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# Tile Drainage: A Strategy to Cope with the Food Challenge Facing Mexico

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**Abstract:** This paper deals with a drainage strategy to face Mexico' major challenge: food security for its current and future population. The National Development Program of the current administration defined crop priorities and volumes required for each crop. The irrigation districts in northern Mexico contribute 74.4% of the agricultural production and sustains the largest production of priority crops. Unfortunately, salinity threatens those irrigation districts, with about 24% of the northern Mexico irrigation districts affected by salts. The annual salinization rate was estimated at 10,000 ha/yr. Since the mid-1990s, tile drainage has proved to be a very successful tool to reclaim and control salt affected lands of irrigation districts in Mexico. Moreover, after salinity reclamation, drainage has restored land productivity to competitive levels. Tile drained lands not affected by salts have also reached competitive productivity, showing that tile drainage is a profitable investment that undoubtedly may contribute with the nation's food challenge. Salinity of 600,000 ha in the irrigation districts has reduced 1'471,518 t of priority crops such as corn, wheat, sugar cane and sorghum. The national total production goal is 10'970,000 t. It means that tile drainage rehabilitated lands can potentially contribute 13.4% of the national production goal. Some companies have invested in machinery and trained personnel to address this mayor threat to food production. The current estimates of land converted with subsurface drainage is about 100,000 ha in last 20 years. At the current reclamation rate, 5,000 ha/yr, there will be little impact on Mexico's food challenge, unless more land is reclaimed each year at least to cope with the current salinization. The national agricultural policy is designed to assist farmers by funding drainage needs at a 50:50 of cost, but there is still a difficult barrier due to limited matching funding. Researchers and drainage companies are proposing a strategy, whereby costs can be reduced when drainage installation companies work in neighboring areas. To implement such a strategy, farmers' and irrigation district's authorities (as advised by research institutions) need to set priorities and devise regional implementation plans. In this way operation costs could be lowered, and overall benefits optimized to achieve the target of reaching 13.4% of the food production challenge.

**Key words:** irrigation, drainage, salinization

## 1. Introduction

One of Mexico's challenges is to improve the productivity of agricultural lands. Production goals for food security have already been set in a SAGARPA (2013) [1] document, as described in Table 1. An almost eleven million tons gap can also be seen in the table.

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An analysis presented at the same document implies that production rates have been stalled. Some of the main causes are climatic, droughts and floods; degradation phenomena, and farmer's poverty.

Climate events. This is the main cause of the failure of one to three million ha, especially in rainfed agriculture, ranging from droughts to floods.

Land degradation. The most common land degradation process in irrigation is salinity, that affects the most productive lands.

Poverty. Weather extremes and degradation can be neutralized with technology; however, only 9% of Mexican farmers are able to pay for it [1].

**Table 1 Agriculture production goals for Mexico.**

| CROP | Production (million tons) | | Increment % | |
|---|---|---|---|---|
| | 2012 | 2018 | Absolute | Relative |
| White corn | 20.2 | 25 | 4.8 | 24% |
| Yellow corn | 1.8 | 3.0 | 1.2 | 67% |
| Wheat (grain) | 3.3 | 3.6 | 0.3 | 9% |
| Beans | 1.1 | 1.3 | 0.2 | 18% |
| Sorghum (grain) | 7.0 | 8.2 | 1.2 | 17% |
| Rice | 0.18 | 0.27 | 0.09 | 50% |
| Soy beans | 0.25 | 0.39 | 0.14 | 56% |
| Tomate | 2.8 | 3.4 | 0.6 | 21% |
| Sugar | 5.0 | 7.0 | 2.0 | 40% |
| Coffee | 1.36 | 1.8 | 0.44 | 32% |

Poverty in the rural areas is a vicious cycle, a farmer can't increase his land's productivity because he is not subject to credit, and he is not subject to credit because his land is not productive. This proposal is about breaking the cycle.

## 2. Salinity in Irrigation Districts of Mexico

Worldwide, out of 1,475 Mha in agriculture [2], 278.8 Mha are under irrigation [3]. Oldemann (1992) [4] reported 77 Mha affected by salts, where 20 Mha and 21 Mha had median and severe levels, respectively; however, considering that salinity figures are not very reliable, Caspari et al. (2014) [2] estimate 20% of the irrigated area, 55.8 Mha, affected by salts.

The concession area in the irrigation districts of Mexico is 2.53 Mha [5]. Table 2 shows salinity estimations for 1994 and 2015 per Basin Region. The 2015 data show 612,596 ha (24.2%), very close to the world figures. By comparing data from 1994 with 2015, the salinization rate is 11,093.6 ha/yr, little over the 10,000 ha/yr, estimated by Rendon (2000) [6].

**Table 2 Comparison of areal estimations of salt affected soils in 1994 and 2015 and the concession area of the irrigation districts per Basin Region [7, 8].**

| Key | Basin region | Area (ha) | | |
|---|---|---|---|---|
| | | Affected by Salts | | Concession |
| | | 1994 | 2015 | |
| I | Península de Baja California | 38,656 | 93,538 | 221,264 |
| II | Noroeste | 64,541 | 108,000 | 401,110 |
| III | Pacífico norte | 115,525 | 186,458 | 741,929 |
| IV | Balsas | 290 | 2,300 | 152,078 |
| V | Pacífico sur | 9,153 | 15,500 | 34,116 |
| VI | Río Bravo | 102,965 | 143,000 | 343,670 |
| VII | Cuencas centrales del norte | 60 | 0 | 31,721 |
| VIII | Lerma-Santiago-Pacífico | 17,957 | 22,000 | 308,265 |
| IX | Golfo norte | 26,372 | 35,000 | 133,649 |
| X | Golfo centro | 120 | 200 | 28,998 |
| XI | Frontera sur | 1,500 | 2,000 | 27,804 |
| XII | Península de Yucatán | 0 | 100 | 13,817 |
| XIII | Valle de México | 2,492 | 4,500 | 91,090 |
| | Total | 379,631 | 612,596 | 2,529,510 |
| | Percentage | 15.0% | 24.2% | 100.0% |

The Basin Region with the most area affected of the irrigation districts is *Pacifico Norte* with 186,458 ha (30.4%), followed by *Rio Bravo* (23.3%), *Noroeste* (17.6%) and *Peninsula de Baja California* (15.4%) that add up to 530,996 ha (86.7%).

Clayey soils are the most susceptible to salinization, which corresponds to 44%, 1.1 Mha, in the irrigation districts. This type of soils is widely distributed on the above-mentioned Basin Regions, therefore, there is a high potential risk of productivity loss due to salinity.

The loss of productivity of the irrigation districts due to salinity has a socioeconomic implication since it affects 110,000 farmers. Furthermore, there are 3,000 farmers from indigenous communities on four of the largest irrigation districts, and half of them have lands affected by salts.

## 3. Irrigation Districts and Food Security

The area affected by salts in the irrigation districts have serious implications on the food security strategy. Table 3 shows that the irrigation districts have the largest area, and also the largest production, of the priority crops. For example, the Basin Region *Pacifico Norte* is the highest producer of corn, beans and tomato. The Basin Region *Noroeste* Corn is the leading producer of wheat, while Basin Region *Rio Bravo* is the leader for sorghum.

**Table 3 Areal contribution (ha) of the irrigation districts to the priority crops per Basin Region**

| Basin region | Sugar cane | Beans | Tomato | Corn (Grain) | Sorghum (Grain) | Wheat (Grain) |
|---|---|---|---|---|---|---|
| Peninsula de Baja California | 0 | 2,766 | 317 | 5,964 | 5,856 | 103,325 |
| Noroeste | 0 | 4,620 | 1,306 | 26,385 | 8,897 | 263,654 |
| Pacifico norte | 23,201 | 80,388 | 7,957 | 406,495 | 102,054 | 23,381 |
| Balsas | 13,768 | 1,129 | 193 | 36,734 | 8,455 | 238 |
| Pacifico sur | 0 | 87 | 66 | 9,109 | 0 | 0 |
| Rio Bravo | 0 | 535 | 0 | 38,620 | 233,237 | 4,307 |
| Cuencas centrales del norte | 0 | 4 | 50 | 384 | 0 | 0 |
| Lerma-Santiago-Pacifico | 28,416 | 358 | 2,558 | 106,115 | 97,113 | 56,520 |
| Golfo norte | 39,835 | 934 | 496 | 26,145 | 32,496 | 0 |
| Golfo centro | 20,466 | 9 | 23 | 121 | 5 | 0 |
| Frontera sur | 9,038 | 227 | 0 | 17,700 | 29 | 0 |
| Peninsula de Yucatan | 5,505 | 21 | 9 | 107 | 0 | 0 |
| Valle de Maxico | 0 | 1,922 | 42 | 39,083 | 0 | 738 |
| Subtotal | 140,229 | 93,000 | 13,017 | 712,962 | 488,142 | 452,163 |

## 4. Salinity Control and tile Drainage in the Irrigation Districts of Mexico

Drainage is the most effective tool to control soil salinity. Rendon (2000) [6] stated:

"Salinity is steadily increasing in most of the irrigation districts of Mexico. The affected area — in different levels — is about 600,000 ha, out of which, 300,000 have either very low yields or have been abandoned, which means a very significant decrease in the farmers economy.

To cope with this phenomenon — at a rate of 10,000 ha/yr — the best technical and economical choice is tile drainage"

Although it is known that underground drainage with cement tiles have already been installed, the boom started with plastic tubing in Mexico in 1992 due to better costs and equipment. Table 4 shows the extension of tile drainage per Basin Region. The estimated total is 106,842 ha that implies an annual rate of 4,452 ha/yr.

**Table 4 Areal coverage of tile drainage with plastic tubing in Mexico by Basin Region in the period 1992-2016**

| Code | Basin region | Area with tile drainage (Ha) | Percentage (%) |
|---|---|---|---|
| I | Península de Baja California | 6,100 | 5.7% |
| II | Noroeste | 22,300 | 20.9% |
| III | Pacífico norte | 72,100 | 67.5% |
| IV | Balsas | 860 | 0.8% |
| V | Pacífico sur | 70 | 0.1% |
| VI | Río Bravo | 3,842 | 3.6% |
| VII | Cuencas centrales del norte | 0 | 0.0% |
| VIII | Lerma-Santiago-Pacífico | 200 | 0.2% |
| IX | Golfo norte | 70 | 0.1% |
| X | Golfo centro | 1,200 | 1.1% |
| XI | Frontera sur | 100 | 0.1% |
| XII | Península de Yucatán | 0 | 0.0% |
| XIII | Valle de México | 0 | 0.0% |
| | Subtotal | 106,842 | 100.0% |
| | Porcentaje | 4.2% | |

Although it covers almost the whole country, almost 94.1% is in north western Mexico, where salinity is more intense.

Tile drainage has restored the productivity of the lands where it has been installed. The average yield increase is 25%, obtained by surveys conducted by the tile drainage companies on their customers. The average is based on different crops, agricultural systems, protected (shadow nets) and open agriculture, and under pressurized or gravity irrigation conditions.

The plastic tubing tile drainage is a profitable investment, since in most cases its cost can be paid in less than three years and its duration is longer than 50 years with appropriate maintenance. Despite these concepts, the investment is not available to all farmers; therefore, strategies must be designed to make it available for most farmers, especially with land tenure below 10 ha. We have found that getting together several farms, the costs can be significantly abated.

Furthermore, installing tile drainage is five times less than open new agricultural lands, and current regulations make it almost prohibitive. Therefore, there are less opportunities to maintain and increase the nation agricultural productivity and the irrigation districts are a high investment.

### *4.1 Scenarios of Salinity Control with Tile Drainage*

Scenarios have been constructed to analyze the impact of tile drainage on salinity control, assuming a concession area of 2.53 Mha of the irrigation districts, an actual salinized area of 610,000 ha, and a salinization rate of 11,000 ha/yr. The results are shown on Fig. 1.

Scenarios involved annual installation rates of (i) 0, (ii) 5,000, (iii) 10,000, (iv) 15,000, (v) 20,000 and (vi) 30,000 ha/a. The best scenario is at a rate of 30,000 ha/yr where salinity coverage reduces to zero by year 2045. An annual rate of 20,000 ha/yr will reduce salinity by year 2080. The actual trend shows that by 2050 the average yield irrigated area in the districts will be only 1.5 Mha; i.e., 1.0 Mha will be either unproductive or abandoned.

Under the current situation, the food strategy will have a wider gap than the actual deficit of almost 11 million tons.

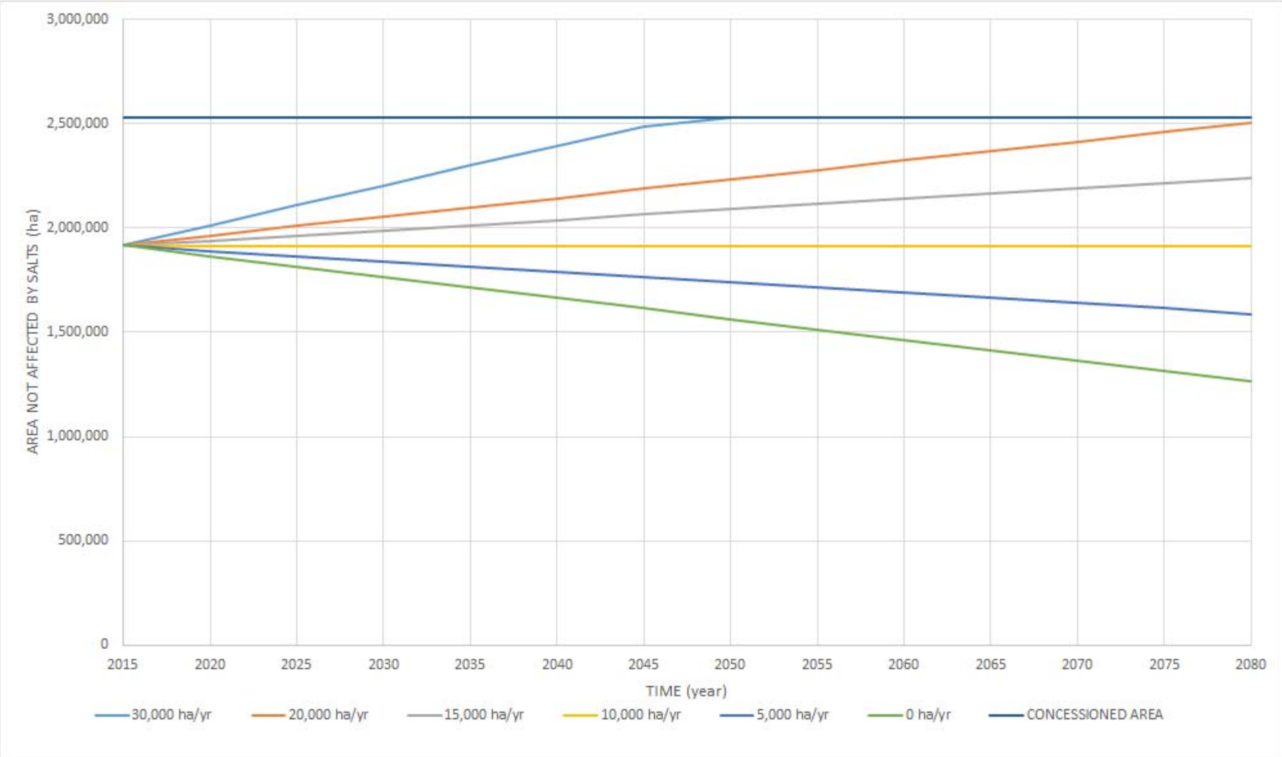


**Fig. 1 Scenarios of salinity control using tile drainage to cope the food strategy.**

On average the power consumption is in the stable sector with 164 kWh per cow and year. Main consumers are the lighting with 29%, the frost protection of the water supply with 19% and the facilities for the dung removal with 18%. In Table 5 it is visible that just in these consumption sectors the variance within the farms is very high. For the height of the power consumption with the lighting the used technics, the illumination level and period are important [9]. The high consumption differences by the frost protection are in the fact that at some farms the water pipes were moved not certainly about frost. Therefore the pipes must be also equipped with heating tapes beside the frost protection of the drinking troughs. The divergences with the energy consumption in the dung removal can be explained largely by the fact that on account of the topographic location, liquid manure must pumped up in the slurry dumps.

Preliminary priority areas are shown in Table 6 for the irrigation districts per Basin Region.

The strategy requires the combined efforts of scientists, farmers, government officials the drainage companies, and the financial institutions. Activities involved in the strategy are:

**Table 5 Short, medium and long-term goals of the Salinity Control Project in the irrigation districts.**

| Parameter | Short term | Medium term | Long term |
|---|---|---|---|
| Period | 2017-2018 | 2018-2030 | 2030-2050 |
| Production increase (t) | 120,000 | 720,000 | 900,000 |
| Restored area (ha) | 40,000 | 240,000 | 300,000 |
| Benefited families (farmers) | 4,000 | 24,000 | 30,000 |
| Indigenous families | 500 | 1,000 | |

a) Propose and discuss the schemas and action plans for the short, medium and long-term, in the priority areas to agree on the area, annual coverage and costs;

b) Establish the base costs for the federal and farmers investment with the drainage companies, based on market prices, and its update;

c) Monitor and evaluate the worked areas to verify its compliance with the national standards, as well as the compliance with the official Handbooks and Operational Rules;

IMTA will be responsible to record the projects, and make them available, in electronic format, as well as the complementary information to improve the planning, design and installation of the projects.

**Table 6 Areal distribution per Basin Region of the Salinity Restoration Program to insure and maintain the land productivity in the irrigation districts.**

| | | Area (ha) for each term | | |
|---|---|---|---|---|
| Code | Basin Region | 2017-2018 | 2018-2030 | 2030-2050 |
| I | Península de Baja California | 10,000 | 60,000 | 24,700 |
| II | Noroeste | 10,000 | 60,000 | 40,000 |
| III | Pacífico norte | 14,000 | 75,000 | 90,000 |
| IV | Balsas | | | |
| V | Pacífico sur | | | |
| VI | Río Bravo | 3,000 | 24,000 | 110,000 |
| VII | Cuencas del norte | | | |
| VIII | Lerma-Santiago-Pacífico | 900 | 9,000 | 12,000 |
| IX | Golfo norte | 1,500 | 9,000 | 23,000 |
| X | Golfo centro | | | |
| XI | Frontera sur | | | |
| XII | Península de Yucatán | | | |
| XIII | Valle de México | 600 | 3,000 | 300 |
| | Total area (ha) | 40,000 | 240,000 | 300,000 |

## 5. Conclusion

Drainage is the most effective tool to control soil salinity. Due to its cost and duration, it is a profitable investment for farmers.

The paper is about a strategy that will break a vicious cycle in the agricultural sector by reducing tile drainage installation costs to increase and maintain the agricultural productivity of the salt affected lands in the irrigation districts of Mexico to cope with the nation's food challenge.

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