IMPROVING SURFACE IRRIGATION IN MEXICO AS
NATIONAL POLICY PRIORITY

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ABSTRACT

Mexico’s population will increase 30% by 2050 demanding a sharp increase in food
mainly from irrigated agriculture. However, agriculture demands water, an
increasingly scarce, variable and shared resource in a context of population growth,
ecological development, climate change and environmental awareness. Irrigated
agriculture has adapted to natural rainfall variability with large investment in hydraulic
infrastructure and conversion from surface irrigation to pressurized irrigation system.
However, surface irrigation systems are still dominant in Mexico covering more than
90% of irrigated land. Consequently, the Mexican government implemented an
integral program to improve surface irrigation called Technified Surface Irrigation
Project (RIGRAT for its acronym in Spanish) in large-scale irrigation districts. This
paper describes the RIGRAT program as adopted in a changing world, operated by
trained field technicians as Water User Associations (WUAs) staff and supervised by
the federal water agency with the following components: scientific irrigation
scheduling, surface irrigation design, irrigation application, volumetric delivery,
irrigation evaluation and irrigation service follow-up. After two water years of
implementing the program, the results indicate that it is possible to reduce field
irrigation depths without decreasing conventional yields, improving irrigation practices
with participation from irrigation extension workers, farmers, WUAs, federal
government and universities under the umbrella of an integral program to improve
surface irrigation as a WUA service.

Keywords: Furrow irrigation, Irrigation service, Irrigation policy, Mexico.

1. INTRODUCTION

Two thirds of Mexican land is arid or semiarid, where irrigation is concentrated. With a
short rainy season from June to September, Mexico depends highly on irrigated
farming for food security. Although irrigated land accounts for one-third of the 20
Million hectares (Mha) agricultural land, it generates about half of the agricultural
production and more than two-thirds of the export oriented agricultural production.

Irrigated areas of Mexico have been classified for institutional purposes into two major
groups: irrigation units and districts. Large economical resources were invested by
the government in irrigation infrastructure to develop 3.4 Mha in 86 large irrigation
districts that were administrated and operated by the public sector until they were
transferred to Water User Associations (WUAs). There is a 3 Mha area distributed in
more than 40,000 small irrigation units that were developed by producers and
receives much less participation from the public sector compared to irrigation districts.
However, the era of massive public investment in irrigation is largely over, as pointed
by Turral et al. (2010). Factors, that drove irrigation development in the past, need to
be balanced with new needs.

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Mexico began its institutionalized irrigation policy in 1926 increasing its irrigated land. Irrigated corn yields have increased at a consistent rate from 2.0 Mg/ha in 1970 to 9.5 Mg/ha in 2014, almost an increase of five times in less than five decades due to improved varieties and better technological packages. On-farm irrigation management has not had important improvements in the last three decades.

One major deficiency of Mexican irrigation districts is the availability of robust field irrigation data. The delivered water is poorly measured at the turnout and farm level resulting in poor estimation of irrigation efficiencies. In most Mexican irrigation districts, ditchriders are responsible for most operation decisions in their command block. Decisions are mainly based on conservative rules acquired over the years (Ojeda et al, 2007). Better technologies do not necessarily mean new, expensive, or sophisticated options (Turral et al., 2010). Since the main application method is surface irrigation, a lot of improvement needs can be executed with low cost at field level to increase agricultural water productivity to produce more with less water.

This paper describes the technically improved Gravity Irrigation (known by its Spanish acronym as RIGRAT) program, implemented in Mexico as a national action. This program is operated by trained irrigation technicians as WUA staff and supervised by the federal water agency (CONAGUA).

1.1 Previous On-Farm irrigation improvement plans

In the past, the Mexican government implemented the on-farm irrigation improvement plan (known by its Spanish acronym as Plamepa) in irrigated districts when they were administrated by the federal government. This plan was in operation for about 10 years (1967-1977) financed mainly by the Inter-American Development Bank (BID). Plamepa concentrated in two main activities to improve water and land productivity on farms below the average district efficiency: i) improvement of operation and distribution of water and ii) on-farm irrigation improvement. Staff from several federal institutions provided technical assistance to farmers not only on irrigation techniques, but also on agricultural technology. Information from about one-million hectares was compiled generating a rich database of soil, climate, topography, and crops. Local capacities were developed to generate an “irrigation recipe” for each farm with information about furrow irrigation design (orientation, inflow and length). Thousands of measuring structures were also built and demonstration plots were established to test and show farmers the importance of good irrigation practices. Unfortunately, Plamepa recommended fixed irrigation schedules and unexpectedly ended in 1977.

On-farm irrigation extension services continued through the Irrigation and Drainage Engineering office (known as “IDRYD” for its initials in Spanish) with staff dedicated to update climatological, hydrological, agrological, topographical, and drainage studies and to offer irrigation service to farmers such as irrigation scheduling, irrigation design, and land leveling. IDRYD was also in charge of improving irrigation water management efficiency both in the conveyance and distribution network (Palacios-Vélez and Pedraza-Oropeza, 2015). After irrigation management transferred to Water User Associations (WUAs), IDRYD functions disappeared and WUAs no longer were in charge of on-farm irrigation extension services. Now, the National Institute of Agricultural Research (INIFAP) and Mexican Institute of Water Technology provided some irrigation extension services to main irrigation districts but they have had very limited impacts. To compensate for this deficiency, private banks and farm-input suppliers often provide their own technical assistance to main clients.

In the last 35 years, most of the technical improvements of irrigation district at farm level was mainly concentrated to convert gravity irrigation system to pressurized system, and targeting WUAs to consolidate irrigation water transfer through staff training, machinery acquisition, improve minor irrigation network, land leveling and drainage. Some of those tasks received funding from international development
banking (World Bank and Inter-American Development Bank) with some contribution from national funds. In this dynamic, some projects were implemented as the Farm development project and On-farm & Minor Irrigation Networks Improvement project (PRODEP for its Spanish acronym). Although minor and farm infrastructure improved in many irrigation districts, surface or gravity-driven irrigation is by large the main application method used by farmers to irrigate crops in México.

1.2 Technical Improvement of Gravity Irrigation (RIGRAT) program

The Mexican government has in operation an ambitious program for Technical improvement of Gravity Irrigation (RIGRAT for its Spanish acronym) in main irrigation districts paid by government and Water User Associations. This low-cost program is based on a personalized irrigation assistance to farmers during a water year through irrigation extension workers.

RIGRAT consider that farming is a risky activity and only the producer takes on the risk. Therefore, the program’s objective is to help the producer to best couple crop water needs with irrigation delivery with as much flexibility as possible. This allows to increase water use efficiency and yields using modern on-farm irrigation management practices considering the irrigation scheme constrain.

The RIGRAT Project has the following components:

**Irrigation extension.** Professional extension support in on-farm irrigation management is the core of this program. Irrigation professionals were hired, one technician per 1,000 ha, to offer irrigation extension services as a link among local water authorities, WUA, producers and irrigators. The WUA staffer offered direct assistance to irrigators to improve the irrigation application during the water year in close communication with WUA staff and water users. One irrigation supervisor is needed per 10 Irrigation Extension staff (IEs) to coordinate and revise advances and program implementation. One of the problems when hiring IEs was the lack of irrigation professionals, as educational agricultural curricula tend to concentrate on single popular agriculture disciplines such as pest control and crop production. Hence, they had minimal knowledge about irrigation management and limited build capacity regarding a needed trans-disciplinary approach (problem-orientated learning). Therefore, IEs received special training and technical support from a research or academic institution, called implementing entity, which overviewed the program at each WUA. Extension staff are paid by the federal government (75%) and WUA (25%). In some districts, the provincial government also participate with some expenses (<15%). IE are competent in irrigation water management, agro-climatology, irrigation engineering. In a second stage, it is necessary to improve competence in crop production, soil science, irrigation economics, and extension for effective intervention with irrigation farmers. IEs also have some demonstration plots to show producers good irrigation management practices and also harvest the plots to compare yields with traditional irrigation management.

**Irrigation design.** To achieve high efficiency and uniformity of irrigation using gravity-water application methods requires attentive field management after performing an optimal irrigation design. The inflow rate into a furrow is an important design factor considering needed water depth, soil type and furrow length. A furrow-design software is used to estimate optimal inflow and length so that the water reaches the end in a reasonable amount of time with minimum water erosion. IEs are responsible for obtaining design parameters, perform furrow irrigation design and follow that irrigators apply the design recommendations and once the water reaches the end of the field irrigators must manage the inflow to reduce tailwater runoff losses. An "irrigation recipe" is generated in advance per each irrigation event considering actual crop irrigation requirements.
Irrigation scheduling. The agronomical concept associated with irrigation scheduling requires applying water in the amount and frequency required by crops to maximize crop production and/or profit and maintaining a reasonably high irrigation efficiency without affecting irrigation scheme performance. Each WUA participating in the RIGRAT program has compiled a database with information about crops, soils, weather, water distribution networks and water users, to estimate the irrigation water needs for each single plot. Recommended irrigation schedules are adjusted by the IE according to the water delivery system capabilities and constraints. RIGRAT staff is responsible also for soil and crop sampling to obtain irrigation scheduling parameters. Automatic agrometeorological station-networks register reference ET data in most irrigation districts in Mexico.

Land levelling. Surface irrigation demands that fields should have a uniform slope in the direction of water flow to obtain high efficiency. The RIGRAT project focuses to increase such uniformity through precision land-leveling in WUAs participating in the project. Land-levelling information is compiled by the IE and financed through federal programs with restrictions in field slopes and soil depth.

Volumetric delivery. Estimation of applied water per irrigation is a key indicator of the program however metering the individual water consumption of each plot is costly and problematic. Volume is estimated at turnout level through flume or weirs where WUA distribute water to several plots or farms. It is more difficult to determine amounts of water applied at plot level when using surface irrigation than when using pressurized methods. Water applied to each furrow is estimated using siphon tube measuring with head-discharge curve. The main constraints to install a hydraulic measuring device in each plot is the low irrigation service fee paid by water users. To solve this, each IE is equipped with a portable flowmeter to estimate flow based on velocity-area method, and later the volume delivered to each plot is estimated as a first step to implement a volumetric pricing in the near future.

Irrigation monitoring. Several farm irrigation monitoring indicators were defined and are evaluated in the field to monitor irrigation events. Soil moisture is also estimated in many WUAs. Each IE is equipped with a TDR-type sensor and used during farms visits to monitor soil moisture.

Program follow-up. As a program that uses public funds, RIGRAT has to measure and publicize quantitative assessment not only of overall project performance, but also of contributions to performance from each WUA in term of water use efficiency and yields. Program follow-up provides a framework for assessing project improvement and as a mean for transparency and accountability.

2. METHODS

The project RIGRAT is now implemented in 200 thousand hectares in Mexico’s main irrigation district. It was expected to grow to one million hectares at the end of the present federal administration. The Mexican Institute of Water Technology is in charge of nine irrigation districts (IDs). One of those IDs is the Irrigation District (ID-075) used as case study in this paper, and organized in 13 Water User Associations (WUAs). The ID-075 is supplied by two reservoirs using two major open channels. ID-075 is located in the northern part of the state of Sinaloa, México; 25.4-26.1° N, and 108.4-109.4° W, and has an average altitude of 20 m through September 31 of the following calendar year. The global district efficiency was estimated about 25% from reservoir to farm due to unlined open-canal networks and surface-based irrigation.

Only four out 13 WUAs are participating in the RIGRAT program as pilot modules: Leyva Solano, Ruiz Cortines, Sevelbampo, and Pascola. In the first year of RIGRAT’s implementation, the water year 2013-2014, ID-075’s total pilot area was 3,944 ha with 384 farm plots at an average plot size of 10.3 ha. One of the goals during this year was to estimate reference irrigation data at farm level.
A database with field data was compiled containing: field length and slope, surface roughness, supplied turnout, and user. The following irrigation data were also compiled for each irrigation event: desired application net depth, net and gross applied irrigation volumes, date, duration, time to cut-off, and inflow rate.

Several average performance indicators were estimated at different integration level, from plot to turnout, WUA, and Irrigation district as compared with conventional irrigation: application efficiency, yield increase, saved irrigation volumes, participating users, plots and area, attending area per IE. At the beginning of the project, a survey was applied to a sample of participating users. This gave a framework about producer’s expectation about program.

3. RESULTS AND DISCUSSION

According to applied survey at the beginning of the project, 79% of the users did not use a method to estimate farm inflow. When asked to users about the causes of deficient irrigation, 40% was attributed to topography, 20% to deficient irrigation service, 20% to irrigators, 10% to deficient support to define timing and duration of irrigation. Most answered that pest and weather were the main problems associated with production, only less than 10% considered irrigation as a main problem. The producers expected from the RIGRAT in order by priority: to increase yields, reduce inputs, and decrease irrigation volumes. Results from the survey gave a diagnosis about the producer before the project’s implementation.

With the implantation of RIGRAT, now it is possible to follow each irrigation and its accumulation at the end of a water year at farm level. Total net and gross depths at plot level during the water year 2013-2014 are indicated in the Figure 1 and estimated application efficiencies are indicated in Figure 2. Both figures show high variability of delivered irrigation depths and are consequences in the application efficiencies at farm level.

![Figure 1. Total net (Lₙ) and gross (Lₖ) depths at plot level during the water year (2013-2014). As reference, the average net and gross depths are indicated are vertical lines.](image-url)
Figure 2. Application efficiencies at plot level during the water year (2013-2014). As reference, the average application efficiency is indicated as vertical line.

Since irrigation’s depths are estimated at several operating levels at a WUA, it is interesting to know the variability of required and delivered volumes at farm and at WUA control point. Figure 3 compares required volume at farm level and volume at WUA level for irrigation district 075.

In spite of large investments in hydraulic investment in irrigation district, efficiencies are low and highly variable among WUA’s for same irrigation district. Figure 4 indicates the average application and global efficiencies for water year 2014-15 for WUA’s participating in the RIGRAT project at ID075. Results indicate that global efficiencies at water source level are very low since the main reservoirs are far away from the agriculture zone with low conduction efficiencies.

Figure 3. Comparison of required at farm and delivered at turnout per WUA in Dam$^3$/ha for water year 2014-2015.

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$^5$ Dam$^3$ is Cubic decameter: 1 Dam$^3 = 1000$ m$^3$
One of the performance indicators of the RIGRAT project is water productivity. Figure 5 indicates contrasting differences in water productivity values among participating WUAs which depend on efficiencies from field, turnout, WUA and ID.

Several problems emerged during the first stage of program implantation:

1. Low quality of irrigation data from previous years complicated to have the reference irrigation data.
2. Low availability of qualified professional irrigation extensionists in participating IDs.
3. Limited local suppliers of irrigation equipment demanded by the program
4. Limited local machinery to perform precise leveling works.
5. Program was initially heavily oriented to on-farm irrigation management but irrigation is only an input of production. Now the program needs to cover other production factors that limit production such as fertilization and crop management.
6. IEs have had problems with opportune salaries since part of their salary come from government.
7. Deficient communication between IE and WUA’s staff.
8. Some WUAs give to IEs other activities different to RIGRAT duties.
9. Most IEs are concentrating only on plot irrigation but this is only part of the whole irrigation service.
10. Several governmental institutions have programs focusing on farm improvement that can be concurrent and integrated to RIGRAT program.

Figure 5. Average water productivity (Kg/m$^3$) estimated for WUAs participating in the RIGRAT at ID075 for water year 2014-2015.
After conclusion of second year of RIGRAT implantation, it would be possible to evaluate program’s performance indicators.

4. CONCLUSIONS

Following one water year of implementing the on-farm irrigation management program, the results indicate that it is possible to reduce field irrigation depths without decreasing yields and improving irrigation practices with participation of irrigation extension staffists, farmers, WUAs, federal government and universities under the umbrella of an integral program to improve surface irrigation as a WUA service.

Qualified professional irrigation extension staff played an important role implementing the on-farm irrigation management program (RIGRAT) as part of WUA staff, not as government employees. Therefore, the promotion of appropriate standards and the professional certification of irrigation extension staff and field irrigators concerning their expertise and experience in the program is highly recommended.

As a subsidized program, RIGRAT provides an incentive to farmers and WUAS for adoption of water efficient irrigation technologies and practices in irrigation districts where surface irrigation is dominant and irrigation service fee is low.

REFERENCES

