate values of crop production statistics of crops for BRW absolutely based on area.

Conclusion

Over the period 2000 – 2013, the WF of agriculture in BRW was 690.37 million m^3/yr with maximum share of WF_{green} (59.74 %) preceded by WF_{blue} and WF_{grey} (39.69 %, 0.56 %). The WF of rice was 7848 m^3/ton, preceded by gram (5782 m^3/ton), wheat (5417 m^3/ton), arhar (4909 m^3/ton), groundnut (4086 m^3/ton), jowar (3739 m^3/ton), soybean (3060 m^3/ton) and maize (2886 m^3/ton). The study was undertaken on the basis of crop evapotranspiration (ETC) evaluated by adopting CWR option of CROPWAT model. However the irrigation scheduling option can also be used which will present the analysis on non-optimal condition specifying the actual irrigation in time. A more intense approach of using remote sensing by preparing crop classification map of the area can also help in achieving more detailed study of the WF in BRW by incorporating other crops grown on marginal scale in the watershed.

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