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Efficacy of influencing factors in the decision-making of irrigation water pricing: a review

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ABSTRACT

The irrigation water-pricing (IWP) system may prove to be an effective tool for meeting the increased demand for water. It includes the totality of costs that water users incur for irrigation purposes, based on principle, i.e., fixed, volumetric and crop-based. Factors like crop type, area irrigated, number of irrigations and total volume of water used by water users are considered for initiating the decision-making process of IWP in many countries of the world. There is no uniform set of principles for fixing water rates; a multiplicity of factors are followed, such as the capacity of irrigators to pay, recovery of water cost, crop water requirement, sources of water supply and its assurance. Linear programming, the Full-cost and Bayesian Network model, Residual value method, Principal Agent model and spot market pricing model have been used to estimate the impact of an IWP policy on water users. In the Indian context, a rationalized IWP mechanism alone will not suffice if the revenue collection mechanism is not streamlined and strengthened throughout the country. In order to develop a full-fledged volumetric IWP system in India, considerable changes need to be made in irrigation water supply infrastructure and operational plans need to be developed, which will provide a good balance between efficiency and equity objectives.

Key words: Cost analysis, Irrigation, Irrigation water price, Volumetric pricing system, Water laws, Water-pricing models

HIGHLIGHTS

- Review of models used for water pricing.
- International and national scenarios for water pricing.
- Factors for water-pricing estimation.
- Implementation of water-pricing legislative and scientific measures.

INTRODUCTION

Irrigation water-pricing (IWP) refers to the sum of payments that a beneficiary makes for the irrigation service, i.e., fixed, volumetric, crop-based, etc. It is assessed in terms of price per unit quantity of water or acres of land irrigated per year. It is considered as the most efficient way for making water resource allocation, improving water-use efficiency, enhancing social equity and securing the financial sustainability of water utilities and principles. In the case of volumetric water pricing, the principle of IWP is clear, whereas in the case of non-volumetric water pricing, an inbuilt water price can be applied by dividing the water charge by the volume of water delivered.

India is the largest groundwater user in the world. It is extracted for irrigation, domestic and industrial purposes. This is leading to a depletion of groundwater levels in many parts of the country at an alarming rate.

So, in order to address water scarcity issues, better water pricing has been recognized as an important tool (Mohayidin *et al.*, 2009). It may be defined as an effective tool for overseeing the increased demand for water. It is expected to (1) provide a source of income to water suppliers to guarantee financial viability and adequate maintenance of the water supply system, (2) reduce demand and guarantee the sustainable use of water resources and (3) reallocate water from low-value to high-value use (Berbel *et al.*, 2007; Iglesias & Blanco, 2008).

Pricing of water and water-related services adequately can encourage people to waste less water, pollute less water and invest more in water-related infrastructure. India is not a water-rich country. It is further challenged by the negative impacts of climate change, huge wastage owing partly to poor irrigation water management and distorted water-pricing policies (Dhawan, 2017). Under the scenarios of poor irrigation water management and a distorted IWP situation, some challenges may be created: (i) introducing a water-pricing system at a time when the most vulnerable to water shortage are already reeling under severe economic hardship. But without any pricing on water usage, it is the vulnerable people who will suffer the worst consequences of a drought, (ii) implementation of water pricing entrenched the political economy in different parts of the world and (iii) intrinsic design problems associated with water pricing.

With a view to ensuring equitable water distribution, the efficiency of the irrigation system and a judicious use of water supplied from public or private systems, water charges are imposed on water users (CWC, 2017a, 2017b). In order to follow the principles of equity, efficiency and economics, water charges should be determined on a volumetric basis. In most of the states of India, there is no water fee or any other charge for irrigation water supply. Due to the inability of the states to address the problem of irrigation and water supply services and poor accountability in revenue generation, irrigation water charges are negligible in various parts of the country (Easter & Liu, 2005; Briscoe & Malik, 2006). In many states, even electricity is provided free of cost for irrigation water pumping (Dhawan, 2017). In some states where water availability is plentiful and the price is relatively low, water pricing has been found to be less successful (Singh & Aslam, 2019). Subsequently, a distorted water-pricing mechanism is resulting in overexploitation of natural resources, which may have long-term negative impacts such as salination and the presence of heavy metals, thus, leading to the practice of converting agricultural lands into non-agricultural lands.

In the light of the above, in this paper, an attempt has been taken to explore the possibility of bringing about a consistent IWP mechanism with an objective of understanding the whole process in terms of implementation and the effectiveness of reforms in India. The broad objectives of the paper include the following: (i) examining the pricing frameworks adopted in India and abroad, (ii) assessing the achievements of the pricing reforms in India and abroad, (iii) identifying the lessons that each country can learn from the other and (iv) reviewing the process of reform and its implementation in India.

Mechanism for IWP

The prevailing IWP mechanisms across India can be grouped into four categories, namely, water market, quotas, non-volumetric pricing and volumetric pricing (Johansson *et al.*, 2002; Reddy, 2008).

The water market method

The water market method refers to the price determination based on the demand and supply of water in a market environment. This has been found to be more flexible in fixing the price of irrigation water. Markets can be formal or informal in nature. In Indian conditions, most water markets are informal (Venkatachalam, 2015). Developing water market mechanisms can help deal with the inefficiencies of conventional irrigation water supply institutions. There should be well-defined water rights and appropriate setting up of institutions to develop formal water markets. A flat quantum of water entitlement per net unit of command area could be reallocated through informal water markets, which are known to be efficient mechanisms of IWP (Rajaraman, 2006).

The quota method

The quota method is used to address the fairness of water distribution and management issues that may arise under the water market method. Under this method, a certain quota of water is allotted, which can deal with equity concerns and can promote efficient allocations of water (Parween *et al.*, 2021).

The non-volumetric pricing method

Under the non-volumetric pricing method, IWP normally depends on the crop and area under cultivation or sometimes on land value. This method is suitable for surface irrigation systems. Due to the high costs of installation of a metered system, this method has been found to be more effective and easy to implement the mechanism of per unit area pricing than the volumetric pricing method (TERI, 2010). Ideally, it includes flat rates, per acre rates, crop-wise rates, etc.

The volumetric pricing method

Under the volumetric pricing method, water use is measured and accordingly charged. This method ensures economic efficiency if processes are kept at the marginal cost of water. This method encourages the idea of water resource management because irrigation water charges increase with the use of water. This method ensures appropriate volume and timing of water supply and also the reliability of supply and, thus, fixed appropriate water charges to water users based on the volumetric water supply (Burt, 2007; Jeet *et al.*, 2016). This method is prevalent in many countries like Australia, England, France, Israel, Jordan, Mexico, Morocco, Spain, USA and so on (Grafton *et al.*, 2020). However, in India, it is recommended by the Government of India under the National Water Policy of 2012 (Parween *et al.*, 2021).

International scenarios of irrigation water prices

The World Bank (2004) has introduced the concept of principled pragmatism, recognizing that water resource management is complex and nuanced than first suggested in the call for full-cost pricing. The Bonn International Conference on Freshwater (2001) emphasized the possible contribution of water pricing to water management and focused on the recovery of operational and financial costs. There can be differences in irrigation water charges within a single country. These may arise in the form of diverse irrigation water sources, degrees of water scarcity, irrigation projects with different technologies, size of landholding, spending in infrastructure, socio-economic conditions, accessibility of skilled manpower, etc. (Giannakis *et al.*, 2016). Therefore, it is often not possible to make a simple statement to describe the system of irrigation water charging at a national level. The World Bank (2004) identifies the differences between agricultural and urban water users in terms of the markets in which they operate. Policies of water pricing and subsidy in one urban centre are said to have no material effect on what is an appropriate price in another urban centre. However, in the irrigation sector, because products are traded nationally and internationally, pricing policies in one location can have a significant impact on what can be charged elsewhere. Webber *et al.* (2008) and Kumar *et al.* (2011) reported that farmers should pay not only their irrigation water charges but also the pumping cost of water. Dono *et al.* (2010) applied a mathematical model to study the economic aspects and the impacts on the usage of water under the volumetric pricing method and the area-based pricing method for a farm sector in a Mediterranean area that relies on a dam for irrigation. Irrigation water charges per unit area are difficult to compare because they are generally set for per crop. For example, in Greece, there is a great variation in water charges from 90 to 21 euro/ha (Rs. 7,609–17,754/ha). In the case of Cyprus, the volumetric irrigation charges are increasing by 41%, while the fixed per-area charges are almost triple. However, irrigators have not charged these water rates due to the political interference or imposition of additional costs on them (Giannakis *et al*., 2016). Saleth & Amarasinghe (2010) outlined the status and effectiveness of various demand management options and opined that the direct returns from demand management investments can improve the efficiency of the irrigation sector and boost the water economy as a whole. Some eastern European countries like Hungary, Poland and the Czech Republic only apply volumetric pricing systems (Jones, 2000). In Jordan and Turkey, water supply for irrigation is charged from groundwater sources (Molle, 2008). Although the volumetric and other irrigation pricing methods are followed, water is still subsidized in most countries. The variations in irrigation water rates are quite substantial across countries (Tables 1 and 2). Despite this factor, the adoption of volumetric and other efficient

Table 1 | Irrigation water charges in selected countries (price per 1,000 m^3).

Countries/regions	Water price (US$/1,000 m^3)
USA	US$ 5 on average per acre foot (range: US$ 2–US$ 200/acre foot); and US$ 19.32/acre foot in some cases
Jordan	US$ 0.04/m^3 for the 1.5 m of irrigation depth and US$ 0.08 for any additional amounts
UK	13–28
Jordan	21.13
Bulgaria	45.54/ha (maize) for two irrigations
Australia	4.36
France	5.26
Morocco	19
Spain	128
Turkey	US$ 12 and US$ 33 (for wheat crop) US$ 34 and US$ 80 (for cotton crop)
Chile	US$ 993–US$ 2,978 per share of 1 lps delivery
Israel	180–290
Netherlands	330
Tanzania	420
Canada and Romania	10

Source: Chaudhuri & Roy (2019) and Reddy (2008).

Table 2 | Irrigation water charges in selected countries (price per hectare).

Countries/regions	Water price (US$/ha)
Bangladesh	150
China	50–150
Greece	92–210
Japan	246
Niger	124 per season
Tunisia	124–538

Source: Chakravorty (2004), Reddy (2008), Calatrava & Garrido (2010), and Chaudhuri & Roy (2019).

water-pricing mechanisms is underpriced in most countries (Reddy, 2008; Wichelns, 2010). In the USA, some growers who have agreements with the Federal Government pay a very nominal charge, which is US$ 5–10/1,000 m^3 (Rs. 373–746/1,000 m^3). Those who buy water from state-level irrigation water agencies normally pay a higher cost, which is US$ 20–100/1,000 m^3 (Rs. 1,491–7,457/1,000 m^3). It was noticed that in Ogallala, aquifer irrigation water prices increased considerably due to the use of groundwater as the main source of water (Parween *et al.*, 2021). US$ 40–50/ha/year (Rs. 2,983–3,729/ha/year) is closer to an average price in most developed countries, but in India, many states' water charges are no more than US$ 10/ha/year (Rs. 746/ha/year). Mohtadullah (1997) reported that the Revenue Department in Pakistan receives approximately US$ 0.33/year (Rs. 25/year). In the southern European countries such as Greece and France, water charges vary in the range of 0.054 to 0.645 euro/m^3 (Rs. 4.50–54.50/m^3) and 0.23–1.50 euro/m^3 (Rs. 19.50–127/m^3), respectively (Giannakis *et al.*, 2016).

Water used for irrigation has essentially a zero marginal cost for most farmers in Canada. This is despite some farmers paying water charge on the basis of acres of agricultural lands irrigated, which is approximately US$ 0.01/m^3 (Rs. 0.75/m^3) (Dinar *et al.*, 2015).

Dinar *et al.* (2015) concluded that irrigation water charges in Brazil are low for the reason that 90% of water withdrawals for agriculture returns to the hydrological cycle. In China, there are multiple pricing patterns for irrigation water. Cultivated area is irrigated by a conjunctive use of surface water and groundwater and is charged on the basis of culturable command area. It also reported that farmers prefer the cost of irrigation water to be around 10–12% of the total cost, which is approximately 5–7% of the total output. Macro-agricultural irrigation water price is 1.023 yuan/m^3 (approximately Rs. 12/m^3), whereas micro-agricultural irrigation water prices for surface water and groundwater range from 0.993 to 1.008 (approximately Rs. 12/m^3) and from 2.343 to 2.358 yuan/m^3 (approximately Rs. 28/m^3), respectively (Ren *et al.*, 2018). In China, irrigation water price is low. This is not due to the farmers' inability to pay but rather due to their refusal to pay and also poor existing irrigation water management facilities (Tang *et al.*, 2013).

Models for irrigation water price calculation in India and abroad

A robust water-pricing system would quantify the allotment of water by sector and maintain an open-sourced, digital geo-database for in-depth and periodic econometric appraisals. Various water resource value estimation approaches based on equilibrium pricing, value mosaic, energy estimation and fuzzy comprehensive evaluation have been reported in the literature. Models that is used for the fixing of IWP significantly reduce the water price when a water duty is imposed (Berbel *et al.*, 2007). Viaggi *et al.* (2010) applied linear programming and a Principal Agent model for water management for agriculture in Northern Italy. They found that the feasibility of incentive-oriented water-pricing system was considerable, even where water was unmetered. The residual imputation model or the Residual value method (RVM) is a technique that has been used to value water productivity where water is used as an intermediate input into production. Upadhyaya & Roy (2020) applied the RVM for the assessment of the cost of irrigation water to grow per kg of rice and wheat in Paliganj distributary of the Sone canal command area in the Indian state of Bihar. They found that existing irrigation water charges were much lower than the actual irrigation water charges. The Bayesian Network (BN) model has been used to estimate the impact of the water-pricing policy on farmers. In contrast, the BN model is widely used in various fields such as natural resource management, groundwater protection and ecological vulnerability assessment. Zhu *et al.* (2018) analysed current water rights trading and management systems and quantified the impact of a water-pricing policy on farmers' planting behaviour using the BN model at Heshuo County, Xinjiang, China. They found that an increase in water charges can effectively reduce irrigation water consumption in agriculture. A water resource management model mainly directed by a water-pricing policy and supplemented by groundwater protection and agricultural subsidy policies could effectively regulate farmers' water-use behaviours, guarantee farmers' income and protect groundwater. Full-cost and BN models are used to calculate and evaluate a water-pricing policy for the purpose of coordinating the relationship between agricultural and ecological water use in arid basin watersheds (Veettil *et al.*, 2011; Zhu *et al.*, 2018). Joshi *et al.* (2017) applied the Hedonic Pricing Method (HPM) model to quantify the economic value of access to irrigation for agricultural areas in Nepal. They found that the value of land with access to irrigation water was roughly 46% higher than the value of non-irrigated lands with a marginal cost of around Rs. 150,840. Aidam (2015) applied the Multi-Analysis Tool for the Agricultural Sector (MATA) model to find out the impact of a water-pricing policy on the demand for water resources in relation to their cropping activities and income in Ghana. He found that the water-pricing policy had a negative impact on the demand for water resources. He also found that if water prices were high, it had a negative impact on cropping activities, farmers' income, employment and crop varieties. Gallego-Ayala *et al.* (2011) applied a simulation model based on positive mathematical programming to simulate farmers' behaviours in response to IWP instruments for analysing the potential consequences of different methods such as area, volumetric, two-part tariff and block-rate methods for IWP and for studying their impact on the sustainability of the irrigated areas of Campos district in the Spanish province of Palencia. They found that IWP have a negative impact on overall sustainability whereas only a slight improvement in environmental sustainability. The block-rate pricing method resulted in high rates of public-sector revenues derived from irrigation water payments and promoted a significant reduction in the demand for irrigation water with the lowest reductions in farm sustainability. Schuck & Green (2002) developed a supply-based water-pricing model to reflect variations in water supply on the price of water. The model combines the techniques of conjunctive-use system management and Ramsey water pricing. They also assessed the impact of the pricing policy on water use, land use and energy use in the district of California using simulation techniques. Riordan (1971) developed a model of optimal water pricing and investment by a publicly owned or regulated monopoly called multistage marginal cost pricing. This model was based on a short-run marginal cost pricing principle. When supply reaches its full capacity, the price necessarily rises, keeping demand within capacity constraints. Dynamic programming techniques are employed to derive the optimal capacity expansions and their adequate timing. Zarnikau (1994) developed a model of spot market pricing for irrigation water. He found that the IWP model was more efficient than average cost pricing, especially when short-run marginal costs varied over time or when water became scarce and rationing methods had to be found.

A sound IWP system should recognize both (a) the cost of irrigation water supply and (b) the value of water used in rural livelihoods (Chandrasekaran *et al.*, 2009). The cost component should include irrigation water supply services, the operation and maintenance of irrigation infrastructure and capital inflation or depreciation. However, it should also include the costs of the creation of livelihoods, equivalent energy costs for pumping and the costs of socio-environmental externalities. The value component goes beyond immediate use (irrigation) and includes all indirect uses as well, such as gains from irrigation return flow, cultural/aesthetic values of water and the contribution of the irrigation scheme. Water supplied to farmers as part of irrigation projects is not limited to irrigation alone but is used for domestic purposes, running local businesses, maintaining rural healthcare facilities and so on. In order to realize the goals of a water-efficient agricultural sector, new technology adoption and best management practices/policy making for bringing about uniformity in water charges, the following decisions need to be made, combined with factoring in the relevance of the modelling approach in the irrigation or water operation and management sector. However, technology adoption depends on the responsiveness of irrigators to water price changes. Nevertheless, irrigation scheduling decision support systems (DSSs) are computer-based tools that provide guidance on when and how much to irrigate (Giannakis *et al.*, 2016).

National scenarios for irrigation water prices

According to the Seventh Schedule of the Indian constitution, water comes under the concurrent list. This implies that either the central or state government has concurrent power to make laws and decrees on this subject, whereas water management falls under the jurisdiction of state governments. In India, water rights are based on riparian law that gives the right to water based on proximity to water resources. According to riparian water rights, communities or individuals that are nearby or have close access to water sources have the primary right to water. In India, irrigation water charge is calculated on an area basis, and this is perhaps the best approach to provide a fixed quantum of water per unit of land (Rajaraman, 2006; Sindhu, 2010). Usually, water charges on area basis consider factors such as the source of water, how water is being supplied, crop season, crop type, duration, land type and type of irrigation project (Parween *et al.*, 2021). The basic idea about the fixing of IWP should be to generate sufficient revenue to at least cover operation and maintenance (O&M) costs, which are required for the maintenance of the system on a sustainable basis (Perry, 2001; Sindhu, 2010). A number of IWP methods have been adopted across countries. There are also variations within each country like India, where different IWP methods are adopted. Water prices are charged according to the local conditions and costs of production (Reddy, 2008). Rajaraman (2006) evaluated IWP for the Indian state of Karnataka and found local user groups as an option for fixing a flat rate and overseeing any informal water trading. Chaudhuri & Roy (2019) applied the volumetric water-pricing method and suggested employing automatic metering devices to charge for the actual volume of water used. No water rates are levied from farmers when they lift water from rivers or in the downstream of a reservoir or barrage in the state of Gujarat. The capacity and certainty of irrigation are kept in view while fixing water rates in Haryana. Maharashtra has fixed water rates by considering the volume of water supplied, paying capacity of the farmer, sufficient recoveries to be at least equal to the annual cost incurred in providing water services, tapping of full potential and the level of the average gross income (Parween *et al.*, 2021). In the states of Haryana, Rajasthan and Punjab where water levels continue to decline, IWP levels are among the lowest for paddy and do not apply to groundwater. In Punjab, Himachal Pradesh and Tripura, spatially uniform and flat water rates apply to paddy, wheat and sugarcane. In West Bengal Minor Irrigation Schemes, water supplied to agriculture is only on pre-payment basis. Some states have no water-pricing system at all. The Maharashtra State Irrigation Commission recommends that rates for flow irrigation be fixed at almost 6% of the gross income in the case of non-cash crops and about 12% of the gross income in the case of cash crops. However, optimum levels of IWP rates should be 5% of the gross income for food crops and 12% for cash crops recommended by the Irrigation Commission of India (Chaudhuri & Roy, 2019).

Factors for IWP decisions

There are a number of factors in water charging that have changed rapidly with the times, such as price charge, recovery rates and price structures. Generally, the water charges imposed by governments comprise the following elements:

i. Types of crop
ii. Area irrigated
iii. Number of irrigations of each crop
iv. Total volume of water used by the farmer

In India, IWP is mostly based on crop area, which is labour-intensive. Moreover, it sets arbitrary charges on irrigation water users and agrarian communities. One way to solve this problem is to introduce a volumetric system using inbuilt automatic metering devices to charge for the actual volume of water used (Chaudhuri &

Roy, 2019). Automation improves accuracy and billing efficiency, which enhance farmers' irrigation opportunities (Aidam, 2015). Irrigation water charging is based on the area cultivated and the crops grown. Many studies have indicated that the prevailing irrigation water rates for different crops in India promote neither efficiency nor cost recovery, reflecting poor performance (Vaidyanathan, 2003). Ideally, IWP should be keyed to the following: (1) type of crops (food vs. cash) and crop water requirement; (2) type of the irrigation method (gravity, lift and drip/sprinkler); (3) land characteristics (wet vs. dry); (4) financial capacity of farmers; (5) scale of an irrigation project (large, medium and small) and (6) water resource vulnerability (Chaudhuri & Roy, 2019). Water rates are not based on the volume of water consumed but are area based and vary across states depending on the type of crop (Soto Rios *et al.*, 2018) and cropping pattern (Tsur & Dinar, 2018). Similarly, crop-specific charges, that is, a fixed charge per hectare of crop, perhaps set higher for more water-consuming crops, will only make farmers switch to less water-consuming crops when the irrigation charges are sufficient to make those less water-consuming crops relatively more profitable (Berbel *et al.*, 2007). Water rates have not been revised regularly in many Indian states. Even now, lower and outdated water rates prevail, and as a result, there has been a drop in the revenue from water charges. Therefore, there is a need for pricing of water such that they reflect the supply cost. A volumetric pricing system can be implemented in wells and tube well-irrigated areas and for surface irrigation, but this requires considerable investment in irrigation water supply infrastructure and the development of operational plans. For irrigation water charges, most countries follow a two-part pricing system such as fixed and volumetric components, with the volumetric component being up to at least 75% of the total water charges (CWC, 2017a, 2017b). Pricing of irrigation water also depends upon the source of water. Finally, there are four types of water-pricing methods that are based on area, crop, block and volumetric pricing (Veettil *et al.*, 2011).

Policies of irrigation water price in India

Water is a state subject in India and the water rates are fixed by state governments. Water pricing, thus, has been treated as a necessity to maintain the financial stability of the state irrigation departments rather than an economically desirable policy. However, canal irrigation water is never supplied free of charge to farmers, though the charges vary across states, since the pricing of water falls under state jurisdiction. In most Indian states, irrigation charges are combined and collected along with land tax or revenue. The difference in land taxes between dry and irrigated areas is the irrigation water charge. This, in fact, encourages governments to expand the areas under irrigation. In addition, it is politically unfavourable to increase water rates. The gap between costs and revenues from irrigation has been increasing. The increasing populism of competing political parties has also adversely affected the recovery of even these meagre water rates, resulting in dwindling departmental finances (Shen & Reddy, 2016). As a result, the water rates vary among states. There is, therefore, no uniformity for fixation of water rates in states and union territories (UTs). There is also considerable delay in revision of water rates by states. As far as irrigation water is concerned, there are wide variations in water rate structures across countries, and the rate per unit volume of water consumed varies greatly for crops. In some Indian states, irrigation charges vary from project to project depending on the mode of irrigation. The rates vary widely for the same crop in the same state depending on season, type of system, etc. There are no uniform set principles in fixing the water rates, and a multiplicity of principles are followed, such as the recovery of cost of water, capacity of irrigators to pay based on gross earnings or net benefit of irrigation, water requirement of crops, sources of water supply and its assurance, classification of land linked with the land revenue system and a combination of various factors. In some states, water cess, betterment levy etc., are also levied. There is no consistency or uniformity regarding how these factors are used in arriving at water rates. The pricing system in a state varies with seasons, crops and irrigated areas. In many states of India, where agricultural crop production is higher, groundwater is the main source of irrigation, especially during the rabi season (November–March). Farmers do not have to pay for the water drawn from tube wells dug on their own lands. Electricity is supplied free of cost or at subsidized rates for agriculture in many states. Likewise, Punjab and Andhra Pradesh provide 100% subsidized electricity to the agriculture sector, while some states such as Tamil Nadu, Maharashtra and Rajasthan do not meter agricultural power consumption (Bassi, 2014). In Karnataka, water rates are levied at specific rates per acre on a crop-specific basis (Rajaraman, 2006).

Indian government initiatives for water pricing

Second Irrigation Commission (1972)

The Second Irrigation Commission report stresses on the role and the importance of levying water charges in return for the water supplied to the users and its adequacy in meeting the O&M cost for ensuring its efficient use. It also stresses on levying water charges by taking into account the following crop basis factors:

- Adequacy and dependability of water supply
- Common policy among neighbouring states
- Crop water requirement
- Review of water rates every 5 years

The report also recommends that the water rates be fixed at 5–12% of the total value of farm produce, with a lower percentage being applicable to fodder and food crops and a higher percentage for cash crops.

Eighth Finance Commission (1984)

The Eighth Finance Commission lays down norms for O&M expenses per hectare of utilized potential for expenditure on regular establishment supporting the project staff, the provision of maintenance of head work, the distribution system and drainage work.

National Water Policy (1987)

The National Water Policy of 1987 states that 'water rates should be such as to convey the scarcity value of the resource to the users and to foster the motivation for economy in water use'.

Ninth Finance Commission (1987)

The report of the Ninth Finance Commission of 1987 suggests that receipts should cover at least the cost of O&M of irrigation projects.

Vaidyanathan Committee (1991)

The Vaidyanathan Committee of 1991 recommends an allocation of 10% of plan provision for major and medium projects for renovating the existing systems and for earmarking the recovery of accumulated arrears towards the cost of deferred O&M in irrigation projects.

Tenth Finance Commission (1992)

The Tenth Finance Commission of 1992 recommends that irrigation receipts not only cover O&M costs but also give a return of 1% per annum on the capital.

National Commission for Integrated Water Resources Development (1999)

The National Commission for Integrated Water Resources Development of 1999 recommends that there is a need for the establishment of a 'water-pricing authority' in order to improve water-use efficiency and measures for systemic pricing of water. It also recommends that water used for irrigation is a key to improving water allocation.

Canal water rates are still area based depending on the type of crops and seasons, etc. There is a wide variation in the rates even for the same crop. The water charges are also very low and have not been revised for many decades. There is no similarity in the water prices followed by various states of the country. There are some states that provide irrigation water free of cost. In some others, irrigation charges are combined with land revenue. In some states, they vary only by seasons, while in a few others, they depend on land classification such as wet or dry. In some states, there are varying rates for water supplied by perennial and non-perennial canals. Some states differentiate between classes of irrigation projects, such as major, medium or minor, for charging water rates.

Twelfth Finance Commission (2002)

The Twelfth Finance Commission of 2002 recommends an O&M cost norm of Rs. 600/ha for utilised irrigation potential and Rs. 300/ha for unutilised irrigation potential, for maintenance of irrigation works of irrigation projects such as major and medium. For minor irrigation project O&M cost norm should be half of those for major and medium irrigation projects.

National Water Policy (2002)

The National Water Policy of 2002 was implemented with the objective that 'the water charges for various uses should be fixed in such a way that they cover at least the O&M charges of providing the service initially and a part of the capital costs subsequently'.

National Water Policy (2012)

The National Water Policy of 2012 was implemented with the objectives that 'pricing of water should reflect its efficient use and reward its conservation; there should be equitable access to water for all and its fair pricing for drinking and other uses should be undertaken by a statutory regulatory authority; and water charges should be determined on a volumetric basis'.

Fourteenth Finance Commission (2015)

The Fourteenth Finance Commission of 2015 recommended that all states consider full volumetric measurement of the use of irrigation water.

National Water Framework Bill (2016)

According to the National Water Framework Bill of 2016, water used for agriculture should be priced on full economic pricing basis.

Ground Water Conservation Fee (2019)

Under the Ground Water Conservation Fee law of 2019, the irrigation sector, which accounts for 90% of the groundwater consumed, is surprisingly exempted. This law is mainly applicable for industrial and domestic water users for consumption beyond a certain limit. This law is mainly implemented to discourage the setting up of new industries in overexploited and critical groundwater areas.

Irrigation water prices vary across states in India under flow as well as lift irrigation (Tables 3 and 4). No water charge is levied for agricultural purposes in most of the north-eastern states, except Manipur and Tripura. Odisha charges a flat basic compulsory water rate for paddy cultivation in all major and medium projects irrespective of water usage, while crop-specific rates are charged for other crops. In West Bengal, water from minor systems is supplied only on a pre-payment basis. In Jammu and Kashmir, Haryana, West Bengal and Kerala, the variations in water rates appear to be marginal. In most states, public water supplies for irrigation are levied on the basis of the area irrigated in the case of irrigation by surface water, while water charges are levied on the basis of the number of hours of watering or volume of water in the case of public tube well irrigation (Shen & Reddy, 2016).

Table 3 | Water rates for flow irrigation by states/UTs.

States/UTs	Rate (Rs./ha)	Date since applicable
Andhra Pradesh	148.20–864.50	07-01-1996
Assam	150–751	30-03-2000
Bihar	74.10–370.50	Nov, 2011
Chhattisgarh	123.50–741	15-06-1999
Delhi	34.03–148.20	2009
Goa	72–360	01-04-2013
Gujarat	160–300	01-01-2007
Haryana	24.70–197.60	27-07-2000
Himachal Pradesh	49.92	04-01-2015
Jammu and Kashmir	121.03–298.87	04-01-2015
Jharkhand	74.10–370.50	26-11-2001
Karnataka	37–99	13-07-2000
Kerala	37–988.40	18-09-1974
Madhya Pradesh	50–960	31-12-2005
Maharashtra	119–6,297	07-01-2003
Manipur	184–602	24-08-2013
Odisha	60–930	04-05-2002
Punjab	123.50	12-11-2014
Rajasthan	29.64–286.52	24-05-1999
Sikkim	10–250	2002
Tamil Nadu	2.77–61.78	11-06-1987
Tripura	312.50	10-01-2003
Uttarakhand	30–474	18-09-1995
Uttar Pradesh	30–474	18-09-1995
West Bengal	37.06–123.50	01-07-2003
Dadra and Nagar Haveli	110–830	19-01-1996
Daman and Diu	286	2007

Source: Water Related Statistics Directorate, Central Water Commission (2019).

In states/UTs like Assam, Chhattisgarh, Jharkhand, Madhya Pradesh, Manipur, Punjab, Tripura and Daman and Diu, water charges for lift irrigation have similar rates as water rates for flow irrigation. The states/UTs of Lakshadweep, Arunachal Pradesh, Meghalaya, Mizoram, Nagaland and Andaman and Nicobar Islands have no water rates fixed by their respective irrigation departments. In these states/UTs, there are also no fixed water rates. In most of the states, public water supplies for irrigation are levied on the basis of area irrigated (in the case of surface irrigation), while water charges are levied on the basis of the number of hours of watering or the volume of water (in the case of public tube well irrigation). The rates for perennial crops are often higher than those for other crops.

Table 4 | Water rates for lift irrigation by states/UTs.

States/UTs	Rate (Rs./ha)	Date since applicable
Delhi	33.35–148.20	2009
Goa	144–720	04-01-2013
Gujarat	53.33–100	01-01-2007
Haryana	12.35–98.80	27-07-2000
Himachal Pradesh	99.81	04-01-2015
Jammu and Kashmir	298.87–2,998.58	04-01-2015
Karnataka	74–1,976.80	13-07-2000
Kerala	93–148.50	18-09-1974
Maharashtra	20–5,405	07-01-2003
Rajasthan	14.82–573.04	24-05-1999
Uttarakhand	15–237	18-09-1995
Uttar Pradesh	15–237	18-09-1995
West Bengal	251.94–2,015.52	01-07-2003
Dadra and Nagar Haveli	75–275	29-01-1996

Source: Water Related Statistics Directorate, Central Water Commission (2019).

Irrigation water price scenarios in Indian states

Bihar Irrigation Act (1997)

According to the Bihar Irrigation Act of 1997, the charges for water are applicable whenever

(i) water is supplied, made available or used for the purposes of irrigation, municipal supply and industrial or commercial use from any irrigation work belonging to, or constructed by, or that is carried out on behalf of, the state government; and
(ii) water from any such work, by direct flow or percolation or by indirect flow, percolation or drainage from or through adjoining land, irrigates any land under cultivation or flows into a reservoir and thereafter by direct flow or percolation or by indirect flow, percolation or drainage from or through adjoining land irrigates any land under cultivation and, in the opinion of the Divisional Canal Officer, such irrigation is beneficial to crops.

Water rates in Bihar are fixed keeping in view the following parameters:

- Cost of maintenance and repair
- Abnormal rise in labour rate
- Cost of the creation of irrigation potential
- Support price of agricultural products
- Comparison of water rates vis-à-vis those in other departments, namely minor irrigation
- Department of the State and the Irrigation Departments of other neighbouring states
- Paying capacity of farmers

In Bihar, the cultivation of summer crops such as paddy, maize, sunflower, litchi, mango, banana and vegetables is uncommon due to the high cost of irrigation and high crop water requirement (Kishore *et al.*, 2017). In this state, farmers pay charges for irrigation on the basis of per unit area and not by hours (Table 5). The

Table 5 | Crop-wise water rates in Bihar.

Seasons	Name of crops	Water rates (Rs./ha) Perennial	Non-perennial
Rabi (26th October–25th March)	Wheat	185.25	138.32
	Barley, potato, onion	148.20	111.15
	Dalhan, tilhan, peas, gram	98.80	74.10
Kharif (25th June–25th October)	Paddy	217.36	108.68
Other	Sugarcane	370.50	–
	Jute	98.80	–
Hot season (25th February–25th June)	Litchi, mango, banana, vegetables	–	296.40
	Paddy, maize, sunflower		247
	Chillies		98.80

Source: Hydrological Data Directorate, CWC, 2017a, 2017b.

irrigation rate in the state has been fixed by the Minor Irrigation Department (MID), and it is Rs. 320/ha/watering during the *kharif* and summer seasons and Rs. 400/ha/watering in the *rabi* season. Irrigation, along with its diesel pumps, costs more than twice as much, and its cost, along with a rented diesel pump, is even higher (Kishore *et al.*, 2017; Upadhyaya & Roy, 2020). According to the reports of the Commission on Agricultural Cost and Price (CACP), farmers in Bihar undertake, on an average, less than 3 h of irrigation per hectare per year for paddy cultivation under normal rainfall conditions, whereas they spend 20–25 h of irrigation per year for paddy cultivation under drought situations.

Irrigation infrastructure and operational plan in India

From the financial year 2005–2006 onwards, the Indian government provided assistance/grant to state governments for the construction of 297 major and medium irrigation projects under the Accelerated Irrigation Benefits Programme (AIBP). Till 2016, for the development of irrigation infrastructure, the central government has sanctioned a total sum of Rs. 55,601.11 crore to state governments, with the goal of achieving an irrigation potential of 9,089.29 thousand hectares (CWC, 2019). Under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)-AIBP, 99 additional major and medium irrigation projects have been sanctioned for the overall development of irrigation infrastructure till 2020, with the aim of increasing the total irrigation potential up to 76.03 lakh ha. Similarly, during the years 2016–2017, 2017–2018, 2018–2019 and 2019–2020, a central assistance of Rs. 3,309.47 crore, Rs. 3,596.626 crore, Rs. 2,849.08 crore and Rs. 1,738.78 crore has been invested for realizing an irrigation potential of 5.088, 3.912, 5.0722 and 3.2225 lakh ha, respectively, for achieving a cumulative irrigation potential of 61.0115 lakh ha till 2020 (CWC, 2021). The irrigation project development and operational plan aims to provide assured supply of irrigation water to every farm field by bringing in improvements to water-use efficiency and to strengthen the participatory irrigation management by the transfer of control and the management of the irrigation system to Water Users' Associations (WUAs). Till 2017–2018, to support irrigation projects, a total of 1,372 WUAs have been formed in the different states of India. But, the IWP mechanism finalized by the WUAs in different states is not uniform. It is not fixed and varies from state to state. For financial stability, in 75% of cases, there is an increased in water charges under control of WUAs (Gandhi *et al.*, 2020).

Gaps in rationalization of IWP

The economic value of irrigation water use in agriculture is much lower than in other sectors. The main stumbling block to implementing a robust water-pricing system in India is the lack of a periodic revision of rates. A rationalized IWP mechanism alone is not sufficient if the revenue collection mechanism is not streamlined and strengthened. In most states, there is a wide gap between the revenue assessed and the revenue realized by the government agency. In order to develop a full-fledged volumetric pricing system in the country, considerable investment is required to make the necessary changes in irrigation water supply infrastructure and develop operational plans that provide a good balance between efficiency and equity objectives. Revisions should be based on regional hydro-climatic traits, live reservoir capacities and recharge patterns. In addition, distinctions have to be made between irrigation and non-irrigation usage. A number of mutually reinforcing social and socio-political factors combine to prevent any rational arrangement of IWP. These include a lack of (1) farmers' participation in the irrigation project design or implementation; (2) transparency between farmers and regional irrigation management authorities, leading to communication gaps and farmers' unwillingness to comply with water-pricing systems; (3) penalties for project personnel who fail to provide the desired level of services; (4) user penalties for non-payments; (5) transparency in water fee collection (often, the water bills are fabricated) and (6) agro-power subsidies (pump at will). Also, rampant water piracy (diverting irrigation water supply for other uses) hinders an accurate estimation of irrigation water use. Another issue is poor irrigation service delivery time mismatch between times of need (e.g., peak cropping season) and when irrigation services are available (Molle, 2008). The duration of services adds to the concern too, both within a day and within the cropping season as a whole. The gap between tariff and the value of irrigation and water supply services has fuelled endemic corruption. In addition, the volume of water necessary and that which is actually delivered through irrigation services often do not tally. An overriding factor that constrains opportunities for IWP is the strong political entrenchment of agrarian policies (Chaudhuri & Roy, 2019).

CONCLUSIONS

Pricing is the only long-term, sustainable solution to promote efficient and equitable use of available precious natural resources. IWP mechanisms differ from country to country at the global level. According to the various reports and documents, in the Indian context, it is observed that low revenue collection is mainly due to low water taxes, non-periodic revision and flaws in the current revenue collection mechanism across different states of the country. In some states, the water rate is recommended as 3–12% of the gross income. A volumetric pricing system can be implemented in the case of wells and tube wells where the timing is controllable and measurable. IWP for the agriculture sector should be reviewed and revised on the basis of factors such as the type of crop, irrigated areas through different sources, number of irrigations to crop and total volume of water used by water users, all of which impact water pricing. Several models such as Linear programming, the Full-cost and BN model, RVM, Principal Agent model and spot market pricing model and DSS are used to estimate IWP, and these models considering the IWP influencing factors as individual or in complexity. Various government policies have been implemented for revising the guidelines of IWP in India, but there has been no recommendation with regard to the uniform allocation of pricing of irrigation water, except the National Water Policy of 2012. An efficient IWP in India can be developed if sizeable investment is made in irrigation water supply infrastructure and if an operational plan is developed that provides a balance between efficiency and equity of irrigation projects. In order to achieve equity, efficiency and economics in irrigation projects, water charges should preferably be determined on volumetric basis. Irrigation water charges should be reviewed periodically. A rationalization of IWP will improve water-use efficiency/water productivity in the command areas.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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