Revolutionizing Water Footprint Assessment with Object Detection Models

*

Shikha Kushwaha
Department of Computer Science
KIET Group of Institutions
Ghaziabad, India
shikhakushwaha0912@gmail.com

Sumit Tiwari
Department of Computer Science
KIET Group of Institutions
Ghaziabad, India
sumittiwari00204@gmail.com

Shivanshu Srivastava
Department of Computer Science
KIET Group of Institutions
Ghaziabad, India
shivanshusrivastava160704@gmail.com

Suraj Jain
Department of Computer Science
KIET Group of Institutions
Ghaziabad, India
suraj.2125cs1087@kiet.edu

Dr. Vivek Kumar Sharma
Department of Computer Science
KIET Group of Institutions
Ghaziabad, India
vivek.sharma@kiet.edu

Abstract*—Some the acute environmental issues of the twentyfirst century include water supply and quality, and excessive consumption of freshwater. Solving these tasks, it is necessary to develop and apply new approaches and concepts to measure and control water use. The WF concept offered an integrated index for quantifying not only the direct and indirect water use but also in the processes of production and using of the goods and services. Expanding on previous WF assessment literature, this paper proposes the development of an easy-to-use mobile application that would enable users estimate and analyze the WF of ordinary products. The development of this app will work with IT technologies such as image recognition and minimal input data to deliver WF insights users to encourage sustainable water use behaviors. This tool will be an interactive means of integrating global datasets and consumption patterns as well as general and product-specific WFs; it can form a link between science-based data and real-life applications. This paper mainly focuses on arguing why WF has value as sustainability measurement, how it has been used across various sectors, and how the proposed methodological framework for the app could be beneficial for individuals who need to make choices regarding the use and conservation of water assets.*

I. INTRODUCTION

As a universal solvent, water is the most aptly named substance, a necessity for human life and the global economy, but due to over-population, urbanization, and Industrialization, the available fresh water sources are limited globally. This remains a challenge prevalent especially in the regions that experience significantly high demand for water, than what is obtainable in sustainable water sources such as India. [1].Therefore simple metrics like total withdrawal statistics, do not capture the intricate relationship between direct and indirect water use, pollution and globalization. To overcome these limitations, an improved approach based on the application of the water Footprint (WF) and the Water Footprint Assessment (WFA) framework will be proposed in this paper.

The Water Footprint first defined as a concept by Arjen Y. Hoekstra in 2002 takes into consideration the total amount of water consumed – even that used upstream in the production process. It considers three key components: green water (rainwater), blue water (water from surface and groundwater sources) and grey water (freshwater required for dilution of wastes). By combining these dimensions, WFA uncovers the water that is locked in the flow of goods and services and therefore in the global economy. It also combines local water use and international water trading as well as the importance of virtual water to overcome water scarcity and sustainable issues.

India itself has 18 percent of world population and only 4 percent of fresh water resources and therefore has a high level need for implementing new ideas /techniques of water management. Despite it using about 80 percent of its fresh water resource in agriculture every year, inefficient irrigation practices, lack of proper regulation in this country contributes to water stress and deterioration of environment. Problems are aggravated by lower regional variation of freshwater resources, regional fluctuations of monsoons, and climate change. At the same time, as India becomes increasingly involved in global agricultural exports virtual water trade and the above consequence suggest the need to address the issue of water security for the country.

This is where Water Footprint Assessment come in handy in a powerful approach in tackling these challenges. Sustainability performance of water users can in this way be assessed, opportunities for water savings as well as more effective investments be pinpointed, and successful reform models be eventually implemented. For instance, an analysis of the internal and external water scarcity has the potential to explain the impact of water consumption in production of exported goods on water available here as well as food security. Furthermore, evaluation of green and gray water components could help to elaborate more sustainable approaches to distribute rain-fed agriculture and minimize water pollution.

Pertaining to this background, this paper seeks to discuss the development of WFA as a model for sustainable water management with especial reference to India. Through most of its findings derived from literature review techniques, it is able to explain the viable application of WFA in current challenges including water rationing, resource management and environmental conservation. Thus, it is imperative for present study to establish that water future of India can be protected by implementing integrated water management approach along with WFA.

Fig. 1.1. Jeans Cycle

II. LITERATURE REVIEW

Mekonnen and Hoekstra quantified the green, blue and grey water footprint of global crop production for the period 19962005. Considering the water footprints of primary crops, we see that the global average water footprint per ton of crop increases from sugar crops (about 200 m3/ton), vegetables (300 m3/ton), roots and tubers (400 m3/ton), fruits (1000 m3/ton), cereals (1600 m3/ton), oil crops (2400 m3/ton), pulses (4000 m3/ton), spices (7000 m3 /ton) to nuts (9000 m3/ton). The water footprint varies, across different crops per crop category and per production region as well. When considered per ton of product, commodities with relatively large water footprints are: coffee, tea, cocoa, tobacco, spices, nuts, rubber and fibres.[2]

"The importance of water footprint is linked to the need of taking consciousness about water content in products and services and of the achievable changes in productions, diets and market trades. In early studies, the main aim of WFP study was to assess products' water trade on a global scale, while in the subsequent years, goal was the rigorous quantification of its three parts for specific crops and in specific geographical areas. In the recent assessments, similarities about the methodology and the employed tools emerged. About 78 percent of studies on WFP aimed to quantify Water Footprint, while the remaining 22 percent analysed methodology, uncertainty, future trends and comparisons with other footprints. About 33 percent studies quantified Water Footprint concerned with cereals, among which maize and wheat were the most investigated ones. In 46 percent of studies all the three components were assessed., Only blue or green and blue components were quantified in 37 percent studies.[3].

Makonnen and Gerbens-Leenes carried "the study on water footprint of global food production and found that agricultural production is the main consumer of water. The estimated global consumptive (green and blue) water footprint ranges from 5938 to 8508 km3/year. The water footprint is projected to increase by 22 percent due to climate change and land use change by 2090. Approximately 57 percent of the global blue water footprint is shown to violate the environmental flow requirements. Therefore, to improve the sustainability of water and protect ecosystems needful action may be done towards increasing water productivity, setting benchmarks, setting caps on the water footprint per river basin, shifting the diets to food items with low water requirements, and reducing food waste. The unsustainable footprint is dominated by only six crops, wheat, rice, cotton, sugar cane, fodder, and maize, and are located in only five countries, India, China, the US, Pakistan, and Iran. Population growth and dietary shifts, e.g., larger meat consumption, is expected to increase demand for water. The estimated global WF ranges from 5938 to 8508 km3/year, increasing by 20 percent-30 percent between 2010 and 2050".[4]

Study on water security analysis using water footprint approach was done in a river basin (Taranto, Italy) under human pressures by D'Ambrosio et. al. "Considering all the anthropogenic activities in the basin, including agriculture and the treated effluent disposed via wastewater treatment plants, the average annual water footprint was found to be 213.9 Mm3, of which 37.2 percent, 9.2 percent and 53.6 percent comprised respectively for green, blue and grey water footprint. The study revealed that pollution was the main factor affecting surface water security" (Weersoorya et al, 2021).[29] Turkey's blue and green WF of wheat production, consumption and virtual water trade between 2008 and 2019 was analyzed by Muratoglu. He found "total annual consumptive WF of wheat production and consumption of Turkey as 39.3 and 48.1 Gm3, respectively. The average blue and green VW contents of wheat production through Turkey are assessed to be 1161 and 748 m3/ton, respectively. The water footprint parameters of each province are calculated and discussed using climatic and agricultural data. VW transfer of Turkey's international wheat trade is also analyzed. Total national water saving is calculated as 7.8 Gm3/year which is mostly imported from Russia. Global VW deficit due to international wheat trade is calculated to be 1.76 Gm3/year" Muratoglu (2020).[5]

Firda and Purwanto[6] carried the study on Water Footprint Assessment in the Agro-industry. They studied that the sustainable use of water resources bring challenges related to the production and consumption phase of water intensive related goods in the agro-industry. The total water footprint from soy sauce production in Grobogan Regency Indonesia was studied which was equal to the sum of the supply chain water footprint and the operational water footprint. The assessment is based on the production chain diagram of soy sauce production which presenting the relevant process stages from the source to the final product. The result of this research is the total water footprint of soy sauce production is 1986.35 L/kg with fraction of green water 78.43 percent, blue water 21.4 percent and gray water 0.17 percent.

"Industrial sector is mostly accused for the increased water pressure with high water consumption rates and increased grey water footprints. Industries must take action toward implementing water conservation strategies to enhance natural water cycle, increase water-use efficiency and address future challenges. The significance of water footprint as a driving force to water conservation is spotlighted with severe water scarcity. Sustainable Development Goals proposed by the United Nations are focused on creating a sustainable way of life to reduce the impacts on ecology and achieve economic and social benefits which are interlinked with sustainable water use as water is a central part in sustainable development. The concept of water footprint should be used to achieve Sustainable Development Goals in relation to industrial water conservation and the future pathways that lead to sustainable water resource management" [7].

III. METHODOLGY FOR CALCULATION OF WF

A. Define the Data Structure for the Water Footprint of Materials

Constructing a database for the water footprint of materials requires the identification of an information structure that includes all the data needed to characterize each material. The data structure must be accurate with the water footprints and cover all aspects of material production and processing. The following attributes are essential for the structure:

1) *Material ID:* Every material must be assigned a unique identifier, called the Material ID. This ID serves as a primary key in the database, ensuring that each material is clearly defined and can be accessed or referenced by its unique name. The Material ID ensures that any operations or calculations involving the material are executed accurately.

2) *Material Name:* The field named *Material Name* stores the common name or designation of the material (e.g., "Cotton," "Steel"). This makes it easy to locate materials when searching the database. It is also essential for the user interface and reporting purposes to present the material's water footprint in an understandable manner.

3) *Water Footprint (WF prod):* The Water Footprint (denoted as *WF prod*) is an essential attribute that represents all the water used in the production process to obtain one unit of the material. This value is usually expressed in terms of volume per mass, such as liters per kilogram (L/kg) or cubic meters per ton (m^3/ton). It refers to the actual water employed in manufacturing the material before any additional processes (e.g., refinement, assembly) are applied.

B. Scan the Objects Through Object Detection Model

To improve the rating of output data for the water footprint of products and make the calculations more accurate and faster, it is possible and effective to use the object detection models for scanning materials in production sites. Object detection models can help in automating material recognition and further linking of objects scanned and captured to water footprint database. It also helps to quicken access to the data and improves accuracy and standardization of water consumption calculations connected with several materials.

Object detection in turn is a formal sub-discipline of computer vision; the primary goal of which is to detect and circumscribe objects within images or in sequences of images. It is possible to teach object detection models like YOLO (You Only Look Once), SSD (Single Shot Detector), or Faster R-CNN (Region-based Convolutional Neural Network) for acknowledging and categorizing materials like cotton, steel, or wood when the mentioned algorithms are trained on the labeled datasets. These models are capable of learning the different visual patterns of the materials and enable them to do detection in different production settings..

Therefore, when object detection model is trained, it can be used to real application scenario, for instance, in the storehouses or in the manufacturing plants. For instance, the model can move through a series of images or video streams in order to locate the materials. It will also identify and encircle items such as cotton or steel and then sort them according to certain predefined categories using boxes. The material we have identified is then associated with a code like Material ID or Material Name, more likely and is stored in a database.

C. Take the weights of materials

In cases where the set up of the model and computations seem complex, it is possible to perform a minimal input process where the key data only are input such as the weights of the materials. By eliminating some input data, the system guarantees simplicity and restricts the complexity of the entered data a must requirement for operations in industrial environments with real time data. Users would be required to provide weights of each of the material that is used in the process of production. For instance, an employee in a factory can enter the amount of weight of cotton or steel when manufacturing.

Once the weights of each material have been input, the system is able to select the water footprint data from a previously constructed database, which contains the water footprint values for the various materials. It is easy to understand why the concept of the minimal input approach is advantageous whereby organizations located in environments that require quick keying in of data such as a warehouse or production line. This also considerably shortens a number of steps required for the water footprint calculations and guarantees that all information used in the process is the most up-to-date and adequate, making this process not only efficient, but userfriendly as well. When associated with the minimal inputs fed into the system, the data stored in the database, regarding water footprint, can be used to timeously deliver sufficient information to companies about water usage so that they can promote environmental responsibility with little effort.

D. Calculation of Water Footprint of Each Material and Sum of All WF's of Materials

Relevant data has to be retrieved for calculating water footprints, which is critical in an automated system, especially when several materials for one final product may be involved. The first step is the identification of the materials taking part in this process, which are usually acknowledged by their Material Names. Every Material Name is a search term for the database in which the data for that specific material should contain categories such as material name, mass, and WF. In the case of a product consisting of more than one material, the system requires determining the water consumed in producing that material in proportion to its percentage in the total product.

This begins by the user typing in the Material Names of each material active in the product, for example, ‘Cotton,’ ‘Wood,’ and ‘Steel.’[8] For each of the materials, the system checks the database to get the Material ID and WF/kg of the material. A typical database query might look like:

SELECT MaterialID, WaterFootprintPerKg
FROM Materials
WHERE MaterialName = ’Cotton’;

After obtaining the water footprint data for individual materials, the system has to then determine the water footprint of the whole product. The water footprint of the final product is a function of the mass of the material and the proportion of the material to the total weight of the product. It is here that the concept of Product Fractions ($f_p[i]$) comes into play.

Product Fractions, $f_p[i]$, are defined as the product of all the communication fractions at one point in the process or for one product element. The Product Fraction expresses the ratio of each mass contribution of the material of construction to the total mass of the product.[9]

The total water footprint (WF_{total}) can be calculated by summing the water footprint of each material multiplied by its corresponding product fraction:

$$WF_{total} = \sum_{i=1}^{n} (f_p[i] \times WF_{prod}[i])$$

Where:

WF_{total} = Total water footprint, which represents the total water used in the production of the final product.

$f_p[i]$ = Product fraction, representing the quantity of material i in the final product.

$WF_{prod}[i]$ = Water footprint per kilogram of material representing the total water used for the production of the material.

P = Summation, indicating that the formula is applied to all the materials involved in the production of the final product.

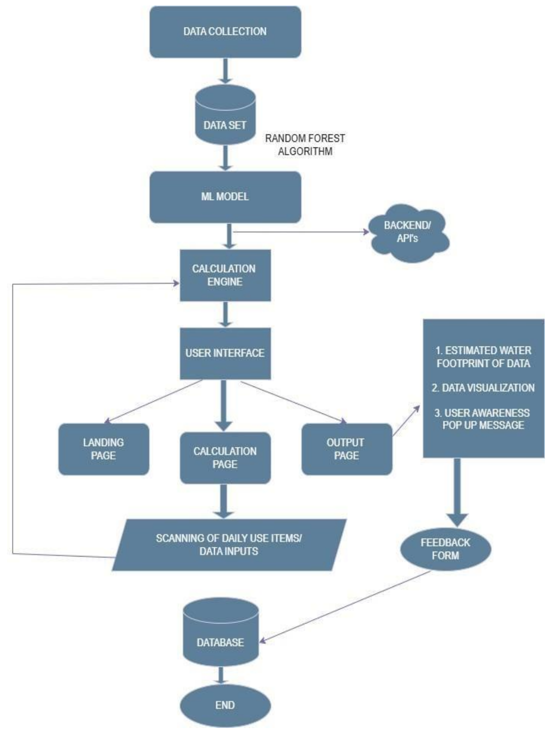

Fig. 3.1. Flow Chart

IV. Outputs and Suggestions

A. Understanding Water Use in Local Contexts

Volumetric Water Footprints (WFs) are of great concern to evaluate the effectiveness and effects of water usage whilst considering region specific information. This means using the amount of water used to that which is supplied in that area of the world.

WFs can be compared to total water resource which has been established by various studies in the region and other research on the natural standards of the environment. Consequently if water use surpasses water availability it results in water shortage. What is more, it sometimes pollutes water, which affects both water systems and people’s health when the level of pollution becomes intolerable. On a global scale, Four billion individuals suffer from blue water scarcity, or the absence of freshwater, on a monthly basis, at minimum. Around 50 percent of global green water is being over exploited; plants and other vegetation are using more water than is available through the rains and which is retained by the soil. Increased pollution of the water is making the various sub catchment areas to be polluted by things like fertilizer and other materials affecting the water quality. Water Footprint assessments assist us in seeing what human activities are causing these issues to occur. These data can be applied in an attempt to avoid wastage and pollution of water because it assists those in production, using water and those in leadership to formulate strategies that would enable them control water use.

B. Global Dimension of Water Use and Virtual Water Trade

Virtual water includes the unseen water content of products and services which are imported and exported between countries. This idea overarches the way water is employed in

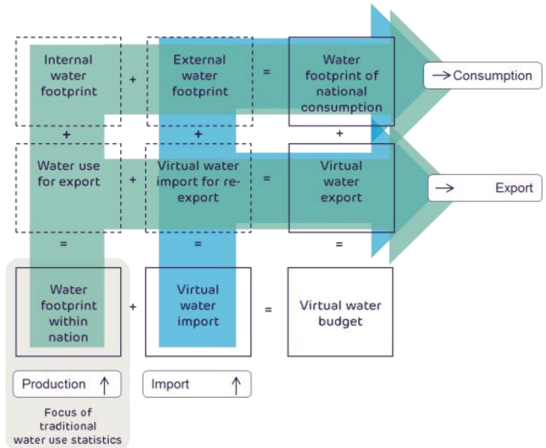

Fig. 4.1 The Hidden Water In Trade

manufacturing activities where goods are imported or exported across the globe tying nations together through complex value webs. Virtual water exchange is a vital tool in the water scarcity mitigation because it enables water-short countries to import water in water-intensive commodities brought in from countries with more water availability. For instance, countries that have surplus water availability in making food crops such as Brazil, the United States send water intensive products such as grains and cotton to arid regions of the world such as Saudi Arabia and Kuwait. This trade enables water-short areas stay fed and industrialized without using up their water, in essence outsourcing water use in water-endowed areas.

C. Strategies to Reduce Water Footprints

Here are some possible measures to decrease water consumption in various domains: These strategies help conserve water and promote more sustainable practices:

1) *Irrigation Efficiency:* Irrigation water in farming can be managed well through better methods of irrigation. For instance, with the drip irrigation system, water is relayed directly to the root area, thus minimizing the use of water. Subsurface irrigation involves placing water below the ground, while deficit irrigation involves applying less water at a time when it is possible to get less water[10], but plants continue to grow fine. A layer of mulch acts as a reservoir of moisture, thus minimizing the time required for watering.

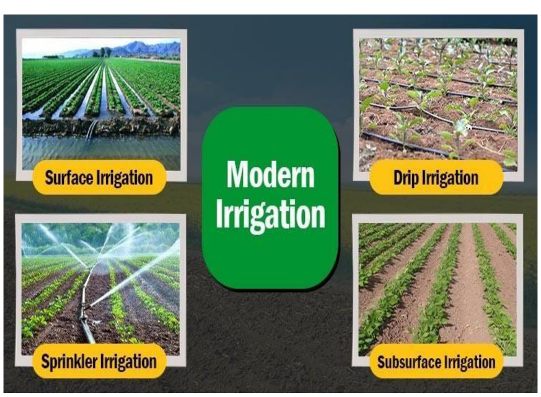

Fig. 4.3 Modern Irrigation Techniques for Efficient Water Use

Fig. 4.2 Water Conservation

2) *Water Conservation Measures:* Water conservation involves various strategies to reduce overall water consumption, such as improving rainwater harvesting, managing watersheds better, and cultivating drought-tolerant crops.

3) *Industrial Water:* Instead of being wasted, water in industries can be recycled and used again. The total water footprint of production can be decreased by reducing back on water-intensive industrial activities.

4) *Consumption Shift:* Water use can be minimised through encouraging consumers to pick less water-intensive items, such as plant-based diets rather than meat. This can be accomplished by encouraging sustainable dietary modifications and running awareness campaigns.[11]

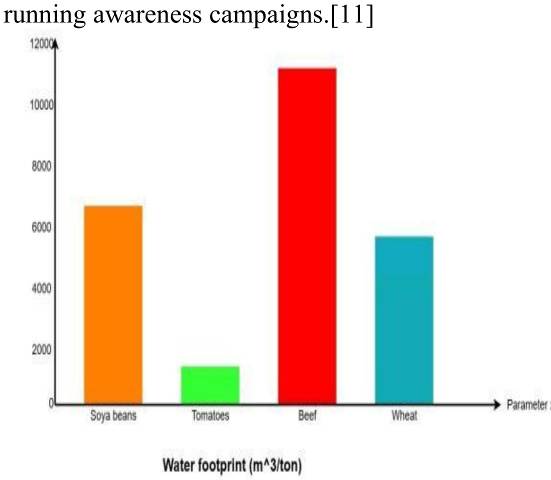

Fig. 4.4 WF of Materials

5) *Water Pricing and Rights:* Governments are able to encourage businesses and individuals to utilise water more efficiently by enacting water tariffs. Better distribution and use of water resources according to demands are made possible by water rights and water markets.

6) *International Trade:* Water-intensive crops and products can be imported by countries experiencing water scarcity from areas with greater water availability. This prevents overuse of water resources and helps lower local water demand.For example,due to its arid climate and scarcity of freshwater resources, the Middle East and North Africa

(MENA) area is mostly dependent on virtual water imports to meet its food security requirements. For example, water-rich nations like the United States and Canada supply Saudi Arabia and other countries with significant amounts of wheat and other cereals. Saudi Arabia saves its limited freshwater resources by importing wheat, which requires a lot of water to grow

D. Impact on Consumer Behavior and Lifestyles

Global water dependencies are created when people's consumption patterns transfer the cost of water use to other nations. This implies that the water used to manufacture the things that people in one country consume frequently originates from other areas, sometimes from areas that are already experiencing water scarcity.

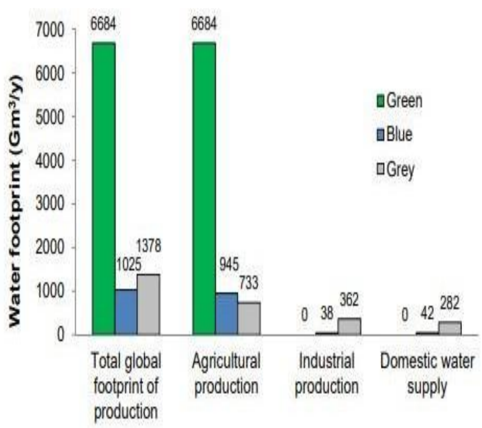

Fig. 4.5 Sectors WF

1) *Externalized Water Footprints :* The water footprint of consumers in affluent nations is "externalised" to other nations to a significant extent. For instance:The water footprint of Dutch consumers is 95Water-constrained areas account for about half of this footprint, where water resources are already scarce.

2) *Global Water Dependencies :* Countries indirectly rely on the water resources of exporting nations when they buy water-intensive commodities like meat, cotton, or coffee. Since more water is used to produce things for export rather than for local consumption, this could make the water shortage in those areas worse.[12]

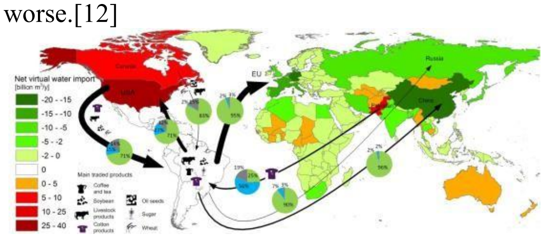

Fig. 4.6 Dependency Network

E. Policy Framework and Initiatives:

Strong legislative frameworks and focused programs are necessary for sustainable water management in order to tackle the problems of water scarcity and mismanagement. For instance, the National Water Policy of India, which was originally presented in 1987 and updated in 2002 and 2012, places a strong emphasis on environmentally sustainable practices, equitable distribution, and effective water use. In order to guarantee sustainable use of water resources, the policy highlights the necessity of demand-side management, conservation techniques, and integrated water resource management. To help achieve these objectives, a number of significant projects have been started. The National Water Mission emphasises the value of conserving water and reducing waste while concentrating on the fair allocation of water resources. A groundwater management program called the Atal Bhujal Yojana seeks to raise groundwater levels by encouraging sustainable practices and community involvement. Additionally, by encouraging micro-irrigation methods like drip and sprinkler systems, the Pradhan Mantri Krishi Sinchayee Yojana aims to improve agricultural water-use efficiency. Together, these policies and programs provide a comprehensive framework to address the complexities of water management. They promote an integrated approach that includes resource conservation, community engagement, and technological advancements to meet present and future water demands sustainably.[13]

F. Pollution Control Through Water Footprint Assessment (WFA)

One of the most important tools for controlling and reducing water pollution is the Water Footprint Assessment (WFA). It aids in measuring the "grey water footprint," or the amount of water needed to get pollutants down to acceptable levels. Through the identification of pollution hotspots—areas with the highest levels of contamination—WFA helps industry, academics, and policymakers to put specific pollution reduction strategies into place. For instance, overuse of fertilisers and pesticides in agriculture frequently results in phosphate and nitrate leakage into adjacent water bodies, which damages aquatic ecosystems and causes eutrophication.

WFA can identify the locations where fertiliser use above safe criteria and compute the grey water footprint of a certain farming zone. Using this information, farmers can reduce pollution by using precision agriculture methods like organic substitutes and regulated application of fertiliser.WFA can evaluate the grey water footprint of industrial facilities that release raw wastewater into rivers that contains chemicals, dyes, or heavy metals. For instance, because of the chemicals and dyes used in their manufacture, the textile industry frequently contributes significantly to water contamination.

To lessen their influence on nearby water systems, these sectors can use WFA to identify their most polluting activities and make investments in wastewater treatment technologies like bioremediation or reverse osmosis.An actual example is the Ganges River in India, which has become severely contaminated due to untreated effluent from factories and agricultural runoff. In order to implement measures like more stringent industrial discharge laws and better wastewater treatment facilities under the ”Namami Gange” project, stakeholders used WFA studies to identify major contributors to pollution.

V. CONCLUSION

A basic resource, water is necessary to support ecosystems, human existence, and the world economy. However, in many parts of the world, increasing demands from urbanisation, population growth, industrialisation, and climate change have made water scarcity and water quality worse. In addition to endangering human livelihoods, these issues also damage ecosystems, reduce biodiversity, and interfere with the natural cycles that sustain all life. The importance of the Water Footprint (WF) and Water Footprint Assessment (WFA) frameworks in comprehending and resolving these issues is highlighted by this study. A thorough understanding of both direct and indirect water use in production, trade, and consumption is offered by the WF concept, which encompasses green, blue, and grey water. This makes it possible to comprehend the complex relationships that exist between pollution, ecosystem health, and water usage. Finding conservation possibilities and inefficiencies is essential to sustainable water management. WFA is a potent instrument for evaluating sustainability, examining the effects of water consumption, and guiding better water resource management. For example, knowing how to use green and grey water can help communities and ecosystems by reducing pollution from overuse of fertiliser and improving rain-fed farming methods.[14]

This study suggests creating a mobile application that enables consumers to calculate and evaluate the WF of products in order to improve accessibility and awareness. This program can help people make educated judgements about how much water they use and promote sustainable practices by combining cutting-edge technologies like picture recognition with global information. In summary, pollution and water scarcity are ecological issues that require comprehensive, scientifically based solutions. They are not merely human problems. Individuals, producers, and legislators can work together to preserve freshwater resources and ecosystems for future generations by embracing frameworks like WFA and utilising cutting-edge technologies. We can guarantee that water continues to be a shared and sustainable resource for all species on Earth by raising awareness, educating people, and implementing focused actions.

VI. FUTURE SCOPE

There are several chances for additional investigation and advancement in tackling water sustainability issues in the Water Footprint Assessment (WFA) research. The points listed below suggest possible directions for further research and use:

A. Integration with Advanced Technologies

In order to improve accuracy, forecast trends, and provide tailored suggestions for sustainable water use, the suggested mobile application for Water Footprint assessment can make use of cutting-edge technology like artificial intelligence and machine learning. Global statistics can be processed using big data analytics, which can reveal information about consumption trends and environmental effects. Furthermore, blockchain technology can provide accountability and transparency in water use, especially in agriculture and industry, allowing for safe supply chain tracing. The app may become a comprehensive resource for encouraging sustainable water management as a result of these integrations.

B. Sector-Specific Water Management

To effectively handle their particular difficulties, water management plans need to be customised for each industry. Water usage in agriculture can be decreased by using droughtresistant crops and effective irrigation techniques like drip irrigation. Waste may be reduced for industries by implementing water recycling technologies and increasing process efficiency. Encouraging conservation measures like rainwater collection and water-efficient appliances lowers demand in both the home and commercial sectors. While urban regions should concentrate on sustainable infrastructure, including green spaces for rainwater infiltration, the energy industry can profit from optimising water use in cooling systems. Longterm sustainability and water conservation are ensured by tailoring these tactics to each sector.

C. Public Awareness and Education

Integrating educational initiatives in schools, colleges, and community programs can help increase public knowledge about water conservation through Water Footprint evaluations. To attract a larger audience, future initiatives might involve developing gamified tools and interesting instructional content. Additionally, conducting awareness campaigns on digital platforms and social media can promote responsible water usage practices among businesses and consumers.

D. Climate Change and Resilience Planning

Future studies could look at the connection between climate change and water footprints, analysing how variations in precipitation, droughts, and extreme weather events impact water availability and consumption. By incorporating resilience planning into Water Footprint Assessment (WFA), communities and enterprises would be better equipped to anticipate and respond to climate change-driven water-related concerns.

REFERENCES

[1] M. K. Mehla, M. Kothari, P. K. Singh, S. R. Bhakar, and K. K. Yadav, “Water footprint assessment and its importance in Indian context: a meta-review,” *Water Supply*, vol. 23, no. 8, pp. 3113–3127, 2023, doi: 10.2166/ws.2023.174.

[2] H. A. Mekonnen MM, “The green, blue and grey water footprint of crops and derived crop products. Hydrology and earth system sciences.,” 2011.

[3] J. B. and M. F. Daniela Lovarelli, “Water Footprint of

crop productions: A review. Science of the total Environment," 2016.

[4] G.-L. W. Mekonnen MM, "The Water Footprint of Global Food Production. Water," 2020.

[5] Muratoglu A, "Assessment of wheat's water footprint and virtual water trade: a case study for Turkey," 2020, [Online]. Available: https://doi.org/10.1186/s13717-020-0217-1

[6] P. Firda AA, "Water Footprint Assessment in the Agro-industry: A Case Study of Soy Sauce Production.," *2nd Int. Conf. Energy, Environ. Inf. Syst. (ICENIS)*, 2017, [Online]. Available: https://doi.org/10.1051/e3sconf/201831 08018

[7] and G. M. Weerasooriya RR. Liyanage LPK, Rathnappriya RHK, Bandara WBMAC, Perera TANT, Jayasinghe GY, "Industrial water conservation by water footprint and sustainable development goals: a review.," *Env. Dev Sustain*, 2021.

[8] A. Y. Hoekstra, "Water Footprint Assessment: Evolvement of a New Research Field," *Water Resour. Manag.*, vol. 31, no. 10, pp. 3061–3081, 2017, doi: 10.1007/s11269-017-1618-5.

[9] M. Egan, *The Water Footprint Assessment Manual. Setting the Global Standard*, vol. 31, no. 2. 2011. doi: 10.1080/0969160x.2011.593864.

[10] R. J. Hogeboom, "The Water Footprint Concept and Water's Grand Environmental Challenges," *One Earth*, vol. 2, no. 3, pp. 218–222, 2020, doi: 10.1016/j.oneear.2020.02.010.

[11] A. D. Chukalla, M. S. Krol, and A. Y. Hoekstra, "Marginal cost curves for water footprint reduction in irrigated agriculture: Guiding a cost-effective reduction of crop water consumption to a permit or benchmark level," *Hydrol. Earth Syst. Sci.*, vol. 21, no. 7, pp. 3507–3524, 2017, doi: 10.5194/hess-21-3507-2017.

[12] "https://www.waterfootprint.org/time-for-action/what-can-governments-do/."

[13] M. M. Aldaya, P. Martínez-Santos, and M. R. Llamas, "Incorporating the water footprint and virtual water into policy: Reflections from the Mancha Occidental region, Spain," *Water Resour. Manag.*, vol. 24, no. 5, pp. 941–958, 2010, doi: 10.1007/s11269-009-9480-8.

[14] "https://www.sciencedirect.com/science/article/pii/S2590332220300919."