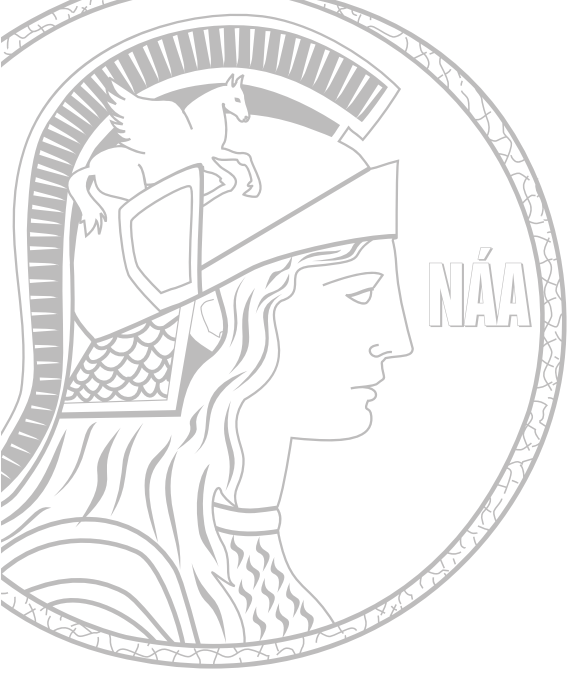

An Acad Bras Cienc (2023) 95(1): e20220823 DOI 10.1590/0001-3765202320220823
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

SOCIAL SCIENCES

Evolution of water governance systems in agriculture in developing countries and proposals for improvement. The case of the Hermosillo Coast, Mexico

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Abstract: This paper aims to study the determinants of the governance model of water resources in the agriculture of the Hermosillo-Coast (Mexico). To achieve this objective, a literature review, in-depth interviews and a workshop were carried out. The results show that the main threats to the system come from the model of granting concessions for access to water resources, the lack of supervision by the competent authority and the control of a group of stakeholders over water in relation to the rest of the interested parties. Finally, measures aimed at improving the sustainability of agricultural activity in the area are proposed.

Key words: agricultural intensification, Mexico, rural development, sustainability, water resources management.

INTRODUCTION

Agriculture is an activity of utmost importance to human society, as it plays a crucial role in global food production and contributes directly to wealth generation, being the only means of household income in depressed rural regions (Mateos et al. 2013). The introduction of technological improvements and intensification of agriculture have increased production, reducing the number of undernourished people (Alexandratos & Bruinsma 2012) and meeting the growing demand for richer and more resource-intensive diets (Foley et al. 2011, Tilman et al. 2011). Agricultural activities also generate employment, enhance economic growth and boost the service sector (Du Pisani 2006).

The development of agricultural activities is closely linked to the availability of water resources, being the main limiting factor for the expansion or intensification of agriculture. Agricultural ecosystems are the main providers of food, but they are also the main users of water resources globally (Forouzani & Karami 2011, Fu et al. 2013). These ecosystems use between 60% and 90% of available water, depending on the climate and economic development of the region (Pedro-Monzonís et al. 2015, Adeyemi et al. 2017). It has been estimated that, to meet food demand in 2050, global production needs to increase by 70% (Wu & Ma 2015), either to meet the demand for vegetal products or for animal production, especially intensive livestock production. In a low production scenario, meeting this target will require an increase in global water use of 53% (De Fraiture & Wichelns 2010), about 60% in developing countries and 16% in developed countries (Melo-Zurita et al. 2018).

It has been increasingly recognised that many of the problems in water management

are more associated with governance failures than with resource issues (e.g., scarcity). Water governance refers to the political, economic, social and administrative framework that determines who has access to water, where, when and under what conditions, who benefits from its use, and how the costs of water-related services are shared (Parra-Armenta & Salazar-Adams 2017, Pahl-Wostl 2019). Thus, it has been argued that a paradigm shift away from technocratic water management strategies and towards regimes that appreciate the institutional complexities and human dimensions of water resources is needed (Pahl-Wostl et al. 2010). A key problem with global water governance, and global environmental governance more generally, has been that international regimes have generally adopted a boundary-setting vision, shying away from approaches where the challenge is to develop new mechanisms to address socio-ecological disputes.

Agricultural activity is particularly relevant for developing countries, which have based their growth model on this sector to provide food, jobs and income to the most vulnerable families in rural areas (Martínez-Yrízar et al. 2017). Mexico is a paradigmatic example of rural development based on agricultural production. It has an area of 198 million hectares, of which approximately 73% is used for agricultural activities (FAO 2019). Despite representing only 4% of the national gross domestic product (GDP), Mexican agricultural activity is of great importance, not only in terms of surface area, but also as one of the world's leading food exporters (WTO 2019, Ochoa-Noriega et al. 2021). One of the factors that has made Mexican agricultural development possible was the conversion from traditional agriculture to commercial agriculture, through a process that was intensified by the North American Free Trade Agreement (NAFTA) (Oswald 2011, Martínez-Yrízar et al. 2017). As a result, a new regionally differentiated agriculture took shape, with the northern border states specialising in export-oriented agricultural activities (CONAGUA 2010, Mateos et al. 2013). These changes have had negative effects on Mexico's rural areas, notably in terms of food insufficiency, as the production of traditional crops that are fundamental to the Mexican diet has been abandoned. On the other hand, water availability in Mexico is conditioned by regional geographic characteristics. Thus, the northern half of the country experiences a rainfall deficit while in the south and southeast rainfall is abundant (CONAGUA 2010, Martínez-Yrízar et al. 2017).

In this context, since 2000, there has been an increase in research oriented towards the study of improving the sustainability of Mexican agriculture, which has become a priority over the last decade (Ocha-Noriega et. al 2021). This trend is a worldwide phenomenon, especially linked to the achievement of the Sustainable Development Goals of the United Nations 2030 Agenda. In the same way, the sustainable management of water resources in Mexican agriculture is a priority issue (Ochoa-Noriega et al. 2022). Therefore, this paper aims to contribute to this line of research by analysing the main determinants of the governance model of water resources in agriculture on the Hermosillo Coast, in order to detect its possible limitations and make appropriate proposals aimed at improving its sustainability. To achieve this objective, a literature review is carried out, including legislative documents, reports and other grey literature, which has been completed with in-depth interviews and a workshop with experts in the field.

MATERIALS AND METHODS

Methods

In this study, different qualitative research methods have been combined to collect, synthesise and organise the information in order to be able to make a diagnosis of the water management processes in agriculture in the study area and to be able to draw up proposals for improvement. As a starting point, a bibliographic review was carried out to gather as much secondary information as possible on the case study. Secondly, in-depth interviews were carried out with experts in different fields of knowledge related to the topic of study in order to complete the information and identify the main problems. Finally, a workshop was held to assess the different points of view and to elaborate a proposal for improvement measures.

The literature review is considered a necessary task in all research studies (Flick 2007). This methodological tool aims to identify the most relevant contributions that define the concepts and theories to be applied and structure the research problem (Grant & Booth 2009). The literature review included both scientific and grey literature. Major literature repositories such as Dialnet, Scielo and Scopus were used. Documents published by official sources such as the National Water Commission, the Mexican Official Gazette or the United Nations were included.

In-depth interviews can be defined as more or less structured conversations with the aim of eliciting knowledge (Qu & Dumay 2011). As an exploratory research method, they aim to find new aspects and develop research questions on topics that are not clearly defined (Næss 2018). This allows to genere an exchange of ideas through interactive conversations with stakeholders, in order to obtain comprehensive and meaningful answers (Rosenthal 2016). These interviews are based on a script with a series of open-ended questions that are answered during the interview (DiCicco-Bloom & Crabtree 2006). In our research a total of seven experts participated: two from academia, two from business, two from administration and one technical professional. The experts were selected from among people of recognised prestige within the agricultural sector due to their leadership position within a relevant organisation (public or private), their number of scientific publications and/or years of experience.

Finally, a workshop was held to pool the knowledge of the members of the panel consulted. This methodology allows the collaboration of different actors to share their knowledge on the topic of study (Ahmed & Asraf 2018) and to synthesise and value knowledge from a variety of fields (MacMillan & Marshall 2006, Coleman et al. 2017). It can also strengthen the connection between researchers and policy makers, enabling the development of knowledge that can inform policy (Oreszczyn & Carr 2008). The use of this methodology seeks to present all the knowledge obtained in the previous stages of the research, incorporate the different points of view of the actors and arrive at a consensual proposal that allows the development of proposals for improvement agreed with different key actors.

Case study: the Hermosillo Coast

The study was conducted on the Hermosillo Coast, in the northwestern region of Mexico, on the central coast of the state of Sonora. The Hermosillo Coast measures 100 km in a straight line between the city of Hermosillo and Bahía de Kino, located on the Gulf of California. The climate is semi-arid, with an average annual rainfall of around 100 mm, an average annual temperature of 24 °C and high solar radiation (Hernández-Pérez 2012). The water supply for irrigation

comes almost exclusively from underground sources, representing 90% of the water available for this sector (Olavarrieta-Carmona 2010), being one of the most prominent pumped irrigation districts in the country (Martínez-Peralta 2014). The Costa de Hermosillo aquifer (2619) has an average recharge of 250 hm^3/year and an average extraction of 346 hm^3/year (Martínez-Peralta 2014). This results in an average deficit of 96 hm^3/year. Consequently, there has been a reduction in the total volume of water, leading to a process of marine intrusion, reducing water quality (CONAGUA 2020). This aquifer has been declared as one of the 17 Mexican aquifers with saline intrusion, and as one of the 115 overexploited aquifers at the national level, with the greatest deficit of the 61 existing in the state of Sonora (Manzanares-Rivera 2016). The poor quality water resource has led to the abandonment of unproductive farms due to the salinity of the soil, making the concession of new farms impossible and increasing rivalry between different water users.

RESULTS

Context of agriculture in Mexico

Historical evolution of agriculture in Mexico

The development of agriculture in Mexico has its background in a series of social, economic, legal and political transformations, which began with the revolutionary movement of 1910 (Cordera 2015). The main objective of the revolutionary struggle was to change the land ownership regime, and to evolve towards a more equitable and efficient system. The first step was the dismantling of rural production structures, articulated as large latifundia properties, in the hands of a dominant group of hacendados (owners of agricultural holdings) who had control over fertile land and operated as the economic unit of national agricultural production (Morett 2006, Grijalva-Díaz 2011). These changes would take place with the Agrarian Law of 6 January 1915, which declared null and void all alienations of land, water and mountains belonging to the towns, and which stipulated the return of land to the towns that had been dispossessed (Patiño 2015). "This Law would be the seed that made it possible to establish the legal body that made it possible for the three most important types of land tenure to be considered in the Political Constitution of the United Mexican States: the ejido (collective management field), the community and the small property" (Patiño 2015:17).

With the approval of the 1917 Constitution, the Agrarian Reform began. Article 27 of the Constitution, on the forms of land ownership, would fulfil the main objective of the Mexican Revolution of expropriating land from the large estates for agrarian distribution. This article states: "The ownership of the lands and waters included within the limits of the national territory, corresponds originally to the Nation, which has had and has the right to transmit the domain of them to private individuals, constituting private property" (DOF 1917). According to Romero (2002:9), "with Article 27, two forms of agrarian property emerged: the ejido and the small property, legally eliminating the possibility of the survival of latifundist land ownership". The post-revolutionary governments continued to deepen agrarian reform and land distribution, and the process of technification and modernisation of the countryside to increase agricultural production, thanks, especially, to the importation of inputs from the United States (Gracia-Hernández 2010).

However, it was not until the Cardenista period (1934-1940) that the agrarian reform process took on special relevance. The agrarian distribution in this period intensified, the land

distributed was used for subsistence crops that would be distributed to the domestic market (SADER 2020). During this period, the land tenure structure was altered through the creation of collective ejidos, with 800 cooperatives being set up nationwide. By 1940, the ejidos represented 50% of the total productive land, with the other 50% remaining private property (Romero 2002). The agrarian distribution led to the modification of land use, incorporating previously unexploited areas into the agricultural area, which in turn required investment in irrigation infrastructure, and the allocation of budget lines to enable access to financing and technical assistance (Romero 2002). To channel these economic resources, regional banks such as the Banco Hipotecario and Agrícola del Pacifico emerged, which prioritised credits focused on financing agricultural production through the integration of farmers into organisations for the cultivation of rice, wheat and beans. As such, a variety of producer organisations and associations proliferate in order to gain access to credit to finance their activity (Grijalva-Díaz 2011).

From 1940 onwards, this scenario would change because the official stimuli that were intended for cooperatives, associations or collective ejidos would be granted to private entrepreneurial agriculture (Cárdenas 2008). This change was due to internal and external factors, such as the outbreak of the Second World War, which accelerated a process of greater development of the domestic market with the strategy of industrialisation via import substitution (Cordera 2015). This new industrialisation-oriented development model generated negative changes in the countryside, as the bulk of the country's productive resources were allocated to the needs for the accelerated growth of industry (Cárdenas 2008). The marginalisation of rural subsistence producers did not take long to appear, as corporate agriculture demanded more intensive production methods, imposing the adoption of technologies promoted by the Green Revolution, such as the use of industrial inputs, machinery, fertilisers and herbicides (Romero 2002). The demand for these inputs raised production costs and, without access to credit, farmers had only small plots of land, mostly located on low-quality rainfed land (Quintero-Peralta 2017). According to Calva (1988), for agricultural producers, the result of this new relationship between industry and agriculture would be the imposition of unprofitable prices and the substitution of national production by imported products, and, consequently, their exclusion as an essential factor of wage containment, which would gradually deteriorate rural economies and exclude them from production and development.

Against this backdrop, the latifundios became small private property that enjoyed the privileges granted by Article 27 of the Mexican Constitution of 1917. This amendment put an end to the latifundia, but redefined the conditions for the existence of private property in terms favourable to agricultural entrepreneurs. As a result of this change, in 1955, 54.3% of the total national agricultural product was produced by 3.3% of the agricultural production units (Romero 2002). From those years onwards, a new process of modernisation began in the countryside, with the creation of new irrigation zones as a driving force to address the problems of underdevelopment and the backwardness of the Mexican economy. The Federal Government's programmes focused on the construction of large hydraulic works, the organisation and control of irrigation districts aimed at orienting agriculture towards national demand and the promotion of export agriculture (Lorenzana-Durán 2019). These works were concentrated in the northern and northwestern states of the country.

However, from 1965 to 1980, Mexican agriculture experienced a crisis caused by the loss of dynamism of exports and the increase in imports of primary products (Gracia-Hernández 2010). This was due to the change in the national population's dietary patterns, the dependence on imported products such as grain, and the isolation of a large number of poor farmers (Soto-Mora 2003). Data show that agricultural GDP fell from 7.1% in 1970 to 5.1% in 1982. In those years, rainfed land decreased its share of the national harvested area from 84% to 71%, while irrigated land increased its share from 16% to 29% (Romero 2002). The changes resulting from the modernisation process experienced in the countryside since the Green Revolution were very positive for the private agricultural sector. On the one hand, it supplied the domestic market and, on the other, the surpluses were destined for the external market, thanks to the diversification of crops demanded by external markets, such as oilseeds, vegetables and fruit (Macías-Macías 2010). This led to a sustained increase in agricultural GDP, in what the economic literature called "the Mexican miracle" (Cordera 2015). However, for rural producers, this led to a decrease in the area harvested, mainly on rainfed land, affecting staple food crops associated with this type of land, such as maize and wheat.

From the 1980s onwards, government policy in Mexico laid the foundations for the privatisation of the economy, encouraging foreign investment through trade liberalisation and leaving behind the policies of the "welfare state", such as public spending subsidies and the absence of state presence in the commercialisation processes in the agricultural sector (Romero 2002, Morett 2006). The reactivation of the agricultural sector was driven by the modification of the land tenure structure, creating a more favourable legal framework to attract domestic and foreign private sector investment, and thus generate economies of scale in agriculture (Ortega et al. 2010). In this context, one of the most relevant developments in Mexican agriculture was the conversion from traditional agriculture to commercial agriculture, a process that intensified with the North American Free Trade Agreement (NAFTA). As a result, a new regional agricultural order took shape, in which the states belonging to the northern fringe specialised in agricultural export activities (Hernández-Moreno et al. 2008). This meant deepening the situation of marginalisation of rural producers and generating a polarisation in agriculture from north to south, and increasing the concentration of productive resources by large producers in the northern region (Lorenzana-Durán 2019).

Impact of the North American Free Trade Agreement (NAFTA) on Mexican Agriculture

The preamble to the commercial liberalisation of Mexican agriculture had begun in the 1980s with the Ley de Fomento Agropecuario of 2 January 1981, which allowed ejidatarios to rent their land to private investors under the requirement that they would be employed as wage earners on their own land (DOF 1981). In 1986, as part of the globalisation process, Mexico joined the General Agreement on Tariffs and Trade (GATT). In 1991, Article 27 of the Constitution on forms of land ownership was amended, putting an end to the expropriation of land from large estates, which had been one of the main objectives of the Mexican revolution (Rosas & Valtonen 1994). This again opened the way for the de facto concentration of large tracts of land. Furthermore, the 1992 decree of the National Water Law grants concessions of water rights to private users, allowing the concentration of the use of water resources for irrigation of these large agricultural areas (DOF 1992). These two

facts are decisive in the current configuration of Mexican agriculture.

In the mid-1990s, Mexico agreed to establish a free trade agreement with Canada and the United States. In the agricultural field, two separate agreements were signed, one between Mexico and the United States, and the other between Mexico and Canada, due to pressure from the latter (SICE 1992). With the regulation of trade exchanges derived from the entry into force of the North American Free Trade Agreement (NAFTA) on 1 January 1994, the strategy of change in Mexico's structural reforms was defined, with the aim of putting an end to the policies and institutions of the welfare state in order to build the neoliberal economic model that has prevailed up to the present day (Moreno-Vázquez 2005). The main objective of NAFTA was the elimination of tariff barriers to the import and export of goods and services, establishing a wide-ranging agreement where, based on economic integration between the three countries, trade and investment would converge, thus generating economic growth in the trade bloc (SICE 1992).

In terms of the agricultural sector, NAFTA aimed to generate an increase in the area of crops with export potential, which would increase employment in the agricultural sector and, in turn, an increase in the wages of producers, which would reduce migration to the United States (Lechuga-Jardínez et al. 2014). The results show that, although there was an increase in foreign direct investment flows from the United States to Mexico, it was more concentrated in the services sector. However, the agricultural sector experienced an increase in cultivated area and, consequently, an increase in the volume of exports from Mexico to the United States (Lechuga-Jardínez et al. 2014). In addition, there was a significant change in terms of the reconversion of the production structure from traditional crops (maize, wheat, beans) to export crops (fruits, vegetables and industrial agriculture) (Moreno-Vázquez 2005). But this did not increase employment, wages or growth rates in the terms initially estimated, due to the limited use of foreign direct investment in technology transfer and the promotion of innovation, which highlighted the asymmetries between the three countries (Cordera 2015).

On the other hand, the reconversion of the productive structure of agriculture increased the harvested area and the relative share by crop groups in direct national employment. This is a consequence of the expansion of crops such as fruit, vegetables, oilseeds and industrial crops, which have a greater capacity to occupy labour per unit of cultivated area (Lechuga-Jardínez et al. 2014). While maize production in 1994 occupied 61.2% of the harvested area and employed 37% of the economically active population (EAP) employed in agriculture; vegetables, with less than 3% of the cultivated area, employed 15.2% of the agricultural EAP in the same year (Lechuga-Jardínez et al. 2014). The change in the pattern of crops would mitigate the problem of unemployment in the fields, since traditional crops employ less than 6% of the daily wages generated, while other perennial crops accounted for 8.8%, vegetables 13.7% and grapevines would occupy more than 70% of the total number of workers in the region (Cordera 2015).

Crop reconversion modified the productive structure, leading to an increase in imports of basic products (beans, maize, wheat and rice) to meet national demand, resulting in a food supply problem (Borja-Bravo & García-Salazar 2008). The disappearance of subsidies granted to producers and shops through price guarantees accentuated this problem; a specific case was the disappearance of the National Company of Popular Subsistence (CONASUPO) (Borja-Bravo

& García-Salazar 2008). The reconversion also led to the polarisation of agricultural activity in terms of the existence of a small group of highly competitive commercial producers and a huge group of subsistence farmers. This concentration of production in the hands of large producers is mainly due to the fact that, as these crops require large investments, generally only recoverable through economies of scale, practically only large producers with extensive surface areas can survive in this environment (Macías-Macías 2010).

Small producers dedicated to subsistence agriculture, mainly farmers in the south of the country specialised in grain production, found a brake on their capacity for growth (Quintero-Peralta 2017), and were displaced from international trade, exacerbating their precarious situation. These producers had to seek new formulas for marketing their harvests, such as direct sales or fair trade, as soon as the agrarian sector ceased to be a priority in state public policies with the Mexican state's adoption of the neoliberal economic model (Quintero-Peralta 2017). While NAFTA had a positive impact in terms of the evolution of variables related to foreign trade (imports, exports and foreign direct investment), it also had adverse consequences. On the one hand, it led to the concentration of domestic production in a group of export-oriented crops (tomato, avocado, green chilli, onion, asparagus, cucumber, watermelon, strawberry, orange, melon and papaya), thus de-supplying domestic demand. On the other hand, it led to a geographical polarisation of production, mainly on the country's northern border (Baja California, Sonora, Chihuahua, Coahuila, Nuevo León and Tamaulipas), creating a new structure in Mexican agriculture, dividing north and south.

Administration of water rights on the Hermosillo Coast

The Hermosillo Coast was established as an agricultural district in 1949 and from its beginning land was concentrated in a few hands, which meant an unequal and inequitable distribution of water. According to Vargas (1959), smallholders had 77% of the land and 85% of the wells, colonists had 29% of the available area and 14% of the wells, and ejidos had 3% and 0.5%, respectively. Two years after the creation of this agricultural district, the number of wells increased by around 50%, the sown area by more than 60% and water extraction by more than 70% (Moreno-Vázquez 2005). The lack of control over water pumping led to a serious problem of depletion of groundwater resources, which they tried to reverse by issuing several legal ordinances: four decrees of closure (1951, 1954, 1963 and 1967), an exploitation regulation (1963) which in fact constituted the first programme to reduce extractions, an operating regulation for the irrigation district (1966) and the creation of a council for the conservation of geohydrological resources (1956). These regulations achieved little or nothing due to the lack of real control over abstractions.

Therefore, in 1977, a plan was approved to reduce irrigation withdrawals from the Hermosillo Coast by 50% in thirteen years. However, the objectives set out in this plan were not achieved, as the authorities and farmers took a back seat to the favourable economic conditions that resulted in higher water allocations for the development of highly profitable crops such as cotton and wheat. During the period of validity of this plan, there were only significant decreases in water extraction due to the fall in crop prices (in the 1982-1983 cycle for cotton and from 1987-1988 for wheat) and the increase in production costs generated by the restriction of subsidies for electricity consumption available

to irrigation districts (in 1990) (Moreno-Vázquez 2005). Eventually, this plan did not achieve its objectives. In this period, at the beginning of 1980, another important decree was approved with the aim of rehabilitating the irrigation district through the ratification of the reduction programme initiated in 1977 and the relocation of several wells on the coast due to the saline water filtration that had occurred and which endangered the fertility of the land. In short, the regulations developed to try to improve the situation of the aquifer and reduce extractions did not bear fruit, mainly because the extraction of water depended on elements linked to the economy, leaving aside the conservation and administration of the natural resource. During this period, a strategy of crop reconversion was initiated (perennial crops became more important than grain crops such as cotton and wheat) and irrigation technification (installation of pressurized irrigation) was started by farmers with greater resources in order to maintain their profitability, which increased inequality with respect to colonists and ejidos.

The regulatory regime for water resources management in Sonora is framed within Mexico's 1992 National Water Law. Based on this law, water concessions to private actors are allowed. The current configuration of agriculture in Mexico shows that, as with land management, it is in the areas with the greatest water scarcity that the concentration of the resource by a small group of economic agents for agricultural use is most intensified (Moncada et al. 2013, Gómez-Arias & Moctezuma 2020). This situation was institutionalised with the new model developed under NAFTA. Although Sonora was able to position itself among the three most important states in terms of the value of agricultural production at the national level, it also generated a series of conflicts over access to the region's water resources for agricultural activities (Vázquez 2020). This factor has been the most important limiting factor for the sustainability of agricultural activity, as well as for the region's needs as a whole, such as supplying communities. In this sense, the most complex task is to maintain the ecological balance of the ecosystems, along with the economic development of the regions, based especially on the exploitation of agriculture. In the same way, and no less difficult to achieve, breaking the current system of access to the resource, in order to avoid resource concentration, may be at the heart of the solution.

It is, therefore, necessary to analyse the governance processes and sustainable practices that have been developed for the management of water resources in the area. In this way, it is important to understand the system and the decisions that, both in the short and long term, have triggered the water resources problems in the area. Knowledge of the environmental history of the territory is fundamental to understand the relationships that prevail to the present day and that have marked the history of the region (Alimonda 2011), as well as the environmental transformations generated by the introduction of technological models associated with progress and modernity, entrepreneurship and the expansion of the agricultural frontier (Lorenzana-Durán 2019).

The management of water resources in the country was configured on the basis of the regional structure established by the National Water Commission (CONAGUA) on the basis of the 1992 National Water Law. In this way, 13 basin organisations were created to manage and administer the volumes of water distributed for agricultural use in the irrigation districts. The Northwest basin organisation is the one in which the irrigation districts within the state of Sonora are included. These districts are: 018. Colonias Yaqui, Sonora; 037. Altar-Pitiquito-Caborca,

Son; 038. Mayo River, Son; 041. Yaqui River, Son; 051. Hermosillo Coast, Son; 083. Papigochic, Chih.; and 084. Guaymas, Son. All of these irrigation districts are fed by the Sonora River, except irrigation district 083, which comprises agriculture in the Sonora highlands bordering Chihuahua and its Papigochic River (CONAGUA 2019). Figure 1 shows the organisational structure of the Northwest basin, including the irrigation districts distributed throughout the state of Sonora, highlighting irrigation district 051 Costa de Hermosillo, the object of study of this paper.

The Basin Councils have been established as instances of coordination and mediation between the National Water Commission and the three levels of government existing in Mexico (Federal, State and Municipal), and the representatives of the users of the respective hydrological basin, represented through the Users' Association. The objects conferred on the Councils by the Water Law are i) to formulate and implement programmes and actions for the better administration of water, ii) the development of hydraulic infrastructure and the respective services, and iii) the preservation of the resources of the corresponding basin. In turn, for their operation, Basin Councils may have auxiliary bodies at sub-basin, micro-basin or aquifer level. The Basin Commissions and Committees, subordinated to their corresponding Basin Councils, are formed for the resolution of problems that, due to their seriousness or complexity, require specialised or temporary attention, which means that they are formed with functions ad hoc to the areas to which they belong.

The Upper Northwest River Basin Council was created on 19 March 1999, with the objective of managing the basins of the Sonoyta, Concepción, Santa Cruz-San Pedro and Sonora rivers, which in total represent 48.7% of the territorial extension comprising the Northwest Hydrological Administrative Region, equivalent to 96,300 km2 (CONAGUA 2014). The capacity of the Basin Councils in northwest Mexico to develop in accordance with the principles of

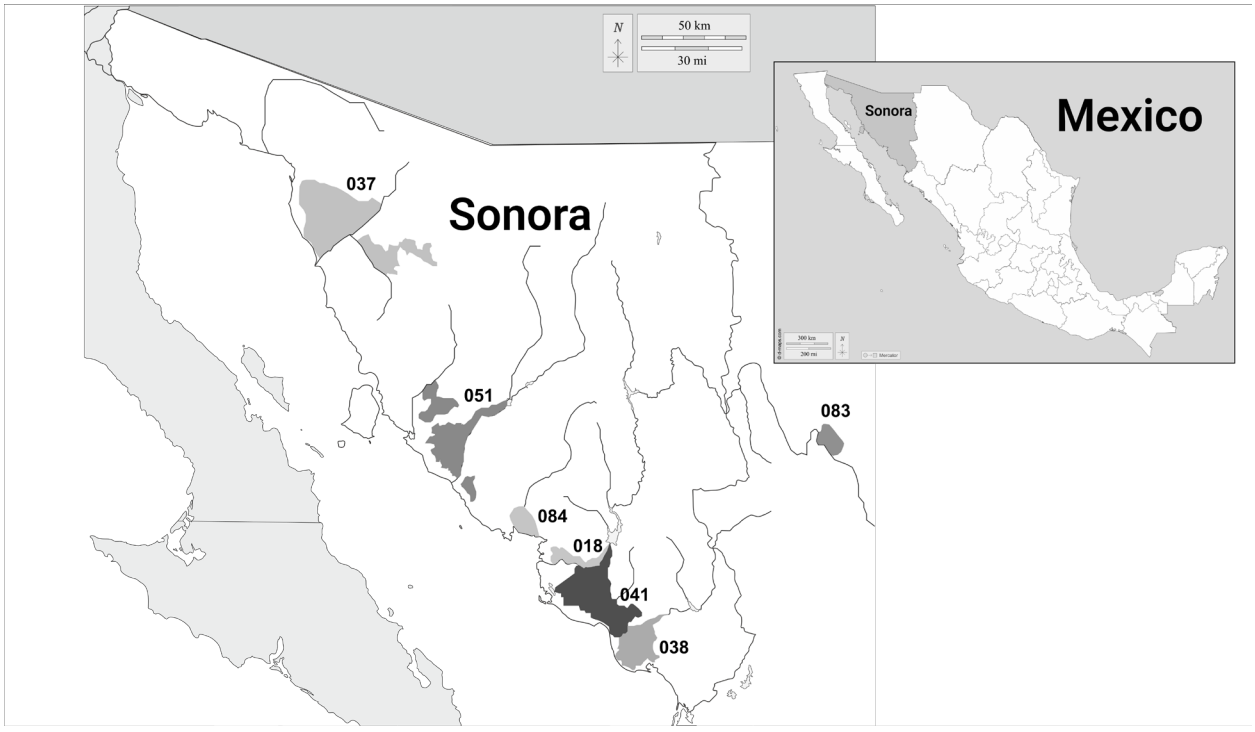

Figure 1. Irrigation districts of the North West Basin Agency. Source: Own elaboration.

Integrated Water Resources Management is very limited in terms of their own structure, the internal dynamics of their functioning and the possibility of facing the most relevant challenges in their respective basins (Parra-Armenta & Salazar-Adams 2017). The main limitations presented are the scarcity of resources, due to the reduced budget granted by the federal and state governments; and the lack of communication with all stakeholders.

In the State of Sonora, the management of water resources is different depending on the type of water: surface or groundwater. In the case of surface water, CONAGUA manages water flow through a system of dams, including the Mopusari on the Mayo; and the Oviachi, the Novillo del Yaqui, and the Ojo de Agua dam in Guaymas (Reyes 2009). In order to access the resource, farmers must organise themselves autonomously by irrigation districts. In this way, CONAGUA provides and conducts water to each irrigation community, and each community manages its water resources autonomously (Pineda 2020). In the case of groundwater bodies, CONAGUA does not carry out direct control and management of the resource, but its role is limited to supervision through inspections that it carries out from time to time (Salazar-Adams et al. 2012).

The Costa de Hermosillo irrigation district is located on a coastal strip, with no surface water available, so it relies solely on groundwater. In this district, the 051 Users' Association is constituted for the administration and control of the allocated water resources, corresponding to the main aquifer of the system, which is identified as aquifer 2619. As mentioned above, this aquifer presents an average annual deficit of 96 hm^3/year, which has resulted in a reduction of the total volume of water, giving rise to a process of water intrusion, contaminating the available freshwater (CONAGUA 2020). The 051 Users' Association holds the group concession for the district's groundwater and manages water use rights among its private farmers. Most farmers extract more water than allowed or dig wells without permits, thanks to the fact that they are responsible for their own supervision (Moreno-Vázquez 2005), thanks to the permissiveness of the regulatory regime, as the national water law of 1992, following NAFTA, increased the overexploitation of the aquifer. This situation is the cause of the problem of overexploitation of the aquifer and the saline intrusion present in the area.

According to the Ministry of Agriculture, Livestock, Hydraulic Resources, Fisheries and Aquaculture (SAGHARPA), this area has an area of approximately 50,000 hectares open to cultivation, specialised in the production of fruit and vegetable crops, aimed at the export market, whose intensive production schemes are based on the use of groundwater and irrigation by pumping (SAGHARPA 2016). Table I shows the volumes of water distributed in the district and the modality of the three harvesting seasons (autumn, spring and perennial) in irrigation. Tables II and III show the information on land tenure, irrigated surface area and volume of water distributed by irrigation district in the Northwest basin, differentiating in the type of water used. While the first one reports on surface water, the second one reports on groundwater. Agriculture in the Costa de Hermosillo district is the only one supported exclusively by pumping wells, with a distributed volume of 366,528.6 thousand m^3 and where export crops predominate: fruit and vegetables in an irrigated area of 49,523 hectares. Land tenure is concentrated in private ownership.

At present, the Hermosillo Coast is experiencing a problem of overexploitation of its water resources, as a result of a series of events resulting from the decisions and

Table I. Irrigation District 051 Hermosillo Coast (Sonora).

Cycle 2017-2018	Modality	Crop	Harvested area (ha)	Production (T)	Production value (Thousands $)
Autumn-winter	Irrigated		25,511	65,210	545,277.70
		Safflower	2,950	7,818	57,957.62
		Forages	65	2,763	2,834.25
		Chickpea	14,700	24,990	364,854.00
		Wheat grano	4,796	29,639	119,631.84
Spring-Summer	Irrigated		9,500	441,393	3,087,575.75
		Courgette	1,834	49,517	342,671.02
		Onion	12	116	1,291.66
		Green chilli	777	69,093	897,300.33
		Bean	800	1,600	27,200.00
		Tomato	95	10,882	43,271.71
		Melon	840	27,269	201,281.99
		Cucumber	419	37,412	256,669.17
		Watermelon	4,623	244,944	1,315,077.07
		Sorghum	100	560	3,212.16
Perennes	Irrigated		17,513	237,269	3,776,183.78
		Alfalfa	410	36,500	20,069.30
		Buffel	935	34,511	37,142.99
		Citrus fruit	2,745	86,797	431,855.27
		Peach	36	360	2,463.80
		Asparagus	367	3,842	134,487.15
		Higuerilla	1,400	3,080	17,420.48
		Apple	13	176	2,071.29
		Walnut	6,825	13,650	1,197,292.96
		Persimmon	13	176	3,055.58
		Grapes	4,769	58,177	1,929,324.95
Total			49,524	743,872	7,409,037.23

Source: own elaboration based on CONAGUA (2019).

implementation of the National Water Law (1992) in force for the development of this area. The existence of group-type concession granting and the absolute power of private producers to manage the resource accentuates the weak organisational structure. Secondly, there is little or no administrative control over water resources, mainly because management is centralised from Mexico City by CONAGUA (Montaño 2020).

Table II. Physical irrigated surfaces and volumes distributed by type of use and tenure in the irrigation districts of the Northwest basin organisation (gravity-dams).

Irrigation district	Users		Irrigated area (ha)		Volume distributed (Thousands of m3)	
	Ejidal	Private	Ejidal	Private	Ejidal	Private
Colonias Yaqui	2,446	-	19,902.10	-	253,269.40	-
Altar Pitiquito, Caborca	41	18	188.00	188.00	2,500.80	2,500.80
Río Mayo	6,960	4,130	41,726.00	34,863.20	329,374.40	245,398.50
Río Yaqui	15,331	7,256	106,845.70	93,302.10	970,705.50	855,316.40
Costa de Hermosillo	-	-	-	-	-	-
Papigochi	42	525	349.50	3,260.60	3,400.70	31,726.70
Guaymas	703	182	7,517.50	7,435.70	45,772.00	42,374.50
Total	24,673	11,140	170,585.50	130,245.90	1,445,783.20	1,008,434.00

Source: own elaboration based on CONAGUA (2019).

Table III. Physical irrigated surfaces and volumes distributed by type of use and tenure in the irrigation districts of the Northwest basin organisation (pumping-wells).

Irrigation district	Users		Irrigated area (ha)		Volume distributed (Thousands of m3)	
	Ejidal	Private	Ejidal	Private	Ejidal	Private
Colonias Yaqui	-	-	-	-	-	-
Altar Pitiquito, Caborca	1,014.00	508.00	6,327.60	16,706.40	657,230.00	223,878.10
Río Mayo	-	-	-	-	96,151.90	84,379.20
Río Yaqui	385.00	142.00	3,022.60	2,021.10	280,946.20	202,135.80
Costa de Hermosillo	160.00	872.00	1,007.30	48,516.70	7,760.40	366,528.60
Papigochi	-	-	-	-	-	-
Guaymas	-	-	-	-	-	-
Total	1,433.00	1,458.00	9,370.80	66,331.20	1,031,629.50	869,950.70

Source: own elaboration based on CONAGUA (2019).

DISCUSSION

As has been explained, the current governance model allows for almost absolute control by private owners, through the users' association. There is laxity on the part of the Administration in terms of its supervision and control functions, in order to maintain the good status of water bodies. Furthermore, there is discrimination against other users on the part of private landowners, especially marginalising small producers. Government investments were concentrated on technical infrastructure, credits and subsidies for irrigated land, resulting in great inequality because this land is mainly concentrated in large private landowners (Pérez 2014). Subsidies for agricultural activity, such as electricity, are oriented towards consumption, resulting in

the exclusion of smaller producers with less economic capacity (Olavarrieta-Carmona 2010). The electricity subsidy (tariff subsidy 09) was created with the objective of promoting food production and guaranteeing the profitability of agriculture. However, this subsidy indirectly influences water consumption by facilitating the extraction of high volumes of this resource. In the case of the Hermosillo Coast, the energy quota is higher than that needed to extract the endowment assigned to each individual well, which has made it possible to extract a greater volume of water at preferential costs and subsidise the low efficiency of pumping equipment and water use (Olavarrieta-Carmona 2010, Salazar et al. 2012). Furthermore, there is great inequity in the distribution of this subsidy, as 40% of electricity subsidies are concentrated in just twelve large producers (Olavarrieta-Carmona 2010)

On the other hand, small farmers and ejidatarios do not have the resources to improve their productive and technological capacity, which has made it impossible for many of them to survive in this sector (Hernández 2019). Pressurised irrigation systems only represent around 40% of the cultivated area (Olavarrieta-Carmona 2010, Martínez & Moreno 2016), and overall irrigation efficiency in Mexico is around 35% (Martínez-Austria et al. 2019). In short, the concentration of irrigated land among large producers gives them great power, as well as allowing them to modify their production system towards crops with greater demand and economic value in export markets thanks to the installation of technified irrigation systems. However, these producers consider agriculture as an economic activity without taking into account the existing problems with water and with little interest in guaranteeing the sustainability of this resource.

It is therefore imperative to rethink the governance model of the resource, through collaborative processes that can take place within the basin councils. The development of a new model must include producers, institutions and academics specialising in this issue, so that all points of view are taken into account and water use is maximised, without discriminating against any group. It is also essential to give access to small producers. In this sense, in other groundwater districts, the COTAS system has represented an alternative for the supervision and compliance with the regulations in force in aquifers around the country. The COTAS were promoted by the National Water Commission to address the overexploitation of groundwater, as well as to promote and implement rural development policies. There are successful cases of both administrative and regularising functioning of COTAS, such as Comundú or Santo Domingo in Baja California Sur (Salazar et al. 2012, Valdés 2014). However, many COTAS have not been able to achieve the objective of balancing abstractions to recharge due to their lack of financial autonomy and authority to address illegal abstractions or abstractions in excess of concessions (Cisneros 2008). In any case, according to experts, in the Hermosillo Coast this system is not a viable option because of the level of deficiency and vicious circle in the concentration of resource administration and management via group concessions.

Several studies establish that the overexploitation of Mexican aquifers for agricultural use is mainly due to non-compliance with the LAN in relation to illegal extraction without concessions and the extraction of a greater volume than the concessioned volume, in addition to subsidies from the electricity tariff for pumping (Marañón & López 2008, Rivero-Cob & García-Romero 2011, Lara-Álvarez & Magaña-Lemus 2014, Martínez-Austria et al. 2019). Therefore, the fact that concessions are carried out individually or in groups is not decisive in tackling the situation of overexploitation of

aquifers. However, a shift towards a system of individual concessions in the study area could improve efficiency in groundwater management by encouraging a better distribution of water rights as in other cases such as in the Cuauhtémoc aquifer (Chihuahua) (Santos-Hernández et al. 2019) or the Calera and Chupaderos aquifers (Zacatecas) (Vélez-Rodríguez et al. 2015), while preventing a small group of users from making decisions for their own benefit. To achieve this objective, it is essential to encourage the participation of all stakeholders in decision-making (Marañón & López 2008).

In order for there to be real protection of water bodies, a decentralised management, administration and control mechanism must be developed for the concessions granted for groundwater use, not only through permits and inspections programmed from Mexico City. In this way, detailed management of the drilled wells is made possible, not only by delegating the responsibility to the users in this area, but also by sharing the work of a permanent administrative body set up for this purpose.

On the other hand, a greater effort is needed to promote collective know-how including farmers, institutions and researchers through the formation of groundwater monitoring committees in order to manage and develop a procedure for the control and enforcement of current regulations. In addition, within this framework, regulations should be developed to fill the regulatory gaps in specific aspects of daily functioning and operation. For example, in the case of the pumped irrigation district of the Hermosillo Coast, it is found that the regulations developed since LAN (1992) allow the concession through a group origin title, which implies decentralised management of the resource, and makes possible the sale of water on a temporary basis and with partial volumes. This has meant that the resource can be used or exploited by third parties and the disappearance of some social actors (Martínez 2020).

The modifications to the current governance model proposed in this paper are as follows:

1) In relation to the system of concessions for access to water from the Costa de Hermosillo aquifer. Change the model for granting concessions for access to water resources in a way that:
2) Concessions are made on an individual rather than a group basis. In this way, a concession can be guaranteed on the basis of individual characteristics of the farm, the crop, the production system, etc.
3) Concessions are granted and supervised by the federal government together with an independent agency that represents the interests of all stakeholders and not by the irrigation community as a whole through the users' association. In this way, more transparent and effective management is pursued, trying to maximise access to the resource, as well as its productivity.
4) In relation to the monitoring and control system for the management of individual water bodies and at basin level. Change the type of supervision and control model in terms of compliance with current regulations, access to the aquifer by means of well drilling concessions, as well as the volumes extracted, involving the different stakeholders and eliminating the current control in the hands of the Users' Association and CONAGUA, which is the centralised body. To this end, it is proposed to move to an effectively decentralised model, providing sufficient funding and autonomy to the bodies in charge of the management of the basins and groundwater bodies or for each irrigation district, with competencies in terms of supervision and control. This institutional system of districts or basins

must act in a coordinated manner to manage the bodies of water that exceed the district limits, in such a way as to ensure equitable access for the whole of the State, and to prevent overexploitation at the headwaters of the basins, making it impossible for them to continue downstream.

5) To create a permanent working group for the planning and development of regulatory proposals aimed at achieving the sustainability of the water resources management model, including all interested parties. In this way, the aim is to establish a permanent dialogue between the different agents involved, to share information on the different areas of knowledge, as well as to confront and reconcile the different interests.

In this way, the aim is to develop networks between farmers, institutions and researchers as a fundamental factor in achieving management objectives. The latter are the main producers of knowledge in the different disciplines involved in resource management. The different profiles of farmers are the main users of water, so they have a fundamental role in the implementation of any action and, in turn, are the main stakeholders in the sustainability of access to the resource. The administration has the main responsibility for policy development, implementation, monitoring and control, and must look after the common interest, especially of the most vulnerable. In addition, to support the transformation process, it is considered necessary to carry out a communication plan aimed at:

- To achieve a level of environmental awareness among farmers that encourages them to take actions to preserve their water resources.
- To develop greater collaboration between researchers, institutions, local and transnational farmers, allowing the sector to be constantly updated based on the needs of producers and the fulfilment of environmental objectives.
- To evaluate the feasibility of the practices and replicate the success stories as examples for the rest of the producers.

CONCLUSIONS

The aim of this study was to analyse the main aspects of the governance model for water resources in agriculture on the Hermosillo Coast, in order to detect its possible limitations and make appropriate proposals aimed at improving its sustainability. To this end, a review has been carried out, mainly of grey literature, which has been completed with participatory methodologies based on the criteria of experts. The results have shown that the regulatory framework emanates mainly from the 1992 National Water Law, and that the institution responsible for granting water use rights is the National Water Commission, which delegates its functions to the Users' Association.

This management model gives rise to inefficiencies in the use of the resource that are synthesised in restricted access to water, being monopolised by private land owners, a predominance of export-oriented production of cash crops, and an impact on water bodies as a consequence of overexploitation. In order to address these problems, a set of modifications to the governance model are proposed, which are specified as follows:

- To change the model for granting concessions for access to water resources so that they are processed on an individual rather than a group basis. Furthermore, these concessions should be granted by an institutional body rather than by the irrigators as a whole through the users' association.
- To move from the current de facto centralised model in the country's capital

to a decentralised one, through the creation of fully operational institutional bodies for the management of each basin organisation and/or irrigation district.

- To create a permanent working group for the planning and development of proposals that integrates all the social agents involved.
- In order to address the process of updating the traditional governance model, it is considered appropriate to promote education and awareness-raising mechanisms aimed at achieving a level of environmental awareness among farmers that will encourage them to take actions to preserve their water resources; to develop greater collaboration between researchers, institutions, local and transnational farmers, enabling the constant updating of the sector based on the needs of producers and compliance with environmental objectives; and to evaluate the viability of practices and replicate success stories as examples for other producers.

Acknowledgments

This work was partially supported by the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund by means of the research project ECO2017-82347-P. And by the FPU19/04549 Predoctoral Contract to Belén López-Felices.

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How to cite

VELASCO-MUÑOZ JF, OCHOA-NORIEGA CA, ROMÁN-SANCHEZ IM & LÓPEZ-FELICES B. 2023. Evolution of water governance systems in agriculture in developing countries and proposals for improvement. The case of the Hermosillo Coast, Mexico. An Acad Bras Cienc 95: e20220823. DOI 10.1590/0001-3765202320220823.

Manuscript received on September 22, 2022;
accepted for publication on February 11, 2023

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