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PLANNING FOR INCREASING IRRIGATION EFFICIENCY IN MEXICO

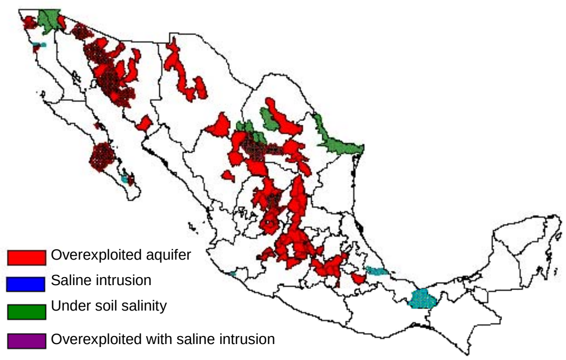
Ignacio Sánchez Cohen, Hilario Macías Rodríguez, Phil Heilman and Roy Mann *

ABSTRACT: In 1996, Mexico joined the International Council of Watersheds. Within this council, the society participates in decision taking regarding natural resources management. This scheme has relevancy in the northern states of Mexico given the severe drought that this part of the country has suffered since 1990. This paper presents a strategy linking researchers, officials and water users of the irrigation district No. 017 in the Comarca Lagunera which belongs to the hydrological region 36 in northern Mexico. Users participated in building a matrix of problems and possible solutions. A Decision Support System (Facilitator) was used for making decisions. Solution alternatives have been valuated by expert opinion. Results have been analyzed considering different order of importance. According the findings, the price of water needs to be increased to make the system sustainable. Other important alternatives are: to train water users in irrigation matters, increase conveyance efficiency and to provide basic knowledge for agribusiness.
KEY TERMS: irrigation district, decision, watershed, sustainability.

INTRODUCTION

In Mexico there are 6.2 millions of hectares under irrigation. Out of that, 90% are under surface irrigation methods. In this way, as in many Irrigation Districts (ID) of the world, the main problem in the ID's of Mexico is the low overall irrigation efficiency. Thus, it is estimated that loss of water by conduction, distribution and application is as low as 63% (CNA, 2000). Some indexes highlight the low efficiency at plot level as: low water productivity, water loss, social conflicts, soil degradation, insufficient hydraulic infrastructure conservation and rehabilitation. Nevertheless, one can group the problems in the ID's of Mexico in two: oversize of the area of the ID's and overexploited aquifers, see Figure 1.

* Respectively, Research Leader, Researcher at the National Center for Disciplinary Research on Water, Soil Plant and Atmosphere Relationships (INIFAP CENID RASPA) Km 6.5 Canal Sacramento Gomez Palacio, Durango Mexico, Phone: (871) 7191076, FAX: (871) 7191134. E-mail: sanchez.ignacio@inifap.gob.mx, macias.hilario@inifap.gob.mx, Researcher at the Agricultural Research Service, Tucson Az, Southwest Watershed Research Center, 2000 E. Allen Rd. Tucson, AZ 85719, Phone: (520) 670-6380 x148; Fax (520) 670-5550, E-mail : heilman@tucson.ars.ag.gov; NRCS Retired, 1301 Tamarisk West Inn, OR 97068, Phone: (503) 650 8220, E-mail: rsmann@eleport.com



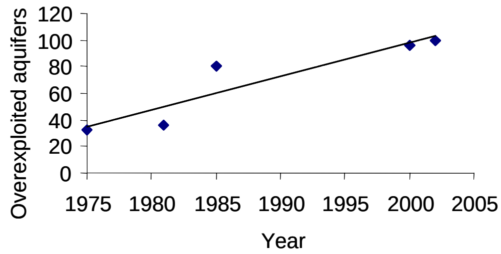


Figure 1: Overexploited and saline aquifers in Mexico and trend. (CNA, 2003, Sánchez 2005)

Beginning 1996, Mexico joined the International Council of Watersheds. Within this council, the society participates in decision taking regarding natural resources management through the regional Watershed Councils. The Watershed Council encompasses the ID's which after their release to the users, have been organized in irrigation modules which involves water users with several productive interests. This difference in interests along with the water market make the decision process a difficult task each year when officials and water users have to come to an agreement on how much water and when should be released from the dams for the agricultural year. For helping this decision taking process, a decision support system was proposed to the hydraulic committee of the irrigation district No. 017 in the Comarca Lagunera which belongs to the hydrological region 36 in northern Mexico. Users participated in building a matrix of problems and possible solutions.

Approach

The strategy was to link researchers, officials and water users of the irrigation district seeking to build a matrix of problems and possible solutions. A Decision Support System (Facilitator) was used for making decisions.

The approach used in this paper was first proposed by Wymore in 1988. An application of this method to water quality problems in agriculture is described in Heilman *et al*. (2004). The software is a generic, multiobjective decision-making tool called the Facilitator, and incorporates the hierarchy tree of decision criteria by Yakowitz and Weltz (1998). This application uses information from various sources to build the effects matrix that quantifies the impacts of the options on each decision criterion (Lawrence and Shaw, 2002).

The three steps to make a decision using the Facilitator are: 1.) create a table of the effects of each alternative on each criterion by defining the decision variables or criteria, the management alternatives to be considered, and quantifying the effects of the alternatives on the criteria; 2.) use available data, models and expert opinion to score all values in the table to eliminate units and normalize elements to a scale of 0.0 to 1.0, with 1.0 being as good as possible; and 3.) rank the decision variables in order of importance, graphically examine the results, and select the alternative(s) to implement or study in more depth.

When performing the first step with the Facilitator, decision-makers (DM) are responsible for excluding unacceptable alternatives. Unacceptable alternatives refers to those alternatives that impact only to one sector of the water users, are redundant, have a very high cost of implementation, are politically driven or serve personal or particular interests.

In the second step, DM select score functions for each decision variable. Within the Facilitator there are five options of score functions: more is better (parabolic), more is worst, desirable range, more is better linear and non desirable range. For this case, a more is better linear function was selected since the information came from the stakeholders and specialists directly.

The third step assumes a simple additive value function of the form:

$$V(w,v) = \sum_i w_i v_i \qquad 1$$

to calculate an overall value, V, as the sum of the products of a weight, w, associated with each decision variable, or criterion, i, and the score, v, for that decision variable. Although conceptually simple, the approach can be difficult to apply because decision-makers find it difficult to assign weights. Yakowitz *et al*. (1993) developed a method that eliminates the need for decision-makers to specify a weight for each decision variable. Instead, the decision-makers rank the decision variables in order of importance and the software calculates the range of possible weighting combinations for the decision variables. This method calculates a range of values representing the alternative, rather than a scalar value that quantifies the overall value of the alternative.

Suppose there are n criteria, which the decision-maker has ranked in importance. Let V_{ij} be the score of alternative j evaluated with respect to criterion i in the importance order. If w_i indicates the unknown weight factor associated with criterion i, the highest (lowest) or best (worst) additive composite score for alternative j, consistent with the importance order, is found by solving the following linear program described for the weights w_i:

$$\begin{aligned} max(min)\ V_j &= \sum_{i=1}^{n} w_i v_{ij} \\ subject\ to\ \sum_{i=1}^{n} w_i &= 1 \\ w_1 \geq w_2 \geq \ldots &\geq w_n \geq 0. \end{aligned} \qquad 2$$

In both cases (maximizing or minimizing) the first constraint normalizes the sum of the weights to 1, while the second requires that the solution be consistent with the importance order and restricts the weights to be nonnegative. Yakowitz et al. (1993) also showed that the best and worst composite scores could be calculated in closed form, as the maximum or minimum composite score can be calculated by solving the following k problems, starting at the highest ranked criterion and adding criteria until they have all been considered:

$$v_{kj} = \frac{1}{k} \sum_{i=1}^{n} v_{ij} \qquad 3$$

The best or worst composite score for alternative j is then selected from the results as:

$$BestScore = BV_j = \max_k \{v_{kj}\},$$
$$WorstScore = WV_j = \min_k \{v_{kj}\} \quad 4$$

A later study (Yakowitz and Weltz, 1998) improved the weighting algorithm by incorporating a hierarchical importance ordering, so that a number of sub-objectives could be grouped under categories such as “erosion” and “water level” being grouped under “sustainability”.

Site Description

The irrigation district *017* consists of 20 Civil User’s Associations, 17 of which are along the Rio Nazas and 3 along the Río Aguanaval. There are 224,000 hectares in the district, of which 93,000 are irrigated. The district consists of almost 38,000 members, 85% of the members belong to the collective landholding organizations, or *ejidos*, with the remainder considered small landholders. Almost 2,500 km of canals are used to distribute an authorized annual average water volume of just over eight hundred thousand cubic meters.

Within the context of the hydraulic committee farmers decide which crops to plant based on their allocation of water .The main crops are cotton, vegetables, and forages. Because of the varying supply of water and fluctuating prices, the area planted with each crop varies significantly each year.

From the point of water delivering, there is a substantial problem with the efficiency of the system delivering water from the dams to the irrigated areas. Estimates of efficiency indicate that 63% of the water is lost between the module hydraulic infrastructure and application on irrigated fields. Irrigation water needs to be transported long distances to individual irrigated fields, rather than short distances to compact areas that are completely irrigated. A further complicating factor is the shift in responsibility for managing the canal network from the central government to the user groups. This shift has exacerbated planning and maintenance problems for the network of canals.

The alternatives considered include:

- Changing the cropping pattern to less water demanding crops
- Changing to winter forage crops to reduce evapotranspiration
- Training members of the irrigation district in water conserving technology
- Rehabilitating the hydraulic infrastructure
- Shrinking the irrigated area and introducing a water market
- Varying the price of water according to amount in reservoirs
- Training for agribusiness
- Delivering water by volume
- Baseline – Continuing with current management

Effects were estimated on a scale of 0 to 1.0, with 1.0 being as high as possible (maximum benefit / minimum impact). As previously written the estimates were directly generated as scores, so there was no need to use a score function to eliminate units. If the baseline situation continued, the effect would be a score of 0.5 for each of the four alternatives. The DSS tool calculates all possible combinations of weights that are consistent with the importance order of the criteria according equations 2 through 4.

Results

Alternatives were grouped under three general groups: Economic criteria, Social criteria and Technical criteria. Software runs were performed for the different ordering of the criteria. Independently of the criteria of evaluation selected, the alternative vary the water price scored the highest for achieving the overall objective of increasing water productivity in the irrigation district. At the present, water is not charged to irrigation users, they only pay the rights and services for using water. On the other hand as the Irrigation Districts have been transferred to the users, the management and conservation is suppose to be on the water users association but no effort has been put on maintenance of the basic hydraulic infrastructure which impacts global efficiency and demerits the effort of irrigation technical improvements at farm level. On second place, the alternatives that will yield satisfactory results are: delivering water by volume, hydraulic infrastructure rehabilitation and irrigation training to users. Nevertheless, any alternative will do better than the current management system.

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