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Articles

Water grabbing risk index: A methodological proposal for water justice

Índice de Riesgo por acaparamiento del agua: propuesta metodológica de justicia hídrica

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Abstract

This is a proposal to establish a Water Grabbing Risk Index (IRAA, according to its initials in Spanish) capable of territorially differentiating grabbers, considering the use they give to water, the volumes they accumulate, as well as water status in each basin and aquifer. Grabbing pattern is established by identifying concessionaires and water uses when the volumes granted concentrate at least 80 % of the municipality surface and/or groundwater. The IRAA integrates water stress index to determine risk and makes it possible to link water management and land use management, since water grabbing activities are identified in each municipality. The index was applied in the state of Puebla where, from 174 municipalities that met methodological requirements, 45.4 % were at very high risk, 41.4 % were at high risk, 10.9 % were at medium risk and 2.3 % were at low risk. None entered the very low risk category, showing a strong tendency towards water grabbing risk in the state, which is confirmed by the presence of inter-municipal grabbers, also identified in this study. Through the IRAA it is possible to identify priority areas in the transformation of water management that transcends basin organizations and integrates municipal territories. In turn, it proposes arguments for environmental justice. The methods and techniques used are in the field of data science.

Keywords: Grabbing concessionaires, grabbing uses, water stress index, inter-municipal grabbing concessionaires, municipalities.

Resumen

Se propone la conformación de un índice de riesgo por acaparamiento del agua (IRAA) capaz de diferenciar territorialmente a los acaparadores, tomando en consideración el uso que éstos le dan al agua, los volúmenes que acumulan, así como el estatus del recurso en cada cuenca y acuífero. El patrón de acaparamiento se establece al identificar a concesionarios y usos cuando los volúmenes otorgados concentran al menos 80 % de las aguas superficiales y/o subterráneas del municipio. El IRAA integra el grado de presión sobre el recurso hídrico para determinar el riesgo y permite vincular la gestión hídrica y la gestión de los usos de suelo, puesto que las actividades acaparadoras de agua quedan identificadas en cada municipio. El índice se aplicó en el estado de Puebla, donde de 174 municipios que cumplieron con los requerimientos metodológicos, 45.4 % resultó con riesgo muy alto, 41.4 % con riesgo alto, 10.9 % con riesgo medio y 2.3 % con riesgo bajo. Ninguno entró en la categoría de riesgo muy bajo, mostrando una tendencia marcada de riesgo hídrico por acaparamiento en el estado, que se corrobora con la presencia de acaparadores intermunicipales, también identificados en este estudio. A través del IRAA es posible determinar zonas de prioridad en la transformación de la gestión del agua que trasciende los organismos de

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cuenca e incorpora los territorios municipales. Propone a su vez argumentos para la justicia ambiental. Los métodos y técnicas empleadas se ubican en el ámbito de la ciencia de datos.

Palabras clave: concesionarios acaparadores, usos acaparadores, grado de presión hídrica, concesionarios intermunicipales acaparadores, municipios.

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Introduction

In recent decades, the analysis of environmental problems made by organized communities, scholars and international organizations has been aimed at critically identifying the patterns and causes of planetary degradation that lead to a global environmental crisis (Leff, 2004; Toledo, 2013; Barkin, Ortega, Saldaña, Mirafuentes, & Pérez-Riaño, 2020). These analyzes have as their goal the substantial transformation of the forms of appropriation of nature.

Capitalist anthropocentrism, whose benefits are only accessible to a minority, is the economic and ideological framework that has guaranteed the validation and reproduction of deterioration, in which the physical and biotic resources of the planet are subjected to a wild overexploitation and levels of damages for which the common citizen should not be held responsible.

The identification of green grabbing, water grabbing, and land grabbing as well as their close interrelation ((Rulli & D'Odorico, 2013; Dell'Angelo, D'Odorico, & Rulli, 2017), has been documented especially in African countries (Grain, 2012; Duvail, Médard, Hamerlynck, & Nyingi, 2012), Latin America (Rocheleau, 2015; Vazquez, 2017) and Asia (Corbera, Hunsberger, & Vaddhanaphuti, 2017). It is no coincidence that this is the case, since it is precisely the poor countries that suffer the greatest extractivism of transnational capital (Dell'Angelo, Rulli, & D'Odorico, 2018). Although the impacts of water deterioration and depletion are global, direct impacts have large regional differences, with the countries of the global south being the most affected (Fairhead, Leach, & Scoones, 2012) and also where water conflicts, and socio-environmental conflicts in general, have multiplied in the face of the threat of the very existence of life in the communities (Weeber, 2016).

Some data from the United Nations Educational, Scientific and Cultural Organization (UNESCO) (UNESCO, 2019; UNESCO, 2020) state that the demand and use of water has a sustained growth of 1 % annually since the decade of 1980s; its availability, in contrast, decreases rapidly, having more than 2 billion people inhabiting countries with a strong water stress, optimal quality water body loss, strong impacts associated to changes in hydro morphology, increase in emerging pollutants, and spread of invasive species. In addition, variability, and climate change show that 90 % of extreme events are associated to water, causing drought and flooding episodes throughout the planet. Water use is therefore involved in most environmental degradation processes, resulting in loss of plant and animal biodiversity, including humans.

While the high complexity of water-related problems does not allow for simplistic solutions, the orientation of such solutions should be aimed at reversing the destructive processes of appropriation of planetary resources; in other words, it must reverse privatization and grabbing that the legal frameworks of most countries have allowed in favor, fundamentally, of domestic or foreign capital investment.

As far as Mexico in concerned, the current system of granting the resource by the Mexican State dates from the still-in-force National Water Act of 1992, which takes over the neoliberal approach emanated from the Dublin Conference; (Rolland & Vega, 2010) held in January of the same year, in which the water resource is established as an "economic good" (UNEP, 1992) that is concessional. As a result of this, in Mexico the priority orientation of the resource to the fulfillment of human needs and consequently to the Human Right to Water is relegated (Martinez-Austria & Vargas-Hidalgo, 2017). Currently, more than 7.8 million homes (INEGI, 2020), which account for 28.3 million people, do not have piped water in Mexico.

Several studies have shown the ways in which Mexico has transited in the management of water resource (Peña, 2006; De-Alba, Noiseux, & Nava, 2006; Ethos, 2019; Franco, 2020). Also, proposals for improvement have been developed based on the basin approach to integrated water management (Cottler, 2007). However, the body that concentrates decisions on the resource is a federal agency (with regional representations called River Basin Councils) whose link with local authorities has proved to be exclusionary and discretionary (Pérez & Fuerte, 2019), ineffective and institutionally incapable of solving the problems of each basin (Pineda, Moreno, & Díaz, 2017; Parra & Salazar, 2017). In the end, these decisions obeyed the neoliberal policies embodied in legislation, which have produced the big millionaires or water grabbers (Gomez-Arias & Moctezuma, 2020). Corruption, which gratifies the designers and/or implementers of legislation and regulations, amplifies inequalities in the access to water, the possibilities of ecocides, and the very control of the resource in a few hands.

An academic task to contribute in the fight against environmental injustice, and in particular to water injustice, consists of generating tools that in different regional contexts, identify areas of water risk and environmental damage derived from water grabbing. These tools must contribute to Community defense actions, nourish new public policy guidelines with arguments and contribute to the transformation of existing legislation. They also must take into account that the presence and quantity of water varies geographically and temporarily, and that grabbing and deterioration levels cause different impacts in regions depending on these spatial and temporal differences and may increase regional population and environment vulnerability in areas which are overexploited, polluted, with inhabitants that have no access to water and suffer health damage, among others.

Materials and methods

In this work, the proposed water grabbing risk index (IRAA) was developed based on data of concessions registered in the Public Registry of Water Rights (REPDA)) (Repda, s.f.; Conagua, s.f.) and georeferencing works —up to 2019— of this information by the organization Agua para Todos [Water for All] (aguaparatodos, s.f.), previously verified and validated. It is expressed at the municipal level in the state of Puebla, where management can take place more directly. This indicator evaluates and expresses the indissoluble water-land relationship in the area since water uses, as human activities, have a high degree of correspondence with land uses. This perspective takes a step forward in the unification of water-soil management aimed at the search for environmental justice.

Information from CONAGUA, through downloadable geodatabases (Conagua, 2019), was also used in this work, specifically for information on water stress level (GP, according to its initials in Spanish).

The geostatistical framework used is that of INEGI 2018 (INEGI, s.f.) at the municipal level. For the purposes of this study, only consumptive water uses are evaluated, thus excluding electric power generation (hydropower). Likewise, public-urban water use is excluded at this scale of work because it is assumed that its distribution is for the general population, although within urban centers it is worth deepening the inequality in its distribution. However, this aspect is beyond the scope of the present work for the time being.

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Problem formulation

The formulation of Water Grabbing Risk Index (IRAA) at the municipal level has two components, which are outlined below and subsequently detailed. The first component is the Water Grabbing Index (IAA) and the second is Water Stress (GP). Grabber(s) means the group of concessionaires (or concessionaire) on the one hand, and the set of uses (or use) of water on the other, which concentrate at least 80 % of the volume registered by 2019 in municipality i before REPDA. The smaller the number of concessionaires or uses that concentrate 80 % of the total volume (surface and underground), the greater the grabbing. The concept of Risk is introduced into the index on the basis of the consideration of GP, which warns of the danger of zero water availability. High grabbing levels coupled with high levels of water stress, generate a greater risk to guarantee Water Security in the municipality under study, as current and future "capacity to protect sustainable access to water for the maintenance of livelihoods, welfare and socio-economic development" is lost (fondosdeagua.org, s.f.).

Water Grabbing Index (IAA) is evaluated in two ways: the first one considers grabbing concessionaires (CrAs) from both sources of resource extraction. The second one measures the concentration by type of water use and identifies grabbing uses (UA) in each type of extraction source, according to the following formulation (Equation (1)):

$$IAA_i = CrA_i\, w_1 + UA_i w_2 \qquad (1)$$

Where w_1 and w_2 are weighting factors that can be given to one or another component for analysis, adjusting IAA to values between 0 and 1. 0 represents maximum grabbing and 1, maximum distribution among concessionaires of the municipality *i*. This relationship is the one that makes possible to link water and soil management since, as described above, grabbing of both resources is intimately linked in the territory.

The grabbing concessionaires (CrAs) component was calculated as follows:

$$CrA_i = \frac{Ca_i}{\sum Cs_i} \qquad (2)$$

$$\forall \sum Cs_i > 1$$

Where Ca_i is the number of holders that grab at least 80 % of water granted, while ∑Cs is the total of titles granted in municipality *i*. It should be remembered that several titles can be awarded to the same concessionaire, and this ratio measures such concentration. According to the Equation (2), this operation is only evaluated in those municipalities in which there are more than 1 concessions to avoid bias in the results with an apparent maximum distribution with a single concession that meets the conditions of consumptive use, excluding the urban-public one.

The second component of IAA is the grabbing of water uses (UA), and was evaluated according to the following formulation:

$$UA_i = \beta_{sup,i} \frac{Ua_{i\,sup}}{\sum U_{i\,sup}} + \beta_{sub,i} \frac{Ua_{i\,sub}}{\sum U_{i\,sub}} \tag{3}$$

$$\forall(\sum U_{i,sup} + \sum U_{i,sub}) > 1, si\ (\sum U_{i,sup} + \sum U_{i,sub}) = 1\ \ then\ \ UA_i = \beta_{sup,i}(Ua_{i,sup} - \sum U_{i,sup}) + \beta_{sub,i}\,(Ua_{i,sub} - \sum U_{i,sub}) \tag{3.a}$$

Where factors β_{sup} and β_{sub} represent the percentage of surface and/or groundwater granted in municipality i, thus granting the weight of each source of extraction in the territorial analysis unit (municipality). Surface or underground UA_i refers to the use or uses that concentrate at least 80 % of the water by type of source, while $\sum U_i$ represents the total uses of water present in municipality *i*, according to its source of extraction. The addition of grabbed water ratio from each extraction source gives use grabbing in values ranging from 0 to 1.

The double clamp that establishes this indicator for grabbing determination at the municipal level lies, on one hand, in that it seeks to measure the entire volume granted to the same holder, even if it corresponds to different uses of water. On the other, it evaluates the concentration of water for the same use, as the predominant activity in the municipality.

IAA is itself a parameter that demonstrates water injustice in municipalities without considering other elements of the environment. However, the municipal context can help in outlining, in the beginning, how serious grabbing is under other conditions. Due to its current and future relevance, we introduce, as the second major component of the IRAA, Water Stress Index on the resource existing in municipal areas according to what is described above. This allows to more clearly reflect grabbing risk in terms of availability, according to the following formula:

$$IRAA_i = IAA_i - GP_i \quad (4)$$

In which Water Grabbing Risk Index (IRAA) of the municipality *i*, is the result of Water grabbing index (IAA) minus Water Stress Index (GP) on the water resource evaluated in the current municipality. According to the formulation established by Conagua (2019), GP is obtained as follows (Equation (5)):

$$GP = Agua\ extraida/Disponibilidad\ Natural\ Media \quad (5)$$

Where water extracted corresponds to the annual volume (in hm^3) of extraction of water from any source, whether surface or underground, (only applicable for consumptive uses), divided by the total average natural availability (or renewable water, in hm^3). GP is a component that considers water cycle integrally, with both sources of extraction included. GP varies spatially and temporarily, depending on the specific conditions of basins and aquifers. It is estimated to be high or very high when percentage is greater than 40 %; it makes grabbing levels measurement more sensitive, since these can worsen access to water for other uses/users in areas with less or no current availability of the resource. In this work the values of GP_i were not calculated; they were taken from the values by hydrological-administrative region (RHA) set forth by CONAGUA for the year 2019 (Conagua, 2019), in which there is a suitable geographical overlap of surface units evaluated (municipality).

By integrating Water Stress Index in Water Grabbing Risk Index, its range of values is extended, and can become negative or exceed the unit, depending on the specific conditions of each municipality. To establish a more homogeneous measurement, it is proposed to standardize the index obtained according to the following formulation:

$$IRAA_{i,nor} = \frac{IRAA_i - minIRAA}{maxIRAA - minIRAA} \tag{6}$$

Where the maximum and minimum values of the risk index are extracted from the municipal data set pertaining to the field studied (region, state, country).

Results

Area under study

The index was applied in the state of Puebla, Mexico (Figure 1). Records of consumptive uses excluding the urban-public one were identified in the REPDA in 189 of the 217 entity's municipalities. According to the methodology, the municipalities where the number of municipal

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concessions was equal to 1 were excluded due to it can be interpreted as a maximum distribution or maximum concentration and biases the results of the evaluation. Therefore, the index evaluation universe was limited to 174 municipalities (see Annex 1, file titled ANNEX_1.xlsx, which can be found on the journal's website), excluding 15 with one single concession (see Annex 2, file titled ANNEX_2.xlsx).

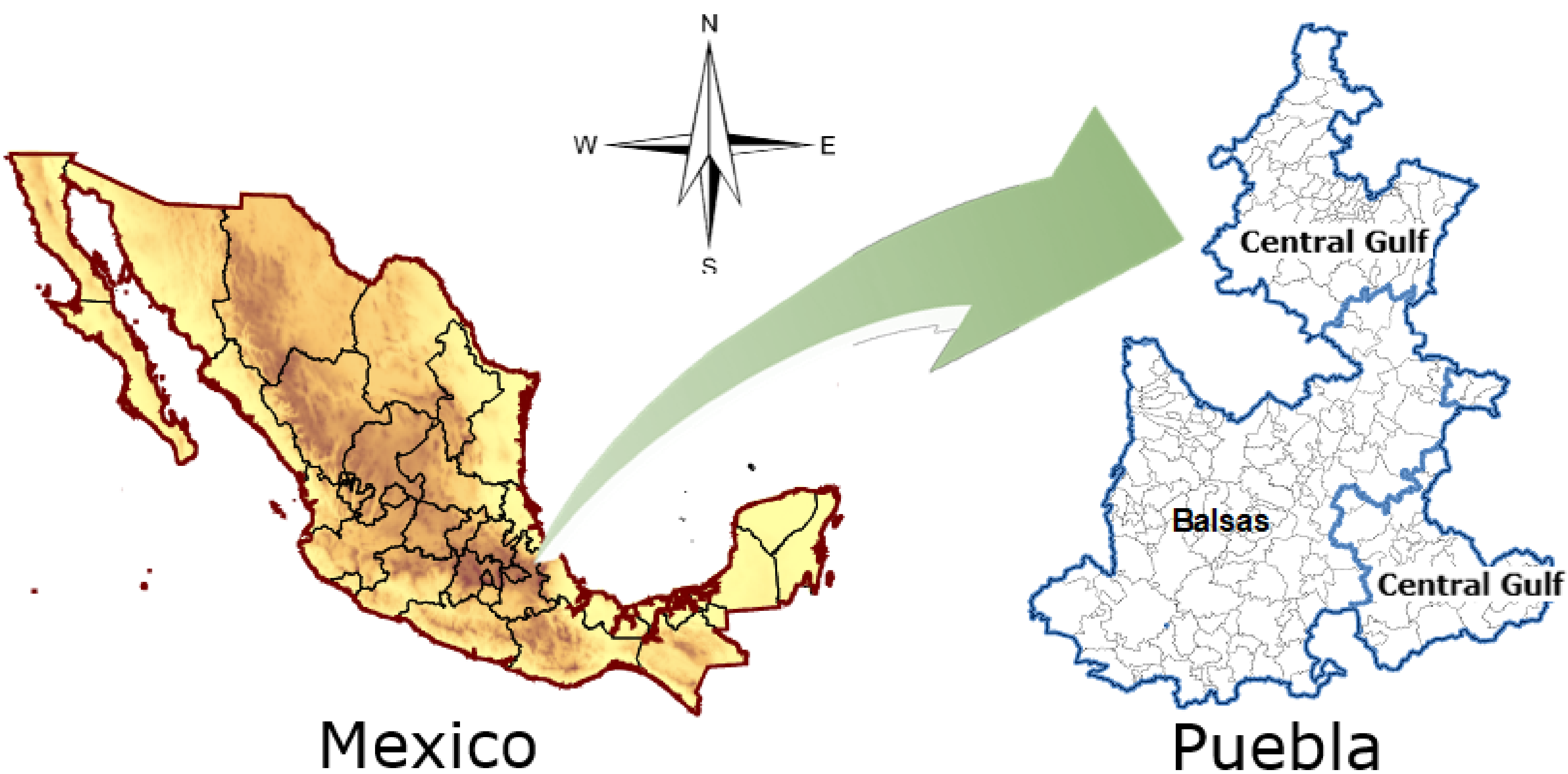

Figure 1. Location of the Study Area and its Hydrological-Administrative Regions (RHA).

In this set there are 117 municipalities with a surface extraction source, and 142 with an underground one. Municipalities with concessions in both extraction sources were 85. The analyzed volume, which corresponds to the evaluated uses, totaled 1 838.72 hm^3 granted in 7 703 titles for 6 653 concessionaires.

Databases were processed with Visual FoxPro applications (VFP, 2007) in order to link them to a geographic information system.

The values assigned for weighting factors ω_1 and ω_2 were 0.8 and 0.2, respectively.

Data mining prior to grabbing index calculation consisted of summing up municipal level concessions data ordered in each source of extraction type. Subsequently, adding frequencies and percentages of water volumes by concession, the number of titles, uses and concessionaires that grab at least 80 % of the water in each municipality was identified, excluding, as described above, non-consumptive uses (generation of electric power from hydroelectric plants) and urban public use.

With these data, the components of the Grabbing Risk Index were calculated, including Water Stress Index in each municipality, according to the formulation described. The results obtained for each component of the index were grouped into 5 equal classes with a 0.2 range, obtaining the following qualitative levels of water grabbing: very high (0 to ≤ 0.2) high (> 0.2 to ≤ 0.4) medium (> 0.4 to ≤ 0.6), low (> 0.6 to ≤ 0.8) and very low (> 0.8 to 1).

About grabbing concessionaires (CrAs)

This component was calculated, as described by the formulation, for all cases in which the total of concessions in the municipality was greater than 1. According to Table 1, the presence of water grabbing by concessionaires was observed at a very high and high level in 53.4 % of the municipalities evaluated, and at a medium level in 32.2 %. Low and very low levels of water grabbing were observed in 14.4 % of said municipalities, with the following spatial distribution (Figure 1).

Table 1. Number of municipalities according to their grabbing level, per IRAA component.

Level	Value	CrA	UA	IAA	IRAA
Very high	0 to 0.2	36	77	32	79
High	>0.2 to 0.4	57	46	73	72
Medium	>0.4 to 0.6	56	36	61	19
Low	>0.6 to 0.8	21	6	4	4
Very low	>0.8 to 1	4	9	4	0

The volume of water concentrated by CrAs in the municipalities was 1 579.4 hm^3, equivalent to 85.9 % of the evaluated volume, distributed in slightly more than one third of the concessionaires (2 305) that hold 2 796 concession titles registered in the REPDA. The 15 municipalities with most grabbing by concessionaires were Pantepec, Francisco Z. Mena, Tianguismanalco, Coxcatlán, Jalpan, Venustiano Carranza, Santa Isabel Cholula, Coyomeapan, Xicotepec, Santiago Muahuatlán, Izúcar de Matamoros, Tlacuilotepec, San Miguel Xoxtla, Huehuetlán El Chico and Tlapanala (Annex 1, file titled ANNEX_1.xlsx).

About grabbing uses (UA)

Evaluation by grabbing uses also yielded results that tend to water concentration in few uses, as can be seen in Figure 2b. 70.7 % of the municipalities analyzed showed very high and high levels of water concentration in few uses. This group includes 50 municipalities in which there is only consumptive use (excluding public-urban). By these means it was possible to differentiate where the maximum diversification of the uses actually occurred and where there is total grabbing (with a value of 0). In the latter case, 50 of the 77 municipalities with a very high level of water grabbing by type of water use were identified. With respect to the medium level, 20.7 % of the municipalities were counted, while in the low and very low levels of grabbing by use, we found only 8.6 % of the municipalities evaluated.

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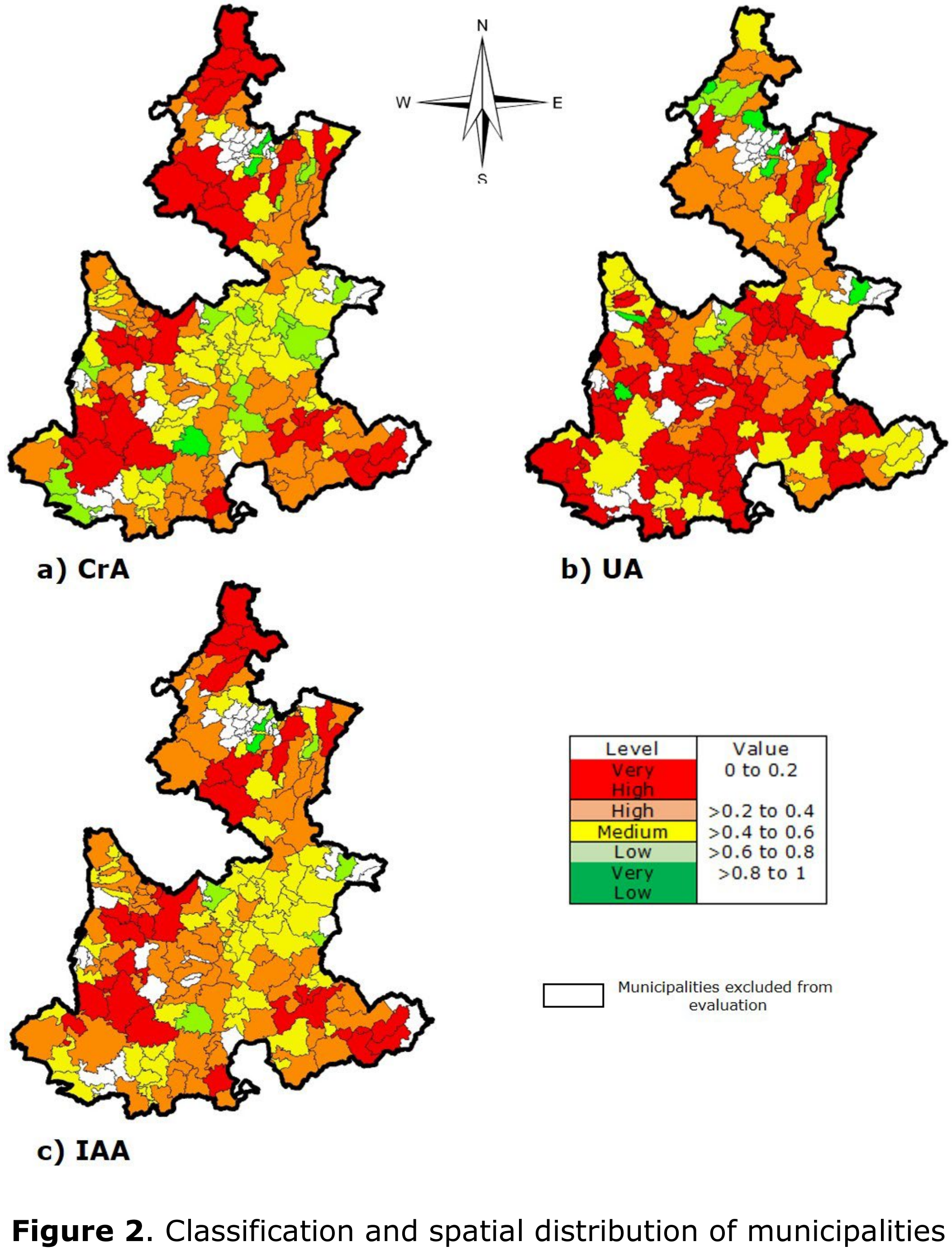

Figure 2. Classification and spatial distribution of municipalities according to values obtained by component: a) Grabbing by concessionaires (CrAs); b) grabbing by water use (UA), and c) water grabbing index (IAA).

The 15 municipalities with the highest level of grabbing by use in the very high classification are Chietla (agricultural), Tehuacán (agricultural), Huaquechula (agricultural), Tepeojuma (agricultural), Coatzingo (industrial and agricultural), Tilapa (agricultural), San Salvador El Seco (agricultural), Huauchinango (industrial and aquaculture), Zinacatepec (agricultural), Tepanco de López (agricultural), San Gabriel Chilac (agricultural), Acatzingo (agricultural), Chiautzingo (agricultural), Santa Isabel Cholula (agricultural) and Tlaquitepec (agricultural).

Water grabbing index (IAA)

When adding the components described above according to the stated formulae, the results obtained yielded the Water Grabbing Index (IAA), whose distribution in municipalities corresponds to Figure 1.

It was observed that only 4.6 % of the municipalities evaluated obtained a low or very low level grabbing, 35.1 % are in a medium level, and in the remaining 60.4 % of the municipalities high and very high level water grabbing prevails.

In the very high level of IAA, due to the volume of water grabbed (in hm^3), the following municipalities stand out: Izúcar de Matamoros with 123.3, Chietla, 86.05; Atlixco, 65.6; Tehuacán, 50.6; Tianguismanalco, 37.8 and Tepeojuma with 34.1. Only these 6 municipalities total, in volume grabbed, 397.6 hm^3 per year of water in the hands of 132 grabbing holders; that is, 21.6 % of the water granted in the state for consumptive uses, excluding the public-urban, is in the hands of 1.7 % of total holders (Annex 1, file titled ANNEX_1.xlsx).

In the high level of IAA, which groups the largest number of municipalities, the ones that stand out, also due to volume grabbed (in hm^3 per year) are: Huaquechula, with 44.3; Coatzingo, 32.66; San Martín Texmelucan, 21.2; Tlauapan, 17.8, Chignahuapan, 15.9 and Zacatlán, with 12.9, the addition of which (144.8 hm^3) represents 7.9 % of the annual volume granted for uses evaluated in the hands of 1.9 % of the representatives of concession titles.

Water Grabbing Risk Index (IRAA)

With these results, the calculation of the Water Grabbing Risk Index was performed, incorporating Water Stress Index. By subtracting Water Stress Index from the IAA, the range of values was extended from -0.442 to 0.934 and standardized between 0 and 1. Municipality grouping with respect to the values obtained is expressed in Figure 3 and Figure 3a.

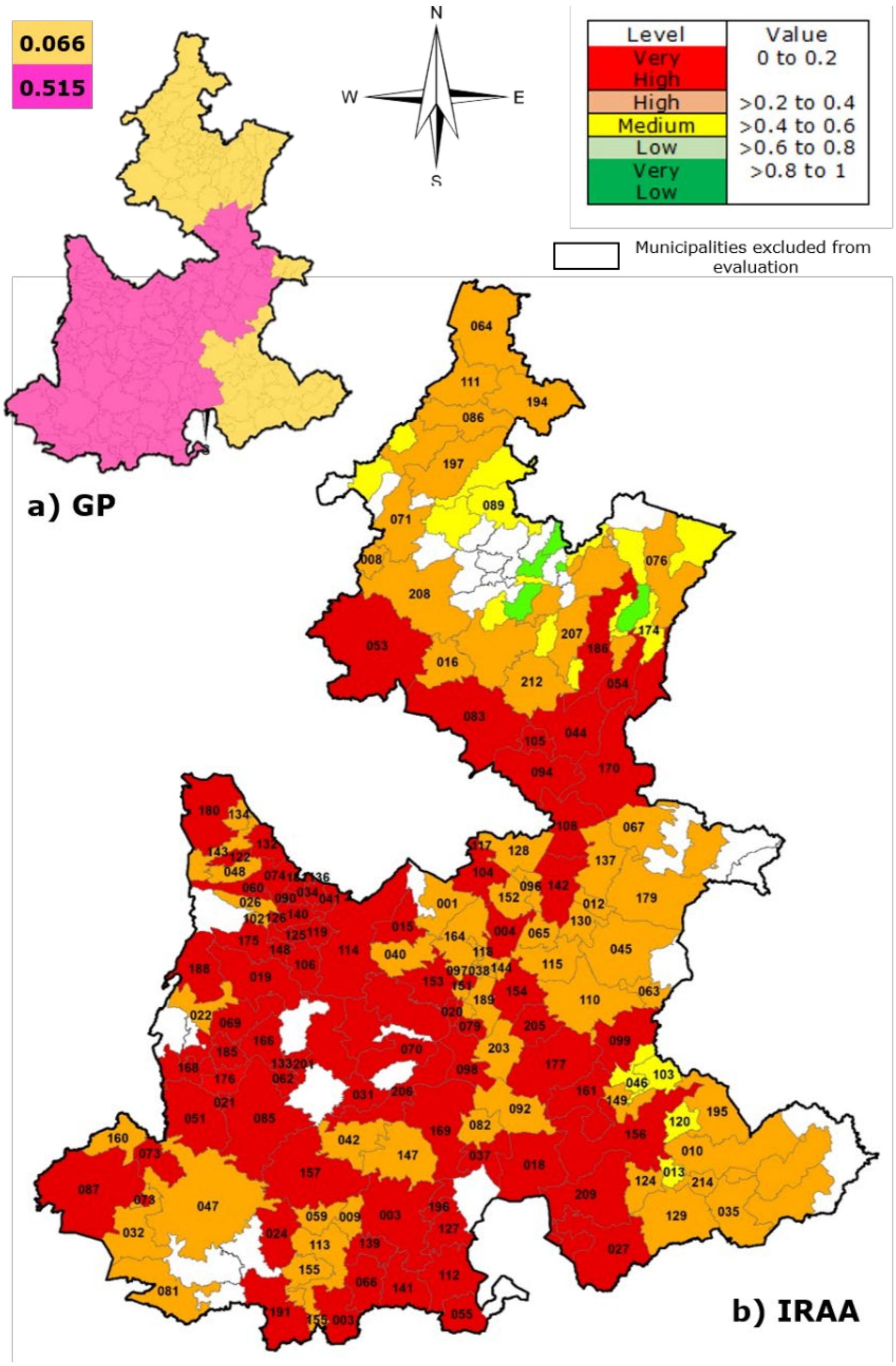

Figure 3. Classification and spatial distribution of Water Grabbing Risk Index (IRAA): (A) Water Stress (GP) component on water resource and (b) IRAA by municipality.

Names of Municipalities

001, ACAJETE
002, ACATENO
003, ACATLAN
004, ACATZINGO
006, AHUACATLAN
008, AHUAZOTEPEC
009, AHUEHUETITLAN INEGI AHUEHUETITLA
010, AJALPAN
011, ALBINO ZERTUCHE
012, ALJOJUCA
013, ALTEPEXI
014, AMIXTLAN
015, AMOZOC
016, AQUIXTLA
017, ATEMPAN
018, ATEXCAL
019, ATLIXCO
020, ATOYATEMPAN
021, ATZALA
022, ATZITZIHUACAN
023, ATZITZINTLA
024, AXUTLA
025, AYOTOXCO DE GUERRERO
026, CALPAN
027, CALTEPEC
031, COATZINGO
032, COHETZALA
034, CORONANGO
035, COXCATLAN
036, COYOMEAPAN
037, COYOTEPEC
038, CUAPIAXTLA DE MADERO
039, CUAUTEMPAN
040, CUAUTINCHAN
041, CUAUTLANCINGO
042, CUAYUCA DE ANDRADE
043, CUETZALAN DEL PROGRESO
044, CUYOACO
045, CHALCHICOMULA DE SESMA
046, CHAPULCO
047, CHIAUTLA
048, CHIAUTZINGO
050, CHICHIQUILA
051, CHIETLA
053, CHIGNAHUAPAN
054, CHIGNAUTLA
055, CHILA
056, CHILA DE LA SAL
057, CHILA HONEY INEGI HONEY
058, CHILCHOTLA
059, CHINANTLA
060, DOMINGO ARENAS
062, EPATLAN
063, ESPERANZA
064, FRANCISCO Z MENA
065, GENERAL FELIPE ANGELES
066, GUADALUPE
067, GUADALUPE VICTORIA
069, HUAQUECHULA
070, HUATLATLAUCA
071, HUAUCHINANGO
072, HUEHUETLA
073, HUEHUETLAN EL CHICO
074, HUEJOTZINGO
075, HUEYAPAN
076, HUEYTAMALCO
077, HUEYTLALPAN
078, HUITZILAN DE SERDAN
079, HUITZILTEPEC
081, IXCAMILPA DE GUERRERO
082, IXCAQUIXTLA
083, IXTACAMAXTITLAN
085, IZUCAR DE MATAMOROS
086, JALPAN
087, JOLALPAN
088, JONOTLA
089, JOPALA
090, JUAN C BONILLA
092, JUAN N MENDEZ
093, LAFRAGUA
094, LIBRES
096, MAZAPILTEPEC DE JUAREZ
097, MIXTLA
098, MOLCAXAC
099, CANADA MORELOS
102, NEALTICAN
103, NICOLAS BRAVO
104, NOPALUCAN
105, OCOTEPEC
106, OCOYUCAN
107, OLINTLA
108, ORIENTAL
109, PAHUATLAN
110, PALMAR DE BRAVO
111, PANTEPEC
112, PETLALCINGO
113, PIAXTLA
114, PUEBLA
115, QUECHOLAC
117, RAFAEL LARA GRAJALES
118, LOS REYES DE JUAREZ
119, SAN ANDRES CHOLULA
120, SAN ANTONIO CANADA
122, SAN FELIPE TEOTLALCINGO
124, SAN GABRIEL CHILAC
125, SAN GREGORIO ATZOMPA
126, SAN JERONIMO TECUANIPAN
127, SAN JERONIMO XAYACATLAN
128, SAN JOSE CHIAPA
129, SAN JOSE MIAHUATLAN
130, SAN JUAN ATENCO
132, SAN MARTIN TEXMELUCAN
133, SAN MARTIN TOTOLTEPEC
134, SAN MATIAS TLALANCALECA
136, SAN MIGUEL XOXTLA
137, SAN NICOLAS BUENOS AIRES
139, SAN PABLO ANICANO
140, SAN PEDRO CHOLULA
141, SAN PEDRO YELOIXTLAHUACA
142, SAN SALVADOR EL SECO
143, SAN SALVADOR EL VERDE
144, SAN SALVADOR HUIXCOLOTLA
147, SANTA INES AHUATEMPAN
148, SANTA ISABEL CHOLULA
149, SANTIAGO MIAHUATLAN
150, HUEHUETLAN EL GRANDE
151, SANTO TOMAS HUEYOTLIPAN
152, SOLTEPEC
153, TECALI DE HERRERA
154, TECAMACHALCO
155, TECOMATLAN
156, TEHUACAN
157, TEHUITZINGO
158, TENAMPULCO
159, TEOPANTLAN
160, TEOTLALCO
161, TEPANCO DE LOPEZ
162, TEPANGO DE RODRIGUEZ
164, TEPEACA
165, TEPEMAXALCO
166, TEPEOJUMA
168, TEPEXCO
169, TEPEXI DE RODRIGUEZ
170, TEPEYAHUALCO
171, TEPEYAHUALCO DE CUAUHTEMOC
172, TETELA DE OCAMPO
173, TETELES DE AVILA CASTILLO
174, TEZIUTLAN
175, TIANGUISMANALCO
176, TILAPA
177, TLACOTEPEC DE BENITO JUAREZ
178, TLACUILOTEPEC
179, TLACHICHUCA
180, TLAHUAPAN
181, TLALTENANGO
182, TLANEPANTLA
183, TLAOLA
184, TLAPACOYA
185, TLAPANALA
186, TLATLAUQUITEPEC
187, TLAXCO
188, TOCHIMILCO
189, TOCHTEPEC
191, TULCINGO
192, TUZAMAPAN DE GALEANA
193, TZICATLACOYAN
194, VENUSTIANO CARRANZA
195, VICENTE GUERRERO
196, XAYACATLAN DE BRAVO
197, XICOTEPEC
198, XICOTLAN
199, XIUTETELCO
200, XOCHIAPULCO
201, XOCHILTEPEC
202, XOCHITLAN DE VICENTE SUAREZ
203, XOCHITLAN TODOS SANTOS
204, YAONAHUAC
205, YEHUALTEPEC
206, ZACAPALA
207, ZACAPOAXTLA
208, ZACATLAN
209, ZAPOTITLAN
210, ZAPOTITLAN DE MENDEZ
211, ZARAGOZA
212, ZAUTLA
213, ZIHUATEUTLA
214, ZINACATEPEC
216, ZOQUIAPAN
217, ZOQUITLAN

Figure 3a. List of municipalities in the state of Puebla.

The water grabbing risk was very high and high in 86.8 % of the municipalities evaluated; medium risk was found in 10.9 %, and only 2.3 % identified with a grabbing risk low level. According to this index, there are no municipalities with a very low risk level.

Discussion

The establishment of IRAA is novel research, and no elements could be found to allow comparison of the results. This section therefore provides additional aspects identified in the intermediate data mining process that, without being part of the index, yielded elements that confirm grabbing trends.

It starts with histogram value distribution, which shows a clear trend toward their concentration in the highest grabbing area (Figure 4).

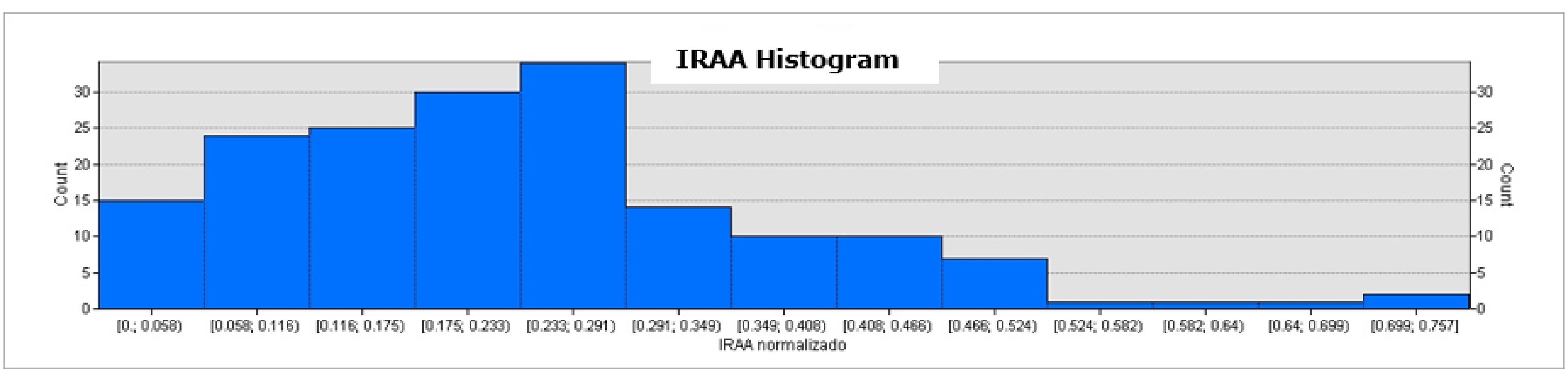

Figure 4. (Standardized) IRAA Municipal Value Distribution.

The introduction of Water Stress Index in the IRAA leads, as expected, to an increase in Grabbing Risk. This points out the importance of its consideration in the current context, addressed by this study, but also in future scenes, taking into account rainfall variations associated to climate change.

Inter-municipal grabbing concessionaires

For the purposes of having an impact on water management from the municipal level, the CrA reflects water grabbing by concession title representatives within each municipality. However, grabbing extent exceeds these boundaries. Due to data mining intermediate processes, it was possible to identify holders with concessions in more than one municipality. For the purposes of this specific analysis, the 189 municipalities that until 2019 registered concessions in the consumptive uses evaluated (with 7718 concession titles granted to 6668 representatives) were included, since it was intended to identify grabbers that we call "inter-municipal". Without considering concessions granted to Irrigation Units for Development (URDERALES), the total number of inter-municipal concessionaires totaled 113 located in 90 municipalities in Puebla. These ones concentrate 431 titles with a volume of 72.36 hm^3 per year (see Annex 3, file titled ANNEX_3.xlsx). Within this group, 23 concessionaires with more than 0.5 hm^3 grab 55.74 hm^3 (77 %) and according to the parameters of this work, they are considered as *inter-municipal grabbers* (see Anex 3, file titled ANNEX_3.xlsx).

The municipalities with the largest amount of grabbers (with more than 3 inter-municipal concessionaires) are 22, in which 71.2 % (51.5 hm^3) of the volume grabbed is extracted inter-municipally (Figure 5). Izúcar de Matamoros stands out, where 26.34 hm^3 (36.3 %) are extracted through inter-municipal grabbing concessionaires. The municipalities with the largest number of grabbers are Tehuacán, Tepanco de López, Atlixco and Puebla; each of them harbors, respectively, 19, 14, 13 and 12 holders with these characteristics.

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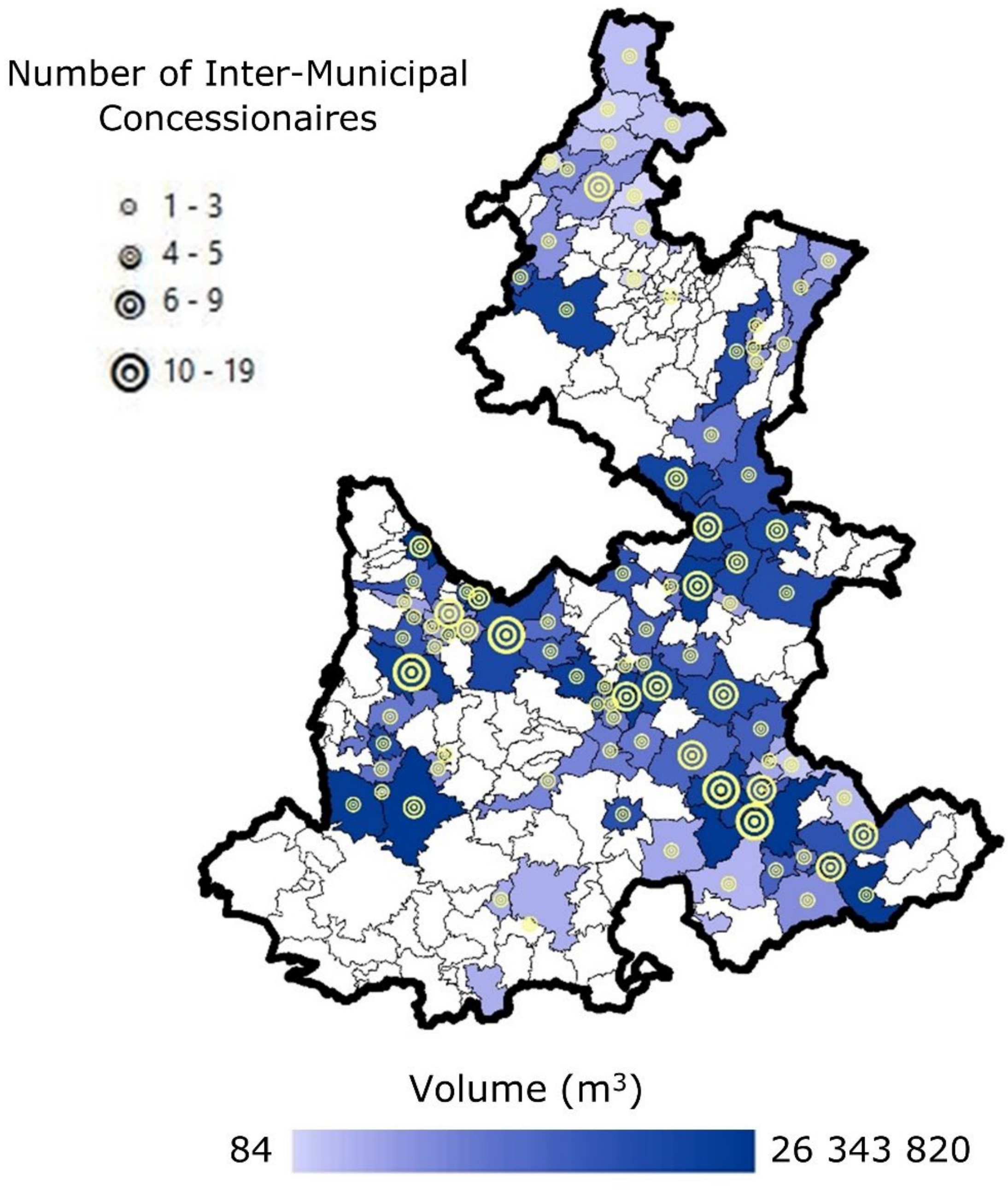

Figure 5. Grabbing volume and number of inter-municipal concessionaires present in the municipality.

According to Figure 5, we can observe that in 41 of the municipalities with a very high level grabbing risk there is overlap with those in which inter-municipal grabbing concessionaires are present. With a high level, overlap occurs in 37 municipalities, and with a medium level, in 11. The impact that inter-municipal grabbers exert on the increase of IRAA is demonstrated through these results.

To conclude the discussion on inter-municipal grabbing by concessionaires, it must be noted that in this study only full name matches in several concessions were evaluated. In this evaluation, it was common to find the same name of the holder as an individual and as a corporation; another type of coincidence was to find the name of the holder alone and also together with another or other holders (as individuals), or as corporations with different denominations (Annex 4, file titled ANNEX_4.xlsx).

Grabbing amounts could rise if the concessions granted to families were added, since different titles were found on behalf of persons with the same surnames, or with surnames in common, so that some type of family relationship is inferred. These cases were more frequent in Tehuacán Santiago Miahuatlán, Ajalpan and Tepanco de López, among others. In this paper they could not be mentioned as they are different holders and the investigation of family relationships goes beyond the scope of this research.

Grabbing uses as predominant activities in municipalities

With this measurement, an approximation was reached to the concepts of economic Specialization or Diversification of municipalities in terms of water uses for their productive activities, which offers territorial elements for more equitable water management.

The seven consumptive uses documented in the state of Puebla (excluding urban-public) are: aquaculture, agricultural, various uses, household, industrial, livestock and services. A greater diversity of predominant water uses per municipality was identified in the case of surface water (7 of 7), while for groundwater, from the 7 uses, 4 were predominant in municipalities.

Agricultural use is predominant in 80.3 % of municipalities with surface extraction and 87.7 % with underground extraction. Industrial use, although for surface waters it is the fourth after livestock and aquaculture use, is predominant in 3 municipalities where the volume of water grabbed represents 31.7 % of the water granted in the state for that specific source of extraction. In the case of groundwater, industrial use is the second most important, after agricultural use, being predominant in 10 municipalities in which 2.9 % of groundwater granted (Figure 6).

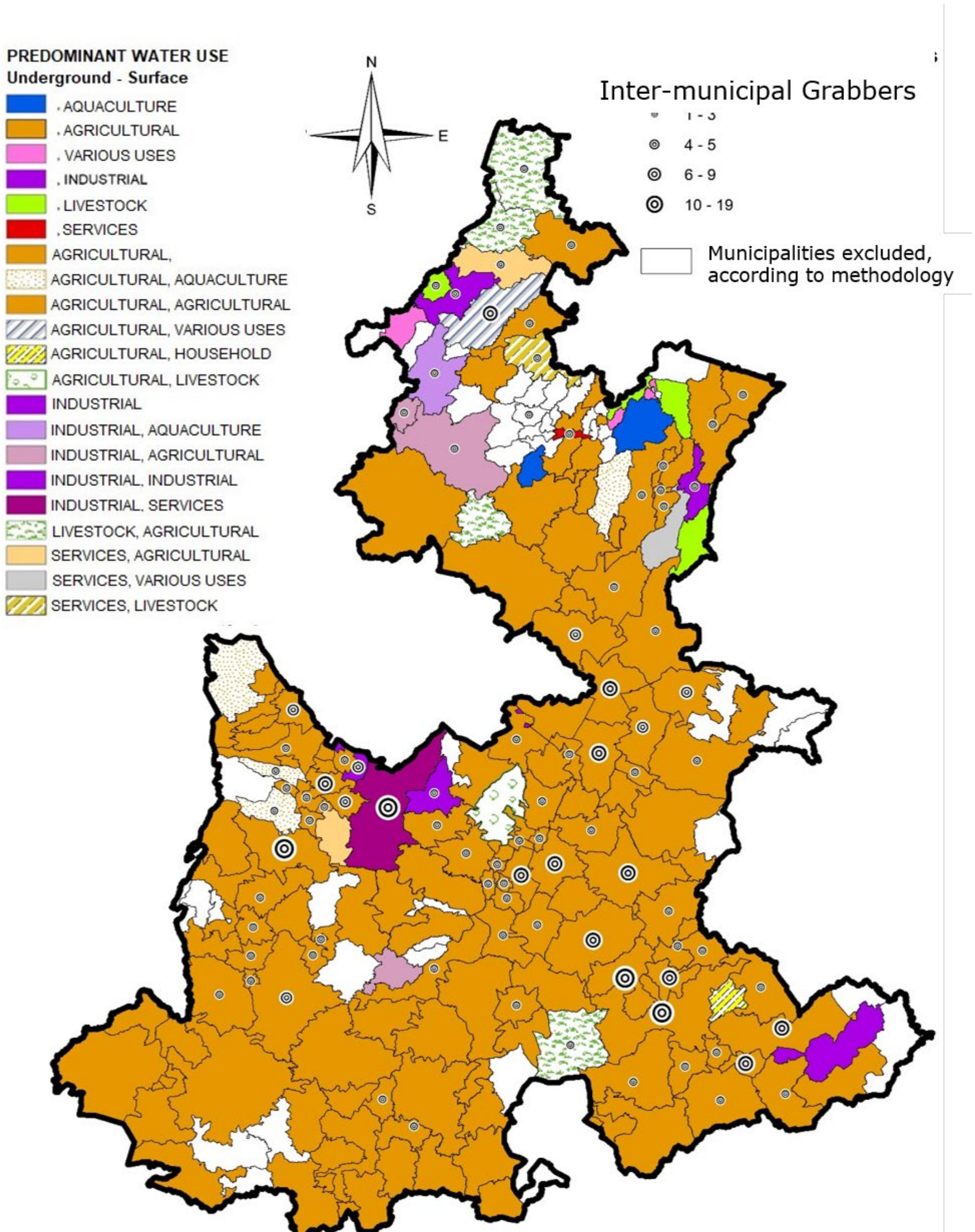

Figure 6. Predominant water uses per municipality, per source of extraction.

Conclusion

Water Grabbing Risk Index (IRAA) is a useful tool in building alternatives towards water justice that can be applied at the national level. Its evaluation in the state of Puebla showed a strong grabbing tendency that subjects 86.8 % of municipalities evaluated to very high and high Risk levels; 10.9 % to a medium risk level, and only 2.3 % to a low risk level. No municipality obtained a very low level grabbing risk.

Grabbing concessionaires of the 174 municipalities analyzed (2305) represent 34.6 % of the total, in whose hands 85.9 % of water granted from both extraction sources is concentrated. The predominant use is the agricultural one (80.3 % of the municipalities with surface extraction and 87.7 % with underground extraction), although industrial use predominates in 13 municipalities, among which the municipality of Puebla and the metropolitan area stand out at the center, and the Northern Sierra of the state, the latter mainly due to mining activities.

The results of the IAA component showed that in only 6 municipalities where the predominant use is the agricultural (Izúcar de Matamoros, Chietla, Atlixco, Tehuacán, Tianguismanalco and Tepeojuma), 132 holders grab 397.6 hm^3; this means that 21.6 % of water granted (for consumptive uses excluding the public-urban) is in the hands of 1.7 % of the state's concessionaires.

Although it was not part of the IRAA, inter-municipal grabbing identified with 113 concessionaires in 90 municipalities confirmed, by means of its overlap, the high and very high Water Grabbing Risk trend in 78 municipalities, and in 11, the medium risk one. Tehuacán, Tepanco de López, Atlixco and Puebla concentrate more than half (51.3 %) of this class of grabbers in their territories.

Transferring water grabbing evaluation to the municipal level encourages the intrusion of the rest of social subjects (in this case those included in the municipal territories) in decision-making on water use.

The index can be applied in both sector and territory management areas (regions, states, and municipalities) and it can reveal hotspots in areas with a serious grabbing risk which, together with water pressure, may put their Water Security at risk. While grabbing reversion by fair distribution does not by itself imply a solution to the complex water problem, it does represent a fundamental step to transform the deteriorating forms of appropriation of one of vital resources for the continuity of human being existence, and that of its biodiverse environments.

For further research, it is desirable to make the calculation of Water Stress Index at a more disaggregated scale, at least by sub-basin, in order to make results more specific. It is also necessary to include climate change scenarios that clarify the order of priorities over time regarding water management.

Finally, it is necessary to contrast this index with other qualitative and quantitative socio-environmental assessments, in order to provide a whole territorial dimension of grabbing, in which regional and/or municipal water needs and emergencies are identified.

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