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Estimating An Individual's Water Footprint: A Review-Based Study

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Abstract - Water scarcity has emerged as a critical challenge, especially in water-stressed nations such as India. Effective water management requires understanding both direct uses (drinking, bathing, cleaning) and indirect uses (products, energy, diet). The concept of the water footprint measures both, revealing the hidden impacts of consumption.

This study evaluates individual water footprints in rural and urban India using a questionnaire and the Water Footprint Network calculator. Results show indirect consumption, especially from diet, dominates over direct use. Meat and dairy intake raise footprints, while vegetarian diets lower them. Urban lifestyles, influenced by packaged foods and modern facilities, increase overall consumption compared to rural patterns. The findings stress the need for awareness, behavior change, rainwater harvesting, and efficient household fixtures.

Keywords - Water footprint, direct consumption, indirect consumption, water scarcity, sustainable water use, urban versus rural, water conservation, India

1. INTRODUCTION

Water's significance transcends basic human needs: it is fundamental to the health of ecosystems, agriculture, industry, and even cultural values. While the Earth's surface may appear abundant in water—with nearly 70% coverage—only a minuscule 0.5% is immediately accessible for direct human use, given the limitations imposed by geography, quality, and accessibility. The pressure on India's water resources is intensifying as it becomes the world's most populous country, combined with rapid urbanization, industrial expansion, and an agricultural sector that remains the backbone of its rural economy. The concomitant decline in per capita water availability—from 5177 m³/year in 1951

to a projected 1140 m³/year by 2050—signals not just resource stress but a looming humanitarian and developmental crisis unless proactive measures are instituted[1]. The “water footprint” (WF) concept, originating in the 1990s, revolutionized the approach to water management by quantifying not just the water seen and used directly, but also the “virtual” water embedded in the production of food, clothing, and energy. This dual outlook provides a more holistic and actionable perspective on sustainable water usage, particularly pertinent in complex societies like India where indirect consumption often comprises the majority of total water use.

2. LITERATURE REVIEW

A growing body of literature underlines the water footprint's potency as an analytical and awareness-raising instrument, while also acknowledging methodological challenges and regional disparities. Global and Regional Variability: Lee et al. (2016) in their case study of Yunlin County, Taiwan, demonstrated remarkable lifestyle-driven discrepancies in personal water footprints, revealing that dietary habits, urbanization, and cultural context shape water usage significantly. Methodological Issues: Jeswani & Azapagic (2011) critiqued the water footprint's assessment methodologies, calling for standardized and universally accepted models, which remains a gap that hinders international comparability.

Awareness and Policy Implications: Chenoweth et al. (2014) highlighted not only methodological inconsistencies but also parents the value of the water footprint as an educational tool, capable of influencing consumer and policy choices. India-Focused Studies: Plappally & Jhaver (2014), through their analysis of water use and associated costs in Indian households, found that public awareness, particularly

regarding indirect or virtual water use, remains strikingly low a barrier to effective conservation.

Significance of Hidden Water: Das et al. (2020) revealed through rural Indian surveys that a vast proportion of household water demand is “hidden” in staples and cooking fuel, amplifying the case for more comprehensive accounting. **Agriculture’s Overwhelming Share:** Hoekstra & Mekonnen (2017) established that, globally, agriculture consumes about 92% of total water used by humanity, with the average water footprint summing up to about 9,087 Gm³/year. **Other Assessments:** Newer regional studies, such as those focusing on Nepal and global food-water-energy systems (Vaidya et al., 2021; Mekonnen & Gerbens-Leenes, 2020), provide additional context and comparative benchmarks.

The collective evidence supports the water footprint’s significance as an environmental metric, but also spotlights persistent research gaps, notably the lack of high-resolution, individual-level studies in the Indian context—a gap directly addressed by the present work.

3. METHODOLOGY

a. Scope I — Direct Consumption

This encompassed all water used directly by individuals in their households, including drinking, cooking, bathing, laundry, dishwashing, cleaning, toilet use, and gardening. These are visible and often easier to measure with direct observation or self-reported data.

b. Scope II — Indirect (Virtual) Consumption

This category captured the water embedded in the production of food, clothing, products, and energy that individuals consume. Indirect use accounts for far more than what is immediately apparent, requiring careful estimation based on dietary habits (e.g., frequency of meat or dairy), lifestyle, and consumer choices.

c. Survey and Data Collection

Instrument: A meticulously crafted online questionnaire with more than 50 questions delved into household demographics, dietary patterns, hygiene practices, product usage, appliance ownership, and energy consumption. **Sampling:** Individuals from both rural and urban backgrounds participated, ensuring diversity in lifestyle and consumption practices. The pilot sample size included 27 respondents. **Validation:** All responses were subjected to dual iteration checks for reliability and consistency. **Computation:** The Water Footprint Network (WFN) calculator a standardized tool—was used for all computations, producing per capita water footprint figures in liters per day for both types of consumption.

d. Analysis Framework

Apart from raw computation, the methodology incorporated cross-comparisons to evaluate: The magnitude of direct vs.

indirect (dietary/product-based) water consumption; Differences between rural and urban patterns; The impact of vegetarian versus non-vegetarian diets; Levels of awareness and technology adoption (such as rainwater harvesting).

4. RESULTS

a. Direct Water Use

Individuals’ direct water usage ranged from 150 to 300 liters per day. The largest contributors were bathing, laundry, and dishwashing. Urban residents typically reported greater consumption, attributed to lifestyle factors such as more frequent showers, greater laundry loads, and the convenience of piped municipal supply. In contrast, rural households tended towards more conservative use, shaped by limited supply, traditional practices, and often a greater appreciation of water’s local scarcity.

b. Indirect Water Use

Here, the numbers were staggering—personal indirect water consumption ranged from 3,000 to 7,000 liters per day. This massive amount was predominantly due to food, with notable differences based on diet: Individuals with diets high in meat and dairy products showed far higher water footprints than those following vegetarian traditions. As an illustration, producing one kilogram of beef can require over 15,000 liters of water, compared to lentils or vegetables that might require 300 to 400 liters for the same amount. Indirect water usage from staples (rice, wheat, pulses), beverages (tea, coffee), and packaged foods also added up significantly. The consumption of manufactured products (clothing, electronics) and energy (especially where thermal power is involved) contributed further.

c. Rural versus Urban Disparities

Urban households, while demonstrating slightly higher direct water use due to modern lifestyle habits, paradoxically had similar indirect water footprints to rural counterparts because both population segments typically consume similar food staples. However, access to “luxury” foods and processed products tends to be more prevalent in cities, providing potential for greater upward shifts in indirect use as diets modernize.

d. Dietary Impact: The dataset exposed the immense potential of dietary changes for conservation. Even incremental reductions in animal product intake translated to substantial water savings. Vegetarian diets, especially when locally sourced and seasonally appropriate, created far lower water burdens on the environment.

e. Awareness and Infrastructure Gaps: Implementation of water-saving appliances and rainwater harvesting systems was rare, even among those aware of their benefits. Urban respondents generally reported greater knowledge of conservation technologies but poor adoption rates, while rural participants cited financial and logistical barriers to implementation.

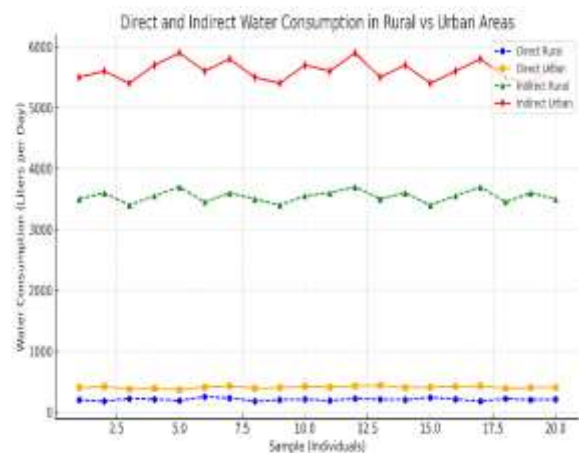


Fig 4.1 Direct and Indirect Water Consumption in Rural vs Urban Area.

5. DISCUSSION

a. Dominance of Indirect Consumption

The study provides compelling evidence that indirect, or virtual, water consumption forms the lion's share of an individual's water footprint in India. Food choices—particularly non-vegetarian diets—loom large, often eclipsing the water used directly in the home by an order of magnitude or more. Consumption of livestock products (meat, dairy, eggs) involves not only the water the animals drink but also the immense resources needed to grow their feed, clean facilities, and process their products.

b. Public Awareness and Behavioral Change

A critical observation is the low level of understanding about indirect or virtual water use among both rural and urban populations. While there is some recognition of the need to conserve water in daily chores, few people are aware of, for instance, the vast water costs associated with producing a single serving of beef, cheese, or imported fruit. Educational efforts focused on the concept of the water footprint—highlighting “invisible” water—could thus prove deeply impactful.

c. Techniques for Reduction

The findings point to a number of possible interventions: Dietary Shifts: Promoting plant-based diets and reducing high-impact animal products yield the largest individual-level benefits. Appliance and Fixture Upgrades: Encouraging the use of low-flow showers, dual flush toilets, and efficient washing machines. Greywater Recycling and Rainwater Harvesting: While the technologies are well understood, they have yet to penetrate mainstream adoption, especially in resource-constrained rural and peri-urban areas. Traditional Wisdom: Many rural households deploy indigenous practices, such as reusing water from washing vegetables for

gardening. These methods offer scalable models for urban adaptation.

d. Comparative Insights

The Indian case aligns with global patterns in that food system-related water use is dominant, but differs in the infrastructural and governance gaps around conservation. Unlike developed nations—which often have integrated water reuse systems, compulsory metering, and widespread household conservation technologies India lags in investment in both awareness and practice.

e. Policy and Governance

Governmental mandates on rainwater harvesting, widespread implementation of water metering, incentive programs for water-efficient devices, and mandatory curriculum on sustainable living in schools could yield transformative impacts. Coordination among policymakers, civil society, and communities is essential to foster a culture of responsible water use.

6. CONCLUSION

The research demonstrates beyond doubt that the battle for India's water sustainability will be fought as much in kitchens and dining rooms as in bathroom showers and laundry areas. The vast disparity between direct and indirect water use demands a two-pronged response: first, shifting public consciousness to recognize the importance of what is consumed, not just what flows through household pipes; second, empowering individuals, communities, and institutions to implement water-saving procedures and technologies.

Rural and urban contexts present unique challenges and opportunities—rural communities can benefit from greater support to integrate low-cost technologies and revive traditional conservation practices, while urban areas must pair lifestyle enhancements with accountability in usage. Dietary changes, supported by robust public information campaigns and incentives, can have a multiplier effect in reducing demand on India's overstretched water reserves. Mandatory rainwater harvesting, judicious water governance, subsidies for efficient appliances, and standardized water footprint assessments in every school and institution should form the backbone of a national response. Only a comprehensive, inclusive, and science-based approach will ensure that rising demands do not outstrip what our natural systems can sustain.

Recommendations for Future Research

Given the limited but insightful sample size of this study, future research must aim to incorporate larger, more diverse populations for greater representativeness. Integrating rigorous life cycle assessments, detailed product-specific

footprint analyses, and urban-rural longitudinal datasets will afford an even deeper understanding of personal and national water demand. Collaboration with international bodies and think tanks could further harmonize methodologies and bring Indian practices within the global dialogue.

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