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RESEARCH ARTICLE

Relationship between Cotton Production and Virtual Water in India

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ABSTRACT

Water is an essential natural resource to live on the earth. We have about 2/3rd of the water on the planet. Still, there is a scarcity of water. It is due to the uneven distribution of water on the earth in many places because of the over-exploitation and the withdrawal of water for personal and agricultural use. This study is conducted to know the impact of the yield on virtual water use in cotton production. The secondary cotton production data was collected from the INDIASTAT. The water requirement for the cotton is calculated by the CROPWAT 8.0 model (software of the FAO). The regression analysis is done to calculate the result. The result is calculated by a statistical package in the social sciences. The result of the study shows that if the farm's yield increases, the virtual water per unit will decrease. The implications of this paper are that to reduce the water requirement for cotton production, India needs to increase the production capacity of cotton, resulting in a decrease in the water requirement. The result of this study can be implied anywhere to get a reduction in the virtual water use in any type of farm product.

Key words: Agriculture, cotton production, CROPWAT, virtual water, water efficiency

INTRODUCTION

India is an agricultural country. Agriculture is a prominent part of the employment of the Indian population. According to Statista,[1] in 2019, 42.6% of India's labor force was involved in agriculture, while the remaining half was evenly divided between industry and services. For agricultural products, there is a need for various inputs and conditions like weather, soil, temperature, tools and techniques, fertilizers, pesticides, and favorable conditions. Besides these inputs and conditions, one crucial thing is required to produce agricultural products, i.e., water. Without water, we cannot imagine anything, including agriculture. The water that is used in the production of industrial and agricultural products is called virtual water. Water is the most important thing for all living beings to survive. We can say that water is the reason why Earth is the only place where life can exist. This all-purpose solvent is one of the most important things we have on Earth. Without water, no one would be able to live. It covers almost 70% of the earth, after all. Even though there is a lot of water, we need to realize that not all of it is safe to drink. Every day, we use water for things that are very important to us. As the population is increasing, safe drinking water availability is decreasing. More water is needed for agricultural production due to the increase in population, resulting in more water withdrawal.[2]

Cotton is a commercial fiber crop that is grown around the world. It is estimated that cotton farming started 7000 years ago, and cotton farming and woven into clothes began in the Indus Valley 3000 years BC.[3] India is the largest cotton-growing nation in land and the second largest in output.[4,5] About 10000–20000 liters of water are used to produce 1 kg of cotton, depending on climatic and soil conditions. The

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world's consumption of cotton products needs 256 Gm3 of water per year for the years 1997–2001.[6]

THEORETICAL FRAMEWORK

Indian Cotton Production

Cotton has been grown in India since at least 3000 BCE, making it one of the oldest crops in the world.[3,7] India is one of the biggest cotton-growing nations. More than 60 million people in India are directly or indirectly employed by the cotton textile and processing industries because of their involvement in farming as well as through direct or indirect employment opportunities provided by cotton textiles and processing.[8] Cotton output in India has increased in recent years, giving the country an advantage in domestic and international markets. Although the United States only generates 14% of the cotton grown worldwide, it exports 38% of what it produces. The United States exported 86% of its output, compared to India's 22%, but the United States had a production cost 5–6 times higher than India.[9] Cotton production has increased due to the adoption of Bt cotton.[2,10-12] Still, our cotton yield in India is less than the world's average yield. It is <500 kg lint/ha, while the average yield of the world's cotton production is 792 kg lint/ha.[8] It can be increased by changing the planting date,[13] and using a high-density planting strategy to cultivate types with a short growing period.[8] The government must take the required steps to improve productivity through research, mechanization, and increased exports through increased production.[14]

Virtual Water Efficiency

This virtual water is the water used to produce food and fiber, as well as energy and other non-food products. Agricultural output accounts for around 87% of the world's freshwater use.[15] Due to rising food demand in water-scarce areas, agricultural water output must be improved.[2,15] For 1 kg of cotton, production water is required in the range of 10,000 to 20,000 liters, depending on the soil texture, temperature, humidity, etc. According to the Water Footprint Network, 1 kg of cotton production requires 22,500 liters of water. At the same time, the world's average water requirement for 1 kg of cotton production is 10,000 liters.[16,17] Increasing the cotton yield is needed to reduce the virtual water use per unit. It reduces irrigation water loss while preserving crop output to improve irrigation water productivity.[18] It is possible by using modern technology,[14,19] changes in planting time,[13] high-density planting techniques, and, according to the country's weather, G. arboreum cotton should be prioritized.[8]

Objectives

The objective of the research paper is to determine the impact of cotton yield on virtual water.
Null hypothesis H_0: There is no relationship between yield and virtual water use.
Alternate hypothesis H_1: There is a relationship between yield and virtual water use.

RESEARCH METHODOLOGY

Data Collection

The secondary data are collected regarding the cotton from the INDIASTAT website, and the data of the virtual water is calculated through the CROPWAT 8.0 model (software of the FAO). Regarding the water use, the actual water requirement is calculated only as the sum of adequate rainfall and actual irrigation requirement.

Virtual Water Calculation

AVW=GVW+BVW
AVWR=actual virtual water requirement (in mm)
GVW=green virtual water (in mm)
BVW=blue virtual water (in mm)

Virtual Water Required for a Hectare

CROPWAT model Calculated virtual water in mm, which is calculated in liters by multiplying 10,000 for one hectare of area. Virtual water needed per kg of cotton was calculated by dividing the total production in hectares.
AVWR (in mm) X 10,000= Virtual water (in liters in a hectare).

Virtual Water Required for a kg Production

Virtual water in a hectare/total production in a hectare.

Data Analysis Technique and Tool

Data are analyzed using a statistical package for social science. The regression model is used in data analysis to know the impact of yield on the use of virtual water in cotton production.

Data Analysis

The table shows the regression analysis performed to check the impact of yield on the virtual water use in cotton production. The yield and virtual water data of different states are shown in the appendix.
The regression equation is: Y = a+bX
Where,
Y = Virtual Water (Dependent Variable)
a = Constant
b = Intersect
X = Yield (Independent Variable)
The value of R Square is depicting the variation in virtual water caused by the yield. The value of the constant shows that if all the independent variables are set to zero, the VW unit will be fixed as written in the column of the constant. The β values of all states are statistically significant at 5%. The level of significance is $P < 0.000$. Therefore, there is a significant impact on virtual water when there is a change in yield. It shows that the increase in one unit of yield will result in a decrease of β units of virtual water.
The above table calculates the relationship between yield and the virtual water use in the cotton production state-wise and the cotton production at the country level. It shows the impact of yield on the use of virtual water. How virtual water per unit decreased as the yield increased. There is a negative relationship between yield and virtual water use.
It can be seen in the above table that in each case, there is a significant impact of the yield on the use of virtual water. So here, we can generalize that if the yield increases, virtual water per unit use decreases. There is the highest impact on the use of virtual water in Punjab, Andhra Pradesh, Gujarat, and Haryana, and the least significant impact of the yield on virtual water is in Rajasthan, Madhya Pradesh, Maharashtra, and Orissa.

CONCLUSION AND IMPLICATIONS

India is one of the top cotton-producing and exporting countries in the world. Cotton farming requires much water to be grown; it is about 10000–20000 liters, depending on the situation of the zone, like climatic conditions, soil conditions, etc. According to the Water Footprint Network, Indian cotton production needs 22,500 liters of water to produce 1 kg of cotton, which is much higher than the world's average water use. The study's findings are that if the cotton yield increases, the water requirement for cotton production decreases. It means that to reduce the water requirement for cotton production, India needs to increase the production capacity of cotton, resulting in a decrease in the water requirement. The result of this study can be implied anywhere to get a reduction in the virtual water use in any type of farm product.

States	R-square	Constant (a)	Standardised β	t-value	*P*-value	Decision	Significant difference
Gujrat	0.860	59150.302	−0.927	−10.792	0.000	Rejected	Yes
Haryana	0.847	32480.904	−0.921	−10.275	0.000	Rejected	Yes
Karnataka	0.847	46800.278	−0.920	−10.266	0.000	Rejected	Yes
Maharashtra	0.806	61160.484	−0.898	−8.872	0.000	Rejected	Yes
Madhya Pradesh	0.772	49272.343	−0.879	−8.031	0.000	Rejected	Yes
Orissa	0.812	36811.583	−0.901	−9.065	0.000	Rejected	Yes
Punjab	0.966	22756.230	−0.983	−23.282	0.000	Rejected	Yes
Rajasthan	0.736	67372.892	−0.858	−7.287	0.000	Rejected	Yes
Tamil Nadu	0.859	44907.335	−0.927	−10.758	0.000	Rejected	Yes
Andhra Pradesh	0.935	37552.327	−0.967	−16.495	0.000	Rejected	Yes

Source: Calculated by SPSS (statistical package for social science)

Policy Implications

As water demand is increasing due to the growing population, agricultural production needs more places to be irrigated, causing more production and irrigation demand. According to many resources, water quality and quantity are degrading and decreasing yearly. To safeguard the nation and prevent water depletion at a higher rate, the government needs to address the agricultural problem by improving the yield of farm products. It is only possible with government intervention. The government should take the necessary steps to increase farm productivity, like giving subsidies for farm mechanization, promoting high-yield varieties, and selecting seeds according to climatic conditions. Promoting the crops as per the region with high yields in the particular area.

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APPENDIX

Gujarat				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	1539.3	2085.6	230	35182.6
2001	1615.3	1161.4	122	66327.9
2002	1749.9	1702.7	165	49042.4
2003	1634.8	1684.6	175	46240
2004	1641	4026.9	417	19405.3
2005	1906.3	4724.8	421	19220.9
2006	1906	6772	604	13397.4
2007	2390	8787	625	12947.2
2008	2422	8276	581	13927.7
2009	2353.6	7013.8	507	15960.6
2010	2464	7986.3	551	14686
2011	2633	10400	671	12059.6
2012	2962	12000	689	11744.6
2013	2497	8850	603	13419.6
2014	2519	10150	685	11813.1
2015	2773	10500	644	12565.2
2016	2722	9400	587	13785.3
2017	2382	8575	612	13222.2
2018	2624	10187	660	12260.6
2019	2660	6279	401	20179.6
2020	2655	8617	552	14659.4
Average	2288.06	7103.77	500.095	21049.9

Green VW in one hectare=444.575*10000=4445750
Blue VW in one hectare=364.625*10000=3646250

Haryana				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in ltrs**
2000	544	1304	408	15806
2001	555	1383	424	15210
2002	630	722	195	33072
2003	518	1038	341	18912
2004	526	1405	454	14205
2005	621	2075	568	11354
2006	583	1499	437	14757
2007	530	1814	582	11081
2008	483	1885	663	9727
2009	455	1858	694	9293
2010	507	1926	646	9983
2011	492	1750	605	10660
2012	641	2650	703	9174
2013	614	2500	692	9319
2014	536	2302	730	8834
2015	648	2300	603	10695
2016	615	993	274	23536
2017	570	2041	609	10589
2018	665	1627	416	15502
2019	708	2013	483	13352
2020	723	2484	584	11043
Average	579.238	1789	529.095	13624

Green VW in one hectare=415.1*10000=4151000
Blue VW in one hectare=229.8*10000=2298000

Karnataka				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	545.7	664.5	207	30716.2
2001	581.8	855.2	263	24175.9
2002	608.5	612.4	171	37182.7
2003	392.7	330.9	143	44463.3
2004	316.7	264.6	142	44776.4
2005	521	688	224	28385
2006	413	554	228	27887.1
2007	376	610	276	23037.1
2008	403	778	328	19384.9
2009	409	866	360	17661.8
2010	457	868.2	323	19685
2011	545	1200	374	17000.7
2012	554	1200	368	17277.9
2013	485	1255	440	14450.6
2014	662	1875	481	13218.8
2015	875	2311	449	14160.9
2016	642	2000	530	11996.7
2017	510	1010	337	18867.2
2018	547	1844	573	11096.4
2019	718	1400	331	19209.2
2020	817	2330	485	13109.8
Average	541.876	1119.85	334.905	22273.5

Green VW in one Hectare=471.65*10000=4716500
Blue VW in one hectare=164.175*10000=1641750

Maharashtra				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in letres**
2000	3254	3099.5	162	41205.2
2001	3076.9	1798.8	99	67426.8
2002	3104.7	2689.6	147	45409.9
2003	2800	2596	158	42248.4
2004	2762	3080	190	35132.9
2005	2840	2939	176	37927.6
2006	2875	3160	187	35696.5
2007	3107	4618	253	26384.4
2008	3195	7015	373	17896.1
2009	3146	4752	257	25973.7
2010	3495	5859	285	23421.9
2011	3942	8500	367	18188.7
2012	4125	7200	297	22475.6
2013	4146	7655	314	21258.8
2014	4192	8834	358	18645.9
2015	4190	7000	284	23504.4
2016	4207	7500	303	22030.5
2017	3800.4	10618.8	475	14053.2
2018	4351	6094	238	28047.3
2019	4218	6593	266	25094.9
2020	4491	6639	251	26594.6
Average	3586.57	5630.51	259.048	29458

Green VW in one Hectare=504.775*10000=5047750
Blue VW in one Hectare=162.75*10000=1627500

Madhya Pradesh				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	487.7	417.2	145	39508.1
2001	497.7	245.1	84	68198.5
2002	541.5	394.3	124	46199
2003	559.3	390.1	119	48140.1
2004	564.1	639	193	29682.2
2005	576.1	626.1	185	30965.8
2006	620.4	745.1	204	28081.7
2007	638.9	828.6	220	26039.4
2008	630.4	864.8	233	24586.6
2009	624.8	856.1	233	24586.6
2010	610.9	855.3	238	24070
2011	650	2000	523	10953.5
2012	706	2000	482	11885.2
2013	608	2200	615	9314.91
2014	514	1730	572	10015.2
2015	547	1750	544	10530.6
2016	563	1800	544	10530.6
2017	599	2050.69	582	9843.08
2018	603	1620	457	12535.4
2019	614	2329	645	8881.66
2020	650	1646	430	13322.5
Average	590.752	1237.49	351.048	23708.1

Green VW in one Hectare=430.8*10000=4308000
Blue VW in one Hectare=142.067*10000=1420670

Orissa				
Year	**Area (In '000' Hectares)**	**Production (in '000' Bales of 170)**	**Yields (in Kg/Hectare)**	**Total VW in Kg in letres**
2000	38.1	61	272	20939.3
2001	40.4	65.3	275	20710.9
2002	63.3	54.7	147	38744.9
2003	29.5	49.9	288	19776
2004	36.7	88.2	409	13925.4
2005	45.9	111.2	412	13824
2006	56.6	144.8	435	13093.1
2007	50.6	107.9	363	15690.1
2008	50.1	124.7	423	13464.5
2009	57.9	146.6	430	13245.3
2010	54	147.2	464	12274.8
2011	74	250	574	9922.47
2012	102	325	542	10508.3
2013	119	400	571	9974.61
2014	124	299	410	13891.5
2015	127	400	535	10645.8
2016	125	300	408	13959.6
2017	136	382	478	11915.3
2018	145	408	478	11915.3
2019	157	455	493	11552.7
2020	170	579	579	9836.79
Average	85.8143	233.31	427.905	14752.9

Green VW in one Hectare=355*10000=3550000
Blue VW in one Hectare=214.55*10000=2145500

Punjab				
Year	**Area (In '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	476	952	340	17032.4
2001	474	1199	430	13467.4
2002	607	1307	366	15822.4
2003	449	1083	410	14124.4
2004	452	1478	556	10415.5
2005	509	2087	697	8308.46
2006	557	2395	731	7922.02
2007	607	2678	750	7721.33
2008	604	2355	663	8734.54
2009	527	2285	737	7857.53
2010	511	2006	667	8682.16
2011	530	2100	674	8591.99
2012	560	2300	698	8296.56
2013	480	2000	708	8179.38
2014	446	1968	750	7721.33
2015	420	1600	648	8936.73
2016	339	750	376	15401.6
2017	285	1031.03	615	9416.26
2018	291	1283	750	7721.33
2019	268	1222	775	7472.26
2020	248	1206	827	7002.42
Average	459.048	1680.24	627.048	9944.19

Green VW in one Hectare=326.65*10000=3266500
Blue VW in one Hectare=252.45*10000=2524500

Rajasthan				
Year	**Area (in '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	583.2	984.2	287	26797.9
2001	510.1	805.4	268	28697.8
2002	510.1	280.8	94	81819.1
2003	385.7	252.4	111	69288.3
2004	343.5	709	351	21911.7
2005	437.8	764.6	297	25895.6
2006	471.6	880.5	317	24261.8
2007	349.6	746.8	363	21187.3
2008	369.2	862.2	397	19372.8
2009	302.5	725.7	408	18850.5
2010	444.4	903.1	345	22292.8
2011	335	900	457	16829.3
2012	470	1335	483	15923.4
2013	450	1400	529	14538.8
2014	393	1287	557	13807.9
2015	487	1527	533	14429.6
2016	448	1214	461	16683.3
2017	471	1401.92	506	15199.6
2018	584	1893	551	13958.3
2019	629	2026	548	14034.7
2020	760	2788	624	12325.3
Average	463.557	1127.93	404.143	24195.5

Green VW in one Hectare=264.6*10000=2646000
Blue VW in one Hectare=504.5*10000=5045000

Tamil Nadu				
Year	**Area (in '000' hectares)**	**Production (in '000' bales of 170)**	**Yields (in kg/hectare)**	**Total VW per kg in litres**
2000	178.3	339.5	324	25017.47
2001	169.9	316.6	317	25569.91
2002	187.8	326.1	295	27476.81
2003	75.6	83.5	188	43115.21
2004	97.8	122.7	213	38054.74
2005	129.4	194.8	256	31662.73
2006	140.5	213.3	258	31417.29
2007	100.3	220.9	374	21672.89
2008	99.3	200.7	344	23562.97
2009	114.5	187.7	279	29052.54
2010	104.1	225	368	22026.25
2011	122	450	627	12927.69
2012	133	450	575	14096.8
2013	128	500	664	12207.32
2014	152	408	456	17775.57
2015	187	686	624	12989.84
2016	142	369	442	18338.6
2017	142	359	430	18850.37
2018	183	445	413	19626.3
2019	133	269	344	23562.97
2020	170	418	418	19391.53
Average	137.5952	323.0857	390.905	23256.94

Green VW in One Hectare=694.633*10000=6946330
Blue VW in one Hectare=115.933*10000=1159330

Andhra Pradesh				
Year	**Area (In '000' Hectares)**	**Production (in '000' Bales of 170)**	**Yields (in Kg/Hectare)**	**Total water used per Kg in litres**
2000	1039	1595	261	26383
2001	1021.7	1662.7	277	24859
2002	1108	1877	288	23910
2003	803.3	1085.7	230	29939
2004	817	1890	384	17932
2005	1178	2190	316	21791
2006	1033	2108	347	19844
2007	972	2181	381	18073
2008	1134	3491	523	13166
2009	1399	3569	434	15866
2010	1467	3227	374	18412
2011	1879	5300	483.8	14233
2012	1879	4900	476	14466
2013	2400	7350	542.5	12693
2014	2389	6956	452.5	15218
2015	2534	6641	482.5	14272
2016	2439	5549	416.5	16533
2017	1881	5008	489.5	14067
2018	2543	7282	507.5	13568
2019	2459	5338	382.5	18003
2020	2784	9341	597.5	11525
Average	1674.24	4216.257	411.7048	17845

One hectare field green water requirement=569.38*10000=5693800
One hectare field blue water requirement=119.22*10000=1192200
Andhra Pradesh and Telangana both are merged due to partition after 2010