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Regional Variation in Agricultural Water Demand and Water Availability in Uttar Pradesh, India

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ABSTRACT

Water is one of the important and scarce natural resource that triggers the growth of crop production. But water availability varies from the region to region depending upon the rainfall, geological formation etc. Due to growing demand of water for various uses and erratic rainfall,the water availability for crop production declining very fast in different regions of Uttar Pradesh. Water scarcity is becoming a serious challenge for government, researchers, economist and policy makers. Much effort is being made to reduce water use by crops and produce 'more crop per drop'. Present study was an attempt to find out region-wise consumptive water demand for crop production and water availability. The study was based on secondary data. The CropWat model was used to find out the crop water requirement. Results suggests that total water demand for Eastern region, Central region, Bundelkhand region and Western region and it was found to be 70478, 38366,13790, 64703 MCM, respectively. Out of total crop water requirement, the highest share comes from wheat, rice and sugarcane in Eastern and Central region. In the Eastern region the share of crop water requirement for wheat, rice (k) and sugarcane was estimated to be 92.93 per cent of the total crop water requirement, whereas in case of Central region it was 87.64 per cent to total crop water demand. In Western region share of water requirement for growing wheat, sugarcane and rice (k) to total crop water requirement was estimated to be 88.79 per cent. During 2013-14, the annual water availability was found more than the crop water demand for Eastern, Central and Bundelkhand region, whereas in case of Western region water demand for crop production was more than the water supply from all the sources.

Highlights

- Decision support systems for farmers to select cropping pattern as well as for policy maker and Government for efficient water management
- Estimation of water requirement, water availability and groundwater draft in different regions of Uttar Pradesh

Keywords: crop share in total water demand, Blue and greenwater availability, CropWat, fresh water resources etc.

Uttar Pradesh is the largest state of the India in terms of population (220.7 million people) and fourth largest in area in the country (24.1 million hectares). Agriculture forms an integral part of UP's economy and the lives of its people. Out of total land in the state, nearly 69 per cent (16.68 million ha) is under cultivation. UP accounted for 13.32 per cent (25.9 mha) of the Gross Cropped Area (194.40 mha) in the country in 2013-14, and 77.9 percent of this was under irrigation (20.17 mha – about 21.7 percent of gross irrigated area in the country in 2013-14). Among the cereal, 9.85 million hectare and 5.87 million hectare was under wheat and rice, respectively in the State. Farming community of state is dominated by small and marginal farmers. Average size of holding is only 0.83 ha per farmer.

However, marginal and small farmers cultivate 92.5 percent of all landholdings in UP which accounts for 64.8 per cent of the total area cultivated in UP. The state contributed 16.8 per cent (42.47 million tonnes) to total food grains production in the country in 2014-15 and 16.26 per cent (20.06 million ha) of total area under food grains cultivation in the country was in Uttar Pradesh. The state produces 28.35 per cent of India's Wheat, 11.66 per cent of Paddy, 38.54 percent of Sugarcane, 19.17 per cent of Bajra, 30.48 percent of lentil, 9.22 per cent of Rape-seed, 10.02 percent of Fruits, 14.11 per cent of Vegetables and 4.25 per cent of spices. Uttar Pradesh is the largest potato producer in the country, contributing 28.60 per cent of the total production in 2014-15. Therefore, Uttar Pradesh Popularly known as the granary or bread-basket of India and state has special important role with respect to agriculture and food security of the country Interestingly, production of cereals went up from 39.4 million tonnes in 2002-03 to 42.47 million tonnes in 2014-15, whereas production of pulses declined significantly from 2.25 million tonnes to 1.82 million tonnes during the same period(Agricultural Statistics at a Glance, 2015). If Uttar Pradesh is to continue playing an important role in surplus production of food grains to ensure food security of State as well as country, productivity levels must rise substantially. It will depend fundamentally on state's water availability and how it is used.

Food policy must not lose sight of surging water scarcity. Water is essential for sustaining all forms of life, food production, economic development, and for general wellbeing. Irrigation development has enabled farmers to diversify their cropping patterns grow more crops during year over a same piece of cultivated land. The expansion of irrigation has trigger to adopt improved cultural practices including high yielding varieties, use of chemical fertilizer resulted enhance the crop yield. Although, irrigated crop yields have increased considerably, they are still lower as compared to other countries. This is mainly because of poor water management at system level and at farmers' field level. Excessive withdrawal of groundwater for irrigation is leading to alarming drops in groundwater levels in many parts of the country. Since scope of supply side intervention is limited, it is imperative to manage irrigation water from demand side interventions for efficient use of water (Singh *et al.,* 2013). Efficient use and management of water is the vital issue for successful farming. Water is one of the important and scarce natural resources need to be managing efficiently at farmers' field level to river basin level to harness the potential of resources and enhancing the agricultural production, improving the standards of living of the millions of people, particularly in the rural areas. The competition for scarce water resources is expected to increase due to population growth, economic development, rising demand for food, urbanization and industrialization. Agriculture is the largest water consuming sector as it consumes about 80 per cent of total water withdrawal in the country faces challenge to produce more food with less water. National Water Policy envisages that the water resources of the country should be developed and managed in an integrated manner.

The average annual rainfall in the country is about 1170 mm with a wide range between 10000 mm in Cherapunji to 100 mm in some parts of Western Rajasthan. Total annual precipitation including snowfall in India is 4000 BCM and total water resources potential of country is 1869 BCM. Out of this, usable water is only 1123 BCM (Bhat, 2014). Out of the total usable water, 690 and 433 BCM is contributed from surface and ground water, respectively (Water and related statistics,2015). In India, Per capita surface water availability during the years 1991 and 2001 were 2309 and 1902 m^3 and these were projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050, respectively (Bhattacharyya *at el.,* 2015). As the water available within the country varies widely as a result of rainfall, ground water reserve and proximity to river basins, As per Falkenmark's criterion, most of the Indian states will have reached the water stress condition by 2025 and water scarcity condition by 2050. Uttar Pradesh has 161.70 BCM of surface water and 75.25 BCM of annual replenishable groundwater resources (EA & EMF report, 2013). However, this water resource is unevenly distributed in space. The regional breakup of this available resource for future development in Western, Central, Eastern, Bundelkhand and foot hill regions is 14.8 BCM, 8.5 BCM, 16 BCM, 2.5 BCM and 1.25 BCM, respectively (Gupta, 2008).

Ground water is the primary source of irrigation in Uttar Pradesh and at present availability of ground

water in state is better than in many other states in India but unsustainable use of the same will soon lead to a water crisis that other states have already begun facing. It is clear from figure 1 of depth of water that maximum stress is in the Western and Bundelkhand regions of Uttar Pradesh due to over-exploitation of ground water in these areas (Ground Water Year Book Uttar Pradesh, 2016)

The sound knowledge of cropping pattern, consumptive water demand for crop production,water resource availability and their distribution at regional level, is important information for policy makers, economists and water resource engenderers to develop long-term sound policies related to crop production and efficient use of available water resources which leads to water and food security. Keeping this in viewpresent investigation was an attempt to estimate the regional water demand for crop production and water resource availability in Uttar Pradesh.

RESEARCH METHODOLOGY

Data Sources

Present study was based on the secondary data. The Uttar Pradesh is divided into four agro-climatic zones viz., Eastern, Western, Central and Bundelkhand region. The district-wise secondary data related to the cropping pattern, area under each crop and water availability etc. were collected from the various sources and it was published by Economic and Statistics Division, Ministry of Agriculture and Farmer Welfare, Government of India, Central Ground Water Board, Central Water Commission, Ministry of Water Resources and Minor Irrigation Census, Government of Uttar Pradesh for the year of 2013-14. The data was collected from various issues of Government publications, viz., *Uttar Pradesh ke Arthik Chhetravar Aakade*, *Uttar Pradesh Ke Krishi Aakde*, and *Sankhayaki Patrika* of UP. The district-wise data was converted into region wise data. Water resource planners frequently focus on identifying potential gaps between water demand and water supply to develop detail plans to ensure that supplies are brought into balance with anticipated demands, thereby eliminating the gap. In this regard various parameters like crop water requirement, total water demand and Replenishable Fresh Water Resources were estimated.

Estimation of Crop Water Requirement

Many past researchers were used CropWat model developed by the Food and Agriculture Organization to estimate the crop water requirement (Bouraima *et al*. 2015; Amarasinghe, *et al*. 2010; Laghari *et al*. 2014; Allen *et al*. 1998*)*. The present study also use CropWat model for estimation of crop water requirement. The crop water requirement was measured in m^3/ha was calculated from the accumulated crop evapo-transpiration (ET_c) measured in mm/day over the complete crop growing period. The evapo-transpiration (ET_c) was calculated by using following formula:

$$ET_c = K_c * ET_0 \quad \ldots (1)$$

Where ET_0 is crop reference evapo-transpiration and Kc is crop coefficients.

The concept of "reference crop evapo-transpiration was introduced by FAO to study the evaporative demand of the atmosphere independently of crop type, crop development and crop management practices. Climate parameters are affecting ET_0. Reference crop evapotranspiration was calculated on the basis of FAO Penman-Monteith equation (Smith *et al*., 1992; Allen *et al*., 1994; Allen *et al*., 1998):

$$ET_0 = \frac{0.408\Delta\left(R_n - G\right) + \gamma\frac{900}{273}U_2\left(e_a - e_d\right)}{\Delta + \gamma\left(1 + 0.34U_2\right)} \quad \ldots(2)$$

Where, ET_0 is Reference crop evapo-transpiration (mm/day); R_n is Net radiation at the crop surface (MJ/m^3 /day); G is Soil heat flux (MJ/m^3 /day); T is Average air temperature (°C);U_2 is Wind speed measured at 2 m height (M/S); e_a is Saturation Vapour Pressure Curve (kPa); e_d is Actual Vapour pressure (kPa); e_a-e_d is Vapour pressure deficit (kPa); Δ is slope of the vapour pressure curve (kPa/°C) and Γ is Psychometric Constant (kPa/°C).

The crop coefficient accounts for the actual crop canopy and aerodynamic resistance relative to the hypothetical reference crop. The crop coefficients serve as an aggregation of the physical and physiological differences between a certain crop and the reference crop.

For estimation of water requirement for rice crop, it includes consumptive water requirement for

the crop production, standing water at the time transplanting of paddy seedlings, standing water maintain in the paddy field and water percolation. Because in paddy field, sufficient amount of water losses from the paddy field in the form of percolation and farmers trying to maintain a certain level of water in the paddy field. For the purpose of maintaining water in paddy field, farmers are frequently irrigating their paddy crop.

Estimation of Total Water Demand

The region-wise total water demand for a particular crop was estimated simply by multiplying the crop water requirement (estimated by using equation 1) with cropped area.

$$TWD = CWR * CA \quad \ldots(3)$$

Where, *TWD* is total water demand (m^3); *CWD*is crop water requirement (m^3 per hectare) and *CA* is area under particular crop measured in hectare.

Estimation of Region-Wise Replenishable Fresh Water Resources

With respect to water supply, groundwater draft for irrigation purpose was collected from published data of central groundwater board. For the estimation of annual replenishable water resource was estimated for all the regions of Uttar Pradesh. For estimation of replenishable water, we used district-wise geographical area and rainfall for the particular

Table 1: Region-wise consumptive water demand for different crop (m^3/ha)

Crop	Eastern			Central			Bundelkhand			Western		
	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water	Blue Water	Green Water	Total Water
Rice (K)	3389	5595	8985	3715	5207	8922	5316	3814	9130	3906	4862	8768
Rice (Z)	9603	1188	10791	10415	1045	11461	10135	1165	11300	9563	1036	10600
Maize (K)	1420	2907	4328	2189	600	2789	1987	2410	4397	1263	3242	4506
Maize (Z)	4967	2143	7110	5474	1804	7278	5204	2022	7226	5166	1552	6719
Jowar	722	2949	3672	1125	2521	3646	1284	2434	3718	1164	2400	3565
Small millets	755	3025	3781	1156	2595	3751	1319	2505	3824	794	3008	3802
Arhar	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Urd (K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Urd (Z)	5084	1114	6198	5501	886	6387	5231	1033	6264	4951	927	5878
Moong (K)	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Moong (Z)	5084	1114	6198	5501	886	6387	5231	1033	6264	4951	927	5878
Moth	540	3269	3809	870	2895	3765	1015	2804	3819	2382	1760	4142
Groundnut	1430	3196	4626	1856	2713	4570	2050	2631	4681	1585	3092	4677
Soybean	1517	3079	4596	1750	2936	4686	1939	2849	4788	2438	2668	5106
Wheat	6959	1176	8136	7256	1018	8275	7357	929	8286	6583	968	7551
Barley	1847	532	2380	1841	537	2378	2041	415	2456	1793	425	2219
Gram	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Pea	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Peas and beans	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Masoor	1754	502	2256	1833	464	2297	2043	366	2409	1723	375	2098
Sunflower	5036	1814	6850	5489	1538	7027	5203	1751	6954	2736	2868	5605
Potato	2297	636	2933	2426	577.5	3004	2737	461	3198	4274	1026	5300
Tobacco	1897	532	2429	2024	464	2488	2247	366	2613	1908	370	2278
Sugarcane	11278	4835	16113	12098	4352	16450	12247	6245	18492	10806	4694	15501
Cotton	2395	4697	7092	2230	5225	7455	2183	5392	7575	3323	3564	6888

K = kharif and Z = zaid

year. We assumed that 75 per cent of actual rainfall can be used for different activities. Mathematically estimation method is represented as:

Annual replenishable water resources (m^3) = GA * AR* 0.75

Where, *GA* is geographical area of the district (m^2) and AR is the annual actual rainfall of the district (meter).

RESULTS AND DISCUSSION

Region-wise Consumptive Water Demand

The CropWat model provides results of actual water requirement for particular crop and it does not considered the water losses from the open crop field, water loss during water supply from source of irrigation to crop field that includes evaporation, percolation, seepage etc. from conveyance channel. Apart from area share of different crops, climatic factors also play a vital role in crop water requirement for various crops and these factors are temperature, wind velocity, relative humidity, sunshine and rainfall. Beside climatic factors, other factors responsible for the enhancing crop water demand are crop variety, crop duration, soil structure, water percolation rate etc. also playing an important role in crop water requirement. So, difference in the consumptive water use in different regions for the same crops varies.

Most of the crops grown during *kharif* season are using both water i.e. green and blue water. The region-wise total water requirement for different crops are presented in Table 1. The major cereal crops grown in different regions of Uttar Pradesh were wheat, rice, maize, jowar, bajra, small millets and barley. Out of these crops, crops grown during kharif season are rice, maize, *jowar*, small millets and wheat, barley in *rabi* season. Among the *kharif* crops, per hectare highest crop water requirement was estimated to be 9130 m^3 for paddy crop in Bundelkhand region, whereas minimum crop water requirement was observed for jowar in Western region with 3565 m^3. While, in *rabi* season highest crop water requirement was estimated for wheat crop in Bundelkhand region (8286 m^3/ha) and minimum water requirement was found for barley (2219 m^3/ha) in Western region of Uttar Pradesh.

Among the pulses, urd, gram, arhar and moong were cultivated during *kharif* season, whereas, gram, pea, peas and beans and masoor were cultivated by farmers of different regions of Uttar Pradesh during *rabi* season. Among the kharif pulses, per hectare highest crop water requirement was in Western region, while, lowest in Central region with an amount of 4142 and 3765 m^3, respectively. The major oilseed crops grown in different regions of Uttar Pradesh were rapeseed-mustard, sesame, groundnut, soybean, linseed, castor and sunflower. Out of these oilseed crops, sesame, groundnut and soybean were grown during *kharif* season, whereas rapeseed-mustard, linseed, castor was grown during *rabi* season. Among the different oilseeds grown during kharif season, per hectare highest crop water requirement was observed for groundnut with 4681 m^3 in Bundelkhand region and minimum crop water requirement was observed for soybean crop with 4596 m^3 in Eastern region.

The major cash crops grown by farmers of different regions of Uttar Pradesh were potato, tobacco, sugarcane and cotton. Among these crops, per hectare highest crop water requirement was estimated for sugarcane crop in Bundelkhand region 18492 m^3 and tobacco crop have minimum water requirement in Western region of Uttar Pradesh with 2278 m^3.

Major crops grown by the farmers of different regions of Uttar Pradesh during zaid were rice, maize, moong, urd and sunflower. Among these crops, area share of rice and sunflower was very small as compared to urd, moong and maize. Per hectare highest crop water requirement was observed for rice in Central region with 11461m^3, while, minimum crop water requirement was estimated for maize crop in Western region with 6719m^3. In zaid pulse category, highest crop water requirement was noted in Central region with 6387m^3/ha and minimum crop water requirement in Western region with 5878 m^3/ha.

Uttar Pradesh agriculture is highly diversified. It produces numerous crops due to its comparative advantage of wide range of agro-climatic variability. We discussed already in introduction part that wheat, paddy, sugarcane and potato are the most important crops of the State. Water demand particularly blue water depends on crop choice and location. From a water-efficiency perspective, for example, it is better to grow sugarcane in the

Western region than in the Bundelkhand region of Uttar Pradesh, but in the context of food security it might be better to develop the cropping system for food crops that require less water. Huge quantity of water could be saved by diversification of cropping pattern from water-intensive crops to less water consuming crops. Like as substitution of paddy by maize, wheat by rapeseed-mustard and gram. As a thumb rule, less area under high water-intensive crops (sugarcane, paddy and wheat) should be allocated in the cropping pattern for sustaining agriculture production. Technological improvement and change in the agricultural practices in general and irrigation practices, in particular, could also help to reduce the water consumption in sugarcane, rice and wheat. However, in reality, low water demand is not the primary driver of crop choice, but rather local to global demand, market prices, and nutrient calorie content play more dominant roles in deciding crop production.

Region-Wise Total Water Demand for Different Crop Production

Crop-wise total water demand in different regions

Table 2: Region-wise and crop-wise area, per hectare water demand and total water demand

Crop	Eastern			Central			Bundelkhand			Western		
	Crop Area (ha)	Water demand (m^3/ha)	TWR (MCM)	Crop Area (ha)	Water demand (m^3/ha)	TWR (MCM)	Crop Area (ha)	Water demand (m^3/ha)	TWR (MCM)	Crop Area (ha)	Water demand (m^3/ha)	TWR (MCM)
Rice (K)	3182585	8986	28597	1142540	8923	10194	79250	9130	724	1429747	8769	12537
Maize (K)	243742	4329	1055	216286	2789	603	27080	4397	119	205231	4506	925
Jowar	50106	3672	184	47392	3646	173	63643	3718	237	4531	3565	16
Bajra	113917	3672	418	95845	3646	349	21487	3718	80	614884	3565	2192
Small millets	7207	3781	27	954	3751	4	236	3824	1	70	3802	0
Arhar	164396	3810	626	35698	3766	134	59696	3819	228	36484	4143	151
Urd (K)	40981	3810	156	104126	3766	392	261131	3819	997	90558	4143	375
Moong (K)	1506	3810	6	7423	3766	28	26806	3819	102	2763	4143	11
Til	21523	4627	100	56216	4570	257	197034	4681	922	17650	4678	83
Groundnut	13240	4627	61	23979	4570	110	46238	4681	216	13049	4678	61
Soybean	51	4597	0	654	4687	3	24332	4788	117	1021	5107	5
Wheat	3673161	8136	29885	1933755	8275	16002	884107	8286	7326	3235584	7552	24434
Barley	48009	2380	114	23257	2379	55	35890	2456	88	48896	2219	109
Gram	124031	2257	280	53322	2297	122	396388	2409	955	3296	2099	7
Masoor	142732	2257	322	53387	2297	123	152815	2409	368	42088	2099	88
Pea	0	2257	0	0	2297	0	0	2409	0	0	2099	0
Peas and beans	78685	2257	178	16595	2297	38	244264	2409	588	11936	2099	25
Rice (Z)	238	10792	3	2666	11461	31	0	11300	0	24145	10600	256
Maize (Z)	11744	7111	84	26937	7278	196	0	7226	0	17557	6719	118
Moong (Z)	11800	6198	73	12478	6388	80	518	6264	3	15757	5878	93
Urd (Z)	22769	6198	141	14867	6388	95	0	6264	0	6796	5878	40
Rapeseed-mustard	105928	6850	726	198991	7027	1398	59048	6954	411	283729	5605	1590
Linseed	12097	6850	83	330	7027	2	13151	6954	91	167	5605	1
Sunflower	338	6850	2	2038	7027	14	256	6954	2	181	5605	1
Potato	113933	2934	334	170765	3004	513	2559	3198	8	193711	5301	1027
Tobacco	2671	2430	6	7773	2488	19	7	2613	0	24575	2279	56
Sugarcane	435431	16114	7016	451639	16450	7429	11189	18492	207	1321245	15502	20481
Cotton	27	7093	0	6	7456	0	0	7575	0	2905	6888	20
TOTAL	8622848		70478	4699919		38366	2607125		13790	7648556		64703

K = kharif, Z = zaid and TWR= Total Water Requirement

of Uttar Pradesh was estimated for the period of 2013-14 and it is presented in Table 2. Total water demand was computed for Eastern region, Central region, Bundelkhand region and Western region and it was found to be 70478, 38366,13790, 64703 MCM,respectively. From the Table 2, it was clear that highest crop water requirement was observed for Eastern region and lowest crop water requirement was found for Bundelkhand region. Out of total crop water requirement, the highest

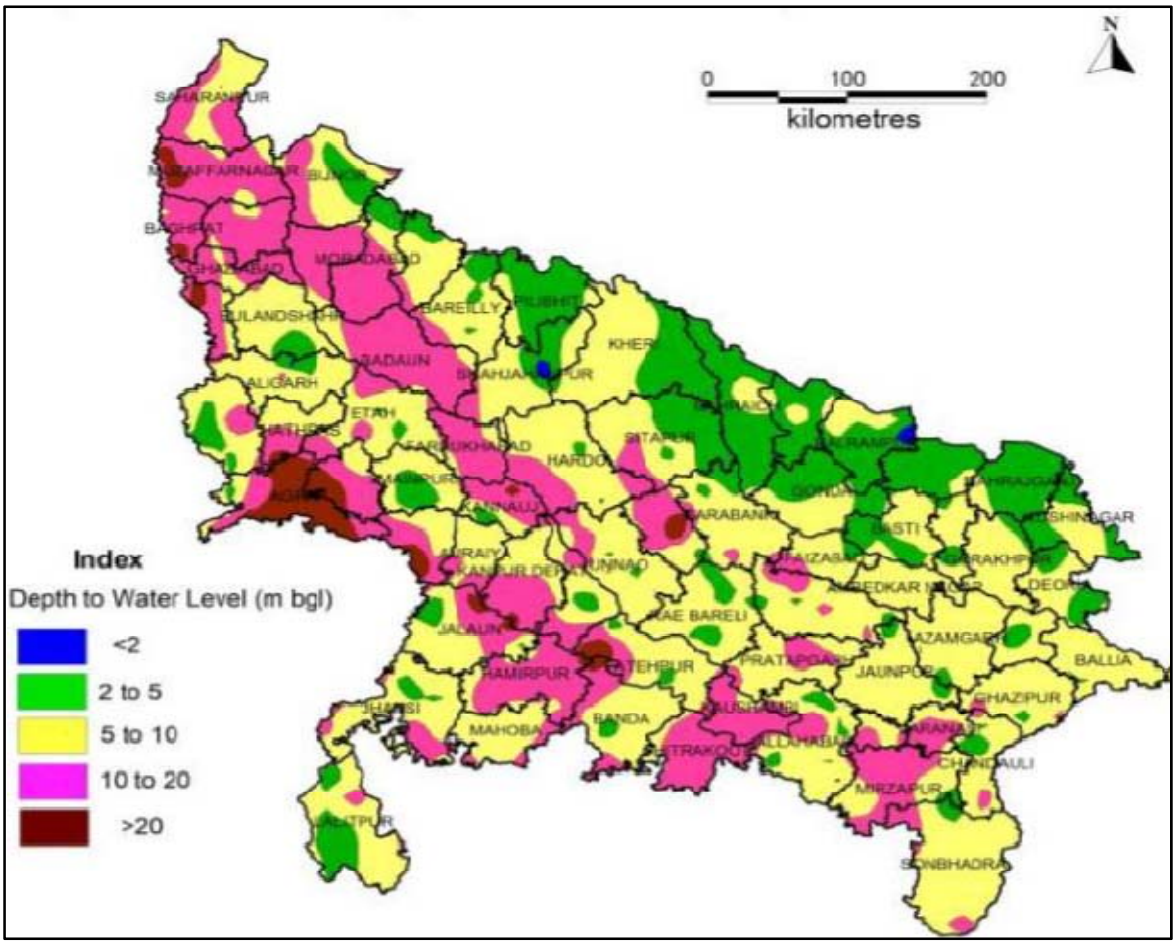

Fig. 1: Depth to Water Level Map of Uttar Pradesh (Pre-Monsoon 2016)

Table 3: Water requirement, water availability and groundwater draft for irrigation in different regions (MCM)

Year	Particulars		Eastern	Central	Bundelkhand	Western
2010-11	Water requirement	Green water	25562	10937	3555	19809
		Blue water	42116	26009	9235	45060
		Total water requirement	67678	36947	12791	**64869**
	Water availability	Ground water draft	16420	9659	2580	17338
		Annual replenishable fresh water	49177	28487	14390	46252
		Total water availability	65597	38146	16970	63590
2013-14	Water requirement	Green water	26790	11581	3585	19916
		Blue water	43688	26785	10206	44787
		Total water requirement	**70478**	**38366**	**13790**	**64703**
	Water availability	Ground water draft	17455	10431	2086	18768
		Annual replenishable fresh water	72023	32729	25814	44581
		Total water supply	89478	43160	27900	63349

share comes from wheat, rice and sugarcane in Eastern and Central region. In the Eastern region the share of crop water requirement for wheat, rice (k) and sugarcane was estimated to be 92.93 per cent of the total crop water requirement, whereas in case of Central region it was 87.64 per cent to total crop water demand. In the case of Bundelkhand region wheat was consuming highest water with 7326 MCM.

Apart from wheat urd (k), gram, til, rice (k), peas and beans crops were also consuming a considerable quantity of the water and the amount was 997, 955, 922, 724 and 588 MCM congruently. In Western region share of water requirement for growing wheat, sugarcane and rice (k) to total crop water requirement was estimated to be 88.79 per cent. In Western region, sugarcane was alone contributing 31.65 per cent of total crop water requirement of the region. The share of water requirement for rice cultivation in Eastern, Central, Bundelkhand and Western region was estimated to be 40.58, 26.57, 5.25 and 19.38 per cent, respectively.

Among the *kharif* pulses, urd (k) was found the maximum water demanding crop (997 MCM) in the Bundelkhand region as compared to other regions of Uttar Pradesh.

In the Eastern region moong (k) was showing least water requirement (6 MCM) compared to other regions. Among oilseed crops til registered huge water demand (922 MCM) than other oilseed crops in Bundelkhand region. In the contrary soybean was depicting lowest water requirement (0.23 MCM) in Eastern region as compared to other regions of Uttar Pradesh.

Among the *rabi* pulses, gram required highest water demand (955 MCM) in Bundelkhand region, while lowest water demand was observed in Western region. In *rabi* oilseeds, rapeseed-mustard was depicting major water demand in the western region (1590 MCM) while least water demanded by linseed in the same region.

Among zaid cereal crops rice (z) was recorded the maximum contribution in total water demand in the Western region and lowest in Eastern region. In zaid season sunflower was found to be maximum water demanding crop in Central region, while it was also showing least water requirement in the Western region.

Region-Wise Agricultural Water Demand and Water Availability

Total water demand for various crops in different regions of Uttar Pradesh were estimated in term of blue (irrigation water) and green (rain-water directly taken by the plant) water and discussed. Here we tried to find out region-wise water availability, water demand for crop production and gap between the demand and supply and it is presented in Table 3.

During 2010-11, the green water (plant/crop use this water directly at the time of rainfall) demand was estimated to be 25562, 10937, 3555 and 19809 MCM in the Eastern, Central, Bundelkhand and Western region, respectively. The blue water (water applied by the farmers to the crop) demand was estimated to be 42116, 26009, 9235 and 45060 MCM for Eastern, Central, Bundelkhand and Western region, respectively. Total water demand (both blue and green water) was estimate to be 67678, 36947, 12791 and 64869 MCM for Eastern, Central, Bundelkhand and Western region, respectively. Against total water demand, total water supply from groundwater draft for irrigation purpose and annual replenishable fresh water was estimated to be 65597, 38147, 16970 and 63590 MCM, for Eastern, Central, Bundelkhand, Western region, respectively.

During 2013-14, total water demand for crop production was estimated to be 70478, 38366, 13790 and 64703 MCM for Eastern, Central, Bundelkhand and Western region, respectively. Against to the total water demand for crop production, total water supply from both sources was found to be 89478, 43160, 27900 and 63349 MCM for Eastern, Central, Bundelkhand and Western region, respectively. The annual water availability was more than the demand was found for Eastern, Central and Bundelkhand region, whereas in case of Western region water demand for crop production was more than the water supply from all the sources.

The scanty rainfall in Bundelkhand region impedes irrigation development. Micro-irrigation techniques (drip and sprinkler systems) have not been adequately publicized in all regions of Uttar Pradesh particularly in Bundelkhand region. These water conservation technologies need to be appropriately incentivized and promoted by the state government in the water-scarce regions of the state, especially in Bundelkhand and Western region which are

relatively more water-stressed than the rest of State, to encourage their adoption. Encouraging farmers for crop diversification (by including less water demanding crops in cropping pattern) as well as adoption of water saving technologieswhich will ensure wider irrigation coverage and sustainable use of available ground water resources for improving agricultural production and growth.

CONCLUSION

Expansion of irrigation facilities helped farmers to diversify their crop production and intensify the crop production over a same piece of land. It also helped farmers to adopt improved agronomic practices including use of high yielding varieties, chemical fertilizers and plant protection measures to harness the potential of land and enhance their economic status. This helped country to becomeself-sufficient on the front of foodgrain production. After success of Green Revolution Technologies in mid-1960 in the country, policy makers, researchers and Government advocated farmers to allocate more and more area under the crops without considering one of the most important and scarce natural resources i.e. water. Resulting to this many regions of the country is now facing the problem of water scarcity.

The climatic factors that responsible for the crop water demand are temperature, wind velocity, relative humidity, sunshine and rainfall. Beside climatic factors, other factors responsible for the enhancing crop water demand are crop variety, crop duration, soil structure, water percolation rate etc. also playing an important role in crop water requirement. Total water demand was computed for Eastern region, Central region, Bundelkhand region and Western region and it was found to be 70478, 38366,13790, 64703 MCM, respectively. Out of total crop water requirement, the highest share comes from sugarcane, rice and wheat in Eastern and Central region.

In the Eastern region the share of crop water requirement for sugarcane, rice (k) and wheat was estimated to be 92.93 per cent of the total crop water requirement, whereas in case of Central region it was 87.64 per cent to total crop water demand. In Western region share of water requirement for growing sugarcane, rice (k) and wheat to total crop water requirement was estimated to be 88.79 per cent. In Western region, sugarcane was alone contributing 31.65 per cent of total crop water requirement of the region. The share of water requirement for rice cultivation in Eastern, Central, Bundelkhand and Western region was estimated to be 40.58, 26.57, 5.25 and 19.38 per cent, respectively. During 2013-14,the annual water availability was more than the crop water demand was found for Eastern, Central and Bundelkhand region, whereas in case of Western region water demand for crop production was more than the water supply from all the sources.

Based on results of present study, the following recommendation can be made for the water policies: [1] Government should make policy for encouraging farmers for adoption of appropriate crop diversification (by considering water resource availability in particular region) as well as water saving technologies which will ensure wider irrigation coverage and sustainable use of available ground water resources for improving agricultural production and growth and[2] In Bundelkhand region farmers should grow less water demanding crops (barley, rapeseed-mustard and gram *etc.*) in *rabi* season and pulses & oilseed crops, jowar and bajra in *kharif* season that can utilize green water efficiently and less dependent on the blue water/ irrigation water.

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