23

Research Report

Performance of Two Transferred Modules in the Lagunera Region: Water Relations

G. Levine, A. Cruz Galvan, D. Garcia, C. Garcés-Restrepo, and S. Johnson III

International Water Management Institute

Research Reports

IWMI's mission is to foster and support sustainable increases in the productivity of irrigated agriculture within the overall context of the water basin. In serving this mission, IWMI concentrates on the *integration* of policies, technologies and management systems to achieve workable solutions to real problems—practical, relevant results in the field of irrigation and water resources.

The publications in this series cover a wide range of subjects—from computer modeling to experience with water users associations—and vary in content from directly applicable research to more basic studies, on which applied work ultimately depends. Some research reports are narrowly focused, analytical, and detailed empirical studies; others are wide-ranging and synthetic overviews of generic problems.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI's own staff and Fellows, and by external reviewers. The reports are published and distributed both in hard copy and electronically (http://www.cgiar.org/iimi) and where possible all data and analyses will be available as separate downloadable files. Reports may be copied freely and cited with due acknowledgment.

Research Report 23

Performance of Two Transferred Modules in the Lagunera Region: Water Relations

G. Levine, A. Cruz Galvan, D. Garcia,
C. Garcés-Restrepo, and S. Johnson III

International Water Management Institute
P O Box 2075, Colombo, Sri Lanka

The authors: D. Garcia is Agricultural Scientist, Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) while G. Levine, A. Cruz Galvan, C. Garcés-Restrepo, and S. Johnson III are Research Fellow, Field Engineer, Head, IWMI-Mexico, and former Head of Mexico and Latin America Program, respectively, of the International Water Management Institute.

Paper presented at the second Seminario Internacional: Transferencia de Sistemas de Riego, Guanajuato, Mexico July 16–19, 1996 (Revised December, 1996).

The authors acknowledge the critical assistance of the staff of the two modules studied and express their sincere appreciation to the *ejiditarios* and *pequeño propietarios* who permitted access to their fields and information. In addition, the authors are very appreciative of the willingness of the CNA to share their data, and their experience. They also express their appreciation to their research colleagues in OSTROM who assisted in evaluating potential salinity impacts.

IWMI gratefully acknowledges the financial support for this study from allocations from the unrestricted support provided by the Governments of Australia, Canada, China, Denmark, France, Germany, Netherlands, and the United States of America; and from the Ford Foundation and the World Bank.

G. Levine, A. Cruz Galvan, D. Garcia, C. Garcés-Restrepo, and S. Johnson III. 1998. *Performance of two transferred modules in the Lagunera region: Water relations.* Research Report 23. Colombo. Sri Lanka. International Water Management Institute.

/ water policy / performance / privatization / irrigation systems / operation / maintenance / irrigation efficiency / water user associations / water rights / water allocation / water supply / Mexico /

ISBN 92-9090-357-0
ISSN 1026-0862

The International Irrigation Management Institute, one of sixteen centers supported by the Consultative Group on International Agricultural Research (CGIAR), was incorporated by an Act of Parliament in Sri Lanka. The Act is currently under amendment to read International Water Management Institute (IWMI).

Contents

Summary

This report evaluates the degree of success of water users in managing water allocations and deliveries in two modules in Irrigation District 017, Coahuilla-Durango, Mexico. The users received O&M responsibilities in 1993. Groundwater, while important in the region, is not under the jurisdiction of the user groups, and is not reported here. Policies and practices are evaluated from the standpoints of the nature of the planning rules, consistency, equity, and efficiency in implementation of the plans. Deliveries were measured at module and field headgates, and yields were measured by sampling. One year's results indicate that the joint management by the users and the Comisión Nacional del Agua has been reasonably successful in implementing water allocation and cropping plans without locational (head/tail) or type of user (*ejido*/private) biases. Relatively low Relative Water Supplies at the parcela level suggest there may be irrigated areas not officially recorded. Overall system water efficiency was approximately 60 percent while field irrigation efficiency averaged 68 percent, using CROPWAT estimations of evapotranspiration. Within-field yield differences (head/end) were approximately 10 percent, suggesting modest possibilities for yield improvement through land leveling or other forms of within-field irrigation improvement.

Performance of Two Transferred Modules in the Lagunera Region: Water Relations

G. Levine, A. Cruz Galvan, D. Garcia, C. Garcés-Restrepo, and S. Johnson III

Introduction

Mexico has a vast land area of approximately two million square kilometers. In excess of 75 percent of the country is classified as arid and semiarid and water is the constraining agricultural production factor in many areas. As a result, the total cropped land is only around 20 million hectares. With such a large extent of arid land, irrigation plays a critical role in terms of overall agricultural production. Irrigation has been practiced in Mexico since pre-Hispanic times, even before the Mayans, with many small diversions and canals being built to meet the agricultural needs of the population.

It is estimated that at the beginning of the Revolution there were approximately 1.2 million hectares of irrigated land. Much of this land had been developed by various land companies, mainly American (USA), for the purpose of growing plantation crops such as sugarcane and cotton. The Constitution of 1917 nationalized the country's water resources and these irrigation systems became the responsibility of the state. After the Revolution, the government continued to expand the irrigated area in the country.

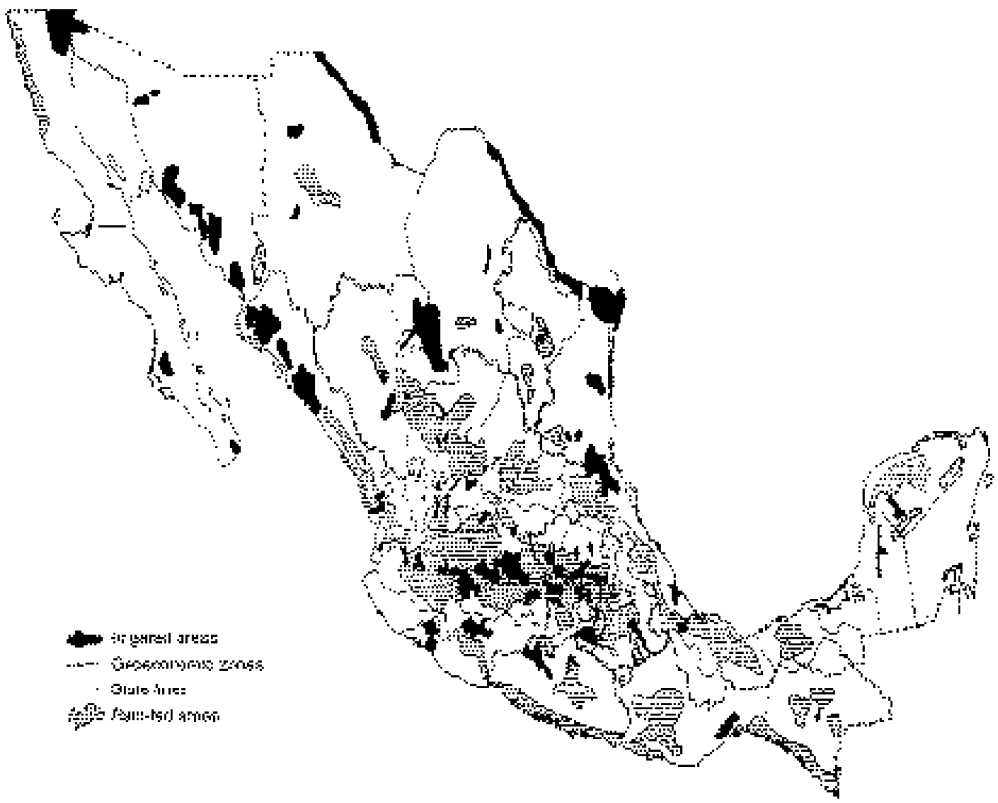
By 1960, the agricultural census reported a total of 4.3 million hectares in the country (Trava 1994). During the 1970s and 1980s irrigation investment continued to be a high priority. As a result, Mexico now has the largest irrigated area in Latin America with a total of 6 million irrigated hectares, including 3.3 million hectares in 80 public irrigation districts and the remainder served by small-scale communal and private systems as well as by deep wells. The distribution of Mexico's irrigated area is shown in figure 1.

In 1989, as part of the National Development Plan (1989-1994), there was a major modification of the water law of Mexico, within which was the creation of the National Water Commission (CNA) (Gorriz, Subramanian, and Simas 1995). The CNA was created with an explicit mandate to define a new policy for the management of the waters of the country. This led to the development of the National Program for Decentralization of the Irrigation Districts under the National Development Plan; this was designed to establish a system of irrigation management co-responsibility between CNA and the water users where the 80 public irrigation systems would become financially self-sufficient (Espinosa de Leon and Trava Manzanilla 1992).

Phase I of the transfer program gradually shifted responsibility for government-managed irrigation districts to water user associations, with each of the water user associations being responsible for the operation and maintenance (O&M), financial resource mobilization, and dispute resolution, within a unit (*module*) [1] that starts at

[1]Modulos are hydraulically defined areas served by one or more secondary channels representing the distribution portion of the irrigation district. They vary in size from 1,000 hectares to as large as 50,000 hectares.

FIGURE 1.
Irrigated and rain-fed areas in Mexico.



the secondary canal level and extends to the individual farm intakes. These water user associations are legal entities under Mexican law. The CNA retains responsibility for managing the water source and the main canal. This program was designed to eliminate government subsidies to the districts, and to improve the efficiency and productivity of the sector. To eliminate the subsidies, it was necessary to increase user water fees to cover all O&M and administrative costs, including the costs incurred by CNA in operating the water source and the main canal.

Phase II of the transfer program creates Limited Responsibility Societies (LRSs) that are federations of the individual modulos. LRSs are responsible for operating all the main canals, drains, and roads of the irrigation district. The federation also permits the pooling of the maintenance equipment provided to the modules, resulting in economies of scale in the use of this equipment. When the LRSs are in place, CNA is responsible for managing the water source, as well as playing a larger role in overall water resource planning and development in the country. Between 1990 and 1995, Mexico transferred responsibility for over 80 percent of the area under government control to the users (CNA 1995).

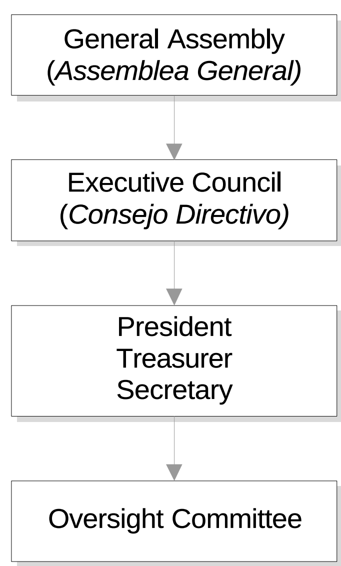
Irrigation districts, prior to transfer, were subdivided into geographically based administrative units (*unidades)* that facilitated planning and operations of the districts. During the process of transfer, the new units, modules, were formed. In most cases these subdivided the unidades into smaller units, as it was felt these would be easier for the WUAs to manage. However, while the modules that were established initially were relatively small, later ones were created larger as it became clear that financial self-sufficiency required a larger area to generate sufficient income. As of 1996, over 380 modules were formed and 7 LRSs established.

The performance of the transferred systems in Mexico is of major interest, not only to the Mexicans, but also to many others in Latin America and other parts of the world where similar transfer programs are in the process of being fostered by the various development banks and bilateral development programs. The study of the performance of transferred systems is an important part of the research program of the International Water Management Institute (IWMI), with data being available for systems in Colombia, Sri Lanka, and the Philippines.

Ideally, a comparison of the performance of the transferred systems with that of the systems prior to transfer would be most useful in evaluating the utility of this approach. However, in very few cases have there been systematic studies prior to transfer. Such is the case in Mexico. Similarly, it would be desirable to study the transferred systems under more or less the same external economic and social conditions as those experienced prior to transfer. Unfortunately, during the period of this study Mexico was experiencing major adjustments in its economy, and in its social contract with the peasant (*ejido*) sector. In addition, 1995 was the third year of an increasingly severe drought, placing the transferred systems in a severe stress condition. This combination of circumstances makes a definitive before and after comparison impossible. The results should be considered only as a determination of the performance of two irrigation systems jointly managed by the users and the government agency during a period of severe water and economic stress. Additionally, it should be remembered that the field results reported here are for only 1 year.

As indicated earlier, the first stage of transfer represents a period of shared management, with the CNA retaining responsibility for the source of the water, and for its conveyance to the modules, including maintenance of the primary canal system. To carry out this responsibility, the CNA is organized with Regional, State, and District offices. At the District level, the CNA organization includes separate offices for operation, maintenance, and administration. The modules have the responsibility for all operation and maintenance below the level of the primary canal, individually from their point (or points) of control. Their organizational structure is illustrated in figure 2.

FIGURE 2.
Typical water user organizational structure.



The operating structure usually includes a Chief Engineer, secretary, statistical office, a number of *canaleros* (ditch riders), equipment operators, etc. The numbers and types of these operating personnel depend upon the size and character of the irrigation system.

Between the CNA District and the Module organization is the *Hydraulic Committee.* This committee is a critical one in the structure of the shared management phase of the transfer program. The committee is composed of the President, who is the Chief Engineer of the District, and representatives (usually the presidents) from each of the water user organizations. Representatives from other interested parties, e.g., federations of producers of specific crops, may be invited to attend the meetings. The committee meets every month, or more frequently if necessary, and is generally charged with fostering the effective functioning of the district, serving as a forum for interchange among the water user organizations, as well as between the users and the CNA. In this respect, the committee serves as a mechanism for reconciling different needs of the CNA and the users. Gorriz, Subramanian, and Simas (1995) give a complete description of the responsibilities of the Hydraulic Committee.

Though the transfer program is relatively new, there are early indications that transfer is perceived by the users to result in improved performance (Gorriz, Subramanian, and Simas 1995). However, there have been few field studies of actual performance of the transferred systems. This report gives an account of the surface water performance as part of a comprehensive study of two modules within Irrigation District 017 Region Lagunera, in the State of Durango. The agricultural area within the Lagunera Region is approximately 220,000 hectares of which slightly less than 95,000 hectares receive irrigation service. Water scarcity is a dominant feature in the region, with yearly rainfall around 200 mm and annual evaporation approximately 2,000 mm. Prior to transfer, there were seven operational unidades in the district. As a part of the transfer process, 20 modules were established and, as of late 1996, 15 of these have been established as WUAs.

Results presented in this report trace *surface water* allocations and deliveries from the reservoir to the field level, with identification of the policies and practices used in delivering the water to the users, differentiating between the *ejiditarios* (communal landholders) and the private landowners. Although very important in the district, the role of groundwater is only discussed briefly at this time since the modules have no operational control of groundwater extraction. (Approximately three-quarters of the total water used by the *pequeño propietarios* (small owner)[2] and one-quarter of that used by the ejiditarios comes from groundwater.) Subsequent studies have addressed groundwater use, as well as the agricultural and economic performance of the transferred units, and the impacts on the rural families.

[2]In Mexico, there are private landowners, limited to 100 hectares or less.

Research Questions

In this study, research focused specifically on six questions:

1. What is the basis for the decision by the Hydraulic Committee on the area permitted for planting, and how well is it implemented?
2. How well is the proportional water allocation rule implemented by the modules and the farmers?
3. How equitable is the distribution of water between head and tail users?
4. How equitable is the distribution of water between ejiditarios and pequeño propietarios?
5. What are the system- and field-level water efficiencies?
6. What are the opportunities for improving system productivity?

Research Methodologies

The study was carried out using information routinely collected by CNA, information from the farmers, and by a measurement program designed to obtain accurate information on the volumes of water reaching the farmers, the distribution of this water among different groups of farmers, and within *parcelas* (the fields) of individual farmers. The details of the procedures follow:

Parcela selection

Parcelas were selected in each of the modules to represent head and tail locations, different land tenure (private and ejido) situations, and differential access to groundwater (pumps and no pumps). Eight parcelas were selected in each module.

Flow measurement

At the point where water management responsibility is transferred to the module (*punto de control*) the CNA makes current meter measurements twice daily (in the morning and late afternoon). The modules check these measurements at times. IWMI made similar measurements during the irrigation season.

Current meter measurements were also made at the entrance to the individual parcelas. This, coupled with the time of irrigation, permitted the determination of the volume delivered.

Distribution within parcelas

Gravimetric soil moisture measurements were made in each parcela 1 day before and 3 days after each irrigation. The soil samples were taken at approximately one-quarter and three-quarters of the length of the parcela; samples were taken at 10 centimeter (cm) depth intervals to a depth of 1.2 meters (m). The rate of extraction so determined was extended to cover the 4 days not included in the measurements. This permitted the determination of water extracted from the profile at each location.

Evapotranspiration

To facilitate comparisons, CROPWAT was used to estimate evapotranspiration. To determine the possible oases effects, the CROPWAT estimates were compared with the water extracted from the soil profile, and the difference calculated.

Yields

Yields were obtained at the one-quarter and three-quarter points in each of the parcelas by field sampling using sampling frames. For row crops, two samples of two rows, each 1 m long, were harvested at each location. For alfalfa, a one by one-meter frame was used.

Results

The following sections present the data to answer the questions as well as discuss the results and their implications.

1. What is the basis for the decision by the Hydraulic Committee on the area permitted for planting, and how well is this decision implemented by the modules and the farmers?

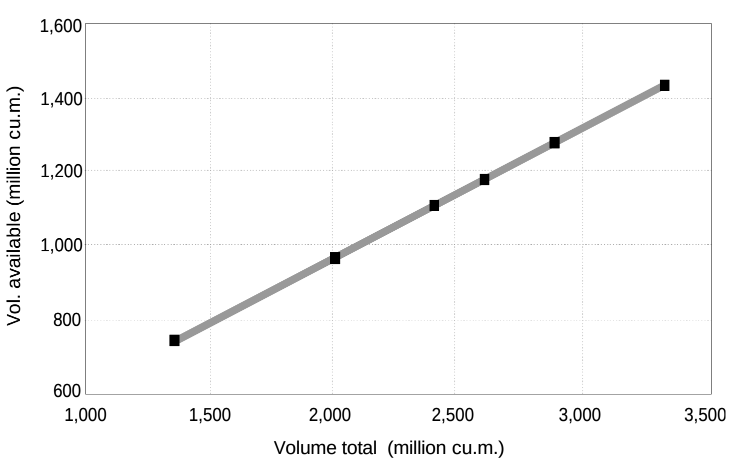
Water rights for irrigation under the revised Mexican water law are based upon the principle that the available water is to be allocated in proportion to the irrigable area. This principle is formalized through a *concession* for a limited time period (usually between 10 and 25 years) negotiated with each module. The concession grants a water allotment, based on the proportion of the district area within the module. In general, the concession is not in the form of a volumetric allocation,[3] but is dependent upon estimations of available seasonal, or annual supply.

The primary source of water for the district is the Rio Nazas, with a total reservoir capacity in Lazaro Cardenas of approximately 3,600 million cubic meters. To specify the area that can be irrigated from the volume considered available in the reservoir, the Comisión Nacional del Agua (CNA) estimates the volume in the reservoir (using the stage/volume relation for the reservoir[4]) as of October 1 each year, and then specifies the volume available. The relation between actual storage and available water is shown in figure 3. The data indicate that between the lowest and highest volumes of available record there is a linear relation between the estimated volume in the reservoir and that considered available for use (with a correlation coefficient, r^2, of .96). The slope of 0.39 implies that approximately 40 percent of the incremental additions of water to the reservoir are considered available for allocation.

[3]Well concessions are stated in volumetric terms of maximum permissible annual withdrawals.

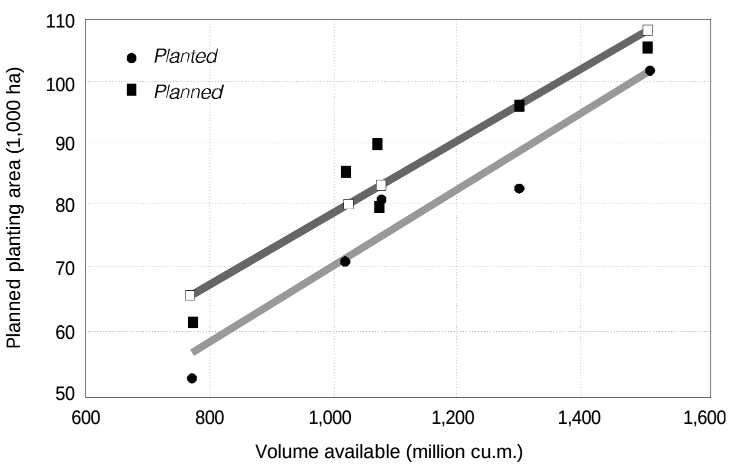
[4]The stage-discharge relation appears to be based on the original surveys. Sedimentation is likely to have reduced the total available storage, but may not have exceeded the dead storage allowance.

FIGURE 3.
Volume of water available as a function of total volume in reservoir.



The specific rationale for this relationship is not apparent. Projecting the relationship to zero storage implies water is still available for allocation, an obvious impossibility. Thus, at some reduced level of storage (clearly less than 50% of capacity), the procedure for estimating availability would have to change. Since the reservoir provides opportunity for intra-seasonal, and even annual carryover, one rationale for the constant ratio is to proportion changes in storage for use over time. Why this proportion should be constant is unclear. The change in losses from seepage and evaporation from the reservoir surface is unlikely to remain a constant proportion of the change in storage, and thus real availability is not strictly proportional at the different stages. That the decision about availability is somewhat arbitrary is illustrated by the special circumstances of the 1996-97 season. When the decision about availability was to be made in 1996, the CNA recommended a volume consistent with the relation shown in figure 3. The Hydraulic Committee objected, referring to the critically constrained irrigation season during 1996 and the need to have the largest possible area for economic recovery; they were able to negotiate for a greater declared availability.

FIGURE 4.
Actual v. planned planting a s a function of planned volume.



Based upon the water considered available in the reservoir and considering the evapotranspiration and expected losses in conveyance, the CNA suggests the area that can be irrigated to the District Hydraulic Committee, which has the nominal authority to make the irrigated area allocations for the district for that season or year. The implicit policy underlying this decision, based upon an analysis of allocations and plantings for a 7-year period is illustrated in figure 4, which shows the planned irrigated area as a function of the estimated available water in the reservoir.

The planned area for irrigation is linearly related to available water supply with a correlation coefficient (r^2) of 0.95. The linear relationship implies that no managerial changes are expected or imposed as the available water supply declines.[5] The relative water supply (planned) (RWSP)[6] implicit in this relationship is approximately 1.7.[7] This suggests that *the maximum overall technical water efficiency*[8] *was estimated to be approximately 58 percent,* though *the actual basin-wide efficiency may be significantly greater* due to the recovery of losses from the conveyance system through the extensive pumping of the groundwater.

Figure 4 also indicates the area actually planted during those same years by the farmers in the district. The average area planted was approximately 10 percent greater than that allocated, and the slope of the relation with volume available is almost parallel to that planned (the slope is slightly steeper—0.068 v. 0.061, and with a similar correlation coefficient of 0.965). This increased level of planting (normalized to a cotton equivalent),[9] would have resulted in increased district-

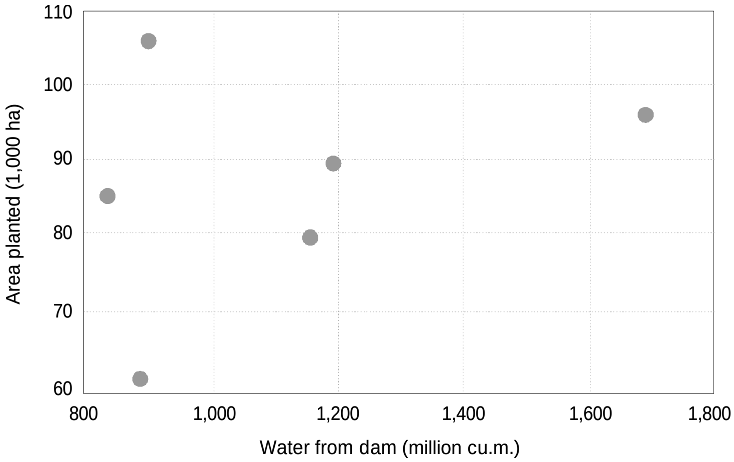
[5]For the 1996 cropping cycle, in a situation of extremely low water supply, the CNA recommended the irrigated area be confined to only a portion of the district, effectively abrogating the district-wide equity, but maintaining the general relationship between area to be irrigated and the available supply.

[6]The Relative Water Supply (RWS) is defined as the ratio of Total Water Supply (irrigation + rainfall) to the Water Requirement. As such, it is mathematically the inverse of the customary technical water efficiency. However, it is used as an *independent* variable, while *efficiency* usually is considered a *dependent* variable. For a more extended discussion of RWS see Levine 1982.

[7]Two methods were used to determine the evapotranspiration which represented the water requirement for the planted area: that recommended by the UN FAO—CROPWAT, and the water extracted

(Continued on page 8)

FIGURE 5.
Actual area planted v. water delivered.



level water efficiency, had the actual water deliveries been as planned. However, an average of approximately 14 percent more water was delivered, resulting in a RWS Actual (RWSA), at the level of the main canal, of approximately 1.86, suggesting an expected *technical water efficiency of 54 percent.* Thus, the farmers, on average, are managing the available water supply somewhat less intensively than anticipated by the CNA. The RWSA at the level of the field—the location at which the individual farmers receive water—is substantially lower, however, as will be shown in a later section.

Figure 5 shows the actual planted area as a function of actual deliveries. As can be seen, there is much greater variation ($r^2 = 0.16$), suggesting that there has been much less control than implied by the planning data. Removing the data for 1992,[10] showing the area irrigated larger (105,858 ha) than the nominal command area, increases the correlation coefficient to 0.55. This was a year of substantial rainfall.

2. How well is the proportional water allocation rule implemented by the modules and the farmers?

While the concession to the modules defines the proportion of the available supply allocated to each module, the water rights of the individual users are only implicitly defined on the same basis. The degree to which this basic equity rule is maintained is evaluated in the succeeding sections.

As indicated earlier, the unidades were the former major subunits of the district. Even though the basic units under the transfer program have become the modules, the unidades have been retained for reporting purposes. Table 1 indicates the average allocation for the unidades and the standard deviation for those allocations, for the 5 years previous to transfer, and for the 2 years after transfer. As can be noted, *more water is being supplied after transfer* (13.8%) with essentially no change in variability in delivery; the respective average standard deviations are 2.64 and 2.46. It should be remembered, however, that the period after transfer has been characterized by severe droughts, which could explain the increased deliveries. Table 2 provides before and after transfer data for 2 years by individual unidades.[11]

Two of the unidades consistently received less than the average for the district. In the case of Unidad San Jacinto, located adjacent to the Naza River, a number of the users pump (without formal authorization) directly from the river, in addition to the canal supply, and thus the total supply is more than the nominal amount indicated in the table. The Unidad Tlahualilo was the first to be transferred to the users, at which time it participated in the *Programa de Desarrollo Interparcelario* (Program of Inter-Parcel Development). Under this program. Almost all the channels were lined and almost all the fields were leveled. In addition, the irrigated area is rela-

from the soil profile as measured by gravimetric moisture sampling in 12 locations in each of the two modulos. The CROPWAT estimate was used in determining RWSP, to permit comparison with other studies.

[8]Technical water efficiency is defined as the ratio of the water required for potential evapotranspiration to that delivered. It is differentiated from economic water efficiency.

[9]As will be detailed in a later section, with the same volumetric water right different crops are allocated different sizes of irrigated area in proportion to their customary number of irrigations. To evaluate the water allocation policy, the areas of each crop were converted to the cotton equivalent, based on the water actually delivered.

[10]1992 was a very high rainfall year (in which the reservoir spilled significantly), and less irrigation was required.

[11]We recognize that this is a weak comparison, but the short time subsequent to transfer prevents a more definitive evaluation.

TABLE 1.
Average volume of water delivered/ha at the unidad level.

Year	Avg. vol. (1,000 m³)	Standard deviation
PRE-TRANSFER		
1992	16.307	3.51
1989	12.396	1.52
1988	11.440	1.53
1987	14.284	2.49
1984	13.549	3.92
1983	12.467	1.77
Avg.	13.407	2.46
POST-TRANSFER		
1994	14.350	2.58
1993	16.161	2.70
Avg.	15.255	2.64

TABLE 2.
Annual volume/ha in D.R. 017, by unidades.

Location	Volume/ha (1,000 m³)	Difference from average
PRE-TRANSFER—1989		
San Pedro	13.53	1.14
Madero	13.79	1.39
Matamoros	11.44	-0.95
Tlahualil	12.15	-0.25
Jerusalem	13.83	1.43
San Jacinto	9.63	-2.76
Average	12.40	
STD	1.52	
POST-TRANSFER—1994		
San Pedro	14.09	-0.26
Madero	17.18	2.83
Matamoros	16.49	2.14
Tlahualil	10.20	-4.15
Jerusalem	16.31	1.96
San Jacinto	11.83	-2.52
Average	14.35	
STD	2.58	

tively compact. This combination permits the water to be used more efficiently, and this is reflected in the water allocations — an example of some degree of fine-tuning of system management to the local conditions.

As indicated earlier, the modules are the basic operating units under the transfer program. *Within the constraints* of the water supplied by the CNA, modules manage the water distribution among the users, both with respect to amount and timing. Although the transfer process used in Mexico is generally the same for all districts, there is significant variation in the methods used by the Hydraulic Committees to determine the water allocation and timing of delivery among the transferred units. In District 017, the committee assumes that irrigation must supply essentially all the water to produce the crop. *To maintain the proportional allocation of water to the individual users, the area approved for planting for specified types of crops is used as the proxy for the appropriate volume.*

The area allocated for each crop is determined by assuming that *each irrigation* will be of the same nominal[12] volume per hectare (30 cm gross per irrigation), irrespective of the crop, and that different numbers of irrigations are appropriate for the different crops.[13] Thus, to maintain the water proportionality rule, those crops that require more irrigations are allocated a smaller area. Table 3 shows the proportional area allocation for each crop, and the nominal total water allocation. As can be noted, there is a difference between the water allocations for the beans and corn-forage and those for corn-grain and vegetables of about 4 percent, but this is well within the precision with which deliveries can be made.

In individual years, there are modest deviations from this policy in the actual planning. For example, the relative allocations for the same crops in the district irrigation plan for 1994-95 are shown in table 4. Similar irrigation plans are prepared by the modules. The plans for Modules V and XII are illustrated in tables 5 and 6, respectively.

The amounts planned at the module level are essentially the same as those at

[12]The nominal depth of irrigation includes the anticipated losses in conveyance as well as accommodation to nonuniformity of application.

[13]In the Lagunera area, as a result of the low probability of rainfall, there is a basic assump-

(Continued on page 10)

TABLE 3.
District crop area allocation, number of irrigations and equivalent water allocation policy.

Crop	Irrigations	Area allocated	Water allocation volume (1,000 m^3)
Beans	1 preplant; 2 auxil.	1.6*	14.4
Corn-forage	1 preplant; 3 auxil.	1.2	14.4
Corn-grain	1 preplant; 4 auxil.	1.0	15.0
Vegetables	1 preplant; 4 auxil.	1.0	15.0

*auxil. = auxiliary.

TABLE 4.
Planned crop water allocations—1994-95, D.R. 017.

Crop	Unit area allocated	Water allocation volume (1,000 m^3)
Beans	1.6	17
Corn-forage	1.2	13
Corn-grain	1.0	15.5
Vegetables	1.0	15.3

Source: Annual Irrigation Plan 1994-95, CNA, Lerdo, Edo. Durango

the district level, with the exception of beans for which the planned allocations are approximately 29 and 7 percent less for Modules V and XII, respectively. These changes appear to reflect the relative value of the crops as well as their actual field needs. This latter can be seen in the RWSA values at the farm level, presented in the following sections.

3. How equitable is the distribution of water between head and tail users?

The *magnitude* of relative water supply (RWS) at the field level indicates the degree of water stress (the higher the RWS the lower the stress) to which the *users' fields* are subjected, and the *uniformity* of RWS among the users reflects the ability of the system to provide equitable water service (recognizing that the equity policy is equality of water allocation for each user right).

TABLE 5.
Planned crop water allocations in Modulo V of District 017.

Crop	Area planned (ha)	Planned allocation per water right (1,000 m^3)	Planned allocation per ha (1,000 m^3)	Total volume supplied (1,000 m^3)	Actual allocation per ha (1,000 m^3)
Beans	46	12.0	7.5	345	7.5
Corn-forage	2,735	14.7	12.3	33,640	12.3
Vegetables and corn-grain	55	12.3	12.3	676	12.3

TABLE 6.
Planned crop water allocations in Modulo XII of District 017.

Crop	Area planned (ha)	Planned allocation per water right (1,000 m^3)	Planned allocation per ha (1,000 m^3)	Total volume supplied[1] (1,000 m^3)	Actual allocation per ha (1,000 m^3)
Beans	1,763	15.8	9.99	17,453	9.8
Corn-forage	1,186	15.3	12.8	15,182	12.8
Vegetables and corn-grain	540	15.6	15.6	8,424	15.8

[1]Data on total volume supplied are from modulo records. Actual water allocation per hectare is calculated from total volume and area planned.

tion that all of the crop water requirement must be met by irrigation. Thus, the irrigation planning limits the area to be planted to ensure the irrigation requirement will be met. This approach is not taken in areas with higher probabilities of rainfall in Mexico.

Table 7 contains the planned and actual RWS values for the major crops for Modules V and XII. As can be seen, in the modules actual RWS values are 11 percent and 20 percent lower than planned, using the CNA estimated values, and 3 percent and 9 percent lower using CROPWAT. This appears to reflect the recognized overplanting, coupled with underestimation of the losses in transmission and/or additional nonauthorized planted area. However, the consistency of RWSA, approximately 20 percent of the average, *irrespective* of the planned irrigation, suggests that local management decisions are being made that effectively equalize the management stress for irrigating the different crops. These decisions are implemented by varying the time allocated to the different locations and crops, to adequately meet the water needs (as evidenced by visual observations in the field). This time of irrigation is determined by the canalero, with more or less influence from the farmers.

These RWSA values are surprisingly low, in comparison to systems in Asia with a similar management pattern, e.g., (1) water measurement primarily at the primary channel level, (2) semiformal timings of irrigation duration, and (3) opportunities for the water users to influence farm deliveries. In these situations, RWSA values of 2–2.5 would be customary.

It is additionally surprising since the combination of area allocations for water, a water tariff based only indirectly on volume, and the opportunity for obtaining additional water through informal arrangements with the canalero, provide few, if any, incentives for more efficient use of the water, other than those for the canalero, who would have more water to accommodate special requests (for which he might receive additional compensation.). One explanation is that, by contrast to humid Asia, the critical dependence on irrigation in Lagunera results in more careful oversight on the part of the users, to ensure they receive their fair share.

4. How equitable is the distribution of water between ejiditarios and pequeño propietarios?

Table 8 presents the RWS for the ejiditarios and pequeños propietarios at the head and tail locations. These data indicate that, on average, the private farmers receive approximately 8 percent more than the ejido farmers, but this does not appear to be a significant delivery bias. Given the disparity in economic power between the ejiditarios and the pequeño propietarios, this is somewhat surprising. However, with the exception of cotton, it appears as if the crops irrigated from the surface water represent a relatively small fraction of

TABLE 7.
Planned and actual relative water supply, by crops.

Crop	RWS planned (ET estimated)	RWS planned (CROPWAT)	RWS actual (CROPWAT)
MODULE V			
Corn	1.89	1.46	1.65
Corn	1.89	1.48	1.53
Cotton	1.56	1.35	1.45
Cotton	1.50	1.38	1.31
Sorghum	1.70	1.68	1.52
Sorghum	1.70	1.68	1.95
Sorghum (Industrial)			
Average	1.70	1.98	1.29
	1.71	1.57	1.52
MODULE XII			
Beans	1.90	1.86	1.13
Beans	1.90	1.47	1.48
Corn	2.38	1.81	1.47
Sorghum	1.77	1.77	1.75
Sorghum	1.77	1.52	1.53
Sorghum (Industrial)	1.34	1.35	1.53
Average	1.84	1.63	1.48

TABLE 8.
Relative water supplies as a function of location and form of ownership.

Location	Ejido	Pequeño propietarios
MODULE V		
Head	1.47	1.48
Tail	1.53	1.63
MODULE XII		
Head	1.3	1.5
Tail	1.5	1.7

the total income for the private sector users, most of whom utilize groundwater for their more valuable crops.[14] This is especially true of alfalfa for dairy forage. The surface water generally is not used to irrigate alfalfa because of a crown rot problem resulting from the use of surface water.

The data show that the often-encountered tail deficit is not evident here. The system delivers approximately 9 percent more water to the tail sections than the head sections, in terms of the actual needs of the crops. The data also suggest that, to fully meet the crop needs, they would have to have a utilization efficiency[15] of at least 70 percent.

[14]Field reports indicate surface water represents only one-quarter of the total water used by the pequeños propietarios, but three-quarters of the supply of the ejiditarios.

[15]Utilization efficiency is defined as the ratio of water used for actual evapotranspiration, in this case estimated by CROPWAT, to water entering the soil profile. Where there is no surface runoff, it would be mathematically equivalent to field application efficiency.

TABLE 9.
Utilization efficiency in Modulos V and XII.

Crop	Efficiency
MODULO V	
Corn	0.62
Cotton	0.72
Sorghum	0.68
MODULO XII	
Beans	0.77
Corn	0.68
Sorghum	0.62

5. What are the system and field-level water efficiencies?

Table 9 presents the utilization efficiency for the various crops for Modules V and XII. These data show that most of the areas have achieved the necessary utilization efficiency. There is no apparent pattern to the variation in utilization efficiency, not surprising since there was no significant head/tail or ownership-type bias in water delivery to the fields.

Table 10 shows the water extracted from the soil profile at the upper quarter and lower quarter of the individual fields, identified by location, ownership type, and crop. Again, there was no consistent pattern to the variation, in relation to location or ownership type. In all cases, the water removed at the upper end of the fields was higher than that of the lower, by approximately 25 percent. This, coupled with the average utilization efficiencies cited earlier suggests that some of the crops in the lower parts of the fields will have had a degree of water stress greater than implied by the average utilization data. This is reflected in somewhat lower yields, as shown in table 11.

As described in the methodology section, the water extracted from the soil profile was determined by gravimetrically measuring the soil moisture in the profile to a depth of 1.2 m, before and after each irrigation. The sum of the water extracted from the profile, in general, exceeded the evapotranspiration calculated using CROPWAT by approximately 10 percent.

This difference is very probably due to the oasis effect resulting from the dispersed nature of the irrigated parcels, with significant opportunities for advective energy to increase the evapotranspiration. This is supported by the lower yields as-

TABLE 10.
Variation in water distribution.

Location	Ownership	Crop	Water from soil profile upper (cm)	Water from soil profile lower (cm)	% difference
			MODULE V		
	Pequeño propietarios	Sorghum	91.6	73.0	20.3
Head		Cotton	111.5	93.1	16.5
	Ejido	Corn	120.5	93.5	22.4
		Sorghum (Industrial)	125.4	89.5	28.6
	Pequeño propietarios	Sorghum	125.4	89.5	28.6
Tail		Cotton	100.5	84.5	15.9
	Ejido	Corn	108.8	81.5	25.1
			MODULE XII		
	Pequeño propietarios	Sorghum	105.8	88.6	16.2
Head	Ejido	Corn	115.8	84.2	27.2
		Beans	58.8	48.6	17.3
	Pequeño propietarios	Beans	78.5	56.7	27.8
Tail	Ejido	Sorghum	102.2	86.5	15.4
		Sorghum (Industrial)	101.3	76.3	24.7

TABLE 11.
Average yields.

Location	Crop	Within-parcela difference lower/upper (%)	Parcela average (t/ha)	Modulo average (t/ha)	District average (t/ha)
			MODULE V		
Head	Corn-forage	90.5	20*	46.8	41.6
	Cotton	93.9	3.2	3.12	2.8
	Sorghum	90.5	60	49.3	40.8
	Sorghum (Industrial)	83.1	6.5	4.0	3.7
Tail	Corn-forage	87.5	30	46.8	41.6
	Cotton	97.2	3.6	3.12	2.8
	Sorghum	96.2	47	49.3	40.8
			MODULE XII		
Head	Beans	77.1	1.55	1.47	1.2
	Corn-grain	91.7	4.6	4.5	3.8
	Sorghum	94.4	70	50.1	40.8
Tail	Beans	71.4	1.8	1.47	1.2
	Sorghum	96.4	55	50.1	40.8
	Sorghum (Industrial)	96.8	6.2	5.57	3.7

*This crop was a grain variety harvested for forage; hence the relatively low yield.

sociated with the lower parts of the fields, which had lower values for water extracted.

To evaluate the possibility that a salinity differential might account for the yield differences between the upper and lower parts of the fields, measurements of salinity in the profile were made.[16] These studies revealed no significant salinity problems associated with the different locations within the parcelas.

6. What are the opportunities for improving system productivity?

The uniformity of delivery of the water, locationally and to the different types of users, coupled with the low relative water supplies suggests that there are relatively modest opportunities to improve the delivery performance of the irrigation system. However, the variation in water distribution within the fields and the resultant variation in yield suggest that some improvement in productivity can occur with improved on-farm irrigation distribution. This might necessitate improved land-leveling, and/or different application methods, e.g., cutback streams, surge irrigation, etc. *Increased productivity can also result if more valuable crops can be grown and marketed, and this might be the most effective approach.*

The difference in RWS at the reservoir and the field levels suggests that there may be opportunities to improve conveyance efficiency. However, this might adversely affect recharge to the groundwater. From another perspective, it is possible that the conveyance losses are overestimated, and this provides a source of water for unauthorized areas.

[16]We are indebted to the OSTROM team currently conducting research at the INIFAP CENID-RASPA for carrying out the salinity measurements.

Conclusions

As indicated in the introduction, the changing climatic and economic environments during the period following transfer prevent a definitive statement about the performance of the transferred units relative to the situation prior to transfer. However, there does not appear to be any significant change in the hydraulic performance of the system. The area served/unit of available water appears to fit the pattern that existed prior to transfer; unfortunately, there are no prior field measurements of head-tail, private producer-ejido equity with which to compare.

The specific conclusions from the study are:

1. Data suggest that even during a period that might be considered a transition/learning time in the transfer process, the combination of CNA and transferred modules has been generally successful in managing their water operations, though more water was supplied to the modules than before transfer.
2. The consistent agreement in planning at the district and module levels, and the agreement with the water allocation policy expressed in the water law indicate that the policy is taken seriously, in planning. It also is probable that the CNA has retained a relatively high degree of influence in planning at the module level.
3. The fact that this same consistency in proportional water allocation is found at the level of the field suggests that the management can and does implement

the policies, though not necessarily with the amounts indicated in the plans.

4. The similarity of RWSA values by crops, suggests either that control of water delivery is effectively in the hands of the canalero, i.e., the module management, or there is an unusual degree of inter-user collaboration. The pattern of management of water delivery, where water flow rates are *estimated* rather than *measured*, and where there is considerable opportunity for the users to take more than their allotted time, is impressive, as greater discrepancies could easily occur.

5. The lack of the head/tail problem that is characteristic of many surface irrigation systems, is additional testimony to the effectiveness of module water management. Different time allocations are used to compensate for water losses in the distributary channels, reflecting a surprising degree of tuning of the management to field conditions.

6. Similarly, the relative uniformity of RWSA among the different types of users suggests that either there is sufficient discipline in the system to prevent significant influence resulting from economic power, or, perhaps more likely, a lack of incentive on the part of the private owners to use that power to obtain more surface water.

7. To achieve higher overall system efficiencies would require additional incentives for saving water—incentives to the farmers and to the canaleros—to compensate for the additional management effort. Increased system efficiency, however, may not result in an increase in basin-level water efficiency due to the recovery of deep percolation through the extensive pumping of groundwater.

Literature Cited

Comisión Nacional del Agua (CNA). 1994-95. *Annual irrigation plan.* Ciudad Lerdo, Edo. Durango: CNA.

CNA. 1995. *Programa de transferencia de distritos de riego: Avance*. Mexico City, Mexico: CNA, Subdireccion General de Infrastructura Hidroagricola. Gerencia de Distritos de Riego. Subgerencia de Transferencia.

Espinosa de Leon, and Trava Manzanilla, Jose Luis. 1992. Transferencia de los Distritos de riego a los usuarios. Paper presented at the ICID (Comisión Internacional de Irrigacion y Drenaje) Tercera Conferencia Regional Panamericana, Mazátlan, Sinaloa, Mexico, November 1992.

Gorriz, C. M., A. Subramanian, and J. Simas. 1995. *Irrigation management transfer in Mexico: Process and progress. Annex 1.* World Bank Technical Paper Number 292. Washington. D.C.: The World Bank.

Levine, G. 1982. *Relative water supply: An explanatory variable for irrigation systems*. Technical Report No. 6. The Determinants of Irrigation Problems in Developing Countries. Ithaca, N.Y.: Cornell University.

Palacios-Velez, Enrique. 1994. *Diagnostico sobre la Administracion de los Modulos operados por las Asociaciones de Usuarios.* Montecillo, Mexico: Informe Técnico, Colegio de Postgraduados.

Trava, Jose. 1994. Transfer of management of irrigation districts to WUAs in Mexico. In *Indicative action plan and proceedings of national seminar on farmers' participation in irrigation management*. Aurangabad, Maharashtra, India: Water and Land Management Institute.

Research Reports

10. *A Plot of One's Own: Gender Relations and Irrigated Land Allocation Policies in Burkina Faso.* Margreet Zwarteveen, 1997.

11. *Impacts of Irrigation Management Transfer: A Review of the Evidence.* Douglas L. Vermillion, 1997.

12. *Water Distribution Rules and Water Distribution Performance: A Case Study in the Tambraparani Irrigation System.* Jeffrey D. Brewer, R. Sakthivadivel, and K.V. Raju, 1997.

13. *Rehabilitation Planning for Small Tanks in Cascades: A Methodology Based on Rapid Assessment.* R. Sakthivadivel, Nihal Fernando, and Jeffrey D. Brewer, 1997.

14. *Water as an Economic Good: A Solution, or a Problem?* C. J. Perry, D. Seckler, and Michael Rock, 1997.

15. *Impact Assessment of Irrigation Management Transfer in the Alto Rio Lerma Irrigation District, Mexico.* Wim H. Kloezen, Carlos Garcés-Restrepo, and Sam H. Johnson III, 1997.

16. *Irrigation Management Transfer in Mexico: A Strategy to Achieve Irrigation District Sustainability.* Sam Johnson III, 1997.

17. *Design and Practice of Water Allocation Rules: Lessons from Warabandi in Pakistan's Punjab.* D. J. Bandaragoda, 1998.

18. *Impact Assessment of Rehabilitation Intervention in the Gal Oya Left Bank.* Upali A. Amarasinghe, R. Sakthivadivel, and Hammond Murray-Rust, 1998.

19. *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues.* David Seckler, Upali Amarasinghe, David Molden, Radhika de Silva, and Randolph Barker, 1998.

20. *Indicators for Comparing Performance of Irrigated Agricultural Systems.* David J. Molden, R. Sakthivadival, Christopher J. Perry, Charlotte de Fraiture, and Wim H. Kloezen, 1998.

21. *Need for Institutional Impact Assessment in Planning Irrigation System Modernization.* D. J. Bandaragoda, 1998.

22. *Assessing Irrigation Performance with Comparative Indicators: The Case of the Alto Rio Lerma Irrigation District, Mexico.* Wim H. Klozen, and Carlos Garcés-Restrepo, 1998.

23. *Performance of Two Transferred Modules in the Lagunera Region: Water Relations.* G. Levine, A. Cruz Galvan, D. Garcia, C. Garcés-Restrepo, and S. Johnson III, 1998.

INTERNATIONAL WATER MANAGEMENT INSTITUTE
P O Box 2075, Colombo, Sri Lanka
Tel (94-1) 867404 • Fax (94-1) 866854 • E-mail IIMI@cgnet.com
Internet Home Page http://www.cgiar.org/iimi

ISBN 92-9090-357-0

ISSN 1026-0862