Chapter 11
Problems Associated with Groundwater Management

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Abstract An important component of water supply of the country is the supply from groundwater sources. They correspond to the use of blue water and they complement the surface water supply. Unlike surface supply sources, for which there is abundant information and analysis, groundwater resources are an area of water management that needs institutional strengthening by increasing their knowledge. Despite this, the diagnoses of this type of resources provide clues that indicate a growing overexploitation and competition, which show the results of institutional arrangements that have promoted the use of water in the country.

Keyword Underground water and management problems

11.1 Groundwater Resources

For the purpose of groundwater management, the country has been divided into 653 aquifers, whose official names were published in the Official Government Gazette of December 5, 2001 (Conagua 2011). The number of aquifers by Hydrological-Administrative Regions (HAR) is shown in Table 11.1, which also presents the extraction, recharge, and availability conditions of the volume of groundwater resource. The statistics in Table 11.1 indicate that the country has an availability of 63 % (1636.130 m^3/s) of its underground resources with respect to the recharge volume. This availability is evident especially in the south, in the XI Southern Border and XII Yucatan Peninsula HAR, where groundwater extraction does not reach 10.5 % of the aquifer recharge.

In the southern and southeastern HAR (IV Balsas, V Southern Pacific and X Central Gulf), groundwater resources availability with respect to discharge is greater than 50 % (Fig. 11.1). On the other hand, the northern HAR, I Baja California Peninsula and VII Central Basins of the North, have exploitation conditions (extraction is greater than recharge) of 32 and 8 %, respectively. Furthermore, HAR located in the northern and central part of the country, II Northwest, VI Rio Bravo, and XIII Waters of the Valley of Mexico, have conditions close to overexploitation

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Table 11.1 Groundwater resource in Mexico

HAR	Name	Aquifers (No.)	Qunderground		Qcondition		
			Extraction (m^3/s)	Recharge (m^3/s)	Availability[a]		Overexploitation[b] (%)
					(m^3/s)	Recharge %	
I	Baja California Peninsula	87	54.477	41.223	−13.254		32.2
II	Northwest	63	97.317	108.638	11.32	10.4	
III	Northern Pacific	24	41.984	103.596	61.612	59.5	
IV	Balsas	46	57.807	146.594	88.787	60.6	
V	Southern Pacific	35	14.523	64.181	49.658	77.4	
VI	Rio Bravo	100	139.047	168.252	29.205	17.4	
VII	Central Basins of the North	68	82.287	75.85	−6.437		8.5
VIII	Lerma-Santiago-Pacific	127	226.63	256.913	30.283	11.8	
IX	Northern Gulf	40	33.264	42.428	9.164	21.6	
X	Central Gulf	22	29.997	135.084	105.086	77.8	
XI	Southern Border	23	19.375	571.252	551.877	96.6	
XII	Yucatan Peninsula	4	84.316	802.765	718.449	89.5	
XIII	Waters of Valley of Mexico	14	73.789	74.169	0.381	0.5	
Total	Mexican Republic	653	954.814	2590.94	1636.13	63.1	

Source Based on data from Conagua (2011)
[a]Availability = Recharge-Extraction
[b]Exploitation = Extraction/Recharge

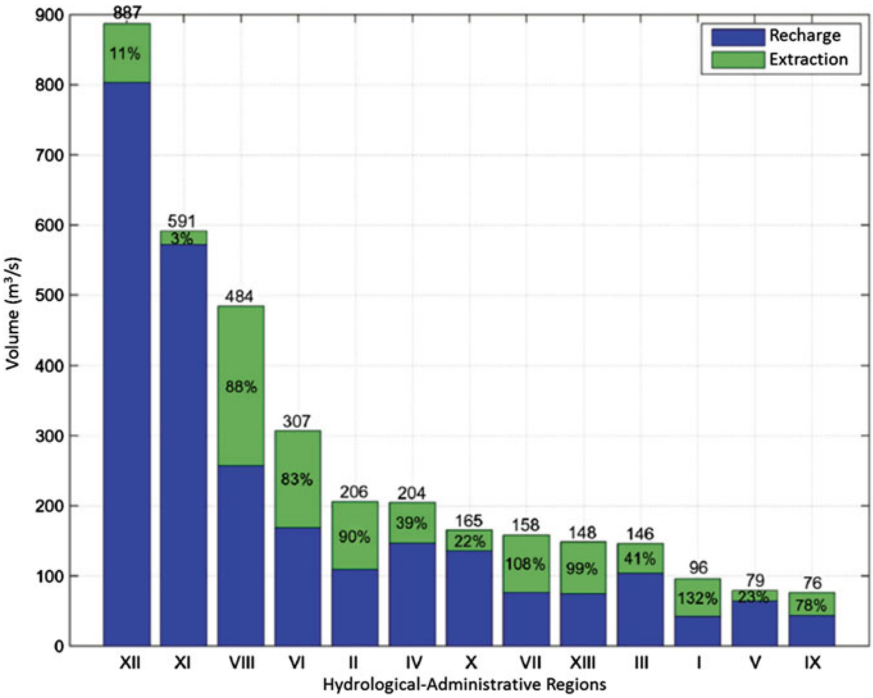

Fig. 11.1 Groundwater volume in HAR, showing the extraction volume percentage compared to the recharge volume. *Source* Based on data from Table 11.1

of groundwater resources, whose recharge available volume scarcely exceeds in 15 % the extraction volume.

Although underground reservoir in the country is substantial (1636.130 m^3/s) and only two of the 13 HAR (I and VII) are overexploited, the global balance does not reflect the critical situation of vast arid and semiarid regions, where water balance is negative and underground storage is running out.

Of the 653 conventionally defined aquifers, 100 are subjected to intensive exploitation (Conagua 2011). The most critical cases are in the northwest, north and center of Mexico (Fig. 11.2), particularly in the Lerma River basin (VI HAR), mainly in the states of Guanajuato and Queretaro; in the Laguna Region (VII HAR) in Coahuila, Durango and Aguascalientes; in Chihuahua (VI HAR), Sonora (II HAR), and the Federal District (XIII HAR).

In areas of overexploited aquifers, this situation compromises the sustainable development of all sectors, with serious implications for the national economy, since several of the most important cities are supplied by aquifers. In addition, the intensive use of groundwater has caused a severe ecological impact, causing the disappearance of lakes and wetlands, reduction of the base flow of rivers, and the loss of ecosystems. There also have been other effects such as the deactivation or decrease in the performance of wells; increased costs of deeper water extraction

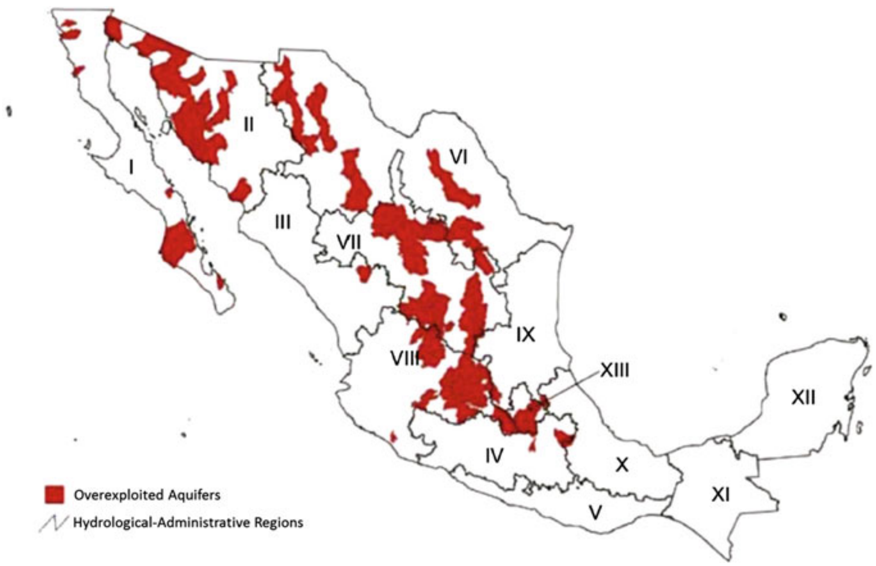

Fig. 11.2 Overexploited aquifers in Mexico. *Source* Conagua (2011)

wells due to the raising consumption of electricity; land settlement and cracking (subsidence phenomena); aquifer pollution and saline intrusion in coastal aquifers, and a strong competition between users. In many cases, the supply to meet water demand of the cities depends on the release of groundwater previously allocated for other uses, by transfer of rights; this problem worsens by the population and economic growth tendency.

An important problem related to groundwater is the limited knowledge of the most important aquifers; this is acceptable for general purposes of water management, but insufficient to guide the management required to reconcile aquifer preservation and satisfy the growing demands for water (Chávez et al. 2006).

Furthermore, water legislation is insufficient and/or inadequate for effective groundwater management, e.g., most of the closures are inoperative and incompatible with current aquifer operating conditions.

11.2 Groundwater Concession

As mentioned in the chapter on water use, 37 % (954.814 m^3/sen 2012) of the total volume allocated for offstream uses in the country comes from aquifers. The importance of groundwater is due to the magnitude of the volume used by all sectors (Fig. 11.3). The major use is for agriculture (69 %), followed by public

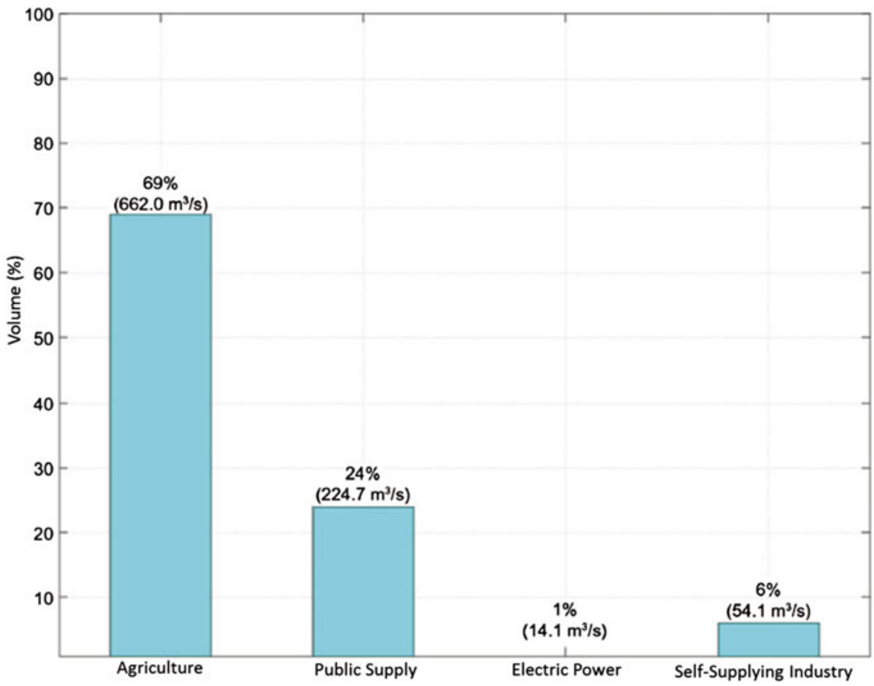

Fig. 11.3 Groundwater volume allocated for offstream uses in Mexico. *Source* Based on data from Repda

supply (24 %); the remaining 7 % is for self-supplying industry (6 %) and electricity generation (1 %). The groundwater for agricultural use (662 m^3/s) is the source that provides water to two million hectares, a third of the total irrigated area. For public supply, it supplies 62 % of the volume required by the cities, benefiting about 75 million people. Groundwater also supplies half (51 %) of the industrial facilities.

On the other hand, Fig. 11.4 shows the way in which groundwater has been allocated for offstream uses in the HAR of the country. It can be observed that the VIII Lerma-Santiago-Pacific HAR is the largest consumer of groundwater (227 m^3/s), followed by the VI Rio Bravo (139 m^3/s) and II Northwest (97 m^3/s) HAR. The rest of the HAR consume groundwater gradually, from 84 m^3/s in the XII Yucatan Peninsula, up to 15 m^3/s in the V Southern Pacific.

It is worth mentioning that most of the groundwater volume allocated for the XIII Waters of the Valley of Mexico HAR (74 m^3/s) is for public supply (76 %), and not for agricultural irrigation as in other HAR. The groundwater volume used for agriculture in the VIII Lerma-Santiago-Pacific HAR (168 m^3/s) is greater than the one used for this purpose in any of the other Hydrological Management Regions.

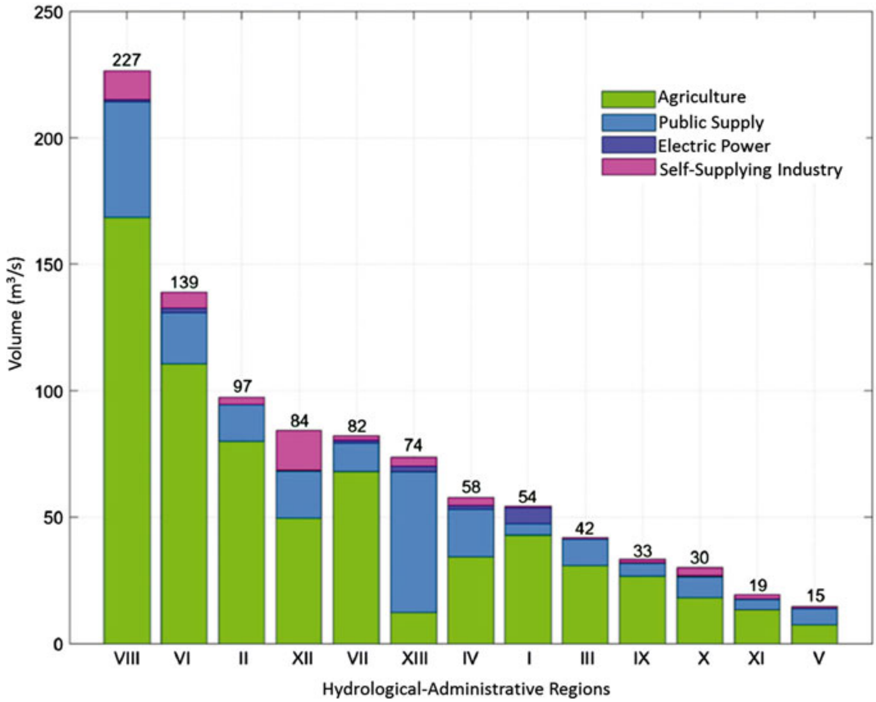

Fig. 11.4 Groundwater volume allocated for offstream uses in the HAR. *Source* Based on data from Repda

11.3 Degree of Groundwater Stress

Similar to the degree of stress exerted on water resources (percentage of water used for offstream uses compared to the renewable water resources), it can be used an index that expresses the degree of groundwater stress caused by agricultural use, i.e., the percentage that represents the groundwater allocated in other offstream uses with respect to agricultural use. Thus, it can be considered that if this percentage is greater than 40 %, there is a strong stress on the agricultural use of groundwater.

Additionally, it can be identified the groundwater use that exerts the highest stress on agricultural use, since each one of the water uses is a partial component of the degree of total stress on the agricultural use of groundwater.

Nationally, the degree of stress on groundwater by agricultural use is 80.5 % on average (Table 11.2), which is considered a high level. This indicates that food security, which depends on irrigation using groundwater, is subject to strong competition between users. In this case, the highest stress (82.5 %) on food security is exerted by Public Supply. The high degree of stress on groundwater resources in the country requires an effective management that includes actions to increase water

Table 11.2 Degree of stress of agriculture on groundwater (percentages)

HAR	Name	PS[a]	SSI[b]	EG[c]	Total	Classification
I	Baja California Peninsula	10.7	1.7	14.7	27.2	Moderate
II	Northwest	18.1	3.5	0	21.5	Moderate
III	Northern Pacific	34.4	2	0	36.4	Moderate
IV	Balsas	55.1	9.4	4.4	69	High
V	Southern Pacific	88.8	8.6	0	97.4	High
VI	Rio Bravo	18.2	5.8	1.7	25.6	Moderate
VII	Central Basins of the North	17	2.9	1.3	21.3	Moderate
VIII	Lerma-Santiago-Pacific	27.2	6.9	0.4	34.6	Moderate
IX	Northern Gulf	19.1	4.7	0.7	24.6	Moderate
X	Central Gulf	47.1	17.9	1.2	66.3	High
XI	Southern Border	30.7	13.7	0	44.4	High
XII	Yucatan Peninsula	37.7	32.3	0.6	70.6	High
XIII	Waters of Valley of Mexico	459	30.8	17.8	507.6	Very high
Average	Mexican Republic	66.4	10.8	3.3	80.5	High

Source Based on data from Conagua (2011)
[a]*PS* Public supply
[b]*SSI* Self-supplying industry
[c]*EG* Electricity generation

availability in aquifers and to promote their preservation, integral, and efficient use and reuse. Meteoric water that has not gone through sources of pollution is a large potential resource to increase aquifer natural recharge. This rainwater can be infiltrated through absorption wells without restrictions as to its quality. On the other hand, despite the high cost of advanced wastewater treatment, this alternative is a considerable potential resource to recharge aquifers artificially because there is a permanent and increasing flow compared to the growth of public demand. In order to prevent groundwater deterioration and damage to public health, especially where there is a risk that the treated wastewater migrates to drinking water intakes, artificial recharge systems should consider subsoil as a natural treatment plant that can be exploited with an appropriate mix of pretreatment–natural treatment–posttreatment, compatible with the recharge method and the intended use for the reclaimed water.

As for the spatial distribution of the degree of stress on agricultural use of groundwater, there is an enormous stress of 508 % in the XIII Waters of the Valley of Mexico HAR (Fig. 11.5). In this HAR, there is one of the most populated urban centers of the planet, Mexico City Metropolitan Area. According to the results of the Census of Population and Housing from 2010, more than 27 million people lived in this area, 24.8 % of the total population, where the greatest contribution to the gross domestic product is generated (just over 20 %). The groundwater allocated for public supply (55.746 m^3/s) and self-supplying industry (3.742 m^3/s), which sustains urban and economic development of this megacity, exceeds almost five times the groundwater allocation volume for agriculture (12.145 m^3/s).

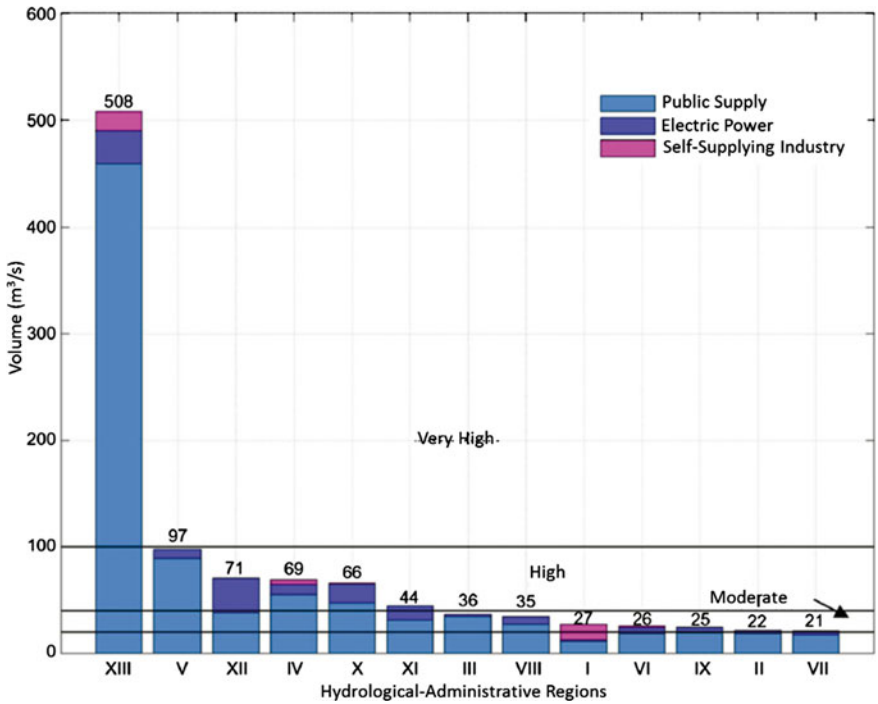

Fig. 11.5 Degree of stress on agricultural use of groundwater for HAR. *Source* Based on data of Table 11.2

In the XIII HAR, it is required an effective groundwater management as a valuable instrument to mitigate the degree of stress on agricultural use. This management should include measures to meet the demand in all sectors as well as actions to increase the natural recharge of the aquifer with rainwater and the artificial recharge with treated wastewater, as suggested for the whole country.

In the urban sector, it is necessary to implement programs to detect leaks and recover lost volume; to tend towards an equitable distribution using metering valves to ensure an appropriate endowment, rather than improve micrometering; and make efficient water use with economic incentives for the installation of devices and water saving systems.

For the industry, it is required the use of treated wastewater for uses where drinking water is not needed; industrial order to encourage the enterprises to generate products that leave a low water footprint and promote the import of those that require large amounts of water in their production processes.

In agriculture, projects for modernization of irrigation are needed to improve efficiency in agricultural water use that includes the change of traditional crops for other more productive and that consume less water, the rehabilitation of agricultural infrastructure, and user training in the application of new technologies.

References

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