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Evaluating the Influence of Water Use Efficiency on India's Economic GDP: A Theoretical Exploration

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Abstract— ***Efficient water usage is critical for sustainable development, particularly in agriculture, which accounts for over 90% of global water consumption. This study examines the complex dynamics of water resource management, technology adoption, and economic growth in India. The research highlights significant challenges posed by inefficient water allocation and management practices, exacerbated by global trade dynamics and local regulatory distortions. Using econometric methods, the study evaluates India's progress in enhancing water usage efficiency through innovations like wastewater recycling and advanced irrigation technologies such as drip irrigation. It underscores initial setbacks in efficiency due to rapid industrial and agricultural expansion but identifies a trend towards improved efficiency as economies mature. The study suggests that integrating modern water-saving technologies with supportive policy frameworks can mitigate water scarcity risks and enhance economic productivity. This study emphasizes the role of education and awareness campaigns in promoting responsible water use practices and advocates for policy incentives that prioritize water-saving strategies.***

By analysing indicators like 6.4.1 from the Sustainable Development Goals (SDGs), which measure the relationship between economic growth and water consumption, the research provides insights into the efficacy of current water management practices in India. It underscores the need for integrated water resource management and cross-sector planning to achieve sustainable development goals while preserving water resources for future generations. In conclusion, this study contributes to the global discourse on sustainable water resource management by offering empirical insights into the interplay between economic development and water use efficiency in India. It calls for concerted efforts from policymakers, industries, and communities to prioritize water conservation and adopt innovative solutions to address the pressing challenges of water scarcity in a rapidly changing global environment.

Index Terms: Water usage efficiency, Wastewater recycling, Drip irrigation, Sustainable Development Goals (SDGs), Technology adoption, Economic growth, Water management, Water scarcity.

I. INTRODUCTION

Over 90% of global water use by humans is attributed to agricultural production, which heavily relies on rainfall and local stocks of groundwater and surface water (Mekonnen and Hoekstra, 2011). Transporting water over long distances is generally prohibitively expensive, yet nearly 25% of all water consumption is embedded in internationally traded agricultural products. Both the input markets for water and the output markets for agriculture worldwide face pervasive distortions. Most farmers extract water as an open-access resource without defined property rights (Libecap, 2008), and agricultural markets are typically influenced by a broad array of subsidies, taxes, tariffs, and trade restrictions (Anderson, Rausser, and Swinnen, 2013). When input market failures prevent the cost of water from reflecting its scarcity, trade liberalization can exacerbate this distortion, leading to adverse long-term effects on resource depletion and welfare (Chichilnisky, 1994).

The efficiency of water usage in the economy is a complex and essential factor that supports a country's sustainable development and environmental responsibility. This index quantifies how effectively a nation employs its water resources to sustain its economic activities across various sectors, including agriculture, industry, energy generation, and domestic usage. A higher water usage efficiency index indicates that the economy can produce more goods and services while utilizing fewer water resources. Improved water usage efficiency not only offers economic benefits but also promotes ecological responsibility by reducing pressure on limited water supplies and addressing the negative environmental consequences associated with excessive water consumption, such as groundwater depletion and the deterioration of aquatic environments.

The interaction between the concentration of resources and the use of technology is of utmost importance. The facilitation of modern water-saving technology can be enhanced by the intentional clustering of industry and cities, resulting in a synergistic effect that optimizes water resource efficiency. Furthermore, allocating resources towards advancing research and development in establishing water technologies can foster economic expansion while tackling the pressing issue of water scarcity. A comprehensive understanding of the complex interplay between resource concentration and technological assimilation is paramount in pursuing sustainable water resource management in India.

The advanced water-saving approach could help the nation manage complex water scarcity concerns. By doing so, it can guarantee the provision of clean water to its populace while preserving the environment for the benefit of future generations. Furthermore, this could also serve as a model for other regions facing similar water resource issues in a water-scarce world.

Innovations in water-efficient manufacturing, irrigation, and water recycling have a major impact. Furthermore, implementing policy measures, such as enforcing rigorous water quality regulations, establishing water pricing mechanisms, and providing incentives to encourage water-saving techniques, can facilitate efficiency enhancements. Monitoring water usage efficiency over time offers policymakers, entrepreneurs, and researchers' valuable insights into the capacity of an economy to effectively manage the trade-off between economic development and environmental preservation. This approach underscores the efficacy of tactics employed in managing water resources, identifies areas that require improvement, and facilitates the assessment of the consequences of different initiatives.

Optimizing water usage efficiency is not only an issue of economic prudence but also of moral and environmental responsibility in a time of rising water scarcity concerns, unpredictable weather, and ecological pressure. This ensures that nations can fulfill the needs of their populations and industries while preserving this invaluable resource for both current and future generations. Therefore, it is imperative for governments, corporations, and communities to persistently prioritize the enhancement of water use efficiency as an essential element of their strategy for sustainable development.

II. BACKGROUND OF WATER SITUATION

Water is crucial for sustaining life on Earth, yet despite its abundance, only about 1 percent is freshwater, and even less is drinkable. More than 40 percent of people worldwide face water scarcity, a figure expected to rise, with two-thirds of the global population projected to live in water-stressed conditions by 2025, exacerbated by climate change (FAO 2015; Bates, Kundzewicz, & Wu, 2008). The water crisis in India is well-documented; the country is water-stressed, with an estimated availability of 1434m³ per person annually. Groundwater extraction in India is escalating rapidly, outpacing that of the USA and China, reaching approximately 780 billion cubic meters annually (FAO, 2018). Fifty-four percent of monitored groundwater wells in India are overexploited, with some states facing even higher rates, such as Karnataka (80%), Maharashtra (75%), and Uttar Pradesh (73%). About 60 percent of India's districts are categorized as water-scarce or suffer from poor water quality (CWC, 2019; Niti Ayog, 2019).

Agriculture accounts for 90 percent of groundwater extraction, providing over 78 percent of the total irrigation potential (CWC, 2019). Apart from other factors, this situation is exacerbated by incentives such as electricity subsidies and low water pricing, which encourage cultivation of water-intensive crops like sugarcane, rice, wheat, and bananas, leading to excessive groundwater usage (Kumar & Singh, 2001). For instance, producing 1 kg of rice requires 2497 liters of water, while producing 1 kg of cotton for shirts requires 10,000 liters, and 1 kg of sugar production consumes 1782 liters of water (Mekonnen & Hoekstra, 2011).

Effective water management involves both supply-side and demand-side strategies, necessitating policy responses. Demand-side management may include promoting water-saving technologies such as Micro Irrigation (MI), incentivizing shifts to less water-intensive crops, and reducing electricity subsidies. Flood irrigation, known for its inefficiency due to significant water loss through leaching, surface runoff, evaporation, and weed growth (Fereres et al., 2011), underscores the importance of MI adoption. Government initiatives like the Per Drop More Crop (PDMC) under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) aim to expand irrigated areas ("Har Khet Ko Pani") and enhance water-use efficiency ("Per Drop More Crop") through MI promotion.

Micro irrigation technologies vary in cost and socio-economic impact, encompassing both low-cost innovations by farmers and commercially available high-cost systems (Namara, Upadhyay, & Nagar, 2007). Low-cost MI solutions include Pepsee kits, micro-sprinklers, and microtube systems, often tailored for small-scale farmers. In contrast, commercial MI systems, such as those offered by Jain Irrigation and Netafim, involve higher capital investments, averaging around Rs. 1.3 lakhs per hectare depending on land characteristics and crop types (GoI Guidelines, 2018). Sprinkler irrigation disperses water over plants in the field, while drip irrigation delivers water drop by drop near the plant roots through tubes and microtubes, making it more capital-intensive than sprinkler irrigation, especially suitable for longer-duration crops like cotton, sugarcane, bananas, and pomegranates (Kumar, 2016).

III. A COMPARISON WITH CHINA

China has also prioritized improving its water utilization efficiency in response to its growing demands. As the most populated country globally and a hub of rapid economic growth, China faces an escalating need for water resources to sustain its industrial sector, agricultural activities, and urban areas. Challenges such as the disparity between supply and demand, unequal distribution of water resources, persistent flooding, waterlogged soil incidents, agricultural expansion, and water conservation issues complicate China's water management landscape. National objectives regarding water scarcity, pollution, and the degradation of rivers and lakes have gained increasing attention. Climate change and pollution further intensify water scarcity, making it a pressing issue.

China's gross domestic product per water unit is considerably lower than the global average. While the global average GDP per cubic meter of water is approximately USD

36, China’s GDP per cubic meter is around USD 3.50. Despite possessing several significant rivers in the South Asian region, China's water resources are unevenly distributed across time and space. Among the 31 administrative regions on the mainland, eight regions face substantial water resource shortfalls, while the remaining 20 regions experience relatively minor water scarcity. These water-scarce provinces encounter significant challenges in water management, impacting agriculture, industry, households, and even drinking water. The lack of accessible water affects people's health, daily lives, and sustainable growth. Additionally, limited production technology in domestic, industrial, and agricultural contexts results in resource wastage and poor water utilization.

China has consistently incorporated water conservation goals into its Five-Year Plans (FYP). The latest, the 14th Five-Year Plan (2021–2025), unveiled in January 2022, aims to substantially enhance China's national water security capacity by 2025 through four primary objectives: (i) enhancing flood and drought mitigation capacity, (ii) improving water resource conservation capacity, (iii) optimizing water resource management and allocation, and (iv) strengthening the ecological protection and governance of major rivers and lakes. The FYP also recommends mitigating agricultural water consumption. In the coming years, China plans to advance reforms in crucial water conservation domains, promote innovative advancements, and modernize its water management framework through a nationwide water-saving campaign and smart water network, alongside significant water infrastructure projects.

Effective management and efficient utilization of water resources have become focal points for China. Two primary strategies have emerged as fundamental pillars to maximize water usage efficiency: the agglomeration of water resources and the implementation of innovative conservation technology. Resource agglomeration involves the strategic development of industries and metropolitan centers to maximize efficient water usage. By clustering industry and urban centers in specific areas, it is possible to enhance water resource allocation and optimize infrastructure for water treatment and distribution, reducing the overall burden on water resources and waste.

Technology adoption plays a crucial role in addressing China's water challenges. Advanced water treatment technologies, such as desalination, wastewater recycling, and efficient irrigation systems, can significantly improve water utilization efficiency. Smart water management systems, leveraging data analytics and sensor technologies, enable real-time monitoring of water quality and consumption patterns, allowing for more agile and efficient resource allocation and improved resource management outcomes.

IV. LITERATURE REVIEW ON WATER USE EFFICIENCY AND ECONOMIC GROWTH

A. Overview

The following literature review examines the factors influencing water use efficiency and its impact on economic growth across various contexts. This review highlights the significance of technological advancements, policy measures, and human behavior in shaping water use efficiency. The studies are organized into two main strands: those focusing on water use efficiency and those concentrating on water resource management technologies or efficiency.

Table I: Literature Summary Table

Study	Focus	Key Findings	Region	Methodology
Xu et al. (2021)	Agricultural water use efficiency	Identified a rebound effect in agricultural water use; negative relationship between water efficiency and total water use	China	Empirical analysis
Callejas Moncaleano et al. (2021)	Water use efficiency	Inefficiency due to slow progress in water use efficiency, particularly in developing nations	Various developing nations	Qualitative analysis
Lu (2019)	Industrial water use efficiency	Water conservation reduces carbon emissions	Not specified	Empirical analysis
Guerrini et al. (2013)	Water sector efficiency	Public utilities can boost efficiency through economies of scale, scope, and density by expanding operations and diversifying investment portfolios	Italy	Empirical analysis
Hatamkhani and Moridi (2021)	Integrated water allocation model	Combines economic and social aspects to optimize water supply and demand	Not specified	Reliability-based multi-objective optimization–simulation approach
Hatamkhani et al.	Hydropower	Optimal design can maximize energy	Not	Simulation–

Study	Focus	Key Findings	Region	Methodology
(2020)	reservoir design	generation and minimize flood damage	specified	optimization model
Qiao et al. (2020)	Water technology economics	Water technologies contribute to GDP growth, with varying effects depending on local water governance. Emphasizes the importance of research, innovation, and effective governance	Northwest China	Empirical analysis
Yang et al. (2022)	Impact of technological advancements	Impact varies by region, with industrial composition significantly influencing water usage reduction	China	Empirical analysis
Qiao et al. (2022)	Nexus between water technology and sustainable development	Water technology enhances the significance of water resources for economic development. Policy-driven measures are crucial for short-term development, while pricing changes drive long-term advancements	Various regions	Empirical analysis
Ji and Wang (2015)	Freshwater utilization efficiency	Technical progress significantly improves total factor productivity in freshwater utilization	China	Empirical analysis
Molinos-Senante (2021)	Water usage efficiency	Technological improvements lead to increased productivity	England	Empirical analysis

B. Understanding Climate Change Effects on Ecosystem Productivity and Efficiency

At the recent COP26 conference, global leaders aimed to keep global warming below 2 degrees Celsius, ideally 1.5 degrees Celsius compared to pre-industrial levels (since the late 1800s). However, the World Meteorological Organization's recent forecast indicates a 48% chance that temperatures will rise to 1.5 degrees Celsius above pre-industrial levels by 2026, driven by increasing carbon dioxide levels (421.72 parts per million). This trend not only affects temperatures but also triggers hydrological and climatic changes, which have significant implications for ecosystems worldwide. India, as part of the South Asian region, faces heightened vulnerability to climate change impacts such as heatwaves, droughts, and floods.

Net Primary Productivity (NPP) and Gross Primary Productivity (GPP) are crucial metrics for assessing ecosystem health and carbon flux efficiency. In India, as in other regions, these metrics are influenced by climate variables such as temperature, solar radiation, and precipitation, particularly in water-limited areas. Understanding these dynamics is essential for formulating effective ecosystem management strategies and ensuring future food and water security in India.

Terrestrial ecosystems' carbon and water cycles are intricately linked through processes like photosynthesis and evapotranspiration. Key Eco physiological indicators such as the ratios of carbon stored to carbon uptake and water loss to carbon gain are crucial for understanding how terrestrial plants respond to climate change. This study utilized data from 10 terrestrial ecosystem models to analyse the impacts of climate, atmospheric CO2 levels, and nitrogen deposition on water use efficiency (WUE) and carbon use efficiency (CUE).

The findings indicate that WUE has generally increased over the 20th century, primarily due to CO2 fertilization and nitrogen deposition, aligning well with experimental studies. However, over the last three decades, there has been a decline in WUE in response to climate changes, contrasting with observational data that suggests a stable WUE. Modelled CUE did not show a clear trend across space and time.

The discrepancies between modelled and observed WUE and CUE are attributed to how models simulate processes such as net primary productivity (NPP), autotrophic respiration, nitrogen cycling, carbon allocation, and soil moisture dynamics. The study suggests that improvements are needed in how ecosystem models handle stomatal conductance and soil-vegetation interactions to better simulate carbon and water cycles.

In summary, understanding these dynamics is essential for refining ecosystem models and improving predictions of how terrestrial ecosystems will respond to ongoing climate change.

C. Clarifying the concepts of water-use efficiency and water productivity

Water Productivity: This measures the economic or biological output per unit of water consumed in a specific production process. It's commonly used in agriculture to assess how efficiently water is used to produce crops or goods.

Water-Use Efficiency: This ratio compares the volume of water used by different sectors (like agriculture, industry, or households) to their gross value added (economic output). It indicates how effectively water resources are managed within these sectors relative to their economic productivity.

Indicator 6.4.1: This indicator[1] focuses on economic growth and its dependence on water resources. It evaluates the extent to which economic growth is achieved while using the same or less water, thus showing the degree of decoupling between economic growth and water use. This means assessing how efficiently economic growth can occur without a corresponding increase in water consumption[2].

- Water use: Refers to water received by industries or households from other sectors, or directly abstracted from the environment (SEEA-Water (ST/ESA/STAT/SER.F/100), para. 2.21).
- Water abstraction: Refers to water removed from the environment by economic activities (SEEA-Water (ST/ESA/STAT/SER.F/100), para. 2.9).
- Water use for irrigation (km³/year): Annual amount of water utilized for irrigating crops. This includes water sourced from renewable freshwater resources, over-extraction of renewable groundwater, or extraction of fossil groundwater, as well as the direct use of agricultural drainage water, treated wastewater, and desalinated water (AQUASTAT Glossary).
- Water use for livestock (watering and cleaning) (km³/year): Annual volume of water used for livestock-related activities, such as watering and sanitation. This includes water sourced from renewable freshwater resources, over-extraction of renewable groundwater, or extraction of fossil groundwater, and may involve the use of agricultural drainage water, treated wastewater, and desalinated water. If connected to the public water supply network, water used for livestock activities is categorized under service water use (AQUASTAT Glossary).
- Water use for aquaculture (km³/year): Annual volume of water used for aquaculture, which includes water sourced from renewable freshwater resources, over-extraction of renewable groundwater, or extraction of fossil groundwater, as well as the direct use of agricultural drainage water, treated wastewater, and desalinated water. Aquaculture involves the farming of aquatic organisms in inland and coastal areas, with human intervention to enhance production and ownership of the cultivated stock (AQUASTAT Glossary).
- Water use for the MIMEC sector (km³/year): Annual volume of water used by the MIMEC sector, including water from renewable freshwater resources, over-extraction of renewable groundwater, or extraction of fossil groundwater, and the use of desalinated water or direct use of treated wastewater. MIMEC refers to self-supplied industries not connected to public distribution networks (AQUASTAT Glossary; MIMEC sectors are referred to as 'industry' by AQUASTAT).
- Water use for services sectors (km³/year): Annual volume of water primarily used by the population, including water sourced from renewable freshwater resources, over-extraction of renewable groundwater, or extraction of fossil groundwater, and the use of desalinated water or direct use of treated wastewater. It typically encompasses total water used by municipal networks, including parts of industries connected to these networks (AQUASTAT Glossary; services sectors are referred to as 'municipal' by AQUASTAT).
- Value added (gross): Gross value added is the net output of a sector, calculated by summing all outputs and deducting intermediate inputs. It does not account for depreciation of fabricated assets or depletion and degradation of natural resources. The industrial classification of value added is determined by the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4 (World Bank Databank, Metadata Glossary, modified)[3].
- If water-use efficiency increases faster than the value added of an economy, it indicates positive progress. This means the economy is using water more efficiently relative to its growth, suggesting a lower risk of water scarcity hindering economic expansion.
- If the indicator shows a similar trend as economic growth, the risk of water scarcity impacting economic growth depends on the overall availability of a country's water resources.
- If water-use efficiency grows slower than the value added of an economy, there is a significant risk of water scarcity becoming a limiting factor for economic growth in the medium to long term. This could potentially threaten the sustainability of economic growth itself.

D. Water Footprint:

India's agricultural sector faces significant water challenges, using approximately 688 cubic kilometers (M3) of water annually, making it the second highest user globally. This high consumption is primarily driven by the production of three key crops: Rice, Wheat, and Sugarcane, which collectively account for 91% of India's crop output.

Specifically, India's water footprint (water used per metric

[1] UN Indicator 6.4.1 “Change in water use efficiency over time”
[2] Source: FAO (2018)
[3] FAO (2019a)

ton of crop produced) for these crops is notable:

- Rice: 2850 M3/MT
- Wheat: 1654 M3/MT
- Sugarcane: 159 M3/MT

Comparing these figures to global averages:

- Rice: Global average is 2291 M3/MT
- Wheat: Global average is 1334 M3/MT
- Sugarcane: Global average is 175 M3/MT

Interestingly, India uses less water per metric ton for Sugarcane compared to the global average, but for Wheat and Rice, the water use is higher than the global average. This discrepancy suggests inefficiencies in water management and irrigation practices.

One of the primary reasons for this inefficiency is the limited adoption of modern irrigation techniques in Indian agriculture. Modern methods such as drip irrigation, sprinkler systems, and precision agriculture technologies can significantly enhance water efficiency. These methods aim to deliver water directly to the roots of plants in controlled amounts, reducing wastage and optimizing water use efficiency.

Therefore, adopting modern irrigation methods is crucial for India to address its water challenges in agriculture. By implementing these techniques, India can potentially reduce water usage, mitigate water scarcity risks, and enhance agricultural productivity sustainably[4].

Table II: Here's the list organized into a table format for clarity:

Measure	**Description**
1. Intensive use of mass awareness/IEC activities, Krishi Vigyan Melas etc	Promoting awareness and education among farmers and the public about efficient water use through events and outreach programs.
2. Promoting and incentivizing efficient use of water	Encouraging practices and technologies that reduce water wastage and optimize usage efficiency in agriculture.
3. Irrigation scheduling	Timing irrigation to match crop water needs and soil moisture levels, reducing water loss through evaporation and runoff.
4. Adopting Piped/micro irrigation system	Installing systems that deliver water directly to plant roots, minimizing losses from evaporation and ensuring efficient water use.
5. Conjunctive use of surface and ground water	Integrating surface water and groundwater resources to optimize irrigation and mitigate depletion risks.
6. Command Area Development in pari passu mode	Developing irrigation infrastructure and management practices in tandem with land development to optimize water distribution and use.
7. SCADA (Supervisory Control and Data Acquisition System) for efficient measurement/allocation/regulation of irrigation water	Using advanced technology for precise monitoring and control of irrigation water distribution.
8. Sensor-based Smart Irrigation Controllers	Utilizing sensors to monitor soil moisture and weather conditions, adjusting irrigation schedules accordingly to optimize water use.
9. Wind and Solar Powered Irrigation	Implementing renewable energy sources to power irrigation systems, reducing dependence on fossil fuels and enhancing sustainability.
10. Less water consuming varieties of seeds	Promoting crop varieties that require less water for cultivation without compromising yield or quality.
11. Laser leveler for field-leveling	Employing technology to level fields accurately, reducing water runoff and ensuring uniform water distribution.
12. No tillage farming	Adopting farming practices that minimize soil disturbance, enhancing water retention and reducing erosion.
13. Mulching and Hydro-Gels	Applying materials to the soil surface to reduce evaporation, retain moisture, and improve soil structure.
14. Cropping Pattern Planning	Designing crop rotations and planting schedules based on local environmental conditions and water availability.
15. Screen houses for plants	Using structures to protect crops from adverse weather conditions, reducing water needs and improving crop yield.
16. Shelter Belt of trees	Planting trees around farms to reduce wind speed and evaporation, conserving water in the soil.
17. Weed Management	Controlling weeds to minimize competition for water and nutrients with crops.
18. Participatory Irrigation Management, Water Users Associations	Involving farmers in managing irrigation systems collectively to optimize water use and distribution.

[4] FAO,2020

Measure	Description
19. Institutional mechanism for access to credit/finance	Providing farmers with financial support and subsidies to adopt modern irrigation practices effectively.
20. Recycling and re-use of water	Treating and reusing wastewater for irrigation to reduce freshwater demand and improve water efficiency.
21. Water Pricing, Water Budgeting & Auditing	Implementing policies and practices to manage water resources effectively, including pricing mechanisms and auditing to monitor water use.
22. Water Footprint and Water Market	Assessing and managing the environmental impact of water use and exploring market-based approaches for water allocation.
23. Public Private Partnership (PPP)	Collaborating with private entities to invest in and implement water-efficient technologies and practices.
24. Performance Evaluation and Benchmarking	Monitoring and comparing water use efficiency across different farms and regions to identify best practices and areas for improvement.

E. Understanding the Relationship Between Economic Growth and Water Consumption

Indicator 6.4.1 not only reveals how efficiently water resources are used in economic and social contexts but also indicates the degree to which economic growth is linked to water use. Specifically, it measures how much water consumption increases as the economic value added grows. If the indicator shows an increase, it means that economic growth is outpacing water use, indicating that water availability is not constraining economic expansion.

F. Why Decoupling Water Usage from Economic Growth is Essential

The indicator aims to pinpoint the stage at which any increases in water use become disconnected from the growth in the economy's value added—this is known as the tipping point. While developing countries may not experience this immediately, it is crucial for water policies to anticipate this point to mitigate the risk of overstretching available resources, especially in countries facing medium to high water stress levels (refer to indicator 6.4.2).

This indicator serves to provide insights into the efficiency of economic and social water resource usage, including the value derived from water in key economic sectors, accounting for losses in distribution networks. The efficiency of water distribution systems is implicit in these calculations and can be made explicit where necessary and data are available.

Water-use efficiency is heavily influenced by a country's economic structure, the proportion of water-intensive sectors, and real improvements or deteriorations. Therefore, the indicator helps in shaping water policy by highlighting sectors or regions with minimal changes in water-use efficiency or high-water demand but low efficiency. This guidance aids countries in enhancing water-use efficiency by adopting successful practices from sectors or regions with higher efficiency levels and applying them where efficiency is lower. Cross-sector planning is supported by implementing Integrated Water Resources Management (IWRM), as measured by indicator 6.5.1 (United Nations Environment Programme [UNEP], 2021).

However, it is important to note that policies aiming to shift water between economic sectors solely to increase water-use efficiency would likely be ineffective in most cases. Imbalances in a country's overall development due to water resource use could signal issues needing attention and change through other SDG indicators, potentially jeopardizing food security and livelihoods in developing countries, especially those heavily reliant on subsistence agriculture (though not directly visible in this indicator, it would be captured by related indicators).

Indicator 6.4.1 specifically targets the goal of "substantially increasing water-use efficiency across all sectors," comparing the economy's value added with the volume of water used across agriculture, industry, energy, and services, including losses in distribution networks. Over time, increasing water-use efficiency aims to decouple economic growth from water use in these primary sectors.

This objective aligns closely with Sustainable Development Goals (SDGs): ensuring sustainable food production (SDG 2), promoting gender equality and managing natural resources (SDG 5), fostering economic growth (SDG 8) through resource efficiency and environmental preservation, advancing infrastructure and industrialization (SDG 9) with sustainable industries, enhancing cities and human settlements (SDG 11) through improved water accessibility and ecosystem health, and promoting efficient consumption and production patterns (SDG 12)[4].

G. Government Initiatives

Water availability per capita in India has undergone a significant decline over the past decades, dropping from 5177 cubic meters (m3) in 1951 to 1567 m3 in 2011, with projections suggesting it could further decrease to around 1140 m3 by 2050. This represents a substantial 78% reduction over 68 years, indicating that India is already

[4] Progress on change in water-use efficiency-FAO 2021

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facing water stress. Despite having only 4% of the world's total fresh water resources, India's irrigated agriculture consumes about 81% of its developed fresh water resources. The traditional Canal Distribution Network, operating with an efficiency of 35-40%, is insufficient to meet the water, food, and energy needs of a rapidly growing population and evolving lifestyles.

Enhancing water use efficiency across all sectors, particularly in irrigation, is therefore critical and urgent for sustaining life amidst the challenges posed by climate change in the water sector today. The paper explores the deep concerns and the Government of India's commitment to improving water use efficiency and its optimal utilization. This commitment is reflected in policies such as the National Water Policy 2012, the National Water Mission under the National Action Plan on Climate Change, and initiatives like the Pradhan Mantri Krishi Sinchai Yojna (PMKSY) aimed at "Har Khet Ko Pani" (Water to Every Field) and "Per Drop More Crop". These efforts include promoting and incentivizing micro-irrigation systems to increase the area under assured or protective irrigation without increasing water consumption.

Additionally, programs like Jal Shakti Abhiyan highlight the challenges in implementing ground-level initiatives and emphasize the role of farmer awareness and active participation through Water Users Associations in Participatory Irrigation Management. These efforts are crucial for achieving common and collective benefits in water management.

1. **National Water Policy (NWP) 2012:** The NWP 2012 emphasizes efficient water use, detailed in Clause 1.2, sub-Clause 4.3 of Clause 4, and Clause 6. Recognizing emerging challenges, a committee was formed in November 2019 to revise the policy through extensive consultations with stakeholders, including state governments.
2. **National Water Mission:** Part of the National Action Plan on Climate Change, the National Water Mission, launched on June 30, 2008, aims to improve water use efficiency across all sectors by 20% by the end of the 12th Five Year Plan (2017), among other objectives.
3. **Pradhan Mantri Krishi Sinchai Yojna (PMKSY):** Launched in July 2015, PMKSY aims at "Har Khet Ko Pani" (water to every farm through assured irrigation) and "Per Drop More Crop" (enhancing productivity through micro irrigation). It integrates four components under three central government ministries, with the micro irrigation component falling under the Ministry of Agriculture, Cooperation & Farmers Welfare.
4. **Piped Irrigation Network Guidelines:** Addressing land acquisition challenges associated with traditional open canal systems, the Central Water Commission introduced guidelines in July 2017 for planning and designing piped irrigation networks. This initiative aims to improve irrigation efficiency and facilitate wider consultation to establish standards.
5. **Micro Irrigation Fund (MIF):** Approved by the Cabinet Committee on Economic Affairs in May 2018, the MIF with an initial corpus of Rs. 5,000 crore under PMKSY supports innovative integrated projects, including public-private partnerships (PPP). It incentivizes micro irrigation adoption through additional subsidies and aims to cover additional areas while complementing state contributions under PMKSY.

These initiatives underscore India's commitment to enhancing water use efficiency through policy frameworks, targeted missions, infrastructure improvements, and financial incentives aimed at sustainable agricultural practices and water resource management.

V. CONCLUSION AND WAY FORWARD

In an era where sustainable management of water resources has become a global imperative, India has also prioritized improving its water utilization efficiency through innovative methods and policy reforms. Effective management and efficient utilization of water resources have emerged as significant priorities to address water-related challenges in the country.

The study examines the dynamic interplay between water resources, technology, and water usage efficiency using systematic econometric methods. The study suggests that while India has significant water resources, the motivation and allocation towards efficient water infrastructure and management systems vary considerably across regions. Adoption of water-saving technologies like wastewater recycling, advanced irrigation systems such as drip irrigation, and efficient water management policies can significantly enhance water usage efficiency in India.

Recycling treated wastewater for agricultural irrigation, industrial processes, and other uses reduces the demand for freshwater resources. Advanced irrigation methods help optimize water utilization and mitigate seasonal fluctuations. Moreover, the study highlights the negative impact of rapid economic development on water usage efficiency during initial stages, as increased industrial and agricultural activities often lead to higher water demands. However, as economies mature, there is a tendency to invest more in water conservation technologies and policies, thereby improving efficiency. Education and awareness campaigns play a crucial role in promoting responsible water use practices among the population. Policies that incentivize water-saving technologies and efficient water management strategies are essential for achieving sustainable water resource management in India. Overall, the study underscores the importance of integrating technological innovations with robust policy frameworks to ensure efficient water resource management amidst growing water scarcity concerns in India.

REFERENCES

[1] Mekonnen, M. M. and A. Y. Hoekstra. 2011. The green, blue and grey water foot print of crops and derived crop products. Hydrology and Earth System Sciences 15 (5):15771600. (Cited on pages 1, 10, 18, 31, 33, 51, and 52.)

[2] Anderson, Kym, Marianne Kurzweil, Will Martin, Damiano Sandri, and Ernesto Valenzuela. 2008. Methodology for measuring distortions to agricultural incen tives. World Bank, Technical Report 2. (Cited on page 11.)

[3] Chichilnisky, Graciela. 1994. North-south trade and the global environment. American Economic Review 84 (4):851874. (Cited on pages 1, 6, and 40.)

[4] DeLUCIA, E. H., Drake, J. E., Thomas, R. B., & Gonzalez-Meler, M. I. Q. U. E. L. (2007). Forest carbon use efficiency: is respiration a constant fraction of gross primary production?. Global Change Biology, 13(6), 1157-1167.

[5] Tang, X., Li, H., Desai, A. R., Nagy, Z., Luo, J., Kolb, T. E., ... & Ammann, C. (2014). How is water-use efficiency of terrestrial ecosystems distributed and changing on Earth?. Scientific reports, 4(1), 7483.

[6] Keenan, T. F., Hollinger, D. Y., Bohrer, G., Dragoni, D., Munger, J. W., Schmid, H. P., & Richardson, A. D. (2013). Increase in forest water-use efficiency as atmospheric carbon dioxide concentrations rise. Nature, 499(7458), 324-327.

[7] Huang, M., Piao, S., Zeng, Z., Peng, S., Ciais, P., Cheng, L., ... & Wang, Y. (2016). Seasonal responses of terrestrial ecosystem water-use efficiency to climate change. Global Change Biology, 22(6), 2165-2177.

[8] Huang, M., Piao, S., Sun, Y., Ciais, P., Cheng, L., Mao, J., ... & Wang, Y. (2015). Change in terrestrial ecosystem water-use efficiency over the last three decades. Global Change Biology, 21(6), 2366-2378.

[9] Vicca, S., Luyssaert, S., Peñuelas, J., Campioli, M., Chapin Iii, F. S., Ciais, P., ... & Janssens, I. A. (2012). Fertile forests produce biomass more efficiently. Ecology letters, 15(6), 520-526.

[10] FAO. (2015, September 02). TOWARDS A WATER AND FOOD SECURE FUTURE Critical Perspectives for Policy-makers. Rome: Food and Agriculture Organisation of the United Nations From United Nations Food and Agriculture Website.

[11] FAO. (2018, September 12). AQUASTAT - FAO's Global Information System on Water and Agriculture. From HYPERLINK "http://www.fao.org/aquastat/ en/" http://www.fao.org/aquastat/en/

[12] Mekonnen, M.M. & Hoekstra, A.Y. (2011) The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15(5): 1577-1600

[13] Fereres, E., Orgaz, F., & Gonzalez-Dugo, V. (2011). Reflections on food security under water scarcity. Journal of experimental botany, 62(12), 4079-4086.

[14] Namara, R. E., Nagar, R. K., & Upadhyay, B. (2007). Economics, adoption determinants, and impacts of micro-irrigation technologies: empirical results from India. Irrigation Science, 25(3), 283-297

[15] GoI. (2018). Agriculture Census. New Delhi: Department of Agriculture, Cooperation and Farmers Welfare.

[16] GoI. (2018, March). Guideline. From Pradhan Mantri Krishi Sinchayi Yojana: https:// pmksy.gov.in/MicroIrrigation/ Archive/GuidelinesMIRevised250817.pdf