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A state-level analysis of the water system management efficiency in Mexico: Two-stage DEA approach

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ABSTRACT

The public water system management in Mexico has recently been criticized due to severe problems with the availability of drinkable water. Significant differences exist between Mexican regions regarding the availability of renewable water and water system distribution. Moreover, water governance in the country is inefficient due to the lack of transparency in the water policies. Therefore, the article aims to investigate whether there is a direct relationship between water system management efficiency and water system improvement efficiency and how the efficiency reflects the size of the population and the availability of renewable water in each state. For this, a two-stage DEA model is constructed to evaluate the water system management efficiency in Mexico. The results indicate high average water management efficiency but very low efficiency in the water system improvements. Furthermore, immense differences in the water system efficiency can be observed with respect to the characteristics and adopted policies.

1. Introduction

The territory of Mexico is 1964 million square kilometers (km^2), of which 1959 million correspond to the continental surface and the rest to the island areas. Due to its geographical location, two-thirds of the territory is considered arid or semi-arid, with annual rainfall less than 500 mm, while one-third, the southeast, is humid, with annual rainfall exceeding 2000 mm per year. In most of Mexico, the rain is more intense in summer, mainly torrential.

Based on data from the 2015 Intercensal Survey of INEGI [1], 74 metropolitan areas (MAs) were defined (Fig. 1), for which, applying the projections of Mexico's National Population Council [2], a population of 78.29 million inhabitants was estimated to 2018, which constitute 62.76% of the projected population for that year. Thirty-seven MAs have more than 500,000 inhabitants, representing 67.77 million people and 54.33% of the national population. The process of concentration of inhabitants in urban localities has accelerated its growth [3], which implies strong pressures on the environment given the increase in demand for services.

The National Water Commission (Conagua), as the administrative, regulatory, technical, and advisory body responsible for water management in Mexico, performs its functions through 13 river basin organizations (Table 1), whose area of competence is the hydrological-administrative regions (HAR). HARs are formed by groupings of basins, considered basic units for the management of water resources [3]. Population, renewable water (RW), and GDP show significant regional variations. The southeast regions (HAR V,

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X, XI, and XII) account for 67% of the country's renewable water, with 20% of the population contributing 20% of the national GDP. Northern (HAR VI, VII, IX), central (HAR IV, VI, VII, XIII), and north-western regions (HAR I, II, III) comprise 33% of the country's renewable water resources, around 10% of the population, and a regional contribution to the national GDP between 10 and 14%. Considering the renewable water per capita, the available water in the Southeastern regions is seven times greater than that available in the rest of the hydrological-administrative regions of our country [2,4,5] (Table 6).

This disproportion between regions causes different demands on water resource management. The percentage of water used for human consumption in relation to renewable water is an indicator of the degree of stress exerted on the water resource of a country, basin, or region [3]. The degree of stress can be very high, high, medium, low, and stress-free, where a percentage greater than 40% represents a high or very high degree of stress. At the national level, Mexico experiences a stress level of 19.7% [5], which is considered low. However, the country's central, northern and north-western areas experience high stress (Table 2).

Regarding the coverage of piped water services, in 2015, the national coverage of access to piped water was 95.3% (97.8% urban, 87.0% rural), while the national coverage of piped water in housing or land was 94.4% (97.2% urban, 85.0% rural) [1]. Changes in coverage rates should be seen in the context of population growth and urban concentration.

2. Literature review

2.1. Water system productivity analysis (water management)

Water management refers to activities directly related to the control of resources (material, financial or human), such as monitoring, analysis, planning, construction, and maintenance [6]. The urban water sector is a complex system, resulting in low sustainability problems, poor resource management, and different stakeholders' needs. That is why it is important to use transdisciplinary processes to mitigate conflicts in decision-making goals [7]. Many quantitative and statistical methods exist to evaluate efficiency and performance. For the benchmarking techniques, frontier analysis has become the most noteworthy approach. The non-parametric approach based on Data Envelopment Analysis (DEA) is the most used method to assess efficiency and productivity [8,9], with a comprehensive number of successful applications in various industries.

For example, Alda and Dammert [10] investigated the police performance of 619 Peruvian municipalities considering the environmental aspects in which police operate. Avilés-Sacoto et al. [11] used DEA to evaluate the environmental performance of 32 states in Mexico. Flegl et al. [12] applied DEA to observe the production and investment efficiency in the Mexican food industry; Linh Le et al.

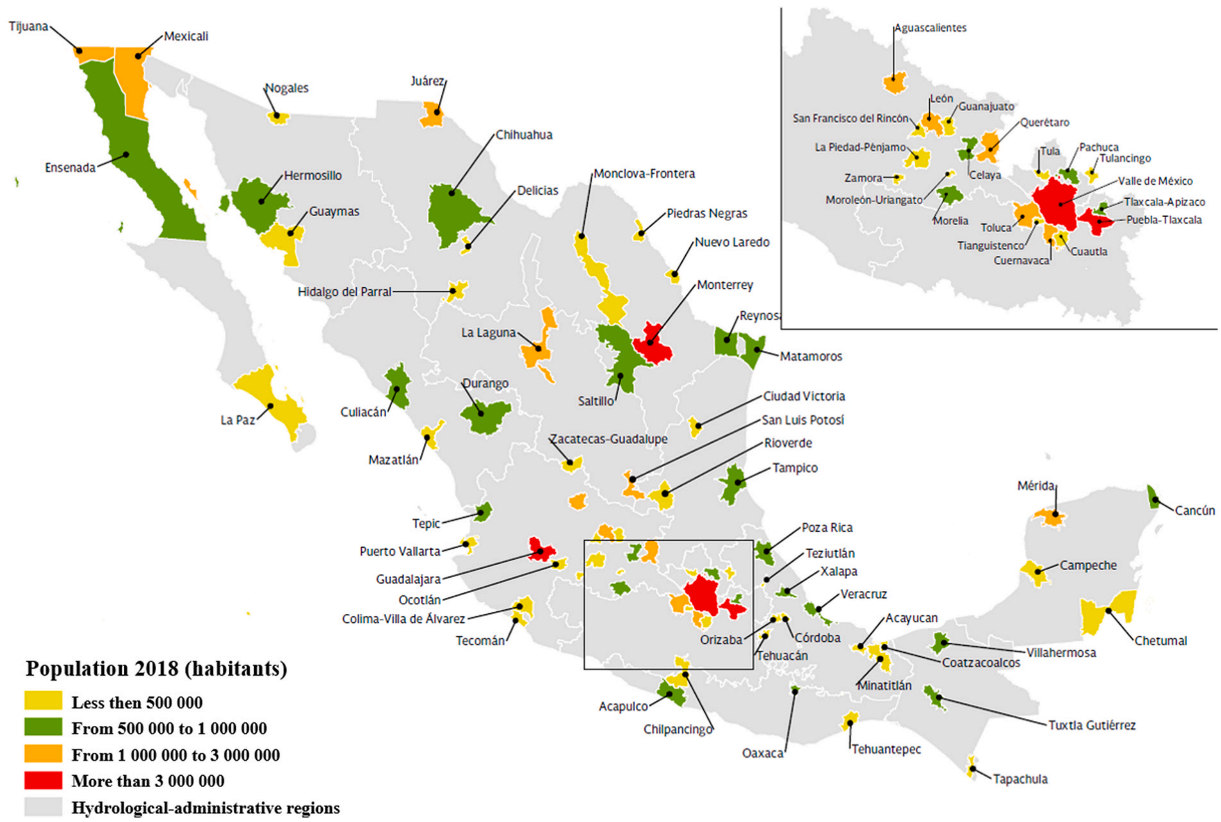

Fig. 1. Metropolitan zones in Mexico [3].

[13] investigated the environmental efficiency of the agricultural sector in East Asian countries for the period from 2002 to 2010; Vikas and Bansal [14] evaluated efficiency of 22 Indian oil and gas sector during 2013–2017 period, among others.

Data Envelopment Analysis has also been widely used to evaluate the technical efficiency in the water and sewerage or sanitization sector. The efficiency in water resource management is understood as a balance between water use and supply so that water resources are not threatened by excessive extraction in the future [15]. In this case, the DEA analyses operated with diverse objectives. First, many analyses focus on water and sewerage companies' efficiency. For example, Barbosa et al. [16] analyzed 12 private and 30 mixed-capital water and sewerage companies in Brazil using a balanced panel data from 2005 to 2013. The objective of the analysis was to investigate the efficiency of Water and Sewerage Companies and explain the governance ownership and regulation effect. Molinos-Senante et al. [17] assessed the production efficiency of the Chilean full private and concessionary water companies from 2007 to 2015 using the Malmquist index. Maziotis et al. [18] calculated the productivity of 22 English and Welsh water companies providing drinking water services from 2001 to 2008. Walker et al. [19] used a double-bootstrap DEA model to evaluate the economic and environmental efficiency of 13 water and sewage companies in the UK and Ireland.

Second, the DEA analyses investigate the efficiency from a regional point of view. For example, Chopra and Ramachandran [20] used a set of 20 multidimensional factors to develop a multidimensional index to quantify the water sector performance in 11 states in India. Hu et al. [21] applied DEA to analyze water use and wastewater treatment in 10 cities located on the Minjiang River in China. Jie et al. [22] evaluated the industrial environmental efficiency in 30 Chinese provinces using a two-stage DEA analysis. Liu and Fukushige [23] measured the efficiency of the water supply and sewerage sector in Japan to investigate the relationship between efficiency and price setting. Pan et al. [24] analyzed the water use efficiency in 17 cities in Shandong Province in China between 2006 and 2015, applying the super-efficiency DEA method. Tourinho et al. [25] assessed water supply and sanitation services' performance in 448 Brazilian municipalities to explore regional differences and the impact of the used governance models, and Yang et al. [26] measured the efficiencies of 30 regional industrial water systems in China during 2008–2014 using dynamic interactive network model.

In Mexico, few DEA applications can be found. Ablanedo-Rosas et al. [27] estimated the operational efficiency of 36 major organizations responsible for supplying potable water in the country. Salazar-Adams [28] studied the efficiency of 359 Mexican water utilities to value the effect of management and reform policies. Andwandter and Ozuna [29] applied DEA to measure the operational efficiency of water utilities to assess the link between private ownership and efficiency.

2.2. Water resource management performance variables

The selection of the variables depends primarily on the objective of each analysis. The majority of the studies included variables related to the management resources, such as invested capital [18,23,24], operational expenditures [18,19,22], chemical treatment [22], personnel [22,30], access to safe drinking water and sanitization [20,21,24], or the water system size [17,19,25]. On the other hand, the outputs commonly referred to billing incomes [16], water quality [20], water production [17,18,30], and used chemicals and water treatment [19,21,22], among others. Table 3 summarizes the DEA applications for the efficiency analyses in water resource management.

2.3. Governance

Governance refers to the administrative, political, and institutional rules, processes, and practices necessary for decision-making

Table 1
Characteristics of the hydrological-administrative regions, 2018 (elaborated based on data from Conagua [3]).

No.	Hydrological-administrative regions	Continental area (km2)	Renewable water 2018 (hm^3/year)	Population in mid-year 2018 (millions of inhabitants)	Renewable water per capita (m^3/inhabitants/year)	Contribution to national GDP 2017 (%)	Municipalities or districts of Mexico City (number)
I	Península de Baja California	154,279	4858	4.67	1040	4.36	11
II	Noroeste	196,326	8274	2.95	2802	3.39	78
III	Pacífico Norte	152,007	26,747	4.63	5772	2.97	51
IV	Balsas	116,439	21,668	12.15	1783	6.51	420
V	Pacífico Sur	82,775	30,836	5.15	5983	2.12	378
VI	Río Bravo	390,440	12,844	12.76	1007	15.27	144
VII	Cuencas Centrales del Norte	187,621	8024	4.70	1709	4.41	78
VIII	Lerma-Santiago-Pacífico	192,722	35,071	24.98	1404	20.00	332
IX	Golfo Norte	127,064	28,655	5.42	5282	2.28	148
X	Golfo Centro	102,354	94,363	10.81	8732	5.09	432
XI	Frontera Sur	99,094	147,195	7.93	18,571	3.98	142
XII	Península de Yucatán	139,897	29,647	4.86	6103	5.42	128
XIII	Aguas del Valle de México	18,229	3401	23.72	143	24.20	121
Total		1,959,248	451,585	124.74	3620	100.00	2463

Table 2
The degree of stress on water resources in the hydrological-administrative regions, 2018 (elaborated based on data from Conagua [3]).

No.	Hydrological-administrative regions	Total volume of water granted (hm^3/year)	Pressure grade (%)	Stress grade classification
I	Península de Baja California	4369	89.9	High
II	Noroeste	7030	85.0	High
III	Pacífico Norte	10,822	40.5	High
IV	Balsas	11,170	51.5	High
V	Pacífico Sur	1587	5.1	Without stress
VI	Río Bravo	9776	76.1	High
VII	Cuencas Centrales del Norte	3839	47.8	High
VIII	Lerma-Santiago-Pacífico	16,002	45.6	High
IX	Golfo Norte	6126	21.4	Medium
X	Golfo Centro	6234	6.6	Without stress
XI	Frontera Sur	2533	1,7	Without stress
XII	Península de Yucatán	4956	16.7	Low
XIII	Aguas del Valle de México	4395	129.2	Very high
Total		88,840	19.7	Low

Table 3
Summary of Data Envelopment Analysis models for water resource management performance.

Article	DMUs	Inputs	Outputs
Ablanedo-Rosas et al. [27]	36 water supply organizations, Mexico	Volume of water distributed; Number of employees; Accounts with on-time payment.	Water production cost/water volume produced ratio; Volume of water paid/Volume of water produced ratio; Total expenses/Total income ratio.
Barbosa et al. [16]	42 Water and Sewerage Companies	Total amount of operational expenditures; Total amount of capital expenditures	Total amount of water billings units; Total amount of sewerage billing units.
Chopra and Ramachandran [20]	11 states of India	Physical availability and variability of water resources; Socio-economic factors; Water scarcity; Environmental factors.	Access to safe water and sanitation; Quality and concern about safe and clean water resources; Water use efficiency in agriculture and industry sectors; Ground and river water quality.
Hu et al. [21]	10 cities in Minjiang river, China, water use and wastewater treatment	Capital invested; Water supply; Reused water; Wastewater treatment; Wastewater.	Wastewater; GDP; Chemical organic demand; Ammonia nitrogen; Reused water.
Jie et al. [22]	30 provinces in China	Labor; Capital; Pollution treatment investments; Industrial wastewater recycling and reusing; Industrial solid wastes recycling and reusing.	Industrial GDP; Industrial wastewater emission; Industrial solid wastes emission; Comprehensive values if wastes re-utilization.
Liu and Fukushige [23]	215 water utilities, Japan	Total number of persons employed; Tangible fixed assets.	Total water delivery; Population served.
Maziotis et al. [18]	22 English and Welsh wáter companies	Operating costs; Capital stock.	Water distributed; Connected properties; Written complaints; Unplanned interruptions; Properties below the reference level.
Molinos-Senante et al. [17]	Chilean water companies	Length of the water and sewerage network; Operating costs; Number of employees.	Volume of distributed water; Number of customers with access to wastewater treatment.
Pan et al. [24]	17 cities in Shandong Province, China	Agriculture water consumption; Industrial water consumption; Domestic water consumption; Total COD discharge quantity; Investment in fixed assets; Labor.	GDP; Grain yield.
Salazar-Adams [28]	359 water utilities, Mexico	Number of staff; Energy costs; Chemical costs.	Total volume of water supplied; Number of connections.
Tourinho et al. [25]	448 municipalities, Brazil	Operating expenditures.	Number of water connections; Number of wastewater connections; Volume of water consumed; Volume of wastewater collected; Volume of wastewater treated; Water supply network length; Wastewater network length.
Walker et al. [19]	13 UK and Irish water and sewage companies	Operational expenditures; Capital expenditures; Operational GHG emissions; Length of mains and sewage pipes.	Water delivered & wastewater treated.
Yang et al. [26]	31 regions in China	Labor; Capital; Freshwater; Recycled water.	Industrial value-added; Wastewater.

and implementation [31]. Due to its characteristics and according to the World Water Council, water is a resource sensitive to governance; therefore, effective governance represents a prerequisite for sustainable and integrated management of water resources [32].

In her Nobel-prize-winning work, Elinor Ostrom demonstrated that adaptive governance of natural resources-water in this study-is more effective in achieving beneficial change where decentralized, self-organizing institutions are rich in information and empowered to make decisions on collective action through dialogue and deliberation [33].

For the Mexican case, the regional and natural water system administration limits are incompatible, and it is vital to consider the inter- and multisectoral coordination of those involved.

Mexico could create its water governance model and promote the adoption and implementation of innovative water governance practices among responsible authorities [34]. Regulatory authorities play a crucial role in governance by supervising providers and ensuring services' sustainability to foster sectors' efficiency [25,35]. For this, water efficiency measurements should be implemented to enhance the service level provided to customers. Consequently, improving water efficiency leads to a reduction in operating costs and a lower necessity to develop new supplies and expand water infrastructure [36].

However, water governance in the country is inefficient because of corruption and the lack of transparency in water policies. In addition, the resistance to change in how the resource is managed among the responsible authorities is an obstacle to the adoption and implementation of new practices [37] that expand and strengthen the capacities to establish clear and effective regulations and implement sound policies [38]. Cetrulo, Marques and Malheiros [39] link this problem to the institutional weakness in Mexico due to the limited regulatory capacities and limited fiscal efficiencies.

Considering the lack of transparency of water policies and the resistance to change regarding the resources management and adoption of new policies in Mexico, the objective of the article is to analyze the efficiency of the public water system management in 32 Mexican states.

The rest of the document is structured as follows: Section 2 presents the model structure, used data, and the method, Section 3 summarizes the obtained results with a detailed evaluation of the research questions, and Section 4 discusses the implications and limitations of the analysis, while Section 5 provides the final remarks.

3. Materials and methods

3.1. Data Envelopment Analysis

Data Envelopment Analysis evaluates decision-making units (DMUs) regarding their multiple inputs and multiple outputs [40]. Each DMU has different m inputs to produce s different outputs. The CCR model developed by Charnes et al. [41] can be used if the model assumes constant returns to scale. The CCR input-oriented model for DMU_o is formulated as follows:

$$e = \max \sum_{r=1}^{s} u_r y_{ro}$$

subjected to

$$\sum_{r=1}^{s} u_r y_{ro} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \ \sum_{i=1}^{m} v_i x_{ij} = 1 v_i \geq \varepsilon, i = 1, 2, \ldots, m; \ u_r \geq \varepsilon, r = 1, 2, \ldots, s \tag{1}$$

where x_{ij} is the quantity of the input i of the DMU_j, y_{rj} is the amount of the output r of the DMU_j, u_r and v_i are the weights of the inputs and outputs $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$, $r = 1, 2, \ldots, s$ and ε is the non-Archimedean element. DMU is 100% efficient if $e = 1$, i.e., whereas DMU is inefficient if $e < 1$.

3.2. Two-stage Data Envelopment Analysis

In many cases, the single-stage process described in (1) may not be suitable to characterize production processes that can be divided into several sub-processes. In this case, some products are outputs of a sub-process on the one hand and the inputs of another sub-process on the other hand (Fig. 2). Considering the notions presented by Kao and Hwang [42], we assume that each DMU_j, $(j = 1, 2, \ldots, n)$ has m inputs x_{ij}, $(i = 1, 2, \ldots, m)$ to the first stage, and D outputs z_{dj}, $(d = 1, 2, \ldots, D)$ from that stage. Then, these D outputs become the inputs to the second stage and are referred to as intermediate measures. The outputs from the second stage are y_{rj}, $(r = 1, 2, \ldots, s)$. In this case, the intermediate measures are the only inputs to the second stage of the process, and there are no additional independent inputs to the second stage.

The efficiency in the first stage is denoted as e_j^1 and in the second stage as e_j^2 for each DMU_j. Using the CCR DEA model defined by Charnes et al. [41], we then define

$$e_j^1 = \frac{\sum_{d=1}^{D} w_d z_{dj}}{\sum_{i=1}^{m} v_i x_{ij}} \text{ and } e_j^2 = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{d=1}^{D} \widetilde{w}_d z_{dj}} \tag{2}$$

where v_i, w_d, $\widetilde{w}_d$ and u_r are unknown non-negative weights, and w_d can be equal to $\widetilde{w}_d$. The overall efficiency of the two-stage process is

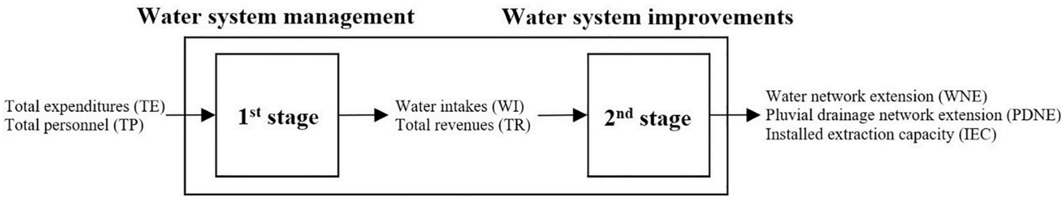

Fig. 2. Structure of the two-stage DEA model.

the product of the efficiencies of the two sub-processes as $e = e_j^1 \cdot e_j^2$.

If we consider a cooperative (centralized) approach as defined by Kao and Hwang [42] or Liang et al. [43], by letting $w_d = \widetilde{w}_d$ in (2), the two-stage model jointly determines the set of optimal weights on the intermediate factors to maximize the efficiency scores.[1] The efficiency scores of both stages are optimized simultaneously. The linear model can be defined as

$$e_o^* = \max \sum_{r=1}^{s} u_r y_{ro} \tag{3}$$

subjected to

$$\begin{aligned}
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} w_d z_{dj} \leq 0, j = 1,2,...,n \\
&\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1,2,...,n \\
&\sum_{i=1}^{m} v_i x_{io} = 1 \\
&w_d \geq \varepsilon, d = 1,2,...,D; \quad v_i \geq \varepsilon, i = 1,2,...,m; \quad u_r \geq \varepsilon, r = 1,2,...,s.
\end{aligned}$$

Model (3) gives the overall efficiency. After the overall efficiency is obtained, the divisional efficiency for each stage can be calculated via the efficiency decomposition [40]. We denote the optimal value to model (3) as e_0^*, then $e_0^* = e_0^{1*} \cdot e_0^{2*}$. The maximum achievable value for e_0^{1*} can be determined as

$$e_o^{1+} = \max \sum_{d=1}^{D} w_d z_{do} \tag{4}$$

subjected to

$$\begin{aligned}
&\sum_{r=1}^{s} u_r y_{r0} = e_0^* \\
&\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1,2,...,n \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} w_d z_{dj} \leq 0, j = 1,2,...,n \\
&\sum_{i=1}^{m} v_i x_{io} = 1 \\
&w_d \geq \varepsilon, d = 1,2,...,D; \quad v_i \geq \varepsilon, i = 1,2,...,m; \quad u_r \geq \varepsilon, r = 1,2,...,s.
\end{aligned}$$

It then follows the minimum of e_0^{2*} is given by $e_0^{2-} = e_0^*/e_0^{1+}$. The maximum of e_0^{2*} can be calculated using the following linear model as

$$e_o^{2+} = \max \sum_{r=1}^{s} u_r y_{ro} \tag{5}$$

subjected to

[1] The cooperative approach is suitable for the analysis as both stages of the two-stage DEA model evaluate processes of the same DMU. The noncooperative approach is characterized by the leader-follower Stackelberg model (see for example Huang and Li [44]), where the efficiency of the second stage is determined subject to the requirements that the efficiency of the first stage is to stay fixed [28].

$$\sum_{r=1}^{s} u_r y_{r0} - e_0^* \cdot \sum_{i=1}^{m} v_i x_{ij} = 0$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{d=1}^{D} w_d z_{dj} \leq 0, j = 1, 2, ..., n$$

$$\sum_{d=1}^{D} w_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1, 2, ..., n$$

$$\sum_{d=1}^{D} w_d z_{do} = 1$$

$$w_d \geq \varepsilon, d = 1, 2, ..., D; \quad v_i \geq \varepsilon, i = 1, 2, ..., m; \quad u_r \geq \varepsilon, r = 1, 2, ..., s.$$

The minimum of e_0^{1*} is then calculated as $e_k^{1-} = e_0^*/e_0^{2+}$.

3.3. Model structure and hypothesis

If the analysis considers a two-stage process evaluation, these two processes usually focus on water use efficiency and wastewater treatment [21,26]. The research presented in this article considers a two-stage process but differs in the second stage. Stage 1 evaluates the water system management, and stage 2 evaluates the water system improvements in each state (Fig. 2). The objective of stage 1 is to evaluate how well each state administrates its public water system network. In this case, the Total expenditures (TE) and Total personnel are considered as the inputs in stage 1, while Water intakes (WI) and Total revenues (TR) are the intermediates that enter stage 2. The objective of stage 2 is to assess the capability of each state to improve the public water system network to overtake the increasing water demand. This improvement is linked to the Water network extension (WNE), Pluvial drainage network extension (PDNE), and lifting of the Installed extraction capacity (IEC).

The analysis aims to investigate the following hypotheses.

H1. There is a direct relationship between water system management efficiency and water system improvement efficiency.

- In this case, two research questions are created: R1) Is there a relation between the efficiency of the water system management and the efficiency of the water system improvements? or, rather, R2) Does a low efficiency of the water system management create higher needs to improve the water system?

H2. The efficiency of the water system management reflects the size of the population and the availability of renewable water in each state.

- In this case, R3) Does the population in each state affects the water system management efficiency? R4) Does the availability of renewable water in each state affects the adopted governance policies?

3.4. Data

The analysis uses data from the National Census of Municipal Governments and Territorial Demarcations of Mexico City in 2019 (Census) [45], which includes statistical and geographic information on the management and performance of the institutions that make up the Public Administration of each municipality with respect to the functions of government, public security, municipal justice, drinking water and sanitation, urban solid waste, and the environment. The methodology of the Census includes information for the years 2017, 2018, and 2019, where some questions are linked to the year of application (2019) and others from the year prior to the coverage (2017). However, most of the data represent the year 2018. The information is related to the Drinking water and sanitation data, i.e., Drinking water service from the public network, Water collection for public supply, Drinking water plants, and Administration.

The total expenditures (TE) indicate the monetary value of the goods and services consumed in the provision of drinking water and sanitation service during the year2018.[2] This variable includes consumption of electrical energy in pumping equipment in intake works for water collection; consumption of chlorine, chlorine gas, or similar reagent used for the disinfection of water in intake works; electrical energy consumption in distribution systems; electricity consumption in water treatment plants; physical-chemical agents, reagents and similar supplies used in purification plants; electrical energy consumption in municipal wastewater treatment plants or sites; physical-chemical agents, reagents and similar inputs used in municipal wastewater treatment sites or plants; salaries paid; rights

[2] The operator of potable water, drainage, sewerage, wastewater treatment and water reuse services of Mexico City is Sacmex (Sistema de Aguas de la Ciudad de México), which operates under the authority of the country's environment ministry Semarnat (Secretariat of Environment and Natural Resources in Mexico). That is why, the Census does not include the information about the Total expenditures and Total incomes for Mexico City. However, the published information by Sacmex include similar expenditure and income chapters.

of exploitation, use or exploitation of water; rights of use of receiving bodies of wastewater discharges; total depreciation; and other expenditures. Total personnel (TP) include the workforce employed by the public network water service. In this case, this variable covers managers and directors, administrative and accounting employees, and technical and operational employees.

The total number of water intakes (WI) summarizes the connections subject to billing under a metered service scheme. This variable represents the supplied volume in m^3 under a metered service scheme of household, industrial, commercial, public, and mixed water intakes.[3] Total revenues (TR) refer to the income for the supply of drinking water and sanitation services. This variable includes Income from drinking water supply; sale of treated water; sanitation; connection and sewerage rights; sale of sludge; water distribution through pipes; other income from supply of goods and services; federal, state, and municipal subsidies; fines and surcharges; and other incomes.

The Water network extension (WNE) refers to the extension and rehabilitation (in kilometers) of the water distribution network in each state. Similarly, the Pluvial drainage network extension (PDNE) refers to the extension and rehabilitation of the pluvial drainage network in kilometers. Finally, the Installed extraction capacity (IEC) is linked to the newly installed water treatment capacity in potability plants in each state. In this case, the IEC variable refers to water extraction from the exploitation of underground sources (such as wells and filtering galleries) or surface (such as rivers, dams, or springs) for the public supply [45].

Data in the model were recalculated per 100,000 inhabitants. Therefore, all the obtained results are considered per capita. Table 4 summarizes the variables used in the model and their descriptive statistics, and Table 7 presents the complete data used in the analysis. Finally, the selected model structure satisfies the discrimination ability required for the DEA models [46].

4. Results

For all the calculations, the MaxDEA 7 Ultra software was used. The model uses constant returns to scale (CRS) as no competition between the states is considered, i.e., each state operates with its specific resources. Further, the output-oriented model was chosen as it is desirable in stage 1 to focus on a greater supplied volume and revenues rather than cut expenses in water treatment, which may affect its quality. Similarly, stage 2 focuses on extending and enhancing the water system rather than lowering the supplied volume. This also goes along with the recommendations proposed by Cetrulo et al. [39] for water system management evaluation in developing countries.

4.1. Water resources management efficiency

The average efficiency in stage 1 of the analysis was 0.690, with a standard deviation of 0.235. In general, stage 1 reveals a very high efficiency of the water system management in Mexico (Table 5). More in detail, Chiapas, Chihuahua, Mexico City, Guanajuato, Querétaro, and Yucatán reached an efficiency of 1.000, whereas the lowest efficiency can be observed in Tabasco (0.096), Campeche (0.302), Tlaxcala (0.365) and Guerrero (0.378). As Fig. 3 shows, no specific pattern regarding the water system management efficiency distribution across the country can be identified.

Regarding stage 2 of the model, the results indicate a quite different efficiency level. In this case, the average efficiency was 0.196, with a standard deviation of 0.348. This indicates a shallow orientation towards the improvements of the water resource management systems in Mexico. Fig. 4 displays a group of states with very high efficiency (Hidalgo, Estado de México, San Luis Potosí, Tlaxcala, and Veracruz) compared to the rest of the country. The highly efficient states are located next to each other in the Center-east of the country.

Putting the results together, the average overall efficiency of the two-stage model was 0.123, with a standard deviation of 0.236. This shows a very low water resource management efficiency in Mexico. The best-evaluated states were Estado de México (0.866), Veracruz (0.757), San Luis Potosí (0.613), Hidalgo (0.577), and Tlaxcala (0.337). Alarming, 21 out of 31 states (65.6%) reported an overall efficiency lower than 0.025, and 25 out of 32 states (78.1%) were lower than 0.1.

4.2. Analysis of the results

In this section, the obtained results are analyzed with respect to the constructed hypotheses and research questions.

H1: There is a direct relationship between water system management efficiency and water system improvement efficiency.

R1) Is there a relation between the efficiency of the water system management and the efficiency of the water system improvements?

The results obtained in stages 1 and 2 gave evidence of high variability in the efficiency both regarding the states and the stages. There is no relation between stage 1 and stage 2, as the correlation is weak at −0.155 and not statistically significant. Fig. 5 summarizes

[3] In the case of Mexico City, the supplied volume was extrapolated due to the missing data. For this, we used the information about the number of water intakes under a metered service scheme in Mexico City compared to the number of water intakes and supplied volume in m^3 under the same scheme in Estado de México, with respect to the total population and connected population to the water system in both states. Such calculation can be considered valid as Mexico City and Estado de México occupy the Metropolitan zone of Mexico City and are registered in the same Hydrological-Administrative Regions of Waters of the Valley of Mexico (Aguas del Valle de México) (Table 1).

Table 4
Introduction of variables and descriptive statistics of the data set.

Variables		Units	Max	Min	Mean	Standard deviation
Water system management subsystem						
Input (x)	Total expenditures	Mexican pesos	131,285,294.31	10,482,436.02	57,805,788.26	35,953,329.29
	Total personnel	Persons	211.66	29.22	100.34	34.68
Intermediates (z)	Water intakes	m^3	374,902,178.91	56,040.35	17,401,298.60	67,421,551.20
	Total revenues	Mexican pesos	144,553,854.85	6,213,118.38	62,597,235.60	39,791,890.64
Water system improvements subsystem						
Output (y)	Water network extension	Kilometers	2,299,434.93	21.49	74,904.87	405.963.23
	Pluvial drainage network extension	Kilometers	4,133.36	0.00	169.19	565.52
	Installed extraction capacity	Liters per second	9883.78	35.74	814.82	2189.29

Table 5
Overall, Stage 1 and stage 2 water resources management efficiency.

State	Overall Score	Stage 1	Stage 2	State	Overall Score	Stage 1	Stage 2
Aguascalientes	0.022	0.779	0.029	Morelos	0.015	0.478	0.031
Baja California	0.013	0.965	0.014	Nayarit	0.021	0.474	0.044
Baja California Sur	0.006	0.641	0.010	Nuevo León	0.002	0.767	0.002
Campeche	0.038	0.302	0.124	Oaxaca	0.145	0.654	0.221
Chiapas	0.029	1.000	0.029	Puebla	0.016	0.664	0.023
Chihuahua	0.037	1.000	0.037	Querétaro	0.042	1.000	0.042
Mexico City	0.012	1.000	0.012	Quintana Roo	0.011	0.944	0.012
Coahuila de Zaragoza	0.010	0.729	0.013	San Luis Potosí	0.613	0.613	1.000
Colima	0.013	0.498	0.027	Sinaloa	0.008	0.630	0.013
Durango	0.023	0.643	0.036	Sonora	0.010	0.597	0.016
Guanajuato	0.014	1.000	0.014	Tabasco	0.021	0.096	0.221
Guerrero	0.005	0.378	0.012	Tamaulipas	0.186	0.623	0.298
Hidalgo	0.577	0.577	1.000	Tlaxcala	0.337	0.365	0.923
Jalisco	0.016	0.845	0.019	Veracruz	0.757	0.757	1.000
Estado de México	0.866	0.907	0.955	Yucatán	0.037	1.000	0.037
Michoacán de Ocampo	0.021	0.540	0.039	Zacatecas	0.011	0.605	0.018

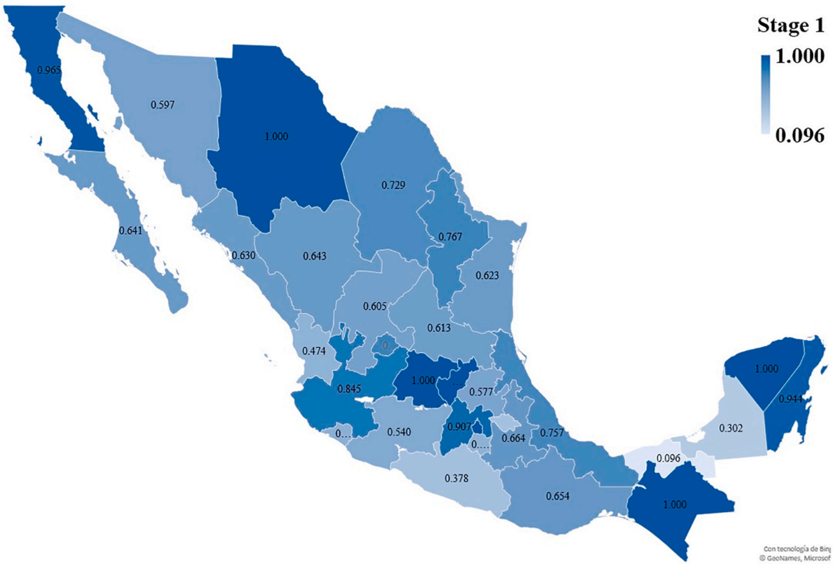

Fig. 3. Stage 1 efficiency of the water system management.

the relation between both stages of the model.

R2) Does a low efficiency of the water system management create higher needs to improve the water system?

We can classify the efficiency of the water system management into four quadrants (Q), as shown in Fig. 6.

Fig. 4. Stage 2 efficiency of the water system improvements.

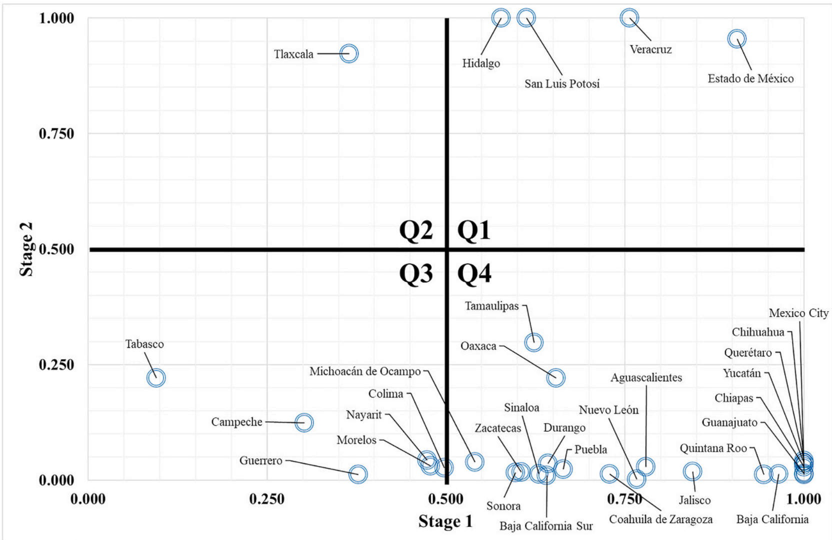

Fig. 5. Relationship between stage 1 and stage 2 of the analysis.

Q1 symbolizes the country's highest efficiency in water system management. The best-performing state is Estado de México, with an efficiency of 0.907 in stage 1 and 0.955 in stage 2. Veracruz, San Luis Potosí, and Hidalgo obtained a lower efficiency in stage 1 but were 1.000 efficient in stage 2.

The Q2 constitutes states with very low water system efficiency but a high orientation towards the improvements. In this case, this quadrant consists of only one state Tlaxcala, whose efficiency is 0.365 in stage 1 and 0.923 in stage 2.

The Q3 represents states with very low efficiency in both stages. More in detail, we can identify two types of states in this quadrant: 1) states with higher efficiency in stage 1 but efficiency close to zero in stage 2 (Guerrero, Morelos, Nayarit), and 2) states with very low efficiency in stage 1, but higher efficiency in stage 2 (Tabasco).

Finally, Q4 includes states with very high efficiency of the water system management (stage 1) but with a lower orientation towards the improvements of the water system (stage 2). The highest orientation towards the system improvements is observed in Tamaulipas (0.298) and Oaxaca (0.221). As seen in Fig. 6, the rest of the states in Q4 perform below 0.120 in stage 2 and across the whole range for stage 1: from 0.540 for Michoacán de Ocampo to 1.000 for Chiapas, Chihuahua, Mexico City, Guanajuato, Querétaro, and Yucatán.

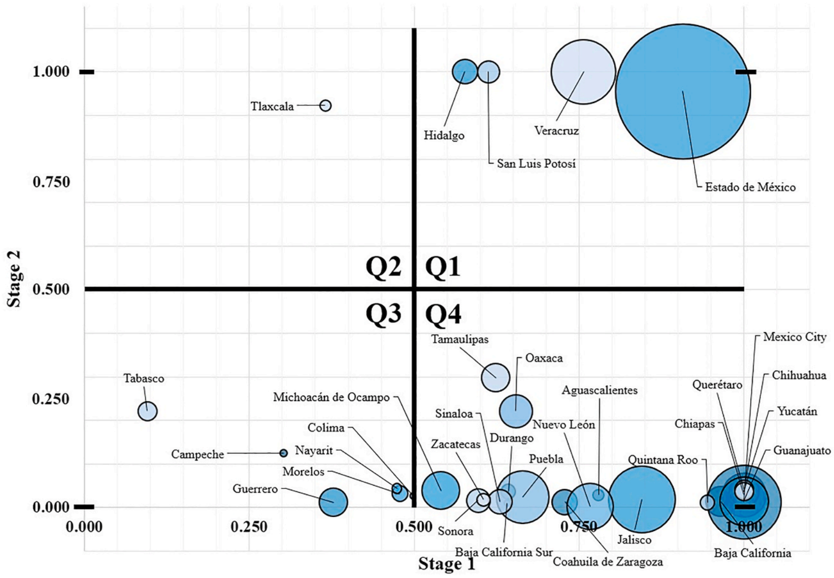

Fig. 6. Relationship between stage 1 and stage 2 considering the population (bubble size).

As a result, the H1 is rejected as no direct relationship was observed between water system management efficiency and water system improvement efficiency.

H2: The efficiency of the water system management reflects the size of the population and the availability of renewable water in each state.

R3) Does the population in each state affects the water system management efficiency?

A question arises, what are the drivers (factors) of such differences between the states regarding their water system management? Fig. 6 shows the relationship between each state's efficiency and population. First, the correlation between the efficiency in stage 1 and population is 0.425* (significant at the 0.05 level (2-tailed), $p = 0.015$), whereas the correlation is 0.313 considering stage 2 and population, i.e., the correlation can be considered as moderate. Nevertheless, the less populated states are mainly located in Q2 and Q3, i.e., in the low water system management efficiency quadrant. The most populated states are in Q4 and Q1 with higher water system efficiency. The result of Estado de México may be surprising, as it is the most populated state (17.6 million people) and the best evaluated in both stages.

R4) Does renewable water availability in each state affect the adopted governance policies?

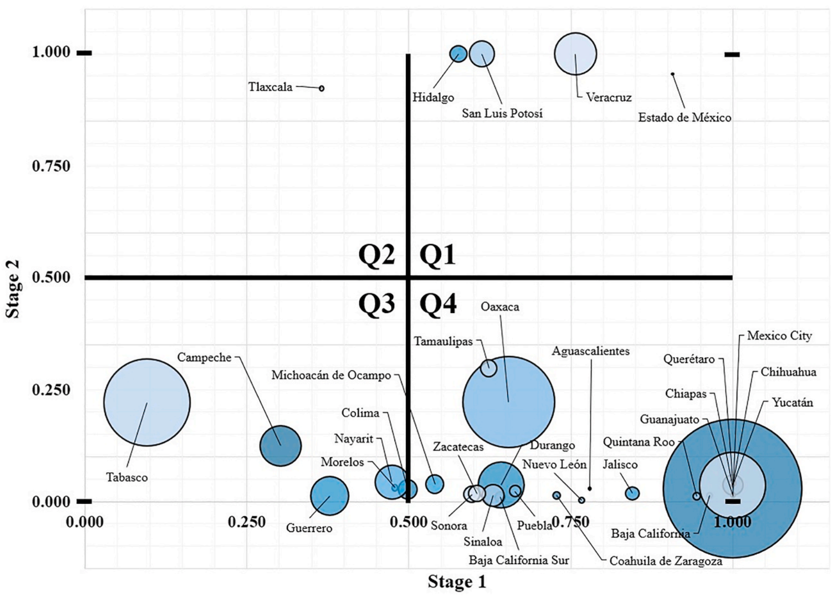

Fig. 7. Relationship between stages 1 and 2 considering the availability of renewable water (bubble size).

Further, water availability in each water system management plays a crucial role, as lower access to water resources may encourage the states to focus more on the improvement part of the management. Fig. 7 shows the link between the availability of renewable water[4] in each state and the efficiencies in the water management system. The average amount of renewable water in Mexico is 3620 m^3/habitant/year, but with high differences between the states (see Table 1). It can be observed that most of the states with the highest level of renewable water are in Q3 and Q4, which can explain their lower tendency toward improvements in water system management, for example, Chiapas with 20,854 m^3 and the efficiency of 0.029 in stage 2, Oaxaca (13,685 m^3, 0.221), Tabasco (13,014 m^3, 0.221) and Yucatán (9917 m^3, 0.037). However, these quadrants also include many states with meager availability of renewable water, such as Aguascalientes (401 m^3, 0.029), Baja California (838 m^3, 0.014), and Guanajuato (653 m^3, 0.014).

Another important case is Mexico City, which has the lowest availability of renewable water in the country (73 m^3) and obtained one of the lowest efficiencies regarding water system improvements; this contrasts with Estado de México, which reports the second lowest availability of renewable water (272 m^3), but its water management works perfectly in both DEA stages. It is surprising, as both states are in the Metropolitan zone of Mexico City and are registered in the same Hydrological-Administrative Regions of Waters of the Valley of Mexico. Finally, Tlaxcala, the only state in Q2, reports only 652 m^3 of renewable water in its territory (far below the average in the country), which may explain its high efficiency in stage 2. As a result, a weak correlation is observed between stage 1 and the availability of renewable water (−0.125), as well as considering stage 2 (−0.034), in both cases, not statistically significant.

As a result, H2 can be rejected as moderate and weak relation between the water system management and population, as well as the availability of renewable water.

5. Discussion

Water management in a country like Mexico, where each state has its hydrological and managerial characteristics, shows a broad efficiency range. This research was designed to study, by using a two-stage DEA model, the water system management and the system improvements to (i) identify if there is a relationship between the two and (ii) to identify if the efficiency of the water system management reflects the size of the population and the availability of renewable water in each state.

The analysis revealed significant differences between the efficiency of the water system management (stage 1) and water system improvements (stage 2). First, although differences between states can be observed, the average efficiency in stage 1 (0.690) can be considered satisfactory. Improvements in the water system management, especially in Tabasco (0.096), Campeche (0.302), Tlaxcala (0.365), and Guerrero (0.378) are still needed, though. Second, the efficiency in stage 2 exposed a lack of improvements across the entire country, resulting in a very low average efficiency of 0.196. More in detail, only five states, Estado de México, Hidalgo, San Luis Potosí, Tlaxcala, and Veracruz, out of 32 states reported DEA efficiency close to 1.000. Third, no clear relation between stage 1 and stage 2 results was identified, nor was the relation with population and water availability in each state.

Such observations create many areas of opportunities for improvements in the water system management in Mexico, which is crucial considering recent water problems. Although, in general, there is a disbelief that quantitative studies can lead to improvements in the water system's performance in developing countries [39], several recommendations for water policies can be proposed to overcome the severe problems with the availability of drinkable water in Mexico.

The following subsections describe each DEA stage results in further detail.

5.1. *Water system management*

With respect to water system management, providing safe drinking water is one of the most pressing challenges that Mexico must overcome to meet the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015 [47]. He et al. [48] mention that potential solutions for urban water scarcity involve increasing water availability and reducing water demand. Approaches to increasing water availability usually include groundwater exploitation, seawater desalination, reservoir construction, and interbasin water transfer. To reduce water demand, it is necessary to improve water-use efficiency, water recycling, and domestic and industrial water use intensity. The water and sewerage industry is highly capital-intensive [49], which calls for resource reductions and quality improvements.

Stage 1 results imply a possible average reduction of 31% on the input part of the model, i.e., a reduction in expenditures and personnel, maintaining the same level of outputs. Moreover, the possible space for the reduction is much higher for the Q3 states (Fig. 5), where the average efficiency is 0.371 (potential improvements of 62.9%). More precisely, the water management system in Q3 states reports −15.76% of expenditures compared to the country's average but +17.82% more employees. What is more, on the output part, these states gain −43.31% in revenues and provide −56.98% of water intake. On the one side, the input reductions can be easier for larger water companies due to the evidence of the increasing returns to scale, suggesting that larger water companies can reduce their costs through scale effects [17]. However, on the other side, such changes may be complex due to the resistance to change in how the resources are managed among the responsible authorities and limited regulatory capacities [37,39]. Therefore, it will require long-term planning and timely capital investments to close the efficiency gap.

[4] Renewable water represents the maximum amount of water that is feasible to exploit annually in a region (state) without altering the ecosystem and that is renewed by means of rain. In this case, the amount is measured as m^3/habitant/year.

5.2. Water system improvements

The results further show a very low tendency for water system improvements, which may look surprising considering the reported water problems in Mexico. However, a similar trend was also observed by Flegl et al. [12] in the Mexican food industry. So, the low efficiency may clearly illustrate infrastructure investment practices in Mexico. As CEFP [50] observed, public investment in Mexico has been extremely volatile in the last three decades, indicating no adequate planning in public budgets regarding investment. In 2018, Mexico invested only 2.82% of GDP into infrastructure (−1.7% compared to 2013), one of the lowest percentages in Latin America and Caribbean. What is more, only 0.08% out of 2.82% corresponded to water infrastructure investments. Above that, water infrastructure, together with hydrocarbons and urban development and housing, belonged within the three types of infrastructure with the largest net decreases of investments during 2013–2018 period [50]. Strengthening the management system and science and technology investments are the ways to improve water resource management.

The necessity for more investments was also stressed by Pan et al. [24], who recommend more R&D personnel to improve the technical efficiency in water management. Similarly, to expand the water resources supply, Sun et al. [51] pointed out that techniques to improve the utilization of water resources must be explored, or the existing water supply structure must be expanded to improve the water supply. In this case, Li et al. [52] suggest that a certain level of supervision is also recommended in areas with relatively high-water resource efficiency to ensure the continued efficient use of water resources. Higher efficiency of companies should lead to more technological investments [49]. This may be understood as a synergy effect between higher service quality and better productivity [18,23]. The possible resource reduction (optimization) in water system management (stage 1) may create a space to allocate resources more efficiently by making savings on capital and other inputs.

It was assumed that the investment in the water system might be linked to the water availability in each state. However, the analysis did not confirm such assumption (see research question 4), as some states with a shallow volume of renewable water, such as Aguascalientes, Baja California, Coahuila, Nuevo León, and Quintana Roo, have very low efficiency in stage 2. More precisely, these states gain +86.90% more in revenues and provide +74.32% more water intakes compared to the country's average, but, on the other hand, register −99.56% less water network extension, −93.31% less pluvial drainage network extension and −80.23% less new installed extraction capacity. This contrasts with Tlaxcala, which demonstrates very low efficiency in stage 1 (0.365) and operates with only 652 m^3/hab/year of renewable water (4th lowest). Nevertheless, its efficiency in stage 2 is 0.923 (5th biggest) as Tlaxacala reports +215.36% more pluvial drainage network extension compared to the other states (no new installed extraction capacity and only 7.21% more water network extension).

Similarly, special attention should be paid to Mexico City. Mexico City has only 73 m^3/hab/year of renewable water (the lowest volume in the country) (Table 6), and the city is located in the Aguas del Valle de México hydrological-administrative region, which reports a very high level of water degree stress (Table 2). Considering this, Mexico City is supplied by the Cutzamala System, one of the world's largest water supply systems [3]. In the analysis, Mexico City obtained a water system management efficiency of 1.000 but a water system improvement efficiency of only 0.012 (5th worst). With respect to the improvements, Mexico City registered −99.97% water network extension, −99.86% pluvial drainage network extension, and −94.95% newly installed extraction capacity compared to the country's average. In this case, the population density may affect the result, which commonly has a positive relationship with water system efficiency [53,54]. This relationship is known as the economy of densities, as there is less network to install and maintain per population and customers, resulting in fewer resource inputs per service output [19,49,55]. However, due to the city's water scarcity, it should be reasonable to invest more in water system improvement to increase the water supply.

Finally, from the other point of view, should the states with a high volume of renewable water take action on water system improvements? The results indicate that the states with the most considerable amount of renewable water are located in Q3 (see Fig. 7) (Campeche, Guerrero, Nayarit, and Tabasco) and Q4 (Chiapas, Durango, Oaxaca, and Yuacatán), i.e., very low efficiency in water system improvements. The high inefficiency in stage 2 may be linked to the prevailing resistance to adopting and implementing new practices [37] but also to their local socio-economic characteristics. For example, Oaxaca, Guerrero, Chiapas, Tabasco, and Campeche are among Mexico's ten poorest states, with a decentralized government in local rural communities [56]. In this case, water governance may face challenges of insufficient data sharing between government offices, lack of monitoring and enforcement of water quality laws, unclear federal policies for water quality surveillance, and administrative and technical management of the water services [57], common for rural communities. This may cause the low improvement orientation of the water system resulting in inadequate water quality management [56,58], although Andwandter and Ozuna [29] and Salazar-Adams [28] observed that neither decentralization to the municipal level nor the establishment of an autonomous regulator had a positive impact on the efficiency in Mexico.

6. Conclusion

This paper performed a state-level two-stage DEA analysis to study the water system management and water system improvements to understand the current situation and identify the best performers to foster water policy and water practices between the states in Mexico.

This research shows that water system management, on average, performs better than water system improvements (0.690 vs. 0.196). The quadrant analysis of the two-stage DEA results helped to analyze the water practices of each state and to identify those doing better - in Q1-than the other states.

The investigation has shown that water system management improvements are possible by increasing water availability techniques and by reducing water demand, which is possible through long-term planning and capital investment. It also shows that water system improvements have more room for improvement for the Mexican states; these improvements are not necessarily linked to each state's water availability, which is usually assumed; these inefficiencies may be linked to the prevailing resistance to adopting and implementing new practices and technologies, and to their socio-economic characteristics.

Nevertheless, caution should be taken when translating DEA efficiency scores into policy recommendations since each state has its demographics, geographic characteristics, and cultural and political practices; these are described in the next section.

6.1. Limitations of the analysis and future works

One of the limitations of the analysis is that the results are related to only one period (2018), and the results can be affected by external factors or events [19]. To eliminate this limitation, the analysis can incorporate the data from the Census for 2011, 2013, 2015, 2017, and 2021 (not yet published) to validate the obtained results. Moreover, including more periods would enable to combine the two-stage model with dynamic models, such as the Window DEA, Malmquist index, and Network DEA [24,40,52,59]. Further, similarly to the previous point, the state level can create misleading conclusions in some cases as significant differences exist regarding development within states (rurality/urbanity). For example, Puebla state includes 217 municipalities, where the capital Puebla has 1, 692,181 people, but many municipalities have less than 5000 people, which results in socio-economic differences. Considering the economy of density, the more rurality exists, the more spending of the water companies as a larger number of smaller size treatment plants are distributed across more rural areas. Such distribution causes inefficiencies in water system management [19]. In this case, the analysis could eliminate this limitation by applying the analysis to the municipal level or a regional level [21,26].

6.2. Study's implications

These findings have significant implications for understanding how the states perform their water system management practices and water system efficiency practices. DEA studies have the goodness of identifying the state peers who perform better, and for those who are not, DEA guides each state on how they can become the best performers. This study can help the state-policy makers to identify how they are performing and to design plans to manage the water better. For example, water managers should share historical best (and worst) projects and policy practices at their meetings, which are not necessarily occurring at the National Governor's Conference[5] (CONAGO, by its acronym in Spanish. CONAGO's Environment, water resources, and climate change committee, for example, has not had meetings in the last three years [60], although water stress in the country has been increasing its importance due to a lack of rain in the north of Mexico.

Authors' contributions

Marien Morán-Valencia involved in Conceptualization, Formal analysis and Writing - Original Draft and Investigation. Martin Flegl involved in Conceptualization, Data Curation, Investigation, Methodology, Software, Formal analysis and Writing - Original Draft. David Güemes-Castorena involved in Investigation, Methodology, Writing - Review & Editing and Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wri.2022.100200.

[5] National Governor's Conference – Conferencia Nacional de Gobernadores, in Spanish.

Appendix

Table 6
Geographic and socio-economic data and renewable water by state in Mexico (elaborated based on data from Conagua [3])

State	Continental area (km2)	Renewable water 2018 (hm^3/year)	Population in mid-year 2018 (millions of inhabitants)	Renewable water per capita (m^3/ inhabitants/year)	Contribution to national GDP 2017 (%)	Municipalities or districts of Mexico City (number)
Aguascalientes	5618	536	1.34	401	1.37	11
Baja California	71,446	3045	3.63	838	3.36	5
Baja California Sur	73,922	1235	0.83	1483	0.90	5
Campeche	57,924	5815	0.95	6131	2.39	11
Coahuila de Zaragoza	151,563	3457	3.06	1128	3.74	38
Colima	5625	2159	0.76	2843	0.62	10
Chiapas	73,289	113,557	5.45	20,854	1.60	123
Chihuahua	247,455	11,759	3.82	3081	3.41	67
Mexico City	1486	644	8.79	73	16.47	16
Durango	123,451	12,594	1.82	6935	1.20	39
Guanajuato	30,608	3886	5.95	653	4.42	46
Guerrero	63,621	20,972	3.63	5785	1.39	81
Hidalgo	20,846	7475	2.98	2508	1.64	84
Jalisco	78,559	15,951	8.20	1946	7.08	125
Estado de México	22,357	4786	17.60	272	8.96	125
Michoacán de Ocampo	58,643	12,633	4.69	2695	2.54	113
Morelos	4893	1848	1.99	930	1.17	33
Nayarit	27,815	6660	1.29	5161	0.73	20
Nuevo León	64,220	4448	5.30	839	7.53	51
Oaxaca	93,793	55,901	4.08	13,685	1,48	570
Puebla	34,290	11,382	6.37	1786	3.45	217
Querétaro	11,684	1940	2.09	927	2.34	18
Quintana Roo	42,361	1741	1.71	1018	1.58	11
San Luis Potosí	60,983	10,862	2.82	3845	2.18	58
Sinaloa	57,377	9903	3.06	3237	2.21	18
Sonora	179,503	7154	3.05	2345	3.44	72
Tabasco	24,738	31,941	2.45	13,014	2.36	17
Tamaulipas	80,175	8962	3.66	2448	2.94	43
Tlaxcala	3991	868	1.33	652	0.56	60
Veracruz	71,820	51,640	8.22	6282	4.54	212
Yucatán	39,612	21,813	2.20	9917	1.45	106
Zacatecas	75,539	4016	1.61	2492	0.95	58
Total	1,959,248	451,585	124.74	3620	100.00	2463

Table 7
Summary of the dataset

State	Total Expenditures (TE)	Total personnel (TP)	Water intakes (WI)	Total revenues (TR)	Water network extension (WNE)	Pluvial drainage network extension (PDNE)	Installed extraction capacity (IEC)
Aguascalientes	82,312,043.36	76.25	3,082,616.90	90,189,712.38	372.36	50.70	454.19
Baja California	113,673,896.70	100.66	5,061,386.81	144,553,854.80	375.25	25.92	160.54
Baja California Sur	110,363,502.40	211.66	3,842,886.13	119,927,887.90	328.54	0.00	128.12
Campeche	18,813,303.20	96.94	405,308.48	12,434,632.79	2427.09	4.51	143.69
Coahuila de Zaragoza	10,482,436.02	57.61	1,824,797.52	21,391,745.13	1614.46	3.90	0.00
Colima	20,698,232.81	96.90	988,101.85	45,971,814.99	263.66	0.09	9.30
Chiapas	90,687,163.21	29.22	1,361,425.65	84,777,977.52	21.49	0.36	57.21
Chihuahua	79,720,770.53	99.12	3,920,859.86	84,690,744.83	322.00	0.19	239.29
Mexico City	115,665,552.90	138.09	2,677,627.02	88,813,013.15	26,466.46	2.73	0.00
Durango	36,981,311.98	84.14	1,351,461.98	42,260,044.91	3615.10	5.90	16.32
Guanajuato	35,110,526.75	86.12	1,205,606.14	67,710,888.00	8879.21	11.42	132.87
Guerrero	37,826,088.43	118.31	1,297,016.52	26,256,817.17	92.44	0.63	95.12
Hidalgo	35,887,801.38	112.49	1,515,036.78	39,745,939.25	319.71	43.63	5386.14
Jalisco	42,557,651.17	79.56	2,404,142.96	58,469,611.69	1301.67	2.83	204.10
	50,338,163.79	82.50	839,838.12	81,613,343.75	5480.23	4133.36	55.22

(continued on next page)

Table 7 (*continued*)

State	Total Expenditures (TE)	Total personnel (TP)	Water intakes (WI)	Total revenues (TR)	Water network extension (WNE)	Pluvial drainage network extension (PDNE)	Installed extraction capacity (IEC)
Estado de México							
Michoacán de Ocampo	35,800,564.60	82.97	792,191.29	36,025,247.50	139.03	30.93	449.46
Morelos	37,446,578.27	109.36	721,177.16	36,099,986.46	6395.44	7.60	2.03
Nayarit	44,707,204.22	126.92	671,897.26	43,096,804.01	269.53	8.59	56.66
Nuevo León	131,285,294.3	99.25	5,288,126.82	121,186,725.40	280.18	6.38	265.30
Oaxaca	12,367,390.30	96.80	173,294.09	18,377,497.68	4016.35	200.23	27.10
Puebla	29,622,291.69	52.57	1,160,722.41	32,205,884.11	4113.60	15.00	12.53
Querétaro	77,932,362.62	77.81	3,656,910.15	115,952,083.10	368.13	130.43	2.96
Quintana Roo	96,618,304.56	94.40	3,587,265.99	144,357,617.60	282.86	3.90	0.00
San Luis Potosí	41,574,520.59	73.59	1,708,187.35	40,725,820.45	269.31	2460.61	49.36
Sinaloa	84,966,588.11	153.22	4,844,762.32	80,302,047.78	3390.12	6.09	26,899.12
Sonora	103,162,254.70	125.81	4,482,472.95	87,957,466.04	246.90	5.91	160.59
Tabasco	37,698,288.85	119.75	427,719.24	6,213,118.38	6712.28	1.564	397.80
Tamaulipas	116,034,729.10	170.62	4,163,015.05	113,100,936.00	192.90	30.91	755.16
Tlaxcala	20,577,498.87	90.40	99,895.31	16,988,791.32	5403.00	821.15	0.00
Veracruz	34,756,868.58	78.52	2,751,934.66	40,928,236.23	2,299,434.93	313.40	93.02
Yucatán	25,397,262.65	83.50	7,545,998.88	24,042,967.81	1903.67	0.00	0.00
Zacatecas	38,718,777.50	105.79	3,026,946.64	36,742,280.87	11.657.92	3.43	0.00

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