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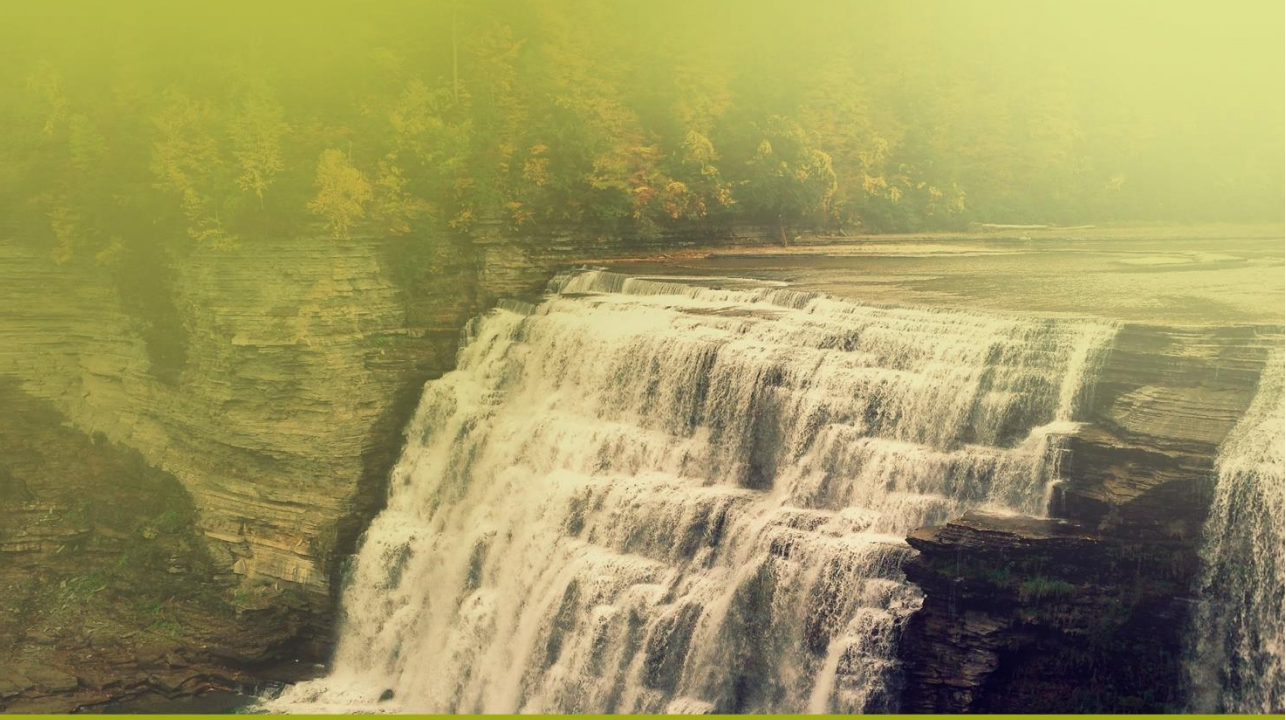

Economía, Organización y Ciencias Sociales

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Index

Abstract

Water resource management in Mexico is not uniform and despite the perceived benefits of decentralization, local administrators have not proved effective at enforcing compliance or at establishing adequate practices that might reduce strain upon underground aquifers. The aim of this review of literature is to investigate the advances that have been made in Mexico regarding the subject. By exploring a number of states in Mexico that seem to be at the forefront of the water crisis, the situation suggests that water use efficiency is often poorly understand or enforced, and that water reclamation efforts are not fully appreciated.

Key words: agriculture, Baja California, Chiapas, Chihuahua, decentralization, Durango, irrigation, National Water Commission, Public Administration, reclamation wastewater, Sonora.

Resumen

La gestión de los recursos hídricos en México no es uniforme y, a pesar de los beneficios percibidos de la descentralización, los administradores locales no han demostrado ser eficaces en el cumplimiento o en el establecimiento de prácticas adecuadas que podrían reducir la presión sobre los acuíferos subterráneos. El objetivo de esta revisión de la literatura es investigar los avances que se han hecho en México sobre el tema. Al explorar una serie de estados en México que parecen estar a la vanguardia de la crisis del agua, la situación sugiere que la eficiencia del uso del agua a menudo se entiende mal o se hace cumplir y que los esfuerzos de recuperación de agua no son plenamente apreciados.

Palabras clave: agricultura, Baja California, Chiapas, Chihuahua, descentralización, Durango, riego, Comisión Nacional del Agua, Administración Pública, aguas residuales de recuperación, Sonora.

Introduction

Water resources are a vital part of any robust agricultural industry in any nation. For a country such as Mexico, a nation with a significant portion of its domestic economy tied up with agriculture, adequate water resources and logistics are particularly important (OECD, 2013). Over the next several pages, the available literature is scoured with the aim of uncovering the state of water resources in Mexico. How effective is water management in Mexico? What needs to be done to improve it? What role does public administration play in this evolution? And, indeed, how must water management in Mexico change in order that the needed improvements occur? To answer these questions, the literature review looks at water management practices in different regions of the country for evidence of reassuring practices and practices that still need to be modernized. In some of the most impoverished regions of Mexico, a legitimate case can be put forward that insufficient progress has been made to even start a comparison and contrast of said region and other parts of the nation. Be that as it may, even a summary review of different principalities and jurisdictions in Mexico vis-à-vis water management can prove useful.

In addition to the broad objectives highlighted above, there are other necessary elements to any book of this sort. Not least of all, the ensuing literature review explores what specific initiatives Mexican governments are performing in order to manage and improve water resources management in the country for agricultural purposes. Beyond enumerating some of the most pertinent government programs, a review of the general results – to the extent they are publicly available – will be undertaken. Finally, in which direction does Mexico appear headed on this vital issue? As will become manifest, the country has taken some positive strides in recent years (OECD, 2013), but there is also a great deal of unevenness from region to region, and the country must address this problem first before it can truly enter the front ranks of agricultural nations. The divergent outcomes, the failures in some regions and the relative successes in others, denotes a nation that has not yet found a way to internally coordinate and integrate water management best practices. That will have to change, or Mexico's troubles will continue indefinitely.

1. A General Overview with a History Lesson in Mexico

Mexico has not been blessed by its climate. The country is predominantly arid and dry, and it appears as though the main irrigation districts fall in areas that simply do not offer a lot of water (Arredondo-Ramírez, Rubio-Castro, Nápoles-Rivera, Ponce-Ortega, Sema-Gonzáles, & El-Halwagi, 2015). Thus, the underlying architecture is already under stress because of limited water resources and because, presumably, large quantities of water must be delivered across substantial distances from remote locations. According to one recent study, at least 70% of the national Gross domestic product (GDP) attributed to agriculture is concentrated in the aforementioned arid areas; the overall efficiency of water use, grimly, falls below 40% in the arid drylands even as 77% of domestic water reserves are set aside for agricultural pursuits (Conagua, 2009). Therefore, Mexico may be described as a nation that needs water for its agricultural production, but does a poor job of managing the water reserves it does possess. Consequently, an already difficult situation is made even worse.

Within Mexico as a whole, the Ministry of Environment and Natural Resources oversees all environmental issues. One of its key agencies is the National Water Commission – also known as Conagua (OECD, 2013c). Conagua oversees a number of federal programmes which appear, on the surface at least, to have relevance to the agricultural sector: The Water Rights Tax Rebate Program that supports improvement in efficiency and infrastructures; The Federal Program for Wastewater Treatment; The Rural Waterworks Development Program; and the National Fund for Infrastructures (OECD, 2013b). Unfortunately, despite the existence of these programs, unsustainable exploitation of underground water continues; water resources continue to be used inefficiently; and there remains insufficient coverage of piped water networks (OECD, 2007).
Conagua oversees all water management, but transfers from the federal government to the states to implement federal programs are confronted by the fact that states frequently lack the indigenous revenues and tools needed to thoroughly implement and oversee operational and maintenance costs (OECD, 2013b). Decentralization in Mexico, almost from the moment the National Water Commission was first established, has met with problems associated with municipalities and states lacking the wherewithal and tools to actually implement policies aimed at bolstering water efficiency and water supply (Guerquin, Ahmed, Hua, Ikeda, Özbilen, & Schuttelaar, 2003). The funding gap is something that probably best explains why some communities

and states are so far in arrears when it comes to creating a comprehensive network for agricultural water use.
Suffice it to say, agricultural water usage in Mexico has not been well-served, at least historically, by the available water conveyance infrastructure. Specifically, waterways are often used as latrines in some of the remotest parts of Mexico and central plumbing (even rather recently) has traditionally been absent in many communities and on many estates (Wilken, 1990). When domestic plumbing and water conveyance amenities are this primitive, then the cost of overhauling irrigation systems and plumbing and water systems can easily become prohibitive. While figures are hard to come by, it is well-known that agricultural producers across Mexico are often compelled to pay rather substantial tariffs for water use that are intended to allow the Mexican government to recover the rather considerable administrative and operational costs associated with getting water to them so that they can conduct their activities (Garrido & Calatrava, 2010). Mexico is not a nation that swims in wealth, which rather graphically explains some of the drastic measures the country has undertaken to maintain access to revenue streams that can aid in the maintenance and upgrading of its elemental water infrastructure.

For an illustration, the country actually bequeaths a significant portion of its share of the water flowing in the binational Colorado River to the United States in exchange for millions of US dollars in infrastructure support – which ostensibly, though it is not explicitly stated, seemingly includes support for its irrigation architecture (Chellaney, 2015). That the central government should feel the need to cede a valuable portion of such water to the Americans in exchange for what seems like a relative pittance, indicates the country's desperate need for funds to cover the expense of infrastructural upgrades. Mexico's irrigation system comes at a cost and that cost demands that farmers pay, and that the Mexican state look for aid wherever it can find it.

For many years, Mexico has acknowledged that policy changes are needed for its water resource management to improve if it was optimizing agricultural output, ensure adequate cost recovery, and ensure that those sectors of the economy dependent upon a reliable water supply were insulated from water scarcity. In the 1970s, apparently in the interests of bureaucratic comity, the Secretariat for Hydraulic Resources (SHR) was merged with the Ministry of Agriculture. The service fees previously administered by the SHR were incorporated into rural development district programs. This led to farmers who had previously paid directly for the privilege of using the irrigation system electing to become far more negligent

in paying for the aforesaid services (The World Bank, 2005). A state of affairs like this manifestly made it harder for any positive changes or upgrades to be carried out.

By the late 1980s, however, the ongoing water crisis finally forced some serious re-evaluation of what needed to be done in order to make the water irrigation system in Mexico sustainable. To promote the decentralization of the irrigation and drainage sectors, the National Water Comission (Conagua) was established in 1989. It became the administrative body charged with the use, allocation, handling and conservation of water resources in urban and rural Mexico for agricultural and industrial activities (Gorriz, Subramanian, & Simas, 1995). Under the 1989 changes, the Conagua is ultimately in charge of the planning, programming, study, construction, administration, operations, management and rehabilitation of the irrigation systems across the land. By the early 1990s, eighty irrigation district offices carried out the bulk of the aforementioned activities at the local level while it appears sub-directorates within the Conagua assumed oversight for critical initiatives in the following areas: Planning and finance; infrastructure; urban and industrial hydraulic infrastructure; water management; and administration (Gorriz, Subramanian, & Simas, 1995). If slothfulness and negligence characterized the administration and oversight of water resources and the nation's irrigation system during the 1970s and much of the 1980s, then the new changes were a belated attempt at enforcing more accountability and jurisdictional clarity.

In that sense, Mexico's late-twentieth century past suggests that the country is most certainly capable of progressive change when the need for change becomes unambiguously clear. But the foresight to anticipate future challenges and likely hurdles is the next level up in terms of public administration of the country's cherished water resources, and that kind of foresight does not have a lengthy history of existence in the Mexican context.

2. Water Resources Managed in Different Parts of Mexico

There are 32 administrative entities in the federal nation of Mexico (Diario Oficial de la Federación, 2014). A book of this size cannot adequately discuss water resource management (particularly in the realm of agricultural activity) in all of them. Nonetheless, there is literature to be found discussing (even if occasionally in rather meager terms) water resource management in areas most characterized by significant, large-scale irrigation projects. The notable ones include the following: Baja California; Chiapas; Chihuahua; Durango and Sonora. These states have a volume of consumed pooled uses in the agricultural sector of 2,586.2 hm3, 1,506.2 hm3, 4,578.4 hm3, 1,362.5 hm3 and 6,100.4 hm3, respectively; Unlike Mexico City which, being the largest urban city in Mexico, only destines 1.2 hm3. It is also necessary to consider that water destined to irrigation in Mexico represents 76.7% (Conagua, 2015). The literature is uneven in places, but it can offer some valuable insight in the aggregate.

2.1 Baja California

As discussed earlier, many of what pass as water conservation programs in Mexico's states emanate from the center. Be that as it may, local municipalities have attempted to help themselves through a process of recycling wastewater in the absence of perennial streams and reliable precipitation (Paez, Holl, Soto, Meeler, & Vercruse, 2010). Further, at least 63 plants in Baja, California Sur, use reverse osmosis technology for the desalination of salt water (Bermudez-Contreras, Thomson, & Infield, 2008). Within the state, the evidence above suggests that desalination is definitely a venture that meets with a warm reception amongst local policy-makers. It is worth adding that the municipalities of Los Cabos and La Paz are warmly supportive of desalination practices and that desalination commonly occur under concessions issued by municipal water authorities (Columbia University Engineering, 2016).

Be that as it may, water shortages have been commonplace and have sparked the introduction of desalinated water into the local region (McEvoy, 2014). Indeed, one modelling approach that integrates economic inputs from agricultural and urban water demand models with hydrological data and infrastructure data, suggests that seawater desalination is really not a good policy alternative because it is not economically optimal for different sectors of Baja California – such as Ensenada. Therefore, at least some scholars have

argued that Baja California should retreat from desalination projects in favor of wastewater reclamation and reuse initiatives; the use of seawater desalination and associated paraphernalia is only a good idea if it is combined with other initiatives, such as the two delineated above (Medellín-Azuara, Mendoza-Espinoza, Lund, & Ramírez-Acosta, 2007).

Moving along, hydro-economic optimization is an ongoing preoccupation in Baja California because population – especially along the northern border – is steadily growing at a rate that appears unsustainable when viewed in conjunction with the existing water architecture. For many years, the discussion has revolved around a few possible alternatives for combating growing residential, agricultural, and industrial concerns: the introduction of water markets; wastewater reuse; seawater desalination; and infrastructure expansions. According to the available literature, proposed water markets fall short of optimizing water use and conservation because conveyance capacity limits their use. Moreover, desalination is simply too costly for Baja California. Thus, when all items are reviewed in full, wastewater reuse and conveyance expansions are seen as the most economically viable if the aim is to increase water saturation across the region and accommodate a growing population and increasing activities – be they agricultural or otherwise (Medellín-Azuara, Mendoza-Espinosa, Lund, Harou, & Howitt, 2009). Unfortunately for Baja California (and the other Mexican states), simple infrastructural expansions cost money - and money, for a developing nation with an uncertain economic future, is not always there when needed, as the nation's checkered past makes abundantly clear (Dias-Cayeros, Estévez, & Magaloni, 2016).

The region's difficulty in accessing water cannot wholly be attributed to a failure to develop targeted water management practices that increase water flow and water use efficiency. Chiefly, Baja California's relatively limited resources make it burdensome for innovative and holistic solutions to be found. Be that as it may, wastewater reuse seems to be something that offers greatest promise – at least relative to desalination – and scholars who have studied events in Baja California are consistent in maintaining that the state should pursue this course in tandem with infrastructure expansions. This is quite in keeping with the paragraph above, but the current study under examination goes onward to report that the most important expansions that should be considered for Baja California (and which have customarily been overlooked) are aqueduct expansions that connect coastal and inland water supply resources. The same scholars also stress that the coastal cities of Baja California will benefit markedly from a wastewater reuse policy that is coupled to aqueduct and infrastructure expansions. The key point to be

taken away at this juncture is that at least some scholars are convinced that aqueduct expansion is the key to optimizing the region's water resources (Medellín-Azuara, Mendoza-Espinosa, Lund, & Howitt, 2008). Ultimately, in assessing water management in Baja California, the inefficacy of long-standing policies – most keenly evidenced by the region's chronic water crisis – should be understood within a context wherein there is some understanding of what needs to be done, but other elements (money, resources, perhaps engineering prowess) keep those valid ideas from being implemented.

Water management in Baja California is not great, but that may not merely be a function of poor political leadership (at least not in this age of more responsible democratic governance) as it is a function of larger socio-economic and geopolitical factors that often bedevil developing nations. And, to the extent there is unevenness vis-à-vis water policy initiatives across Baja California, at least some of the reason for the lack of comity can be traced to the discrepancy in available resources for optimized water resource management best practices. To elaborate, the city of Ensenada has long had three wastewater treatment plants and is actually one of the few cities in the country that treats all of the wastewater it generates. Yet, despite this positive record, the reclaimed water has not traditionally been used for the irrigation of agricultural crops or for the recharging of local aquifers. Additionally, Mexico evidently has a dearth of legislation establishing adequate standards for aquifer recharge from reclaimed water (Mendoza-Espinosa, Orozco-Borbón, & Silva-Nava, 2004). The critical point is that the progressive practices found in Ensenada do not appear to be commonplace throughout the country. And, as if that is not sufficiently problematic, there is a lack of uniform legislation outlining not only how reclaimed water is to be used vis-à-vis aquifers, but also how delineating best practices vis-à-vis the use of treated or reclaimed water for the nourishment of agricultural land. Meagre resources are one thing, but the absence of a clear and focused legislative focus is also something that seems to confound Baja California – and much of the rest of Mexico.

So, from what has been discussed thus far, a combination of legislative inertia and limited resources explains some of the seemingly misguided or careless practices found in various parts of Mexico. But, even when the money should be plentiful, practices can easily be found wanting. In Los Cabos, Baja California, for instance, fully 25% of the state's population is concentrated in this metropolitan cluster, and Los Cabos has a rapidly growing indigenous population, as well. Yet, despite the stress placed upon the San Jose aquifer because of the crushing population growth and tourist

activity, it seems that the private sector – courtesy private desalination plants – has been in advance of the state in coming up with water management alternatives and options (Pombo, Breceda, & Aragon, 2008). While it has been already stated that a lack of capital and other resources can explain why some communities and regions in Baja California lag behind others in terms of water resources management, it also true that, even where the money appears to be flowing in, a lack of vision and imagination means that some parts of Baja California are lacking the water reserves they need to fully satisfy commercial and residential needs – let alone agricultural ones.

2.2 Chiapas

Having discussed the situation in Baja California, it seems necessary to look at events in Chiapas. This is a poorer state than Baja California and is not a tourist mecca in the way its counterpart is. Studies have shown that the population of the state doubled between 1970 and 1990, while the peasant population tripled in that generation. Likewise, arable land quickly disappeared and cultivated land per capita rapidly decreased during the 1980s – as did the water reserves (Nere, 2002). Even though the state is blessed with heavy annual rainfall, access to potable water for crops is limited – which is problematic insofar as crops such as maize and coffee are significant contributors to the local economy (Gaskin-Reyes, 2016). For all its annual rainfall, Chiapas is one of six states publicly listed as facing acute water stress and water shortage (OECD, 2013b). Chiapas, according to research carried out in the early 2000s, has roughly 30% of Mexico's water resources, and agriculture contributes to 8% of the GDP and employs 40% of the economically active population in the state, but its water infrastructure – particularly, its water storage infrastructure – is sorely lacking (OECD, 2003; World Bank, CIAT, & CATIE, 2014). Along with the states of Tabasco, Veracruz, and Oaxaca, Chiapas is the worst state in Mexico for the adequacy of its drinking water system and infrastructure, and more than 50% of its population is rural (Conagua, 2015; Tardanico & Rosenberg, 2000). The water infrastructure appears to quite poor in Chiapas, but the situation is made worse by the fact that, historically, the federal commission overseeing the creation of new pipelines has looked for new watersheds instead of conserving and protecting existing ones or investing in practices that might improve efficiency of use (Lamoreux, McKnight, & Cabrera Hernandez, 2015). Chiapas is a poor state and its water resource management reflects this. For example, its potable water and sanitation services infrastructure is quite poor and haphazard; it has fallen short of the United Nation's Millennium Development goals (OECD, 2013a). Poor leadership and political inefficacy

seems to be an intrinsic part of the Chiapas state insofar as only 58% of Chiapas residences have running water at the same time as Chiapas hydro-power is used to service an estimated 334 high-polluting US firms that moved to Mexico in the immediate aftermath of NAFTA's inception (Weinberg, 2002). Lacking political clout, but sufficient natural water reserves to be useful elsewhere, Chiapas is a much-exploited part of Mexico. The grinding poverty seems to manifest itself in careless water management programs whereby more than 80% of the 118 municipalities within the state actually do not utilize wastewater treatment practices (Gonzales, Corvea Porras, Gutiérrez, & LaMoreaux, 2013). Another reason for the threadbare local policies pertaining to water resource management is the bitter struggles between indigenous groups and the autonomous municipalities, which has historically led to allegations of infrastructure destruction (pipe-busting and presumably other sins) and to real acts of violence (Hernández Castillo, 2004). The focus in Chiapas has been on all of the wrong things, which explains the chronic failures of the state to improve water availability for agricultural pursuits and for domestic activities.

In determining how to make water infrastructure better for both urban and agricultural use, one must recognize that water management in the region may very well be less important than elsewhere because there are significant tracts of land that are not especially populous or that lack the robust local economy to justify large-scale irrigation or water conveyance projects. A good example of this is the region of Larrainzar, which is lowly populated, quite mountainous, and which evidently still relies on upland streams and creeks to deliver water to the local area (Berlin & Berlin, 1996). Since water policy management does not fall directly under the purview of the federal government in Mexico (Diez, 2006), guaranteeing policy comity and certain standards of professional practice for peripheral regions such as Larrainzar (and Chiapas, more generally) is an arduous struggle. Part of the problem, it seems, is that new ordinances decrying exploitation of catchment areas – or, ostensibly, outlining best practices for conservation – seem to radiate towards the remotest regions of Mexico at a glacial pace and ensure that the laws drag behind events on the ground or are too phlegmatically administered to deal with cunning and aggressive parties (Ballabh, 2008). Farmers with rain-fed crops are thus vulnerable to such operators, and the poverty and dearth of infrastructure in the state only compounds their suffering. The sense one has from reviewing the literature is that political upheaval – occasioned by such elements as the Zapatistas or the bitter Lacandon land conflict (Eisenstadt, 2011)– is probably a major reason why administration has been poor and haphazard, and why the local water infrastructure remains so backwards.

2.3 Chihuahua

Scholars note that sewage from public and industrial water supplies are disposed in the Rio Chuviscar and the subsequent allocation of this water into agricultural irrigation areas (Mahlknecht, Horst, Hernández-Limón, & Aravena, 2008). Long-standing practice has been for forage crops situated near the city of Chihuahua to be irrigated with wastewater (Maldonado et al., 2008). This sounds like a solid approach to getting the most possible out of water, but it is not clear what role residential wastewater plays in the irrigation of agricultural produce. This latter item matters since 45% of solid waste generated in a city such as Chihuahua is organic waste (Gómez, Meneses, Ballinas, & Castells, 2009); therefore, any diversion plan that mandates the use of residential water for agricultural irrigation would seem a fitting way of improving water use efficiency.

Happily, water reuse does appear to now be a mainstream tool for the state of Chihuahua. Groundwater remains the primary water for agricultural pursuits and all other activities, but the over-exploitation of underground aquifers in the late 1990s and early 2000s forced a local reassessment that has resulted in the reuse of reclaimed water – at least in the territory around the city of Chihuahua. The problem, however, is that there has been no mandated legislative effort at the local level to direct that water towards agricultural uses; instead, the water is used for tourist attractions, golf courses and educational/industrial zones (Espino, Navarro, & Pérez, 2004). Plainly, reclaimed water is not set aside in any appreciable sense for agriculturalists in at least this part of Chihuahua state.

The scholarship uncovered notes that individual, agricultural well owners (or groups of well owners) must formalize their concessions with a title and, beyond merely specifying the annual volume concessioned based on the discharge of the well and the area of irrigable land reported, they must follow carefully the terms of their title vis-à-vis well repositioning, for cessation of rights for un-utilized volumes, and for the transfer of rights. In Chihuahua (the state, that is), it seems as though farmers are the largest users of groundwater (Scott, Dall'erba, & Caravantes, 2010), so perhaps this explains why reclaimed water in larger urban centers is directed towards industrial and luxury activities and not steered towards them. Yet, strangely enough, longitudinal trends within the state of Chihuahua point to the fact that any diversion of reclaimed water to agriculturalists might not serve the greater cause of water use efficiency and conservation; for instance, commercial agricultural processes in the state are depleting underground aquifers at an alarming rate while, simultaneously, there is an ongoing struggle over

communal versus exclusionary (private) appropriation of water resources (Victor & Quintana, 2013). Until a regime of best practices settles over all agricultural endeavors in the state, redirecting water to the agricultural sector may simply result in greater waste.

At least within the city of Chihuahua, there do exist – and have since at least the 1990s – water utility conservation plans which have managed to inject a degree of austerity into water use (Fullerton & Nava, 2003). So, there is a coherent attempt to manage the available water resources carefully. However, local administrators have also looked the other way when Mexican farmers used water from the tributaries of the Rio Bravo to irrigate their fields at the same time as the state of Mexico failed to deliver water to South Texas agriculturalists as stipulated in a 1944 water treaty (Walsh, 2004). Therefore, Mexican officials have been ostensibly unafraid to violate binational agreements with the US when austerity has failed. To this must be added the fact that radon and uranium levels across the state – and especially around Chihuahua City – are frequently unacceptably high (Villalba et al., 2005). Therefore, the state must do a better job of combining austerity with improved water treatment and with a greater commitment to binational law. In fairness, though, water management that has sparked tension between Mexico and the United States (vis-à-vis water use in Chihuahua and other northern states) can be attributed to the tardiness and secretive, clumsy nature of the International Boundary and Water Commission established between the two lands in the 1944 binational treaty (Fernandez & Carson, 2003).

2.4 Durango

Durango is home to a large irrigation project centered near Torreon. It irrigated cotton, alfalfa and wheat lands from the 1920s onwards, but has fallen short of demand in recent years because of a dropping water table occasioned by excessive groundwater pumping, and by poor irrigation practices that have sparked heightened soil salinization (Kent, 2016). This problem is accompanied by an excessive amount of natural fluoride in various state tributaries and streams that has been blamed for widespread, endemic fluorosis (Fierro & Nyer, 2007). Durango is also a state that has a grim history of periferical vascular diseases that seem associated, at least in part, with high arsenic ingestion from the local water (Selinus, Finkelman, & Centeno, 2010). With regards to the aforementioned fluoride problem, local state officials have consistently shown themselves unwilling or unable to implement water de-fluoridation programs (Molina Frechero et al., 2013). On the matter of excess arsenic levels, Comarca Lagunera, a key cattle-raising

area which lies nestled alongside Durango, continues to experience serious problems as of 2014 (Flora, 2015). Finding a way to remove such toxins as arsenic would certainly put at ease concerns over the use of any reclaimed wastewater being used in agricultural irrigation. In any case, at least as it stands presently, water reclamation in Durango appears to revolve around recapturing or reclaiming it for industrial pursuits (Veillette, Martin, & Larreta, 2008).

Within Durango, there appears to be some acknowledgement of the need for using reclaimed water to relieve the stress produced by over-exploiting underground aquifers. Near the city of Durango, for instance, farmers have increased their yields of corn, alfalfa and oats by using wastewater during periods of drought by as much as 30% while reducing fertilizer use by roughly 50% (Wichelns & Qadir, 2015). The movement towards the use of reclaimed water mirrors positive events elsewhere and suggests that the state is seeking to follow the exemplary model of a few other Mexican states.

Research shows that Durango has a history of focusing on a few key agricultural exports – cotton in the past, milk production and alfalfa production more recently – that are water-intensive: the end result is that water levels in the Principal Aquifer are dangerously low and, in fact, are so low that the pumps now extract water heavily mixed with metals such as arsenic. Additionally, the Nazas and Aguanaval rivers are now are now almost vestigial relative to their formal robustness (Walsh, 2008). To aggravate the situation further, scholarship notes that Durango is a dry bean nexus for Mexico, yet only about 6% of the bean-growing area of North-Central Mexico is irrigated (Zahniser, Vera Torres, Cuéllar Álvarez, López López, & Bhatta, 2010).

2.5 Sonora

Last of all, in the matter of Sonora, there is a broad sense that government officials in Sonora (and not merely in Sonora) do not fully appreciate the merits of the pre-existing wetland system that does exist within the state. For instance, the Cienega de Santa Clara in the Colorado River Delta is widely described as an efficient wetland architecture that is fed by brackish groundwater diverted from the US. The vegetated upper portion of the Cienega provides habitat for endangered avian life while its outflow water pools in the Santa Clara Slough south of the Cienega offer habitat for migratory shorebirds. However, despite the perceived ecological gains, the wetland complex faces significant challenges on account of the Yuma Desalting Plant which diverts water from the Cienega and replaces it with

brine water arising from the desalting process – something which, when coupled with decreased inflow rates, seems to lead irrevocably to the diminishment and deterioration of the wetland complex (Gómez-Sapiens, Tang, Glenn, Lomelí, Ramírez-Hernández, & Pitt, 2013). The exploitation of the Cienega seems a classic instance of government bureaucrats and officials not finding a policy tool that will allow it to bolster domestic water resources without perilously undermining the fragile local ecosystem. That will need to change.

3. Discussion

The available scholarly works tend not to discuss water inefficiency in the agricultural sector of Baja California at any length. Nonetheless, it is well-known that the Mexican government prizes Baja California as a wealthy state; consequently, the state receives comparatively generous water subsidies that seem to recognize its status, while poorer states – such as Oaxaca or Chiapas – receive only a tiny fraction by comparison (OECD, 2006). At the same time, while agriculturalists in Baja California can expect to receive far more subsidy support than they might if they were situated somewhere else, they also must deal with the reality that the urban water allotment increased by fifty-six-fold between 1944 and 2003 (Michel, 2003). It would seem that policies at the state and federal levels have not been able to adequately address the growing pressures upon the country's relatively modest water resources. Thus, Baja California still sees a chronic water shortage for agricultural endeavors (especially as it pertains to wine-making) and this is the reality even though many agriculturalists (particularly in the wine-growing regions of Baja California) have indicated that they support the idea of using reclaimed or treated wastewater for their vineyards. Sadly, even after all of this, nothing has been done. Even more troubling, as of 2015 no data has been collected to show how much it will cost to use reclaimed water on Baja California's wine vineyards (Mendoza-Espinosa et al., 2015).

Public administration plays a key role in all of this via utilizing the latest models, scholarly investigations and bureaucratic expertise to nudge resources towards infrastructural improvements and best practices modifications that will lead to greater water use efficiency and to the establishment of cost-effective treatment centers that can ensure greater exploitation of reclaimed water for agricultural purposes. At the very least, the literature makes it clear that artificial groundwater recharge should be introduced in cities such as Ensenada to address the stark, steep decline in aquifer stores in recent years (Campos-Gaytan, Kretzschmar, & Herrera-Oliva, 2014).

In the case of Chiapas, there is a desperate need for public administration. The literature that deals directly with the situation in Chiapas is disappointingly meagre – usually the state is subsumed within a larger discussion of problems afflicting the whole of Mexico – and it is hard to say what specific aspects of the local administration need to be revitalized or redone. Nonetheless, there is a definite argument to be made that a more aggressive effort must be undertaken to communicate with agriculturalists

and that local state officials need to mobilize to enforce ordinances and bylaws that are intended to protect farmers and the water resources that allow them to ply their trade. In Chiapas, water management practices may best be described as uneven and frequently sloppy.

While there are some aspects of water resource management in Chihuahua, it seems that any positive reclaimed water initiatives in the area directly around Chihuahua City have not been accompanied by altogether progressive practices in the bulk of the state. For example, water sampling and water quality monitoring within the state of Chihuahua was described in the last decade by one scholarly source as underwhelming at best (Li, Arnold, Kozel, & Forster-Cox, 2005). This failure to upgrade water quality and monitoring practices undermines those efforts which do appear to be quite beneficial for the state and its water management architecture: the integrated river basin management programme for the Conchos River; efforts at irrigation modernization in the northern part of the state; and pilot sustainable watershed management projects in the upper basin (Barrios, Rodriguez-Pineda, & Benignos, 2011).

It would appear that public administration in the region will have to make some significant changes as far as universalizing best practices and bolstering the degree of water monitoring and treatment that takes place. There is also a clear demand for a legal framework for the use of underground aquifers, as scholars who have studied the situation in Northern Mexico grimly note that aquifers such as the Mimbres aquifer (which services, amongst others, Los Palomas, Chihuahua) is being significantly stressed in the absence of clear regulations and oversight (Benton-Short, 2014). There should be no question that attention should be directed towards coming up with a coherent and comprehensive water management architecture that protects aquifers and adds support for water purity and safety efforts. The latter problems definitely appear to be significant in the case of Chihuahua.

At the same time as Durango is not effectively screening its water – reclaimed or otherwise – it has also managed to both impoverish local tributaries and water resources and to persistently underfund or under-develop auxiliary irrigation pathways. Public administration will need to find ways of re-allocating resources, or of developing new tools or resources for water resource protection, conservation and amplification, if the state is to turn around its current situation.

Sonora does not, in the end, seem to be as celebrated as some other states in Mexico on the matter of its water resource management, and there may

be good reason for that: political fragmentation has partially contributed to the unfulfilled implementation of legal changes to the national water law that stressed integrated watershed planning and local participation (Wilder, 2010). To make matters worse, there is also a simmering battle involving the Sonora river over the collision between the watershed being seen as a common pool resource and the registration of water rights – with the former being perceived as arguably responsible for water tapping and over-exploitation (Pineda Pablos, Moreno Vázquez, Salazar Adams, & Lutz Ley, 2014).

4. Conclusions

Mexico has made strides in combating its water resource management deficits, but decentralization and integration has not been a resounding success. Conagua has clearly created a clearer demarcation for jurisdictional oversight, but some states lag behind: Baja California is doing well (certainly in the realm of desalination) in the main, but can do more with regards to water reclamation efforts. Chiapas has terrible communication and enforcement of water resource management best practices and guidelines that seems rooted in the general disrepair of the state. Chihuahua has encouraging water reclamation practices in place, but seems to lack the capacity or oversight to guarantee clean water. Durango favors water reclamation, but the state has a serious issue with arsenic overload and overuse has impoverished local tributaries and groundwater reserves. Finally, Sonora appears to have a checkered record of water resource management and public administration characterized by infighting, factionalism, and a lack of integrated watershed conservation and management planning. There is room for improvement everywhere.

Ultimately, public administration can only do so much, but one thing that can be done is to build up local competencies and expertise so that administration is carried out more efficiently. Public administration should also focus efforts on enforcement, since Mexico does have a comprehensive catalogue of policies and initiatives in place to protect water resources for farmers and everyone else. And public administrators should explore every option possible for calculating water use by individual land holders and for identifying individuals who overuse water for their own holdings.

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