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Analysis of water coverage in the municipalities of the State of Guanajuato

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Abstract. The urbanization that most of the municipalities in the State of Guanajuato are undergoing has made it imperative to generate strategies that allow an adequate administration and management of the drinking water service [1]. In this research, the water marginalization index for the State of Guanajuato is constructed using data from the 1990, 2000, 2010 and 2020 Population and Housing Censuses, which allowed for an analysis of the evolution of the effects of the policies adopted by the authorities to meet this challenge. The results indicate a favorable evolution of supply, however, the increase in the percentage rate of the use of rivers or community wells as a source of water supply is noteworthy, going from 6.99 to 31.21 percent from 2010 to 2020, this result indicates an increasing overexploitation of the aquifers, which will cause complications in the future supply of water.
Keywords: Water Marginalization, Water Marginalization Index, Water management, Domestic Water.

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1 Introduction

The lack of water has increased due to several factors, among which the following can be mentioned: population growth, economic activity, and its use as a waste diluent, which makes it unusable for other uses. The effect of climate change is causing the phenomenon of shortages to recur frequently, not only in regions with low rainfall, but also in areas where this was not perceived as a problem [2].

Considering water as one of the fundamental elements for social growth and development, it is essential to carry out studies to promote and strengthen the establishment of public policies and strategic plans for proper management that will also provide sustainability to good sanitation management, since poor management of the resource and contaminated water are linked to diseases such as diarrhea, cholera, dysentery, hepatitis "A" and typhoid fever, These diseases can affect the health of all types of people, especially that of children. In 2018, intestinal infectious diseases related to the use of contaminated water sources in Mexico amounted to more than 5.7 million cases annually [3].

The purpose of this research is to construct the water marginalization index, using the methodology proposed by [4] to classify the municipalities of the State of Guanajuato according to their marginalization in terms of drinking water services and thus analyze their evolution in the years between 1990 and 2020.

2 Problem statement and state of the art

Freshwater scarcity is one of the main environmental problems facing mankind. It is considered that 60% of the world's population suffers from shortages, and the most worrying thing is that it is currently estimated that 1,000 million people do not have access to this vital liquid. For developed countries, water problem affects nature conservation and economic growth possibilities, while in developing nations, in addition, the lack of drinking water is the direct cause of preventable diseases such as diarrhea and cholera, which cause a high percentage of deaths in children under 5 years of age [5].

According to [6], water management planning, historically, it was based on the projection of the population that needed to be satisfied, estimating a per capita water usage of, and simply multiplying one projection by the other to get an estimate of future water. Based on this estimate, the managers' objective was to identify those sources of supply available in the region to add appropriately to existing supply, today and especially since the emergence of ecological, financial, and political constraints in the 1980s and 1990s, this methodology is considered to be deficient.

The problem of water management is considered to have a wide range of factors that play an influential and important role in water resources planning in general and specifically in urban and domestic water [7]. For these reasons, water resource managers should try to understand, modify, and control demand, a generally ignored alternative, and stop considering it as an exogenous and unmodifiable value [8].

Currently, households rely on a variety of water supply sources with different characteristics and service levels (price, distance, quality and reliability). For many households in developing countries, water is a commodity of heterogeneous origin, which is not usually the case in industrialized countries [9].

According to [10], water service is characterized by a large number of variables and parameters that represent a particular water distribution in specific localities such as time and type of service. Multivariate methods such as cluster analysis, principal component analysis, index construction, factor analysis and discriminant analysis are justified for water quality assessment and management [11].

Obtaining water from sources outside the home leads to collection costs, which must be considered when assessing the impact on the household economy. According to [12], the lack of piped drinking water service in homes leads to an increase in household chores for up to three hours.

Researchers have used four main strategies to obtain the necessary information and efficiently model the behavior of water requirements in households in underdeveloped countries. 1) household surveys to complement existing data from public or private sources, 2) direct census of households to know their reaction to hypothetical situations of water use, 3) analysis of the increase in the value of housing by adding potable water services and, 4) experimental methods (including randomized controlled trials) to test how households behave in response to different water supply interventions [13].

For [14], water consumption efficiency would be achieved if water management operated within a competitive market, but this is not the case in reality, in the case of Mexico and other countries, it is observed that most of the water distribution operators are decentralized public sector entities, It is in this context that the analysis becomes more difficult and it becomes more relevant to demonstrate that even with this type of schemes, cost-effective incentives can be applied that allow the efficient use of water during short and long term shortages in most of the Mexican Entities and Municipalities.

According to [15], by the year 2030 in some of the country's regions, the average natural water availability will reach levels close to or even below 1,000 cubic meters inhabitant/year, i.e., a condition qualified as a severe shortage condition.

3 Context of drinking water in Guanajuato

The State of Guanajuato presents a relevant case to analyze considering its scarcity problem and the efforts of the organizations in charge of drinking water management as well as the participatory instruments to carry out an adequate administration of water resources in the region.

According to the National Water Commission (Conagua), 80% of the State's territory belongs to the Lerma-Chapala-Santiago Basin, which in economic and demographic terms has presented a great growth in the last 50 years, and is considered the largest in Mexico, and includes the states of México, Querétaro, Guanajuato, Aguascalientes, Michoacán, Jalisco, and Nayarit, including Zacatecas and Durango with lesser influence. This zone is considered strategic for the country due to the prevailing socioeconomic activity, according to [16], the following difficulties related to water resources are encountered:

1. Overexploitation of its subway aquifers,
2. Progressive pollution of its water bodies.,
3. Growing demand for water facing scarcity and lack of access to water resources.,
4. Need to significantly increase the availability of financial resources to meet the demand for drinking water and sanitation.

The progressive increase in the number of intakes for domestic, industrial, and agro-industrial use is causing extraction levels that are unsustainable for the water supplies in the State that supply these services. The main source of groundwater in the area comes from aquifers; this condition led to the implementation of the Groundwater Technical Committees in the 1990s as a strategy to counteract this deficiency in each of the aquifers, however, different circumstances caused an extraction of 4,000 mm^3 of water from the State's aquifers, which have an annual recharge of 2,800 mm^3 per year $mm^3$1,000, so that there is a deficit of more than mm^3 [17].

Through the Groundwater Technical Committees four integrated management plans were drawn up by the users and the different water authorities, both federal and local, defining different actions to halt or at least reduce groundwater overexploitation, these management plans evaluate the current impact of aquifer mining and the different demand management options through private cost-benefit analyses [1].

One of the goals at the State level is a correct administration of the resource, since its 18 aquifers are overexploited. [18], it is therefore urgent to establish policies and strategies in the sector that will result in the adequate management of water resources.

4 Methodology and data

The water marginalization index was calculated based on INEGI data from the 1990, 2000, 2010 and 2020 Population and Housing Censuses, because they have the coverage, degree of disaggregation and updating of the information necessary for its construction at the Municipal level.

Selected variables. Considering the global context described above, three variables were selected that homogeneously incorporate the precariousness of drinking water service: homes without drinking water service, those that are supplied by a river or community well, and homes that must travel to a hydrant for the vital liquid.

Calculation of water marginalization index indicators:

Percentage of households without drinking water service (p_wdw_{i1}).

For the calculation of this indicator, we first obtained the percentage of homes with potable water service and then used the complement to obtain the percentage of homes without potable water service.

$$p\_wdw_{i1} = 100 - \left[\frac{t\_w_i}{t\_hou_i} * 100\right]$$

where:

t_W_i: is the total number of dwellings with potable water service by municipality i.
t_hou_i: is the total number of dwellings in the municipality i.

Percentage of households supplied with water service by river or well (p_rw_{i2}).
This indicator is obtained by dividing the total number of dwellings in municipality *i* supplied with drinking water by river or well by the sum of all dwellings in the municipality *i*.

$$p\_rw_{i2} = \left[\frac{tr\_w_i}{t\_hou_i} * 100\right]$$

where:

tr_w_i: is the total number of dwellings with drinking water supply by river or well in the municipality *i*.
t_hou_i: is the total number of dwellings in the municipality i.

Percentage of households with potable water service by means of a hydrant (p_hd_{i3}).
To construct this indicator, the total number of homes supplied with drinking water service by means of a hydrant in municipality *i* was divided by the sum of all the homes in the municipality *i*.

$$p\_hd_{i3} = \left[\frac{thd_i}{t\_hou_i} * 100\right]$$

Where:
thd_i: is the total number of dwellings with drinking water supply by means of hydrant in the municipality *i*.
t_hou_i: is the total number of dwellings in the municipality *i*.

The method for constructing the water marginalization index for the municipalities of the State of Guanajuato is the one proposed by [4] in its work "Construction of a composite index and approximation to measure changes over time", which allows reflecting the situation prevailing in the original variables, ordering the units of observation, and measuring the changes over time.

The index:
Sea *p* = number of correlated variables: $x_1, x_2, x_3, \ldots\ldots, x_p$
The index is a linear combination of the form:

$$I = C_1 X_1 + C_2 X_2 + \ldots\ldots + C_p X_p$$

Where, $C_j = \frac{r_i}{S_i S}, S_i = , s_i = Standard\ deviation\ of\ the\ variable_i,$

$$S = \frac{r_1}{S_1} + . \frac{r_2}{S_2} + \quad + \frac{r_p}{S_p},$$

y r_i = root mean square of the correlations between variables *i* and the rest of the variables, given by

$$r_i = \left(\frac{1}{p-1}\sum_{j=1}^{p} r_{ij}^2\right)^{1/2}$$

This for $i = 1, 2, \ldots\ldots, p; with\ i \neq j.$

Thus, the index takes the form:

$$I = \left(\frac{r_1}{S_1 S}\right) X_1 + \left(\frac{r_2}{S_2 S}\right) X_2 + \cdots + \left(\frac{r_p}{S_p S}\right) X_p = \sum_{i=1} \frac{r_i}{S_i S} X_i$$

Either,

$$I = \frac{\left(\frac{r_1}{S_1}\right) X_1 + \left(\frac{r_2}{S_{12}}\right) X_2 + \cdots + \left(\frac{r_p}{S_p}\right) X_p}{\frac{r_1}{S_1} + \frac{r_2}{S_2} + \cdots + \frac{r_p}{S_p}}$$

The index is a weighted arithmetic average, where the sum of the weights is equal to unity. Therefore, it is interpreted in terms of the original variables, in the case of the water marginalization index, will have a value from 0 to 100, where 100 means that all the population has a high marginalization of services and 0 means that all have low marginalization.

Analysis of results

Domestic water management is a paradigmatic case that presents a complex behavior. While its management has historically been based on supply-side policies, it has also been based on supply-side policies, to compensate for the supply of the demand, which depends on a socio-economic and technological system perceived as an exogenous environmental condition, currently, it has serious deficiencies. The proposal to perform an analysis of the effects of decision making in terms of drinking water service through the construction of the water marginalization index offers a clear vision of the problems and the results of the policies and strategies adopted by the Government of the State of Guanajuato during the period 1990 - 2020.

Among the main findings, we observe in Table 1, that the percentage of homes without drinking water service decreased from 1990 to 2000 by 15.40 percentage points, but by 2010, it shows an increase of 20.72%, reaching 34.09%, by 2020, we note a substantial improvement to only 3.45%, Regarding the variable: percentage of homes that are supplied by river or community well, we can see a drop in the percentage rate from 1990 to 2010 of 18.45%, reaching 6.99% by 2010, however, from 2010 to 2020, we can see a considerable increase of 24.22%, placing the indicator at 31.21%, on the other hand, the percentage of dwellings with drinking water service by means of hydrant had a significant decrease from 2.20 to 0.17 percent from 1990 to 2020, which shows the substitution of water supply by hydrant for a more efficient and salubrious means.

Table 1. Summary statistics of selected variables

Selected variable	Year	Media	Media	Standard deviation
Percentage of households without drinking water service.	1990	28.77	22.28	20.41
	2000	13.37	9.02	11.42
	2010	34.09	28.20	20.96
	2020	3.45	1.53	7.38
Percentage of households served by river or community wells.	1990	25.44	18.16	19.34
	2000	8.20	2.91	10.70
	2010	6.99	2.57	8.66
	2020	31.21	32.51	18.70
Percentage of households with drinking water service through hydrants	1990	2.20	2.01	1.27
	2000	2.04	1.35	2.00
	2010	0.96	0.35	2.31
	2020	0.17	0.06	0.35

Source: Own elaboration with data from the 1990, 2000, 2010 and 2020 Population and Housing Censuses.

Regarding the results of the water marginalization index (see Table 2), cases such as the municipalities of Atarjea Victoria and San Felipe stand out, whose indicator shows a great improvement, going from 54.22, 44.47 and 30.17 to 6.77, 1.82 and 1.54 percent, respectively, from 1990 to 2020.

In the municipalities of Celaya, Irapuato, Apaseo el Grande, Moroleón, Purisima del Rincón, Doctor Mora, Jaral del Progreso and Coroneo, good resource management is perceived, since they have maintained a lower rate than the State during the period under analysis.

Tierra Blanca, San Miguel de Allende, Pénjamo, Silao de la Victoria, Xichú, Pueblo Nuevo, Apaseo el Alto, Jerécuaro, Santa Cruz de Juventino Rosas, Comonfort, Valle de Santiago, Salvatierra, Huanímaro, Salamanca, San Francisco del Rincón and Manuel Doblado, show figures above the state average for 2020; however, over the 30 years, their evolution has been favorable, showing a downward trend.

Table 2. Water marginalization index from 1990 to 2020 (in percent).

No.	Municipality	1990 - 2000	2000- 2010	2010 - 2020
1	06 Atarjea	54.22	10.34	6.77
2	43 Victoria	44.47	3.42	1.82
3	30 San Felipe	30.17	14.16	1.54
4	40 Tierra Blanca	18.58	15.07	5.23
5	23 Pénjamo	15.99	7.06	2.88
6	33 San Luis de la Paz	14.09	5.31	1.27
7	22 Ocampo	13.09	5.95	1.42
8	03 San Miguel de Allende	11.63	15.63	9.72
9	37 Silao de la Victoria	10.66	11.33	6.24
10	45 Xichú	10.18	7.45	4.06
11	24 Pueblo Nuevo	8.86	5.09	6.23
12	34 Santa Catarina	8.53	3.82	1.79
13	04 Apaseo el Alto	8.02	4.35	2.88
14	19 Jerécuaro	8.02	6.28	3.59
15	35 Santa Cruz de Juventino Rosas	7.94	11.97	6.00
16	15 Guanajuato	7.78	4.88	1.67
17	09 Comonfort	7.76	7.60	3.42
18	42 Valle de Santiago	7.46	2.90	3.63
19	28 Salvatierra	6.43	6.95	3.96
20	16 Huanímaro	6.32	3.46	5.44
21	27 Salamanca	6.32	4.31	3.61
22	14 Dolores Hidalgo	5.20	3.13	1.69
23	36 Santiago Maravatío	4.56	3.06	1.86
24	41 Uriangato	4.32	3.54	1.38
25	26 Romita	4.23	15.37	1.48
26	31 San Francisco del Rincón	3.96	3.11	2.19
27	44 Villagrán	3.96	4.93	1.70
28	08 Manuel Doblado	3.66	4.44	3.18

Continued table 2. Water marginalization index from 1990 to 2020 (in percent)

No.	Municipality	1990 - 2000	2000- 2010	2010 - 2020
29	32 San José Iturbide	3.43	2.52	0.94
30	46 Yuriria	2.90	1.90	0.90
31	39 Tarimoro	2.86	1.98	0.88
32	29 San Diego de la Unión	2.72	2.83	1.09
33	11 Cortazar	2.46	1.58	1.36
34	01 Abasolo	2.44	1.68	1.21
35	12 Cuerámaro	2.31	1.02	0.92
36	02 Acámbaro	2.29	1.26	1.29
37	20 León	2.18	3.54	2.21
38	38 Tarandacuao	2.12	1.49	1.68
39	07 Celaya	1.85	2.24	1.35
40	17 Irapuato	1.81	2.42	1.52
41	05 Apaseo el Grande	1.58	1.58	1.50
42	21 Moroleón	1.32	1.25	0.43
43	25 Purísima del Rincón	1.22	6.25	0.87
44	13 Doctor Mora	0.94	0.67	0.34
45	18 Jaral del Progreso	0.93	0.61	0.64
46	10 Coroneo	0.41	1.76	0.50
	Index in the Entity	***1.97***	***2.89***	***1.75***

Source: Own elaboration with data from the 1990, 2000, 2010 and 2020 Population and Housing Censuses.

5 Conclusions

Decision-making associated with water resources allocation and planning are complex situations that require multidisciplinary techniques to assess their effects in a social, economic, and environmental context [19].

In Guanajuato, groundwater is the source of six out of every seven liters consumed for all uses, although particularly for domestic use it represents 99%, for agricultural use 60% and for industrial use 100% [20]. From a total of 15,297 active wells in 2016, about 4,000 Hm3 per year are extracted, which is estimated to exceed 1,200 hm3 to the renewable resource [21].

Many of the estimation techniques have been based on prediction systems without theory, a mere predictive adjustment, but without providing knowledge of the structure, and without it, it is difficult to make decisions. If we intend to understand the mechanisms and implications that take place in the social and technological change dimensions, it is necessary to represent them explicitly in the models, the proposed technique to evaluate the performance of water management in the period 1990 - 2020, provides a realistic view of the situation prevailing in the municipalities of the State of Guanajuato, while providing indicators that support decision making.

However, it is a priority to represent the human dimension and a certain level of cognition. This fact is reinforced by the social importance that water is gaining as a resource and that is easily detectable in recent years.

The proposed research is justified by the usefulness of water supply in the domestic, agro-industrial and industrial sectors, not considering the dynamics that are linked to the water consumption demanded by the population results in inefficiency in its

administration, these include social, demographic, economic and territorial factors that in one way or another influence its demand. Therefore, it is necessary to explore and analyze these elements both for the future estimation of the service and for an adequate management of the resource in the different municipalities, in this sense, the options are quite obvious in view of the analysis of the prevailing situation, particularly in the state of Guanajuato.

This scenario poses great challenges to reduce the great inequalities in the sector, as well as the existing gap in infrastructure to guarantee the Human Rights to Water and Sanitation, in this regard, it is considered a success the implementation of the Technical Committees of Groundwater, since according to the results of this work, since its operation, has reduced the marginalization of domestic water in the municipalities of the State, however, the new challenge is the over-exploration of groundwater, which has increased considerably in the last decade (from 6.99 to 31.21 percent), which in the future will represent a serious problem of scarcity.

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