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Abstract: *The production of maize ethanol, a significant biofuel source, has garnered attention due to its potential environmental implications, particularly regarding water usage. This investigates the water footprint of maize ethanol, considering both direct and indirect water consumption throughout the production process. Utilizing the water footprint assessment framework, we evaluate the blue water (ground and surface water) and green water (rainwater which stored intothe soil) usage associated with maize cultivation, processing, and transportation for ethanol production. Our findings highlight the substantial water footprint of maize ethanol, emphasizingthe importance of water-efficient agricultural practices and sustainable water management strategies in mitigating its environmental impact. This paper analyzed "advanced bioethanol" potential from maize species and evaluated its environmental water footprint in India. Understanding the water footprint of maize ethanol is crucial for informing policy decisions,guiding agricultural practices, and promoting the development of more sustainable biofuel production systems.*

Keyword: Biofuel, Cropwat, Maize, Water Footprint, Water Sustainability.

1. Introduction

Maize is India's 3rd most important crop (after rice and wheat) regarding area covered and share of total food grains production. Maize is cultivated in nearly all agri-ecological areas in the country. Millions of gallons of water are consumed and polluted every year due to modern human activities, including industrialization, climate change impacts, growth of population and urbanization. Taking these into consideration impacts, questions such as protecting and improving freshwater resources preventing water pollution Goodly duty sharing between different sectors approximately 70% of the world's water is used in farming. Utilizing advanced bioethanol can reduce emissions, but the EU's capacity to produce enough of it will not allow it to meet its 2030 target of using 3.5% of advanced biofuels in transportation. Moreover, the land and water footprints associated with this use of advanced bioethanol are not less than those of conventional bioethanol. Industries also use and pollute large amounts of water. There is disconnected between the water needs of these industries and the water needed to sustain natural life and ecosystems. [1-8]

One of the biggest gaps in water footprint (WF) measurement is the lack of knowledge about the cultivated area of an agricultural crop pattern. Thus, the area that should be employed for crop cultivation should be determined using remote sensing. The WF can offer fresh perspectives on the increasing strain on the world's freshwater resources as well as potential remedies. The concept of Water Footprint (WF) was first presented by Arjen Hoekstra at the UNESCO-IHE in 2002.[9] WF is calculated by dividing the volume of water used and/or tainted throughout the course of the hours .[10] This idea displays the amount, kind, and timing of water use. Where it was applied within this framework, blue, green, and grey water footprints (WFs) can be characterized as three elements within a multifaceted indicator of water quality and use. [11] BlueWF, which is commonly associated with freshwater, is the total amount of freshwater resources, subsurface and surface, needed to produce the agricultural goods. The total amount of rainwater used to grow crops is known as green WF. In both irrigated and rain-fed agriculture, green WF is important. [12]The amount of nutrients in fertilizers used in sewage, industrial effluent and agricultural is the main cause of grey wastewater flux (WF), an indication of contaminated water [13-14]. It is among the crucial variables that can be applied to the nitrate-vulnerable zone's land management. Whatever the location of product consumption, the production WF is based on the volume of water used for agricultural and industrial uses. Additionally, it offers insight into the appropriateness and sustainability of water use. [15]Agricultural WF has been shown to have the largest contribution in WF studies. As a result, determining and assessing WF resulting from agricultural operations is crucial for determining how sustainable water resources .[16] WF studies, in particular, are predicated on employing crop models to calculate and analyze the WF of crops at different scales. [17-18]

2. Materials and Method

Required meteorological data were collected using the CLIMWATS climatic database, which was created in collaboration with the unit of FAO's water development and management and the department of climate change and bioenergy (Water footprint.org). The crop information was collected from Shuats, Prayagraj Department of Agronomy. The Uttar Pradesh Statistical Abstract provided the average production statistics needed. CROPWAT 8.0 was used to calculate the required Water Footprint.

3. Data Study

The state of Uttar Pradesh's six districts housed weather stations that recorded the monthly mean values of the highest and lowest temperatures, relative humidity, direction of wind, number of daylight hours, and rain [19]Long-term meteorological data was also examined using the CLIMWATS climatic database, which was created in collaboration with the unit of FAO's water development and management and the department of climate change and bioenergy (Water footprint.org). Shuats, Prayagraj Department of Agronomy provided the crop information. This contained details on the length of the several developmental stages, the dates of planting and harvesting, and the properties of the soil. It was believed that Prayagraj might be used in any field. The crop data were acquired from Allen et al, 1998 [20].In order to calculate the crop coefficient (Kc) values for the maize crop [21] The Uttar Pradesh Statistical Abstract provided the average production statistics needed .

4. Data Source

Data on the average monthly high and low temperatures, relative humidity, speed of wind, number of hours of daylight, and rain were collected from local meteorological stations situated in six districts throughout Uttar Pradesh [22]. The CLIMWATS climatic database, a joint publication of the FAO's water development and management unit and the climate change and bioenergy unit (Water footprint.org), was also used to analyze long-term meteorological data. Information on crops was gathered from the Department of Agronomy, Shuats, Prayagraj,In order to determination of crop coefficient (Kc) values for the maize crop, the values for the crop were obtained from Allen et al., 1998 [23] as well as used to determine the crop coefficient (Kc) values for the maize crop. For the study period (2014–2021), data on average yield needed to calculate a crop's water footprint were obtained from the Statistical Abstract of Uttar Pradesh (GOI, http://updes.up.nic.in) [24].

5. Study Area

The study was conducted in the state of Uttar Pradesh, which is located, as figure 1 illustrates, between the longitudes of 84°39'E and 77°3'N and the latitudes of 23°52'N and 31°28'N. This state tops the nation in both population and area. The nine agroclimatic zones that make up the state's geography, climate, and terrain are as follows: According to Gulati et al. (2021) [25]. The study domain that was taken into account for determining the water footprint is displayed in Figure 1 below.

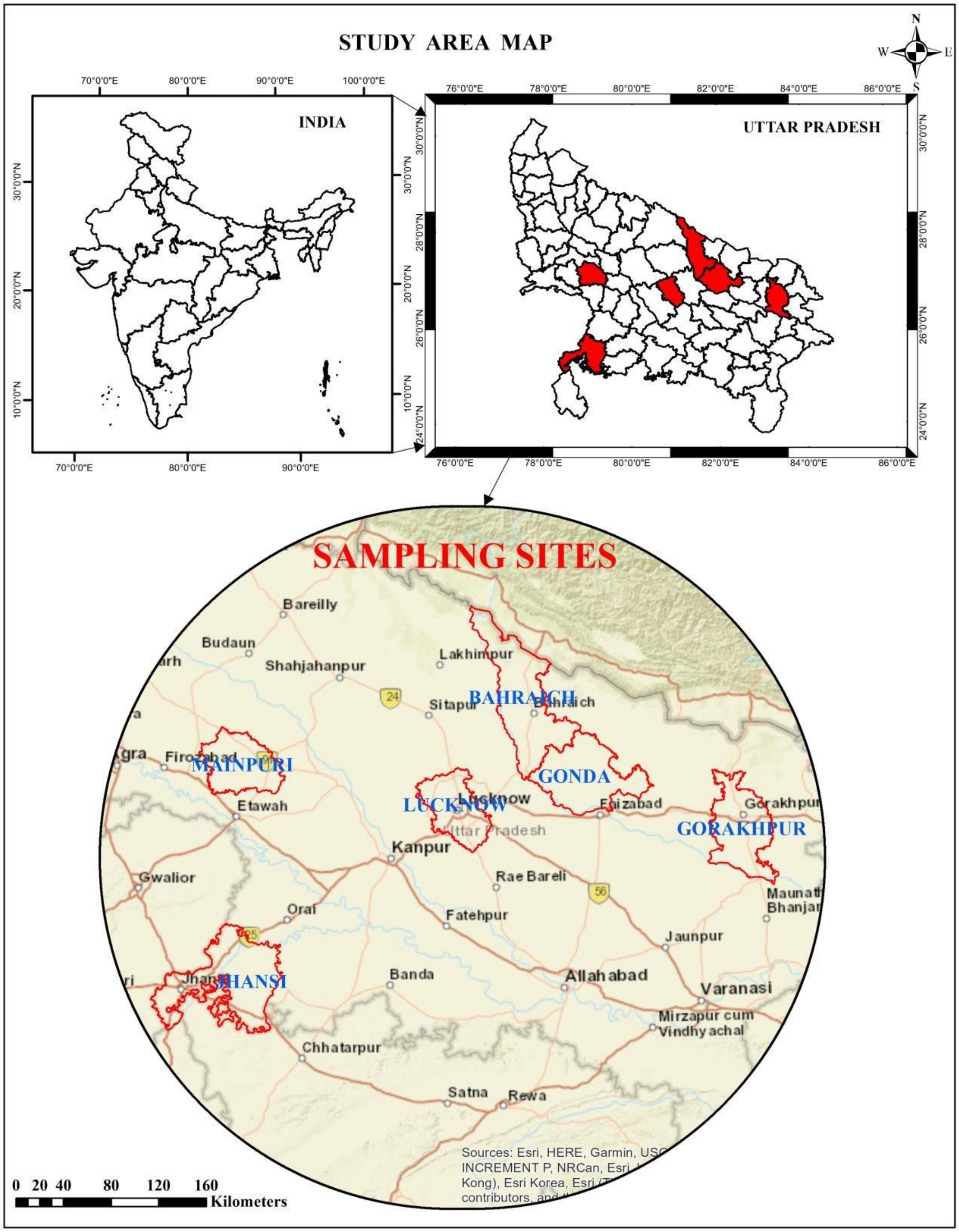


Fig. 1: Study region considered for estimation of Water Footprint

6. Methodology

This study's objective is to calculate the water footprint of producing ethanol from maze in the Uttar Pradesh districts of, Baharaich, Gonda, Gorakhpur, Jhansi, Lucknow and Mainpuri using the techniques described by Hoekstra et al. It is primarily calculated in three steps. First, the WF of the crop, in this case maize, is calculated. (Table 1) This serves as an input for the subsequent calculations of the WF of the byproduct maize and the water footprint of ethanol [26].A crop's water footprint is the summation of its green, blue, and gray water footprints. Equation 1 below illustrates how the Cropwat model 8.0 was used to calculate the crop's ultimate water footprint: crop evapotranspiration (ETc, mm/day) is divided by crop yield (Y, ton/ha) to determine crop water usage (CWU, m^3/ha). The process described in the WF manual is used to determine the blue and green water footprints [27].

$$WF_{blue,\ green} = \frac{\text{CWUblue,green}}{\text{Y}} = \frac{10 \times \sum_{d=1}^{lgp} ETblue,green}{Y} \quad (1)$$

According to equation 2, the rate of chemical application per hectare (AR, kg/ha) is multiplied by the leaching factor (), divided by the maximum acceptable concentration (Cmax, kg/m^3), less the pollutant under consideration's natural concentration (Cnat, kg/m^3) and finally divided by the crop yield (Y, ton/ha) (Suhail, 2017) [28].Is used to compute the crop's grey water footprint (WFgrey, m^3/ton). In this study, we only evaluated the nitrogen's grey water footprint, based on the assumption that 10% of the applied nitrogen fertilizer will typically be lost through leaching (Chapagain et al., 2006)[29]. The US-EPA suggests a criterion of 10 mg of nitrate per liter when tested as nitrate-nitrogen (NO_3-N), however the WHO and the European Union have set a threshold of 50 mg of nitrate (NO_3) per liter. In line with WHO guidelines, we employed a level of nitrate-nitrogen (NO_3-N) in this study of 50 mg/l (WHO, 2007).

$$WF_{grey} = \frac{(\propto \times \text{AR})/(\text{Cmax} - \text{Cnat})}{\text{Y}} \quad (2)$$

The water footprints of the input and output products are represented by WFprod[i], the processing step's water footprint is represented by WFproc[p], the product fraction is fp[p,i], and the value fraction is parameter fv[p]Chooyok et al., 2013)[30].

7. RESULT

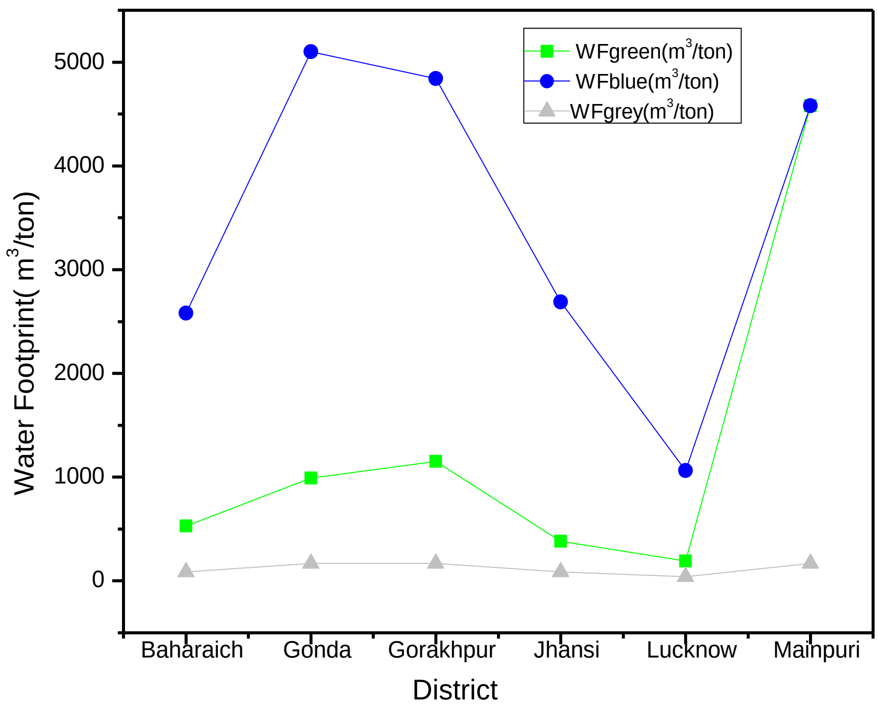
The three main steps in calculating the WF of making ethanol from maize are figuring out the water footprint of growing crops, the WF of generating, and the WF of making ethanol from Therefore, the first stage was calculating the water footprint of the maize crop for each of the six districts of Uttar Pradesh, as indicated in table 2.

Table: 1 Yield of Maize in the selected districts year-wise.

District	YIELD(ton/ha)							
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	Average
Baharaich	13	12	15	17	14	16	15	2
Gonda	12	12	12	13	12	13	12	1
Gorakhpur	15	14	13	6	10	13	5	1
Jhansi	7	9	9	7	11	4	6	1
Lucknow	9	12	16	12	15	17	26	2
Mainpuri	25	29	30	31	34	36	38	3

Table: 2: Calculated Water Footprint of Maize crop in selected districts

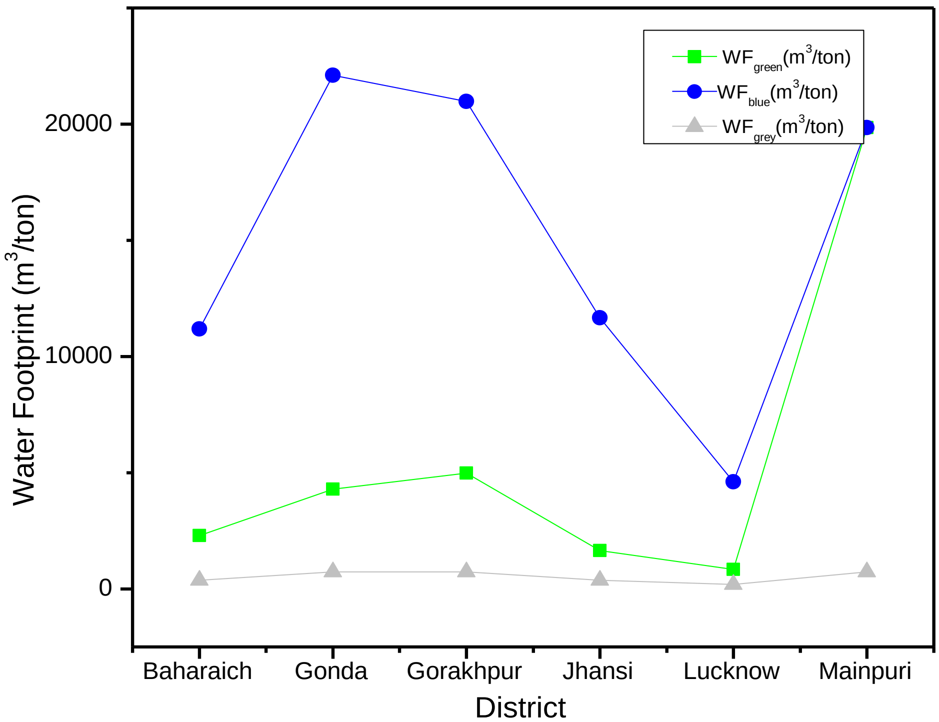
District	WF_{green}(m^3/ton)	WF_{blue}(m^3/ton)	WF_{grey}(m^3/ton)	WF_{total}(m^3/ton)
Baharaich	530	2580	85	3195
Gonda	990	5100	169	6259
Gorakhpur	1150	4840	169	6159
Jhansi	380	2690	85	3155
Lucknow	192	1062	42	1296
Mainpuri	4580	4580	169	9329



Graph 1: Calculated Water Footprint of Maize crop in selected districts

Table 3: Calculated Water Footprint (WF) in Ethanol Production

District	WF_{green} (m^3/ton)	WF_{blue} (m^3/ton)	WF_{grey}(m^3/ton)	WF_{total}(m^3/ton)
Baharaich	2297	11180	368	13845
Gonda	4290	22100	732	27122
Gorakhpur	4983	20973	732	22688
Jhansi	1647	11657	368	13672
Lucknow	832	4602	182	5616
Mainpuri	19847	19847	732	40426



Graph 2: Calculated Water Footprint (WF) in Ethanol Production

8. Discussion

Based on the study results, Mainpuri has the largest green WF (estimated at 4580 m^3/ton), whereas Gonda has the largest blue and gray water footprints (5100 and 169 m^3/ton, respectively) for maize production. (Table 3) It's possible that ineffective irrigation methods that cause a large amount of water loss are the cause of Gonda's high irrigation water demand and low yield per hectare. Investigations into ways to significantly reduce the Gonda water footprint are necessary for the purpose of future water security. To lessen the water footprint of maize grown in other locations, farmers and policymakers should support sustainable farming techniques. Adoption of such approaches by farmers can be greatly aided by incentives and education.

According to the study's findings, Gonda has the highest blue and grey WF for Maize production, measuring 5100 and 169 m^3/ton, respectively, whereas Mainpuri has the highest green WF, estimated to 4580 m^3/ton. The reason for Gonda's high water demand for irrigation and low yield per hectare may be due to inefficient irrigation techniques that result in significant water loss. For the sake of future water security, measures to considerably lower Gonda water footprint must be investigated. Farmers and officials should also encourage sustainable agricultural practices to reduce the water footprint of maize growing in other places aswell. Education and incentives for farmers can play a crucial role in adopting such practices. Second, while maize is a necessary component in the creation of ethanol, its water footprint may reflect present practices. Nevertheless, ethical wastewater treatment must be promoted. Reusing and treating wastewater can reduce its harmful impact on the environment and aid in resource conservation. . Last but not least, it was found that Mainpuri had the second-highest blue WF of ethanol production, at 19847 m^3/ton, behind Gorakhpur, with 20973 m^3/ton. Lucknow has the lowest blue water footprint of any place producing ethanol from maize (4602 m^3/ton), far lower than that of Gorakhpur and Gonda. . Consequently, the yield of ethanol production in Mainpuri may be increased, and programs for bettering water quality and utilization in districts like Gonda, Gorakhpur, and Mainpuri that displayed the greatest blue water footprint should be devised.Nevertheless, Mainpuri has the largest total green water footprint for the production of ethanol at 19847 m^3/ton, followed by Gonda and Gorakhpur at 4290 and 4983 m^3/ton, respectively. For the development of plants and the production of ethanol from maize harvests, Mainpuri, Gonda, and Gorakhpur may thus be preferred among the six districts under consideration. The water footprint of maize production, which is a crucial consideration for both farmers and consumers, emphasizes the overall environmental effect of our dietary choices and the need for sustainable practices to protect water resources availability for future generations.

9. **Conflict of Interest**

Authors declare no conflict of interest.

10. **Acknowledgement and Funding source**

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