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Aspects of the Economic Impact on Irrigated Agriculture in the Juarez Valley due to Salinity and as a Result of the Water Distribution between Mexico and the United States in 1906

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Aspects of the economic impact on irrigated agriculture in the Juarez Valley due to salinity and as a result of the water distribution between Mexico and the United States in 1906

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Abstract

Farmers in the Juarez Valley, Chihuahua, Mexico obtain water from three separate water sources that are linked to the 1906 historic water allocation between Mexico and the United States This article describes the historical and economic impacts that have resulted from the use of Rio Grande surface water, Hueco Bolson groundwater, and Ciudad Juarez wastewater and their respective salinities. This research utilized the mathematical model of Maas and Grattan to examine the crop yield reductions due to salinity. The data consisted of agricultural economic values and crop production data in the Juarez Valley, as well as the salinity content and flow rate of the Rio Grande/Rio Bravo at the International Dam. The salinity of Rio Grande water diverted at the International Dam does not, by itself, cause yield reductions. There are yield reductions as a result of using Hueco Bolson groundwater and Juarez wastewater. Farmers in the Juarez valley were compelled to use these supplies after the treaty of 1906. The 1906 water allocations were not sufficient to irrigate lands that had been irrigated prior to upstream irrigation development in the U.S. Subsequent drainage system deterioration has contributed to the economic impact.. These impacts are quantified for specific periods and two crops in this work.

1. Introduction

Waters containing salinity (dissolved solids) in excess of about 700 ppm (mg/l) tend to inhibit yield for some crops (Oyarzabal-Tamargo 1976).. From 1936 to 1994, about 90 percent of the time, the salinity at the head of Acequia Madre, which is located immediately downstream of the American Dam, was above the 700 ppm level. The historical salinity average at the Acequia Madre is point is 822 ppm. The Acequia Madre supplies water to Mexico's 009 Irrigation District (DR009) and the American Dam diverts water to El Paso County Water Improvement District Number One on the U.S. side.

There are no studies from the Mexican perspective that analyze the economic impact on the Juarez Valley agriculture due to water salinity of the Rio Grande/Rio Bravo associated with the historic water distribution between Mexico and the U.S. in El Paso del Norte region.

Ciudad Juarez is the sixth largest city in Mexico with a population of 1,218,817 (INEGI 2000) and an annual growth rate of 4.4 %. The Juarez Valley is situated at the northern end of Chihuahua, in the border zone with the U.S. The Juarez Valley is located between longitude 105º 30' W and 106º 45' W, and latitude 30º 50' N and 31º 45' N. The 009 Irrigation District occupies part of the municipalities of Juarez, Guadalupe D. B., and Praxedis G. Guerrero. The floodplain of the 009 Irrigation District is bounded by alluvial fans and sand dunes and it is an agricultural area, which had in the 1880´s an irrigated land of approximately 25,000 hectares

(62,500 acres). The Juarez Valley is at an altitude that varies between 1050 – 1130 m.a.s.l. It is 135 km long and 3 km wide.

The U.S.-Mexico border weather is extreme, and is characterized distinct seasonal variations. During winter, records register average low temperatures under 0 °C (32 ºF). In spring and autumn, the average temperatures is about 22 °C (71.6 ºF) while during summer, temperature is about 40 °C (104 ºF). The average annual precipitation in the region is less than 254 mm (10 in).

1.2 Characteristics of the 009 Irrigation District in the Juarez Valley

The 009 Irrigation District (Refer to Figure 1) begins at the International Dam where water is diverted from the Rio Grande/Rio Bravo at a rate of 5.5 m^3/s. At this diversion point, the Km 0+000 of the main channel, also known as the Acequia Madre, is also located. The water diversion is part of the 1906 International Treaty between U.S.-México, and it makes up a volume of 74 Mm^3 (60,000 ac-ft). The Rio Grande/Rio Bravo water is diverted for the irrigation period from approximately March, 17 to September, 17 of each year. The rest of the year (September 18 to March 17), the Juarez Valley waters its lands from Juarez City wastewater and groundwater of the valley. There are 2305 users (farmers) in the district, and the agricultural production value in 2002 was 261 million pesos (26.1 million U.S. dollar; exchange rate, 2002). Although the 009 Irrigation District consists, at present, of 20,815 ha available for framing, only 15,000 ha are under irrigation due to the lack of water resources to irrigate entire area.

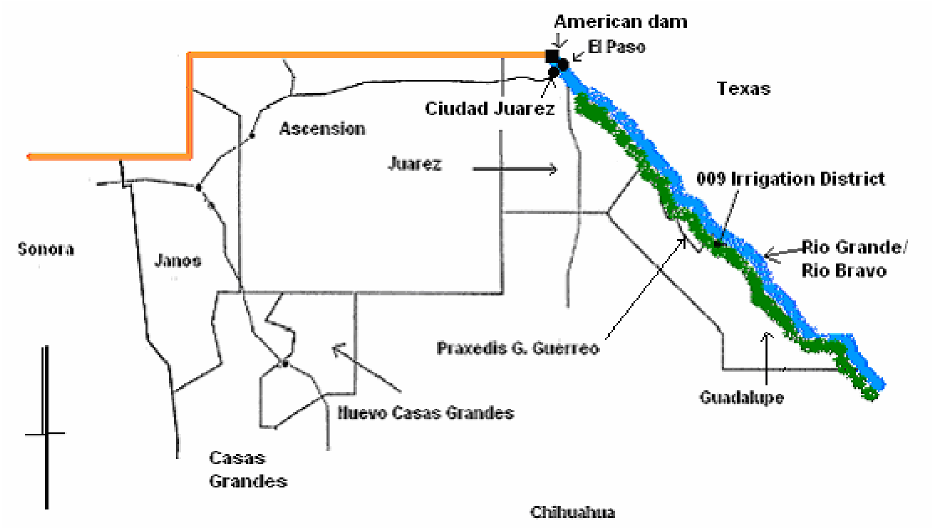

Figure 1. Irrigation District 009 location

Table 1. Main irrigation water sources for the 009 Irrigation District in the Juarez Valley

Table 1. The Main Irrigation Water Resources in the 009 Irrigation District		
Water source	Volume/year	Salinity (mg/l)
Rio Grande	74 Mm^3/year	822 (USBR 2003)
Wastewater	65 Mm^3/year (it varies according to the discharges)	1,721 (009 Irrigation District)
Wells	60 Mm^3/year(it varies according to the Irrigation District budget)	2,295 (Contreras 2000)
Total:	199 Mm^3	
Source: Personal communication, 2002		

Table 2. Main crops for the 009 Irrigation District in the Juarez Valley

Table 2. Main Crops and Hectares in the 009 Irrigation District. Season 1999-2000				
	Area planted		Crop production value (10^3)	
	hectares	acres	Pesos	Dollars *
Cotton	3,956	9,890	166,161.89	16,161.89
Alfalfa	2,160	5,400	36,720.0	3,672.0
Sorghum, forage	2,674	6,685	28,486.5	2,848.65
Wheat	1,808	4,520	12,656.0	1,265.6
Oats, forage	1,070	2,675	7,490.0	0.749.0
Other forage	479	1,197	4,757.9	0.476
Fruits	256	640	4,608.0	0.461
Vegetables	15	37	216.0	0.216
Total:	12,418	31,045	261,096.9	26,109.69
Source: Salazar, 2002. * Exchange rate, 10 pesos/dollar (2002)				

1.3 Salinity problems

One of the main problems for the Mexican agriculture in this region is salinization. Salinization affects approximately 10,000 hectares (25,000 acres). The following factors contribute to the high salinity content in irrigation water used in the 009 Irrigation District:

- 80% of the drainage system in the 009 Irrigation District is not properly working.
- Approximately 4,000 hectares (10,000 acres) rest on top of a very high water table which is between 0.5 to 1.5 m. below the surface. In about 6,000 hectares (15,000 acres), the water table is between 1.5 m to 2.0 m below the surface.. High water tables are the main cause of the salinization processes and the subsequent damage to agriculture. High sodium concentrations in soil and water also contribute to the problem. The water quality of the shallow groundwater is directly associated with wastewater from the city of Juarez, which represents approximately 30% of the water supply.

- Groundwater from wells (30% of the water supply) utilized in the agriculture is classified as highly saline and has a high level of sodium. In 1998, the average salt content was equal to 1721 mg/l, which is higher than the 1,300 mg/l standard (Contreras 2000).

Due to the use of groundwater and wastewater with high salt contents, the 009 Irrigation District is one of the most contaminated by salinization in Mexico (Ortíz 1993).

The use of wastewater from Juarez in the 009 Irrigation District prevents the cultivation of edible crops for human consumption. This economic impact to the Juarez Valley is not included in this study This lack of cropping flexibility negatively impacts the economy of the region because farmers cannot grow high value, labor intensive vegetables that could significantly increase income.

In the 1906 Treaty, the potential for future agricultural development by the Mexican farmers in the Juarez Valley was not taken into account which has condemned agricultural economy of the region to stagnation.

1.4 The treaty of 1906

On February 2, 1848, the U.S.-Mexico war was officially over with the signing of the Guadalupe Hidalgo Treaty. The treaty defines the border between the two countries. After the treaty, many colonists arrived to begin farming on lands located in New Mexico and southern Colorado, particularly in the San Luis Valley. Before 1880, Colorado watered 49,000 hectares (121,000 acres) of land with the Rio Grande/Rio Bravo water. By 1896, the land under farming reached the 129,000 hectares (322,500 acres). In the El Paso-Juarez region, the farmers began to feel the effects of the water diversions in Colorado and New Mexico. The water deliveries were not sufficient to satisfy the irrigation demands of the people in both countries in the Ciudad Jarez/El Paso region. At that time, the only law was "prior appropriation", that is to say, the person who first applies water in a useful way, and continues using it without interruption, has the water property right (Lester 1977).

On November 25, 1886, Francisco Javier Osorno and Anson Mills, commissioners of Mexico and the United States, respectively, and responsible for investigating and judging the situation that prevailed in the El Paso-Juarez region, signed an agreement. The understanding regarding their investigations cited the growth of water diversions in Colorado since 1880, and the average runoff decrease in the El Paso-Juarez valley. They recommended the construction of an international dam as a feasible and adequate solution to the conflict. According to Bustamante (1999), who was the Mexican Commissioner of the International Water Commission (IBWC) from 1979 to 1985, the most important conclusion for Osorno and Mills was that "Mexico has been unjustly deprived, during many years of a part of its rights to the half of the stream of the Rio Grande/Rio Bravo, just as existed in the Guadalupe Hidalgo Treaty".

In 1888, the situation had become critical. The Rio Grande/Rio Bravo stopped running in the Juarez Valley for 60 days, from August to September, and in 1889 remained dry from August 5th to December 20th (Bustamante 1999). In 1892, the Mexican minister in Washington, Don Matías Romero, formulated several charges against the U.S. in which he declared that the population of the Juarez Valley had decreased by almost sixty percent from 18,630 inhabitants to 8,814, chiefly because of the decrease of water diversions caused by irrigation in New Mexico and Colorado. The private and public losses were estimated to be $35 million. The number of the irrigated acres fell from 25,000 hectares (62,500 acres) to 6,050 hectares (15,125 acres)

(Bustamante 1999). Romero also charged the U.S. with having violated Article VII of the Guadalupe Hidalgo Treaty.

On December 12, 1895, the U.S. Attorney in Law, Judson Harmon argued that:

> “... The only right that the treaty established... with regard to the Rio Grande, was that of navigation. The claims of Mexico against the United States and the compensation requested by damages to its agriculture are due to water shortage by the irrigation canals. All those inside the United States in places very far from the navigation place, are not supported in the treaty.” (U.S. Congress 1903).

This point of view was known, by the actors of the water debate at that time, as the Harmon´s doctrine. The heart of this theory is that given the fact that Mexico does not contribute with any amount of water in El Paso-Juarez Valley because this country does not have Rio Grande/Rio Bravo tributaries upstream, the U.S. was not obligated to respond to the Mexican claim for damages. It was an absolute sovereignty criterion.

Finally, on May 21, 1906, the U.S. and Mexico signed a treaty through which the U.S. would supply 74 million m^3 (60,000 ac-ft) per year to the Juarez Valley (USBR 2003). The capacity of the Acequia Madre was determined to be 8.5 m^3/sec (300 ft^3 /sec). At the same time, the Mexican government agreed to resign to all the claims against the U.S. by the previous damages due to water diversions upstream. “The Secretary of the Interior through the U.S. Reclamation Service (USRS) of recent creation at that time, as well as the New Mexico and El Paso water users took charge of the project financing. In agreement with the USRS, the cost of the Elephant Butte Dam was $7.2 million or $40/acre of a total estimated of 180,000 acres of land. After various delays, in 1911 the construction was initiated. The building of this largest dam at that time was finished in 1916 (Lester 1977).

2. Objectives

The economic damage caused by high salinity concentrations in each of the three irrigation water sources is calculated for the Juarez Valley. Historical losses that can be attributed to the water limitations imposed by reduced water allocations of the 1906 treaty are also calculated for the Juarez Valley. Maintenance problems associated with the drainage network of the 009 Irrigation District are also discussed.

3. Methodology

For the historic part of this research, an extensive literature search was carried out with greater emphasis on literature from the International Border and Water Commission, Mexican section.

The Maas and Grattan (1999) model was used to estimate the crop yield reduction due to salinity. The simulation software EXTEND was utilized to carry out this analysis. Data used in this analysis was obtained from the USBR and the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) of Mexico.

3.1 The Model of Maas and Grattan

Maas and Grattan (1999) developed a model that applies the agricultural relationships established by Ayers and Westcott (1985) for the estimation of crop yield potential. They provide a list of salinity coefficients for certain agricultural crops. These coefficients include *threshold and slope.*

> "The salinity threshold (*a*) is the maximum average soil salinity (EC_e) the crop can tolerate in the root zone without a decline in yield. The slope coefficient (*b*) is the percent loss in relative yield the crop will experience for every unit increase in EC_e above the threshold. Using these coefficients, the yield potential (% Yield) can be estimated from the following expression: % Yield = 100 – b(EC_e – a)." (Grattan 2003)

A standard for irrigation water quality for most crops is EC = 1mmho/cm, which is roughly equivalent to1 ton of salt in every acre-foot of water applied (Maas and Grattan 1999).

In the equation % Yield = 100 – b(EC_e – a): EC_e = electrical conductivity of the saturated soil paste in dS/m for the average root zone salinity. In order to obtain the leaching factor (LF) a new EC_e must be calculated. where EC_e is equal to a.

a = Salinity threshold or the maximum average soil salinity the crop can tolerate in the root zone without a decline in yield, in dS/m (decisiemens per meter). One mmho/cm = 1 dS/m.

b = Slope coefficient or percent loss in relative yield the crop will experience for every unit increase in EC_e. The a and b coefficients were obtained through personal communication with Dr. Stephen Grattan in 2003.

EC_w = Electrical conductivity of the irrigation water source in dS/m. Water source salinity.

1 dS/m = 1 mmho/cm = 1 ton/acre-foot = 810.71 mg/l

LF = Leaching Factor which is used to relate the fraction or percent of water applied to the field that actually drains below the root zone. "For example, if 1 acre-foot of water is applied to 1 acre of land, and 0.1 acre-foot drains below the root zone, the leaching factor is 1/10 (10 percent)". (Maas and Grattan 1999).

The equation used was : LF = $EC_w/((5* EC_e)- EC_w)$ (The Arizona University 2003)

In order to get a new EC_e the following relationships by Maas and Grattan (1999) are applied.

LF 10% leads to EC_w x 2.1 = EC_e

LF 15% - 20% leads to EC_w x 1.5 = EC_e

LF 30% leads to EC_w = EC_e

% Yield = yield potential

The experiments were conducted in an area of California similar to the El Paso/Juarez region where the climate is hot and dry during the summer. (Dr. S. Grattan, 2003, personal communication).

Table 3 illustrates the application of this model (period 1994-1995) to alfalfa and cotton.

Table 3. Example of how to obtain the %Yield of the Mass and Grattan Model (Surface water)										
1994	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	1.3	14.94	1.95	100	0	25,074,600	0	0
Cotton	7.7	5.2	1.3	3.49	2.73	100	0	96,643,500	0	0
1995	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	1.3	14.94	1.95	100	0	35,707,200	0	0
Cotton	7.7	5.2	1.3	3.49	2.73	100	0	121,681,600	0	0

Table 4 provides the yield potential in percentage, so that the difference between 100% and the %(Y) will give the production loss. Based on this production damage due to groundwater salinization, and by using the average crop price at that period (2002), it is possible to find the total loss in dollars for alfalfa, and cotton.

Table 4. Example of % yield loses and monetary values using the Mass and Grattan Model applied to groundwater in the Juarez Valley										
1994	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	2.7	36.99	4.05	85.04	0.15	53,925,000	3,752,414	375,241
Cotton	7.7	5.2	2.7	7.54	5.67	100	0	74,656,260	0	0
1995	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	2.7	36.99	4.05	85.04	0.15	35,707,200	5,343,582	534,358
Cotton	7.7	5.2	2.7	7.54	5.67	100	0	121,681,600	0	0

The economic impact due to the use of saline wastewater is presented in Table 5. Cotton is more tolerant of high salinity water than alfalfa

Table 5. Example of how to obtain the %Yield of the Mass and Grattan Model (Wastewater)										
1994	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	3.6	56.25	5.4	0.7518	0.25	25,074,600	6223516	622352
Cotton	7.7	5.2	3.6	10.32	7.56	100	0	96,643,500	0	0
1995	a (dS/m)	b (slope)	EC_w (dS/m)	LF (%)	EC_e (dS/m)	%Yield	Loses in %	Crop production value	Loses in pesos	Loses in dollars
Alfalfa	2	7.3	3.6	56.25	5.4	0.7518	0.25	35,707,200	8862527	886253
Cotton	7.7	5.2	3.6	10.32	7.56	100	0	121,681,600	0	0

Figure 2 shows the crop reduction due to the water sources salinity for alfalfa and cotton.

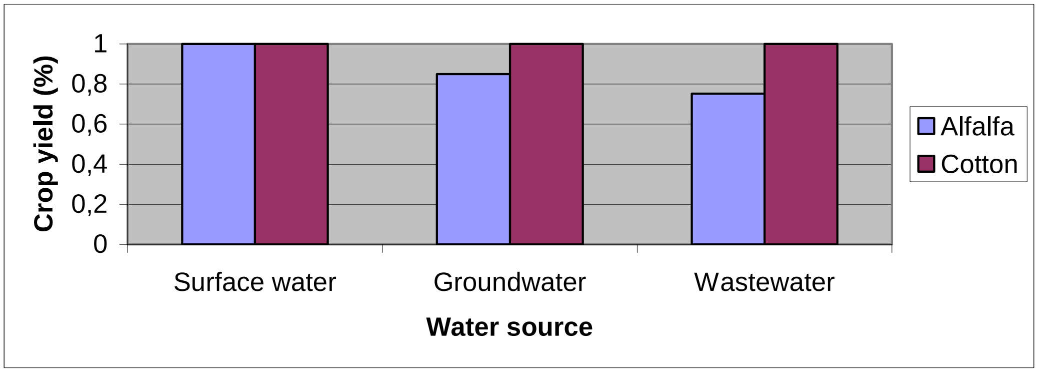

Figure 2. Crop reduction due to water salinity for the example

4. Results

Application of the model of Maas and Grattan to the 009 Irrigation District shows significant agricultural damage to the Juarez Valley due the salt content in both groundwater and wastewater. In addition, there is no damage due to dissolved solids from the waters of the Rio Grande/Rio Bravo. There is no evidence of certain influence of these waters for a potential low crop production in the 009 Irrigation District. Nevertheless, the historical average salt concentration (886 ppm) in the period 1936-1994 is above the 700 ppm threshold value. A summary of the calculated damages in the Juarez Valley is presented in Table 6. for alfalfa for the period 1994-2001. The time value of money using a discount rate has not been taken into account.

Table 6. Crop Yield Reduction (in %) and economic losses in irrigated Agriculture due to Water Salinity (period 1994-2004). Alfalfa

Water source	Alfalfa	Total
Surface water	**0**	**0**
Groundwater	**15**	**6,144707**
Wastewater	**25**	**9,223,936**
Total		**15,368,643**

Discussion

The results indicate a global loss of 153,686,430 pesos (15,368,643 dollars) in the crop mentioned due to salinity of the different types of water supply. Of the total economic losses, 15% from groundwater and 25% from wastewater. Alfalfa has little tolerance to salinity, while wheat, and above all cotton, have a high tolerance.

R. Salazar from the 009 Irrigation District has proposed compensation be paid by the U.S. to the District to permit the 009 Irrigation District to finance both a conservation program schedule (50,000 U.S. dollars), and the rehabilitation and modernization program (200,000 U.S. dollars) for the District (Salazar 2000).

6. Conclusions and recommendations

The model of Maas and Grattan (1999) constitutes an efficient and simple tool for the study of reductions in crop productivity due to water salinity. Based on this model, it was possible to calculate the economic impact on Juarez Valley agriculture due to high salinity concentrations in by this type of contamination. The economic loss is significant and is part of the stagnation of this agricultural zone as a result of the unfavorable distribution of the water between Mexico and the United States since 1906. Due to low water allocations in the 1906 treaty, the farmers have been compelled to utilize the brackish groundwater resources of the Juarez Valley and wastewater from Ciudad Juarez. A factor that acerbates salinity problems is the drainage network of DR-009. A study in the Juarez Valley should be conducted to determine the Maas Grattan´s coefficients and apply the results to this region. The governments of the United States and Mexico, should provide economic support to DR-009 through the National Water Commission (CNA) of Mexico to address drainage system problems.

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