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Mexico, Factor 2: Water Scarcity

Optimizing the bean crop production in Calera Zacatecas by using aspersion irrigation techniques

Water Scarcity

Water is not only crucial in agricultural productivity, but also essential for our existence, and therefore should be managed responsibly, yet it is not hard to realise how little we really care for it on a daily basis: *"Mexicans waste up to 50% of drinking water in homes due to the bad habits of consumption, waste, inadequate facilities and leaking pipes."* (Mendoza, 2011) It is estimated that 73% of Mexico's water bodies are polluted, since 80% of the discharges from urban centres and 85% of industrial discharges is spilled directly into them. Water scarcity is an alarming situation, and in Mexico it is affecting both, cities and rural communities, since population and economic growth have also put pressure over the country's water reserves, causing distribution problems (Enciso, 2012).

One of the main factors that promote water scarcity is the use of inefficient watering techniques, which are employed day by day in the Mexican agricultural industry, during this process 50% of the water used is lost as it evaporates or returns to underground aquifers (Suárez, 2010). It is especially important to raise awareness about water scarcity in Zacatecas because it is the driest state in the country and represents an important agricultural sector in Mexico. More than 55% of the 34 aquifers that exist in Zacatecas are exploited and more than 130 thousand hectares of crops are watered with these aquifers (Castro, 2011), as 85% of the state's water is destined for irrigation purposes, 12% in public water supplies and 3% are industrial used (Regalado, 2011).

About the affected zone: Calera, Zacatecas

The following information about Zacatecas will help us to summarize its problems in order to learn how that relates to the water scarcity problem and be able to address their specific situation:

1) Education: As stated by INEGI Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography) in 2010, 5.5% of Zacatecas' population is illiterate, while the national average is of 6.9%. From people 15 years and older: 66.8% have completed basic education, 14.1% finished high school and only 12.3% third level education. The percentage of beneficiaries of health services in Zacatecas is 68%, 3.9% more than the national average (INEGI, 2010)
2) Access to health care: it is limited for the Huicholes indigenous community, as they live in small rural zones that lack any medical infrastructure and they can't usually attend promptly to bigger communities' health centres. One of the reasons why this particular population is in urgent need of access to health care is the recent increase of chronic degenerative diseases, which researcher Juan Manuel Zepeda from Universidad Autónoma de Chapingo attributes to a change in their diet, because they now consume products with little nutritional value such as sodas and junk food which do reach their communities. As for bigger communities the percentage of people who are attended at social security institutions is 35.7% and the one who is attended at private hospitals and Secretaría de Salud medical services (Ministry of Health) is 64.3% (26.9% and 37.4% respectively) (INSP Instituto Nacional de Salud Pública [National Institue of Public Health], 2012)
3) Most homes in Zacatecas are nuclear households (69.2%), which are constituted by a leader and his or her couple, who could have children or not. The average family size is between 3 and 5 people: two parents with one to three children (INEGI, 2005). More than half of its population (52.1%) earn only up to two minimal wages a month, 29.2% earn from two to five and only 18.7

earn more than five (INEGI, 2000). Lack of income keeps the population from having an adequate diet. The most frequent food products found in the Mexican's diet are: corn tortillas, red tomatoes, chicken eggs, sugary sodas, milk, beans, onion, potatoes, sweet bread, chicken, pasta, white sugar, rice, vegetable oil, beef steaks, Serrano and Jalapeño peppers, white bread, banana, ham and ground meat (INEGI, 1998)

4) Agriculture is a fundamental activity in rural areas; staple, fodder, orchards and vegetable crops are and will be significant structural components in Zacatecas' agricultural production. Family farms, typically located by rural housing tend to vary in size between 0.01ha and 0.1ha; they produce food for their own consumption, agro products, and generate an additional income (INEGI, 2007) (Food and Agriculture Organization)

Regarding the information given, I find that the water scarcity problem is strongly related to Zacatecas' agriculture as both, an economic activity and a provider of nutritious food for families. In order to save water and optimize the production of a determined crop, a water-conscious irrigation technique should be employed. Calera is a small county in Zacatecas. Its hydrological resources used to conform a significant productive potential in such a dry state and crops are still being cultivated there, so I think it would be great to alert farmers in this county for them to efficiently seize their ground and keep contributing to the production one of the most significant components of the Mexican's diet: the bean, which is one of the main resources in Calera, given the fact that Zacatecas is the main bean producer in Mexico (El Debate, 2013).

Table 1 contains some of the most relevant data about bean plantings in Calera compared to the state's production (INEGI, 2011):

	Calera	Zacatecas
Surface	4352 hectares	503,851 hectares
Volume	1349 tons	108,882 tons
Value of the production	1292 USD	94,375 USD

Table 2 summarizes relevant physiographic conditions about Calera (INAFED Instituto Nacional para el Federalismo y el Desarrollo Municipal [National Institute for Federalism and Municipal Development], 2010):

Location	22.908611º latitude, -102.659444º longitude and 1mi 642.67yd altitude
Topography	It is a plain with some hillocks, with no significant elevations
Hydrography	It suffers a shortage of both surface water and groundwater
Yearly Rainfall	The precipitation pattern is among the lowest (570 mm. annual average)
Weather	Generally dry
Temperature	The average is 60.8ºF. Maximum temperatures are recorded in the month of May (86ºF) and minimum in January (24.8ºF).

Beans

Zacatecas' bean planting zone is not only the biggest in Mexico but in the entire world (Ollaquindia, 2014): the bean is a basic and strategic product of Mexico according to the Sustainable Rural Development Act (LDRS, 2001). There are four domesticated bean species out of 50 that have been

identified in Mexico: Common bean (*Phaseolus vulgaris*), Ayocote (*P. Coccineous*), Comba (*P. Lunatus*) and Tepari (*P. acutifolius*). The importance of the common bean resides in the quantity of surface destined for its seed and grain production, given the fact that, in Mexico, it ranks second in terms of acreage and, of course, it is of great socioeconomic significance as it represents the second most notable agricultural activity in the country as well. Appearing in an extensive list of traditional dishes, it is fundamental in the Mexican population's diet due to its nutritional qualities, diversity of varieties, distinguished from other grains because of its high protein content. In addition, it has been historically associated with the development of Hispanic cultures and, even today, it plays a major role in feeding a large amount of the world's population (Treviño Quintero & Rosas Quijano, 2013).

Water availability and temperature are the main abiotic factors that hinder the production of beans; both are closely linked and now their effect has been intensified by climate change. This has affected the production gradually until, in 2011, due to an extreme drought the bean harvest was reduced by 58.9% in Zacatecas and 15.8% more beans were imported from the USA compared to the year before (Treviño Quintero & Rosas Quijano, 2013).

While the crops experience *water stress* (when water demand is more than the amount available for a given period) we can perceive a reduced growth in general, because that induces a sort of self-protecting response that alters their morphology, physiology and metabolism. This ends up producing changes that let carbon dioxide in, which directly affects the photosynthesis process and, therefore, the efficient formation of essential nutrients. In Calera's climatic conditions, water deficit and high temperatures promote a disease known as charcoal rot, caused by an imperfect fungus, which is the most common disease for beans in the country, reporting a 20% to 30% loss from the total production. When an infected plant dies, the remaining pathological component starts a new infection cycle.

According to SAGARPA Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food), in 2009 Mexico occupied the fifth place in the world as a bean producer, eighth as an importer, but doesn't export, which means the grain's main destination is domestic consumption and there's a shortfall.

Several problems that the bean crops suffer in Calera are due to water scarcity, when the land started being cultivated there was no concern for preserving an ecological balance, and I think the farmers should know about the availability, pollution, planning, management and protection of their water resources. Given the fact that it's got a generally dry weather and most part of the region has been declared a protected area, the water resources that used to be considered to have valuable productive potential, demand rationality in their use (Murillo López, 2013).

Proposal

To approach this situation it is convenient to use aspersion irrigation techniques to water the bean crops in the zone, in the next paragraphs I'll explain how does this method work and how it could help to optimize the bean production in Calera, Zacatecas. I think it is important for such a relevant bean-planting zone to recognize the benefits that water-saving irrigation techniques could bring them and that they don't necessarily mean a great expense. By optimizing the bean production with an efficient irrigation technique not only the amount of the water used is less, but we are also raising awareness about water scarcity, as the farmers will ascertain that the aspersion method is appropriate for this area and will help them with determined crop issues:

Irrigation is the amount of water that is applied to the crop artificially. Aspersion watering is a form of irrigation whereby treated water reaches the plants in the form of localized "rain" in which the resource is supplied from a central sump by a pumping system. This technique demands less water than the furrow and flood irrigation methods and could be easily used on uneven surfaces (SEMARNAT Secretaría de

Medio Ambiente y Recursos Naturales [Ministry of the Environment and Environmental Resources]), such as Calera's hillocks.

The bean crop is susceptible to cold temperatures, and while the average temperature of Calera (60.8ºF) seems perfect for the optimal 60.8ºF-75.2ºF range of temperature for healthy bean growth, this is not entirely true, since this average is obtained by measuring the constant, and often abrupt, changes of temperature: winters in Zacatecas could be extremely cold for appropriate production; low temperatures delay growth, as the bean doesn't tolerate frost. (Treviño Quintero & Rosas Quijano, 2013) Irradiation is a phenomenon that occurs when, during the day, the earth is warmed by the sun's rays and at night the heat received irradiates from the ground, lowering its temperature, and it's another factor that intensifies freezing: frosts provoked by irradiation are favoured by Calera's meteorological conditions like dry air (Murillo López, 2013) and low wind (8.1 km/h on average, according to INIFAP Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias' [National Institute for Forestry, Agriculture and Livestock Research] real time report, retrieved August 20th, 2014). A benefit that aspersion irrigation provides for this issue is an active protection, as the water sprinkled functions as a heat source. This works based in the principle that when water freezes it releases a considerable amount of heat and its temperature is maintained at 32ºF as long as water remains in the process of freezing (Fuentes Yagüe, 1987). As the crop won't have to expose itself to intolerable conditions that delay its growth, food availability is increased.

According to the Mexican company Tornado (specialized in irrigation systems) the cost of a modern aspersion irrigation system that covers 3229.2 ft² of land is of 3440.94 USD, translating this to 1 ha (107639 ft²) of bean crops cultivated in Calera means that an estimated budget for this project is of 8771.98 USD, which includes:

- Pumps (1 HP)
- Computer Controllers
- Electromechanical valves
- Rain sensors
- Sprinklers and Nozzles
- Pipes and materials
- Manpower

Table 3 explains how the cost could be distributed:

Provider	Percentage provided
The farmer or the farming company	10%
Non-repayable capital from the government	30%
With the support of a company such as DuPont, Grupo Carso, Nestlé or Monsanto*	60%

This technology could be applied to a family farm without such a great expense. The cost of single artisanal sprinkler is low compared to the one of a sprinkler purchased at a store (Reyes & Cadillo, 2012). A farmer from Peru designed this sprinkler for his family's farm, which is easy to build, use and maintain. The artisanal aspersion irrigation technique will save water and therefore reduce bean's production

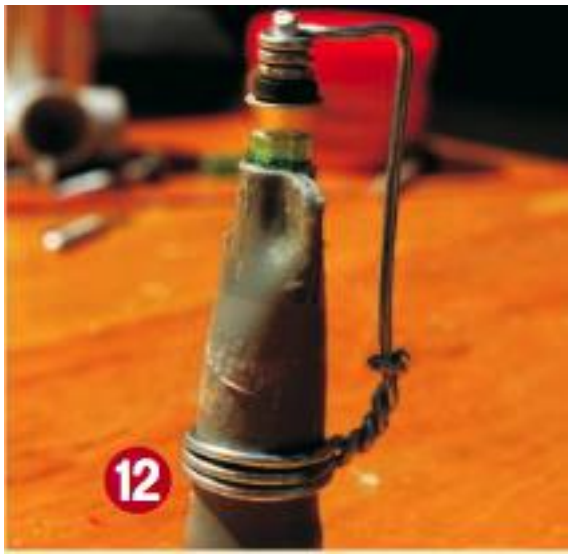
* These companies were selected because they remain conscious about food security or, in the case of Grupo Carso, it has programs for social benefit through several foundations, which belong to the group.

expenses, which would help families to get the most out of their land and will assure having a healthy component of their diet, in case that they cultivate for their own consumption.

Table 4 lists the materials used to build one sprinkler using Moisés Reyes' technique and its approximated cost according to The Home Depot México:

Materials and Tools needed	Approximated Price in Mexico (USD)
Plastic tube ¾'' thick and 23.6 in long	2.17
Mechanical pencil	0.61
15.7 inches of galvanized wire	0.16
Thick-headed screw	0.73
Glue for the plastic tube	1.52
Knife	3.43
Sand paper	0.53
Two tweezers	7.61

The process consists in shaping the end of the Plastic tube (23.6 in long) by applying a little heat, inserting the mechanical pencil's body in its centre, and then seal the sides by flattening them with two tweezers. After applying glue in the modified end of the tube we can now stick the mechanical pencil's body properly, only showing its tip so it'll function as a funnel, and when water is driven through the tube it'll extrude. To create the sprinkling effect, the end of a 15.7 in long galvanized wire is wrapped into a screw's head and the other end is tightly rolled on the tube and adjusted in a way that secures the screw's head 2 millimetres above the tip of the mechanical pencil body's tip (Reyes & Cadillo, 2012).



Technical concerns about the efficiency of this method in Calera's context:
Irrigation is commonly expressed in centimetres (cm) as "thickness" or "sheet irrigation". To obtain the **ns: net sheet irrigation** (quantity of water that should be supplied considering the *Application Efficiency*) we should divide the **gs: gross sheet irrigation** (amount of water that the crop requires to carry out its physiological functions) by the percentage of **AE: *Application Efficiency*** (the relationship between the volume of water actually used by the plants and the volume of water withdrawn at the intake, represented as a percentage). (Servín Palestina, Medina, Casas, & Catalán, 2012)

Formula: Ns=gs/AE

Considering that the average *Application Efficiency* obtained using either pivot or linear sprinklers set on low pressure is of 84% (Harms, 2011) and the average gross sheet irrigation in the Zacatecas irrigation district is of 131cm (CONAGUA Comisión Nacional del Agua [National Water Commission], 2010) we could substitute the formula stated above to estimate the quantity of water that should be supplied considering the *Application Efficiency*:

$$Ns=131cm/84\%$$
$$Ns=2cm$$

In conclusion, an estimate of the net sheet irrigation using sprinklers set on low pressure is of 2cm, a lot less water that the average net sheet irrigation that was used in Mexico between 1990 and 2002: 33cm using an average gross sheet irrigation of 56cm. This is important because it proves that the aspersion irrigation method applied by low-cost artisanal sprinklers works efficiently and could definitely help to optimize the bean production in Calera, remaining conscious about the water scarcity problem.

In this work I showed some of the problems that have a great impact in the daily life of Zacatecas' families and presented the need to implement the aspersion irrigation method as an alternative capable of helping to improve agricultural productivity by guaranteeing the availability of a quality product, which is the bean. As I previously noted, this method could protect the bean from suffering the effect that frosts have in the plantings and winter productions could be improved. The artisanal sprinklers' technique has the advantage of being very simple, having a low cost and low maintenance, besides, as shown in the result listed above, a lot of water is saved in the process, compared to regular irrigation methods. This is why its implementation could result in significant improvements regarding profits. If revenues are higher, people will have access to a healthy and more varied diet, which would improve their lives' quality. Finally, a crucial part of the significance of this irrigation technique in general is that it saves water, yet distributes it efficiently. Using water responsibly is essential to preserve the resource for future productions, assuring this is especially important in a generally dry state that happens to be the main bean producer in Mexico. Saving water in an agricultural process that helps people to earn an income and supply the population's demand for this product is an efficient way to address the water scarcity problem.

During the process of investigating about Calera Zacatecas in order to see how water scarcity affects its bean production, I didn't only learn the facts stated here, but realised that I could come up with a viable solution. I had no idea where do most part of the beans produced in Mexico come from, and I eat them almost everyday. I was so calmly aware of the terrible problem that water scarcity means to humanity and realising this makes me think that maybe most of us remain in this condition. This work has really given me en entire new perspective of my own country and how it faces the world.

I'd like to conclude with a quote that has a lot to do with how I feel about this project:
"If the future's only hoped for we are doomed"–Greg Graffin

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