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A Solution and an Opportunity in Mexico

Toward an Interdisciplinary and Integrated Approach to Agricultural Drainage

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AGRICULTURE AND RURAL DEVELOPMENT

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Preface

This country study was prepared as a contribution to the project—*Agricultural Drainage: Toward an Interdisciplinary and Integrated Approach*, sponsored by the World Bank–Netherlands Partnership Program (BNPP)—Environmental Window for Water Resources Management and the Agricultural and Rural Development Department (ARD) of the World Bank. The activity was task managed by Safwat Abdel-Dayem, drainage advisor ARD, and coordinated by Peter Mollinga, associate professor, Wageningen University. This country study is one of six parallel studies. The other studies are on Bangladesh, Egypt, Indonesia, the Netherlands, and Pakistan. Together they provide the basis for formulating the proposed approach.

The task manager and the coordinator provided general direction for the study and contributed comments on preliminary texts. The country study benefited from the critical comments provided during the workshop held in Wageningen, the Netherlands, October 23–25, 2002, and attended by Bank staff, country officials, and representatives of International organizations, including the Food and Agriculture Organization of the United Nations, the International Progamme for Technology and Research in Irrigation and Drainage, and the International Commission for Irrigation and Drainage.

For the development of this study, the support of the National Water Commission and the Mexican Institute of Water Technology is greatly appreciated. They willingly opened their doors, sharing with the author information and their ideas for the future development of water resources in Mexico.

In the development of the study, Benjamin de León Mojarro and Arturo Gonzalez Casillas from the Mexican Institute of Water Technology participated actively in the preparation of materials and the integration of their experiences in the field of drainage technology. The help of Victor Porras in editing the final draft of this report was crucial in finalizing this task.

Many experts from public and private organizations shared their information, experience, and knowledge. The list is enormous. The author thanks all of them, and hopes that his former colleagues, reading, feel they have been properly considered and that their thoughts have been well recorded. Particular thanks go to Fernando Gonzalez Villarreal, for his support and guidance; to Luis Rendón Pimentel, Leonardo Pulido, and V. R. Namuche for their assistance and their contribution to the discussion of the North region sections of the study; and to Isidro Gaytán, Tomás Valenzuela, and José Antonio Vijosa for their valuable participation in the Tropical regions portion of the study. The environmental and health considerations were possible because of the interest and participation of Enrique Calderón.

A special debt is owed to the many people involved in the field visits, who made excellent presentations on their results and their vision for the future. The author deeply appreciates the interest and commitment from the water and drainage user associations. Only with their support was it possible to address the ambitious objectives of this study.

The author also thanks the outstanding people with whom has had the opportunity to share experiences, thoughts, and dreams during his professional life. This study reflects their knowledge and many of their ideas. For many, drainage offers a solution to some old diseases. The author considers dealing with drainage issues an opportunity to go further ahead in the implementation of integrated water resources management with strong participation of rural society.

Acronyms and Abbreviations

ALCAMPO	Alianza para el Campo [Agricultural Alliance Program]
ANUR	Asociación Nacional al Usuarios de Riego [National Water Users Association]
BNPPEW	The Netherlands–World Bank Partnership Program Environmental Window for Water Resources Management
CENATRID	Centro Nacional de Entrenamiento en Riego y Drenaje [National Training Center for Irrigation and Drainage located in the Valle del Carrizo Irrigation District]
CNI	Comisión Nacional de Irrigación [National Irrigation Commission]
CNPH	Comisión del Plan Nacional Hidráulico [National Water Resources Planning Commission]
DBO	Demanda biológica de oxigeno [biological oxygen demand]
DUA	Drainage user associations
EIA	Environmental impact assessment
EIS	Environmental impact study
FAO	Food and Agriculture Organization of the United Nations
FIRA	Fideicomisos Instituidos Relación Agricultura en el Banco de México [Trust Funds for Agriculture Central Bank]
FIRCO	Fideicomiso de Riesgo Compartido [Trust Fund for Shared Risk Technical Agent of SAGARPA]
GATT	General Agreement on Tariffs and Trade
GNP	Gross national product
GIS	Geographical information system
IBWC	International Boundary and Water Commission
ICID	International Commission on Irrigation and Drainage.
ID	Irrigation district
IMTA	Instituto Mexicano de Tecnología del Agua [Mexican Institute of Water Technology]
INIFAP	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias [National Forestry, Agricultural, and Fisheries Research Institute]
IWRM	Integrated water resources management.
NOM	Norma Oficial Mexicana [Mexican Official Norm]
NAFTA	North American Free Trade Agreement.
NWC	National Water Commission
O&M	Operation and maintenance (of irrigation and rainfed district]
PNH	Plan Nacional Hidráulico [National Water Plan]
PRODERITH	Programa de Desarrollo Rural Integrado del Trópico Húmedo [Rural Development Program for the Tropical Areas]
SAGAR	Secretaría de Agricultura, Ganadería y Desarrollo Rural [Ministry of Agriculture, Livestock and Rural Development]
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación [Ministry of Agriculture, Rural Development, Fisheries and Food]
SARH	Secretaría de Agricultura y Recursos Hidráulicos [Ministry of Agriculture and Water Resources]
SRL	Sociedad de Responsabilidad Limitada [federation of water user associations]
SRH	Secretaría de Recursos Hidráulicos [Ministry of Water Resources]
UCT	Unidad de Cooperación Tecnológica [technical cooperation unit]
USDA	U.S. Department of Agriculture

WHO	World Health Organization
WUA	Water user association.

Currency and Measures

1 peso = US$0.10
1 ha = 2.471 acres

Executive Summary

Sovereignty, land reform, and agricultural self-sufficiency led the development of irrigation and drainage in Mexico in the last century. Today, globalization, the implementation of the General Agreement on Tariffs and Trade (GATT), the North American Free Trade Agreement (NAFTA), and the application of the "Social Neoliberalism" economic theories, are the main drivers for more efficient and sustainable use of water resources with strong stakeholder participation. Agricultural drainage is a fundamental part of this new strategy and demands a more important role in the implementation of an integrated water management approach than it has received in the past. This fact is directly related to the role of drainage in the provision of "new water" and in its environmental relations. Moreover, integrated water management is needed to increase agricultural productivity and diversification. Drainage systems must play an important role in building a more prosperous, equitable, and environmentally responsible society in this new century.

Mexico has a total area of 2 million km^2, 100 million inhabitants, and a per capita income of US$5,910. Regional and sectoral inequalities are among the major concerns in terms of economic and social policies. Around 52 percent of the population is considered poor, and 70 percent of the poor are in the rural sector.

Irrigated and drainage agriculture represent 60 percent of the total agricultural output. Mexico ranks sixth in terms of land under irrigation with 6.4 million ha. Another 2.4 million ha have flood control, service roads, drainage, and water control infrastructure. The water scenarios defined in the Water Program 2001–2025 consider that most of the future water for food will come from the volumes of the present water abstraction. New irrigation and drainage development (490,000 ha to 1 million ha in 25 years) will be located principally in the tropical areas of the country where ample water is available; the rest has to come through more efficient use of water in irrigation.

Water institutions in Mexico have played a substantial role in the development of the country. In accordance with the Mexican Constitution of 1917, water is a national good administrated by the state. The Waters Act of 1992 authorizes concession of water for private and collective use. This law establishes rights and obligations for the different users of water. It enforces water markets, provides for the creation of a water register, and promotes the efficient use of water and private investment. It establishes regional basin councils to broaden participatory management of water resources and makes compulsory the formation of water user associations to manage the irrigation and drainage systems. It also defines the administrative figures to resolve disputes and to reduce costly and time-consuming judiciary procedures.

The National Water Commission (NWC) is the "sole authority in water." The NWC has four distinct functions: it is the guardian of water resources and concessions its use to different sectors; it collects water charges and taxes; it plans, designs, and constructs water infrastructure, and it promotes the decentralization of its use at the basin and local levels. In 1985, the National Water Planning Commission, responsible for developing regional and national water plans, was transformed into the Mexican Institute for Water Technology (IMTA) to strengthen research, training, and development of specific water programs, mainly in water quality and efficient use of water. Water planning was decentralized at the regional-basin level.

Water concessions are granted to individual or collective uses, and wastewater discharge is regulated. An important feature in water administration is the creation of water and drainage user associations (WUAs and DUAs). This process was devised to cope with the deferred maintenance and inefficient water delivery service in the agricultural sector. The irrigation management transfer changed the conception of these services in the country and has influenced the irrigation reform process internationally. Practically all the irrigation and drainage district systems have been transferred to 440 WUAs, 11 SRLs (federations of water user associations which are responsible for the operation and conservation of main canals and drains), formed by WUAs to operate the main irrigation canals and drains, and 26 DUAs. These associations collect water fees, operate and maintain the systems, and keep water user records. They manage water concessions, infrastructure, machinery, and equipment and have offices to perform these obligations. They also participate in programs to rehabilitate and modernize the systems.

Field Study

Study tours were organized (appendix A) to the arid northwest of the country to the Río Mayo Irrigation District, ID 038 (97,000 ha); to the Valle del Carrizo ID 076 (42,000 ha); and to the Improved Rainfed Districts, Centro de Veracruz (75,000 ha), Tesechoacan (18,000 ha), and Zanapa Tonalá (106,900 ha), which were developed by the Program for Integrated Rural Development for the Humid Tropics (PRODERITH). Drainage has been integrated in the development strategy of the regions linked with irrigation in the north and with rural development and flood protection in the south.

Although Río Mayo and Valle del Carrizo are neighboring districts, the availability of water in the Río Mayo aquifer has given different characteristics to their drainage solutions. In Río Mayo, the use of tubewells to supplement irrigation has the double effect of lowering the water table and reducing salinity problems. Because of overirrigation practices, Valle del Carrizo presented more serious problems of salinity. Valle del Carrizo had the lowest benchmarking indicators in terms of water and soil productivity despite its better climate for crop diversification than, for instance, the Río Mayo ID.

In both districts, salinity and the high water table affected the soils—37 of the area in Río Mayo and 72 percent in Valle del Carrizo. In both cases, it was a good opportunity for testing the alternative of installing subsurface irrigation technology. Studies were conducted using the available information and the support of satellite images, geographical position systems (GPS) technology, and field samples. IMTA was responsible for carrying out the initial designs. The results in both cases but particularly in the Valle del Carrizo, have been impressive. The introduction of subsurface drain lines at distances between 25 m and 50 m with diameters starting at 3 inches and discharging into 6-inch collectors benefited a total area of 15,000 ha with average investment costs of less than US$1,000. Today, productivity is similar in these reclaimed lands and in other areas, and property values in Valle del Carrizo have risen tenfold.

Several recommendations were identified in the field visit:

- Volumetric delivery of water, essential for controlling overirrigation practices, can be introduced, as it has been in the neighboring Río Yaqui district north of the perimeter. IMTA has devised a tool kit for this purpose, which is suitable for use in most of districts in this region.

- Maintenance of the discharge system to the lagoons is important to guarantee the correct functioning of the drainage infrastructure.

- Modernization and better water use per unit of output can be obtained by the development of the modernization program now under way. Priority should be given to on-farm irrigation systems using the matching grants provided by the Agricultural Alliance Program.

- To improve drainage design criteria, “Reference Sectors” must be designated, reflecting water and salt balances in the different subareas of the districts. Based on these classifications, subsurface drainage systems could be designed to cover all parts of the region affected by salinity, estimated at 25,000 ha.

- The results of the environmental studies emphasize the need to reduce the use of fertilizers and limit the use of other agrochemicals.

- Formal integration of aquaculture farms into the WUAs is of great importance to prevent future conflicts. These farms are responsible for the obstruction of natural drainage, eutrophication of lagoons, and reverse flows in the drains.

The second field study was conducted in the South region. The tropical lands of Mexico represent the future frontier of rural development in the country. The level of investment in drainage projects is relatively low, around US$1,000 compared with investment in the irrigation districts, of between US$5,000 and US$10,000. The economic return on projects in Mexico’s tropical regions is similar to the return on projects in the irrigated areas (a 14.4 percent internal rate of return for PRODERITH versus 13.8 percent for the irrigation and drainage project). The design of the systems was specific to each of the natural conditions and the farmers’ agricultural interests. It was conscious of the need to protect wetlands. The use of pesticides and fertilizers is still low. Some health problems can be traced to unpurified water supplies for rural dwellers and to some waterlogging in the drains.

The formation of the associations is impressive, and their elected leaders’ active role and conscientiousness are commendable. Some associations established formal agreements with local governments and private agribusinesses in the project areas and have also been able to overcome the problem of collecting fees for maintenance of the drainage systems and amortization of the machinery.

The associations are now responsible for infrastructure maintenance and are doing a much better job than the government did. Maintenance activities are performed in an economical and competitive way. The NWC is helping this process and has authorized “contracts” between the associations and the local governments or private companies for conservation works. To increase the use of the infrastructure and raise productivity, the expansion of the on-farm drainage systems is needed in conjunction with technical assistance from the drainage district offices and the technical cooperation units (UCTs).[A]

The associations have started to get involved in on-farm construction projects and soil conservation work, which can help to materialize the system benefits. Now that some innovative farmers realize the

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[A]UCT is the Spanish acronym for *technical cooperation units*, private companies with service contracts from the NWC to provide technical assistance to the drainage projects. Their employees, former government employees, were encouraged by the government to form private entities. At the beginning of PRODERITH, these professionals were selected, recruited, and trained to perform the critical social mobilization and form agricultural technical assistance cells.

importance of this type of investment, the government started to support these initiatives and authorize the investment funds required.

A new stage of PRODERITH, a program for the consolidation of the improved rainfed districts, could be studied and implemented. This effort could probably win support from the World Bank.

Agricultural Drainage and Integrated Water Resources Management

The planning process at basin level must recognize the different functions of drainage: as a remedy to improve the productivity of irrigated areas and the discharge of excess water from flooding, rainfall, or overirrigation. Vertical drainage and reuse of drainage water from agriculture, industries, and cities is an important source of water for beneficial uses in the basin. With reuse, control and monitoring of water quality become important elements in integrated water management strategy. The interaction between users in the upper part of the basin and those at the tail end of the system is critical to sustain the ecological balance for the different economic activities.

These functions and relations need to be identified and integrated in the basin planning process, not only to calculate water balances or identify projects or remedial actions but also to further integrate the general obligations stated in the concession titles of the different users. These aspects also have to be incorporated in the specific regulations for district operation and maintenance. Drainage needs a special chapter in concession titles, just as irrigation operations have one. Obligations and functions need to be explained and agreed with users at different levels in the systems.

Mexico’s drainage typology was developed on the basis of the country’s 13 hydrological regions. Areas were identified where vertical drainage is present in large and small systems. Another factor was studied where the availability of underground water is not significant, and surface drainage is the main element to eliminate excess water. In the tropical areas, surface drainage is linked to flood control and is conceived to eliminate local runoff from storms. Subsurface drainage systems have been developed in some districts in the north, and their influence is still small. Finally, several hurricane-prone regions have flood control structures.

Recommendations

Mexico is starting a second phase of the Irrigation and Drainage Program aimed at increasing the productivity and efficiency of water use in agriculture. Some of the recommendations outlined in this report could be incorporated in this process.

Planning

- Remote sensing methodology could be used to identify the precise areas affected by salinity and high water tables in the districts.

- To improve design criteria, “reference sectors” could be designated (in areas of about 400 ha) in four districts that have installed subsurface drainage systems. To assist with monitoring and calibration of the design criteria for subsurface drainage, “reference plots” could also be designated (like those agreed with the Food and Agriculture Organization of United Nations, in 20 ha farms). Some of these ideas could be extrapolated to the tropical areas to improve the design criteria.

- To analyze the evolution of the water table, area-curve-graphs should be produced, like as the one developed for the Río Yaqui ID.

An Environmental Impact Assessment related to the use of agrochemicals should be conducted in the coastal lagoons in northwest Mexico for the Colorado, Yaqui, Mayo, Carrizo, Fuerte, Guasave, Sinaloa, San Lorenzo y Piaxtla Elota Irrigation Districts to prevent discharges of pollutants into these unique environments.

Operation

- The UCT concept should be strengthened for agricultural technical assistance, and the demonstration modules of on-farm drainage should be expanded in the tropical areas.

- The evolution of the cropping pattern and the economical evaluation of the Improved Rainfed Districts should be updated.

- Procedures for drainage practices and operations should be developed and inserted in the concession titles, so that the respective roles and responsibilities of the government and the associations are clearly stated.

- Maintenance of the subsurface drainage systems should be integrated into the SRLs' yearly plan

- The development of aquaculture farms in the coastal lagoons should be regulated in order to prevent drainage system congestion at the outlets and to coordinate their participation with the user associations in water concessions and infrastructure maintenance. At the same time, it is important to monitor water quality at the point of discharge into the lagoons.

Implementation

- An integrated program should be drawn up for the development of subsurface drainage for the reclamation of 400,000 ha affected by salinity and high water table. Within the districts, the program should identify the areas affected, evaluate the impact, and promote user participation in implementing the program. Designs and terms of reference for the installation of the subsurface drainage systems should be developed, working with users, associations, companies, and the corresponding agencies. The NWC and the World Bank have incorporated these activities in the recently launched Integrated Irrigation Modernization Project included in this project is the provision for improving the efficiency of water use and reducing the initial problem of overirrigation.

- A third phase of PRODERITH should be started for the consolidation of the Improved Rainfed District. This project can strongly stimulate development in the south and help address the issues of poverty and sector and regional fragmentation. The project could include institutional development of the drainage user associations, rehabilitation of existing works, and on-farm and technical assistance components in 2.2 million ha of existing drainage infrastructure.

1. Introduction

This drainage case study of Mexico offers one of the most illustrative examples of diversity in drainage solutions and integrated water management. It presents a mosaic of practical solutions to drainage:

- A combination of vertical drainage, surface drainage, and subsurface drainage in an international basin in the arid areas in the north, starting in the Colorado Delta

- Flood control and living with water in the tropical areas in the south, in the Usumacinta River Basin (also an international river)

- Vegetable cultivation with modern techniques such as ferti-irrigation in the Valley of Mexico, where the Aztec Empire once flourished, with its ancient approach to drainage;[1]

- Mixing saline water with canal water to expand water supply and mitigate the risks of climate change as in the Río Colorado Baja California, and Río Yaqui and Río Mayo in Sonora.

Most important of all, Mexico is an example of how, by building the participation of farmers in the administration of irrigation and drainage systems, the water sector can contribute to the reduction of poverty and can sustain a more democratic society with less direct government intervention in day-to-day irrigation and drainage operations.

This study, conducted from May to December 2002, included two field studies (appendix A). One field study was in the arid northwest region, where the introduction of subsurface drainage interventions has given new impetus to the reclamation of soils damaged by salinity. The other was the tropical areas, where linkages between rural development and drainage interventions were developed 15 years ago.

2. The Water Sector in Mexico

Sovereignty, land reform, and agricultural self-sufficiency oriented the development of irrigation and drainage in Mexico in the last century. Today, globalization, the implementation of the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA) and the application of the "Social Neoliberalism" economic theories, are the main drivers for more efficient and sustainable use of water resources with strong stakeholder participation. This new reality is the most important issue facing Mexico's water sector. Agricultural drainage, as an integral part of the water management system, is a basic part of this new strategy and demands a more important role in the implementation of an integrated water management approach than it has received in the past. The way Mexican water and agricultural institutions incorporate this concept will substantially influence the building of a more prosperous, equitable, and environmentally responsible society in this new century.

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[1] Ferti-irrigation, is the irrigation technique where plant nutrients and other chemicals are applied to the soil by water

Mexico at a Glance

Mexico has a total area of approximately 2 million km^2, 97.4 million inhabitants, and a per capita income of US$5,910. Recurrent economic crises have roiled Mexico in the last 30 years. Regional and sector inequalities are among the major concerns in terms of economic and social policies. Around 52 percent of the population is considered poor, and 70 percent of the poor are in the rural sector. At the end of 2000, a new administration took office, for the first time in 70 years from a different political party. This administration recognizes the strategic and economic value of water, protection of water bodies, and preservation of the environment for future generations. President Vincente Fox thus declared his water goals for Mexico as "A nation with security in the provision of water for its development using it in an efficient way" (Fox 2001).

In Mexico, the average rainfall is 772 mm a year, concentrated in four months. Total runoff is calculated at 410 Km^3 and a renewable aquifer recharge of 62 Km^3. The total water storage in dams and lakes is 130 Km^3. Of the 72 Km^3 of water abstracted for consumption each year, agriculture takes 80 percent. For water management purposes, Mexico is divided into 13 regions. The southeast part of the country has a total runoff of 68 percent and, with 23 percent of the population, contributes only 14 percent of the GNP(NWC 2001).

Mining of aquifers, pollution from productive activities and urban areas, inefficiencies in water use, and provision of water for 12 million inhabitants and sanitation for 22 million now lacking these services are the principal issues facing Mexico's water sector. To comply with legislation, Mexico has to increase water treatment from only 22 percent now treated to 60 percent in 10 years and to 90 percent by the year 2025. Although the population will stabilize at around 130 million inhabitants by 2025, that is still 30 million more than today, which points to further increases in demand for water.

Irrigated and drainage agriculture represents 60 percent of the total agricultural output. Mexico ranks sixth in the world in terms of land under irrigation with 6.4 million ha. An additional 2.4 million ha have flood control and drainage infrastructure (Gonzalez and Contijoch 1994). In the irrigated areas, 4 million ha have surface drainage systems; subsurface drainage has been installed on only 35,000 ha. Around 1.0 million families live in the irrigation and drainage districts and units. Of the 6.4 million ha of irrigated land, 3.4 million are in 82 large irrigation districts (IDs) and the rest in 40,000 small irrigation units—mainly with wells, direct river diversion systems, and small dams. In the tropical and subtropical areas, 16 Improved Rainfed Districts have been organized. Because of differences in climate and geomorphologic foundation, Mexico has a diversified system of agricultural production with a wide variety of crops and technologies. Drainage development has played a substantial role in achieving production and social objectives and has an important role to fulfill in meeting future requirements.

According to the water scenarios defined in the Water Program 2001–2025, most of the future demand for food will be met from the present abstraction of water and more efficient use of water in irrigation (table 1). New irrigation and drainage development (490,000 to 1 million ha in the next 25 years) will be located principally in the tropical areas where water is abundant.

Irrigated agriculture in Mexico faces strong challenges from: water competition with other uses, profitability for the farmers, unfair competition from other countries, and environmental concerns. Small farmers, even those with irrigation and drainage systems, barely derive enough income to sustain their families. An integrated policy to increase productivity with more efficient use of water has been proposed, linking the diversification of production with agribusiness development and with the implementation of rural development actions. In both cases, sound irrigation and drainage programs are necessary to increase productivity per unit of water used (Fox 2001).

Table 1 Water scenarios, 2025

Concept	*Actual*	*Projected*	*Sustainable*
Modernized hectares (million)	0.8	1.1	5.8
New irrigation development (million ha)	n.a.	490,000	1
Irrigation losses (percent of water abstraction)	54	51	37
Water supply losses (percent of water abstraction)	44	44	24
Water supply services (percent of population)	88	88	97
Sanitation services (percent of population)	73	76	97
Treated wastewater (percent of water discharged)	23	60	90
Water consumption (mm^3)	72	85	75
Total annual investment in water sector (US$ billion)	1.4	1.6	3

n.a. = Not applicable.

Source: NWC 2001.

Mexico has a strong tradition in water development. Starting with the Maya and the Aztec cultures, the concept of drainage has had a solid environmental basis. Both cultures managed water at the basin and subbasin levels. During the Spanish period, reclamation of wetlands for urban development and flood protection was introduced with the construction of drainage systems. At the end of the Mexican Revolution, irrigation became the most important government investment in rural areas. The construction of irrigation districts in the north was part of the colonization strategy devised for reaffirming Mexico's sovereignty along northern borders (Funes and Ortega 1988).

Salinity and Waterlogging: The Rehabilitation Program, 1963

Since 1926, the need for rehabilitation has been recognized and incorporated in new project design. To deal with waterlogging, some projects were designed to consolidate and rehabilitate irrigation districts with the support of the World Bank at the beginning of 1963 (SRH 1976). These included the First Rehabilitation Projects in Yaqui and Mayo in Sonora, La Laguna in Durango and Coahuila, San Juan del Río in Queretaro, Bajo Río Bravo and Bajo Río San Juan in Tamaulipas and Río Fuerte, and Río Sinaloa in Sinaloa state. The results of this policy can be analyzed using the information in the evolution of water tables land curves for the Yaqui district, where the impact of surface drainage construction in the area affected by waterlogging can be observed in the first part in 1952.

Developing the Tropical Regions, 1978

A main conclusion of the Mexican Water Plan 1975–2000 was that the tropical regions should be developed, for that is where most of the agricultural potential had been identified—7.5 million ha of medium- to high-potential soils were underutilized. Physical, technical, institutional and socioeconomic constraints limited the expansion of agricultural development (NWC 1994).

Mexico's humid tropics are located primarily on the Gulf Coast and in the southeast. Rainfall, mainly between June and September, amounts to 1,700 mm. High temperatures and humidity lead to serious disease, pest, and weed problems. There are additional problems of poor access to inputs and outputs, regular flooding of lowland areas, widespread illiteracy, competition for resources from the rapidly developing petroleum industry; and steady expansion of livestock production (World Bank 1985).

Several attempts to introduce an irrigation strategy for these areas had failed for lack of an integrated approach. An integrated rural development approach was devised, and a proposal was designed for the development of the region. The strategy for the initial stage included: development of six pilot projects in an area of 54,000 ha; implementation of an extension service to cover the pilot area, provision for an expansion zone of 600,000 ha, and improvement and expansion of the agricultural, livestock, and forestry research programs in the region. The principal objectives of the project were to demonstrate the feasibility of public investment in the region, based mainly on an integrated rural development strategy, conceived and implemented in the water sector with a strong emphasis on local participation and management (Contijoch 1991).

At the end of the first stage, in 1985, the evaluation confirmed the social, economic, and technical feasibility of developing Mexico's tropical regions (World Bank 1991). The following direct benefits were identified: the crop area was augmented by 40,000 ha, 70 percent of the area; yields of basic crops rose significantly (e.g., between 1979 and 1985, maize yields increased about 60 percent more than yields in average rainfed districts in the same area; drainage infrastructure reduced waterlogging on about 100,000 ha; between 30 percent and 50 percent of the farm families in the area were participating; 32 detailed local development plans were prepared in close collaboration with the communities; more than 950 groups, including 50 women's groups were formed for small agroindustrial projects.

The underlying reasons for the success were: the pilot project approach allowed testing of a wide range of strategies and technical packages for developing the humid tropics before committing to large-scale investment; careful planning of local development schemes before beginning investment and service activities that ensured strong community involvement; maintaining a high caliber of staff was emphasized through team training, strong field supervision, and competitive salaries; extension services were concentrated (one technician to 100 farmers) and use of mass media multiplied the results; strong, project management was effective and stable; frequent meetings of a technical committee, comprising all implementation agencies, ensured a responsible decisionmaking process; effective monitoring and evaluation allowed the project impact to be quantified, enabling PRODERITH to present clear justification for future investments.

From the favorable results obtained in the first phase of PRODERITH, a second phase was prepared by the National Water Resources Planning Commission (CPNH). The rationale for this second phase, stemming from those positive experiences, was supported by the Ministry of Agriculture and Water Resources (SARH 1986), which concluded that, of the many development programs tested in the region, PRODERITH had been the most successful and should therefore be the model for future investments. This is consistent with the strategy of providing more direct productive assistance to poor farmers in rainfed regions, which have traditionally received only limited support.

The project start-up period, 1986–89, was characterized by several institutional changes and a big financial crisis, where government expenditure was drastically reduced, with major impacts on investment projects throughout the country. As a consequence, project start-up was much slower than had been anticipated. Another remarkable event was the transformation of all water institutions in the country: the termination of the river basin commissions, the conversion of the National Planning Commission into the National Institute for Water Technology (IMTA), and the creation of the National Water Commission (NWC).

The history of the second part of the implementation, 1990–94, was characterized by a strong spurt forward on project implementation. Budgets were still small but timely and well distributed among subprojects. After March 1991, IMTA functions were concentrated on technical assistance, training, and institutional development, while NWC was in charge of implementation. Technical coordination units were created to take charge of the extension component, functioning as private enterprises and assisting farmers with production techniques and organization. The support of the Food and Agriculture Organization (FAO) and the Soil Conservation Service of the U.S. Department of Agriculture (USDA) was maintained with excellent results.

During this period, agricultural production diversified and increased in more than 800,000 ha. Production was substantially expanded in tropical fruits, improved pastures, and permanent crops. Also remarkable was the coparticipation of private business in the areas of packing houses, marketing, and some agroindustries. Special attention was also given to women in 300 productive projects (World Bank 1994).

After the new federal administration took over in 1995, several institutional changes affected NWC organization and functions. In this context, the development of the tropical areas was severely curtailed, the budget limited and reallocated to other activities. Only limited contracts with the UCT and some new conservation machinery were authorized.

The administration of President Fox is proposing the Plan Puebla-Panama to foster the development of the tropical areas. It is still to soon to judge whether this plan will build on the positive results achieved by PRODERITH to promote the development of Mexico's tropical areas.

The Program for Irrigation and Drainage (Time Slice), 1990

The financial crisis that began in 1982 nearly halted the rapid expansion of irrigated land. Sharp reduction of public investment characterized the government's subsequent stabilization programs. Public investment and expenditures on water infrastructure, which represented about three quarters of all agricultural sector investment, declined from US$3.6 billion annually to US$230 million between 1981 and 1988. Although this decline followed the general trend of total public investment, investment in irrigation infrastructure was hit worse than investments in other sectors. This was mainly because of the difficulties experienced in the most recent irrigation investments in the Pánuco region and the conflict between social development and land reform and the concentration of capital and land for agribusiness production. With investment cutbacks, irrigated land expanded by only 5,000 ha in 1988. Rehabilitation also declined from 11,400 ha in 1981 to less than 6,000 ha in 1988. The economic crisis affected not only new investments but also the resources available to maintain infrastructure. As a consequence, 0.8 million ha were underutilized as a result of deterioration of infrastructure due to poor maintenance, and a further 1.5 million ha needed rehabilitation in 1988 to restore them to their original efficiency (NWC 1994).

The 1989–94 National Development Plan reinforced the global strategy of increasing agricultural production mainly by improving efficiency in the use of existing irrigation schemes and only as an exception by expanding the irrigated area. This was a change in the strategy pursued in the 1970s and 1980s when the emphasis was placed on expanding the area under irrigation, with little attention to efficiency in the use of resources. This reversal of priorities was a response to the increasing scarcity of financial as well as water resources.

The objectives of the Time Slice project were to:

- Promote the efficient use of existing infrastructure by giving priority to rehabilitation, modernization, and completion of existing works.
- Promote the adoption of improved irrigation techniques, leading to a more efficient use of land and water resources.
- Transfer gradually responsibility for operation and maintenance of the irrigation districts to water user associations (WUAs) and increase the farmers' contribution to o&m expenses and investment costs.
- Prevent the expansion of irrigated areas in regions where water resources are overexploited, except when expansion is the result of improved efficiency in water use.
- Prevent degradation of water resources by controlling the release of toxic substances into water courses and by avoiding overexploitation of aquifers.
- Allocate investment resources, combining cost-effectiveness with social and income distribution criteria.

The implementation of this project had profound results in the irrigation sector in Mexico. The objectives were met. Responsibilities were transferred to farmers in more than 3.3 million ha of the 3.4 million ha within the irrigation districts. By 2002, 444 water user associations had been formed, and 11 federations of water user associations (SRLs) had attained full responsibility for the whole system.

The initial results of the transfer were significant: a 73 percent increase in real terms over 1988 in the conservation works investments. The modernization program covered 543,000 ha, 23 percent of the total requirements identified. More than 1,200 heavy equipment machines with a total cost of US$98.5 million were transferred, and 407 new machines with a total cost of US$35.9 million were bought and transferred to the associations. The farmers acquired 105 more units on their own, at a cost of US$7.9 million, to support conservation and modernization activities. The introduction of new light equipment for deweeding canals and drains reduced the costs and time of these operations. Finally, conveyance and distribution efficiency in the districts increased from 60 percent to 66 percent (Contijoch 1996).

On-Farm and Minor Irrigation Program, 1994

The On-Farm and Minor Irrigation Program was developed to introduce those improvements in the irrigation districts recently transferred to water user associations. Initially it included 14 irrigation districts covering 400,000 ha, later expanded to other districts that met the design criteria.

The total cost of the project, which is completed and closed, was originally calculated at US$570 million of which the Bank financed US$200 million (World Bank 1993). The project sought to make the Mexican irrigation subsector more efficient and less reliant on government funds, through shared investments by beneficiaries. It was the first time a project had been designed to bring about change at the on-farm level to permit water savings, give operational flexibility, and support more intensive cropping, better yields, and diversification into high-value crops. These developments were intended to increase the profitability and sustainability of irrigated agriculture, as well as the potential for exploiting new markets to be developed under the North Atlantic Free Trade Agreement (NAFTA). Increased private investment in irrigation was encouraged by the participation of WUAs and farmers in decisionmaking about investments and priorities, under a sound legal regulatory, and administrative framework.

Specific objectives were to: reduce loss and waste of irrigation water; promote decentralization and private investment in irrigation; increase cropping intensities and yields; and increase crop diversification into higher value crops. In addition to the technical support, communications, and training component, the principle components of the project include minor network improvements and on-farm works, comprising small irrigation and drainage networks in command areas between 80 ha and 500 ha.

With a very favorable system of credit, the project considered a 100 percent cost recovery for on-farm improvements and 50 percent recovery for minor networks improvements. The 100 percent O&M cost recovery presented at the time of appraisal was retained. There was no cost recovery for technical support, communications, or training to help the project develop field studies and designs. The project will benefit more than 40,000 farmers, 50 percent of them on incomes around the minimum wage.

The Agricultural Alliance: an Agricultural Modernization Strategy

Development policies in the agricultural sector have changed substantially the last few years in Mexico. They have shifted from extensive governmental intervention in financing production, pricing, and trading of main inputs and produce toward privately managed and world market–oriented activities. Since 1995, through a new strategy, the Agricultural Alliance Program (ALCAMPO), federal government efforts have continued, especially through investments in agricultural development, increasingly tied to investments by state governments and farmers. Farmers themselves are also managing the execution of works, (FIRCO 2000). The Agricultural Alliance is a result of consensus among farmers, cattle raisers, and state and federal government. The alliance was designed to: increase farm production faster than demographic growth and to fight poverty, participating with producers in investment for the technological transformation of Mexican farms; to assure sufficient food supply; and to support Mexican economic relations with other countries by generating exportable surpluses.

In 1996, the Ferti-Irrigation Program, within the framework of the Agricultural Alliance, was put into effect. It was considered that even the nation’s most advanced agriculture—the segment under irrigation—needed a technological transformation to improve its profitability and productivity.

The Ferti-Irrigation Program under the Agricultural Alliance has a financial cost sharing of 35 percent federal government funds. State governments usually cover 15 percent, and the project beneficiaries finance the remaining 50 percent. This program encompasses the following types of investment: high- and low-pressurized systems, Ferti-irrigation equipment, pipes, pumping equipment, filters, gauges and gauging structures, designs and executive projects, and specialized technical assistance. The producers are in charge of the projects and contract directly for the work.

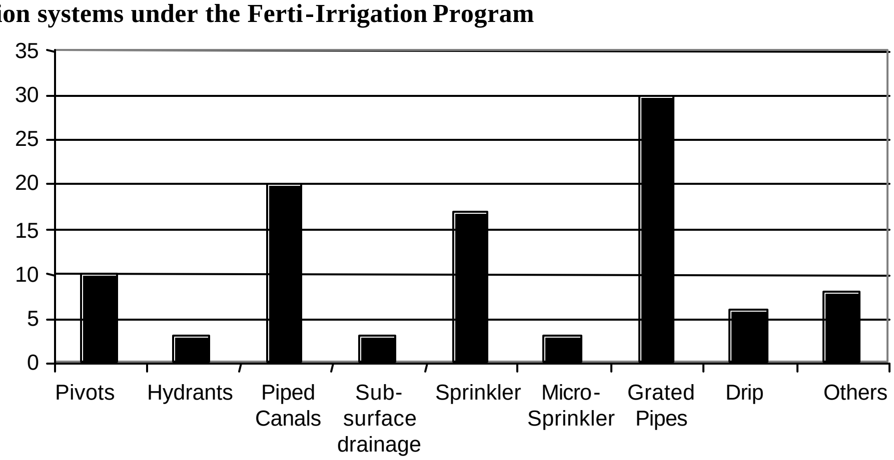
The federal government contributes 35 percent of the total investment, up to US$305/ha, and state governments take on an additional 10 percent. Producers participate with their own resources in the form of credits, their labor, and local materials. In 1998, in an effort to include small farmers (with plots smaller than 5 ha, the participation of federal and state governments was increased to 85 percent of total project cost. Several options were introduced to support the participation of small farmers.

In 1995, Mexico had 6.2 million of ha of irrigated land of which, 380,000 ha were pressurized systems. From 1996 to 2000, improved areas with high- and low-pressurized systems reached 571,889 ha, benefiting 103,174 producers. With these implementation results, the improved area has nearly doubled under the program.

To find out and measure the impact, an analysis was done of the 1995–2000 period when the program promoted 18,092 irrigation projects. Ten different types of high- and low-pressurized systems were installed, and farmers made the decisions, which were reviewed and approved for technical correctness by the Trust Fund for Shared Risk (FIRCO), the program's technical agent (FIRCO 2000). Figure 1 shows the percentage of the different types of systems selected by the farmers. The main results of the Ferti-Irrigation Yes Program included:

- An estimated water saving of 40 percent, 1.97 billion m^3 per year—enough to supply Mexico City's annual demand—and a 32 percent reduction in energy costs
- An 18 percent increase in the harvested area and a 30 percent increase in production
- An increase of 116,899 workdays each year
- An increase of 28 percent in the volume of exportable farm produce
- An internal rate of return of 16 percent, including all costs, representing a 25 percent return on the farmers' investments.

Figure 1 Irrigation systems under the Ferti-Irrigation Program



Source: Aguilar 2000.

More than 400 small and medium enterprises supplied goods and services for the program. In the process, they increased their capacity, installed new plants, and committed themselves to delivering on time goods and services of the requisite quality. Services supplied included design, installation, maintenance, and system servicing.

Agricultural Alliance activities included reclamation of salinity-impaired soils. The objective is to improve the productivity of such soils in irrigated areas through the installation of on-farm drainage and the application of chemicals and organic materials for soil improvement.

Under this program, the federal government funds 35 percent of the total costs of installing drainage systems, supplying materials, and subsoiling and leaching up to US$230/ha and a maximum of US$23,000 per farm. The maximum size of the farm supported in this program is less than 30 ha. The state governments also provide 10 percent of the total costs, and the farmers finance the rest. The cost of design is included in total project costs.

In the areas covered by this program, 87 percent of the farmers reported increased yields, and 90 percent reported better use of irrigation water. The internal rate of return calculated for this projects in 2000 was 27.9 percent

The total investment under the program in 1997–99 was US$12.2 million, an average of US$430/ha for 786 projects on a total area of 28,458 ha. Farmers contributed 57 percent of the total costs. The program helped mainly with the installation of subsurface pipe drainage in Sonora and Baja California states. The National Water Commission provided the use of specialized equipment from the project to support these activities (Aguilar 2000).

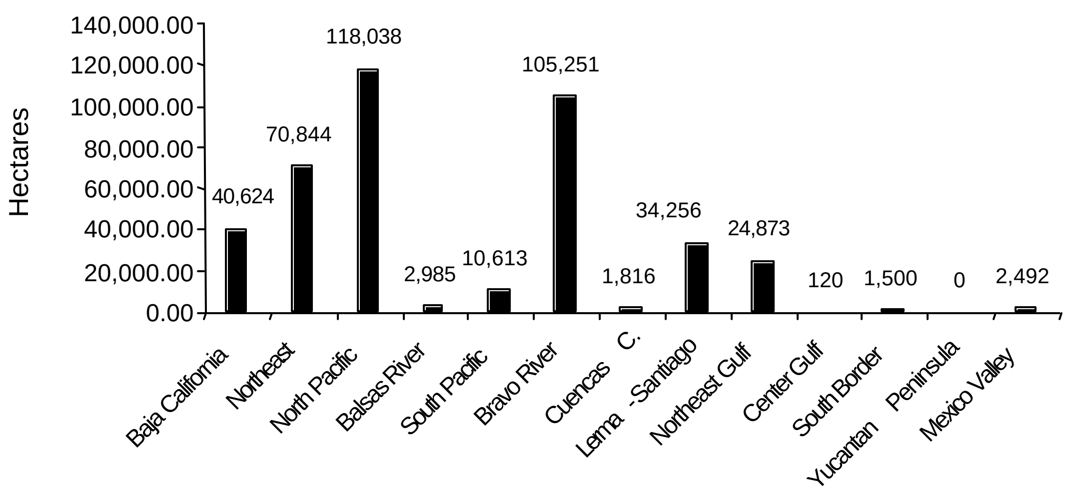
3. Drainage Typology

In Mexico, agricultural land drainage usually consists of surface systems; only recently have subsurface drainage systems been installed. In the irrigation districts, the systems are commonly defined by blocks of 400 ha with a 2 km-secondary canal and a parallel 2 km-secondary drain that discharges into a main drain and a river or lagoon. The effect of tides is minimal, less than 72 cm between high and low tide. In drainage units, the drains follow the topography of the rivers, and the secondary drains are constructed according to the requirements of the agricultural units. At project level, subsurface drain pipes and field ditches usually exit to an open main or collector drain that empties into a river or its tributaries. Depending on the character of the hydrological basin, main drains may discharge drainage water into an evaporation pond, a wetland, or a saline agriculture/agriculture-forestry system (Pulido, et al. 2001).

From a field study conducted by IMTA for the NWC, an inventory of drainage problems was developed in 2001 with strong participation by water user associations. According to the results, the total area, 700,000 ha identified in 1990 as affected by drainage problems, decreased to 413,000 ha. The main reasons are improved maintenance by the water user associations and the initial benefits from the installation of subsurface drainage. The areas affected by salinization and high water table are located in the northwest and north Pacific regions, where the field visit was programmed. In the Bravo region, the other area with significant water table problems, the installation of subsurface drainage systems has to be analyzed in a more general framework to take into consideration the possible reduction of the irrigated area, redefinition of the real availability of water and its allocation to the agricultural sector, drought risk, and reconversion of the cropping pattern. The total area affected by salinity and high water table is significant.

In Mexico, agricultural drainage began to deal with the first waterlogging problems. Later, it was included in design to assure the elimination of excess irrigation water. Although Mexico now has an average 100 ha/km density of open drains, 413,000 ha are affected with salinity or high water table in different levels of intensity (figure 2). Farmers recognize this problem because of lower yields. These figures show that drainage with open drains does not always suffice to control excess water and salinity and that control over water table levels has to be complemented with more efficient systems for moving water, for example, through subsurface pipe systems. This practice has been used to reclaim waterlogged and salinity-damaged land after farmers have gotten very low yields or have had to stop agricultural activities altogether in the affected areas. Some farmers, however, have turned to growing salt-resistant crops (grasses) with low income returns.

Figure 2 Area affected by salinity in Mexico's 13 hydrological regions



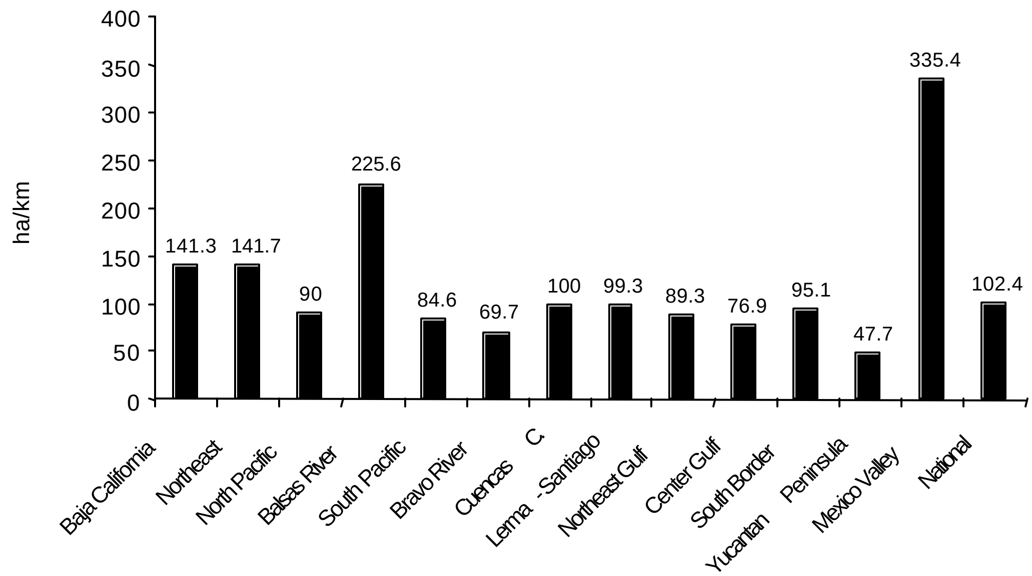
Source: Ramos 1999.

Surface Drainage

Surface drainage is often achieved by land leveling and smoothing to remove isolated depressions or by constructing parallel ditches. Ditches and furrow bottoms are gently graded and discharge into main drains at the field boundary. Although the ditches or furrows are intended primarily to convey excess surface runoff, there is some seepage through the soil into the ditches, depending on the water table position. This could be regarded as a form of shallow subsurface drainage. Surface drainage is especially important in humid regions on flat lands with limited water gradients to nearby rivers or other disposal points. Good surface drainage is also needed in semiarid regions affected by hurricanes.

In figure 3, drainage density by region is presented. Regional differences could be used as a benchmarking indicator in the general drainage study. There are strong differences in the implementation of the drainage infrastructure which corresponds to the different physical conditions existing in the country.

Figure 3 Drain density in the hydrological regions (ha/km)



Source: NWC 2001.

Subsurface Drainage

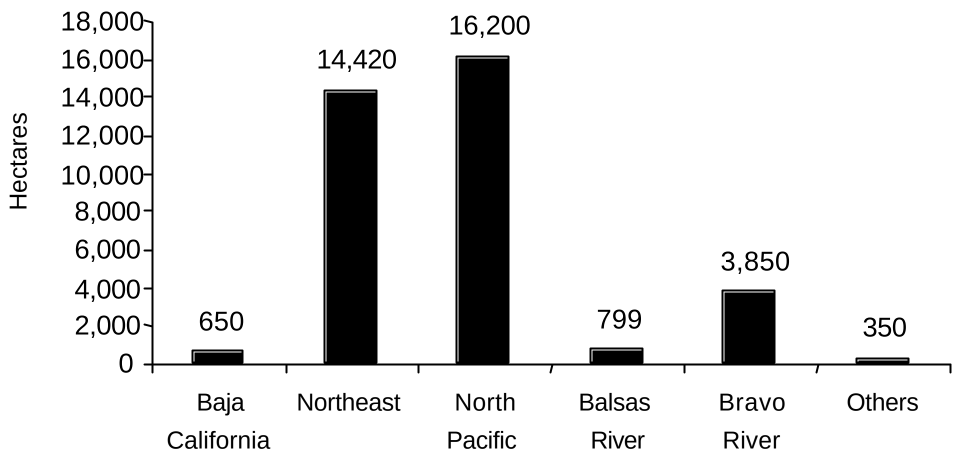
Surface drainage alone is seldom sufficient to remove excess water from the crop root zone. Deep ditches or subsurface pipe drainage systems enable a more rapid drawdown of the water table. The downstream ends of the laterals are normally connected to a collector drain. The required diameter of the pipe collectors increases with the area drained. Drain spacing is usually dependent on soil water conductivity and a design drainage rate coefficient. Depending on topography, land formation, and proximity to a water-receiving body, the collector may discharge by gravity into an open main drain or into a sump. In the latter case, the discharge is pumped to another drain or ultimately to a lake or stream (Schultz 1990).

To establish a typology of drainage needs and designate excess-salinity areas for reclamation with subsurface pipe drainage, in 1997 the NWC and IMTA implemented a research and design program. The investigation pertained to a surface area of 10,000 ha in three irrigation districts: 2,800 ha in Valle del Carrizo ID 076, 5,000 ha in Río Mayo ID 038, and 2,100 ha in Río Yaqui ID 018 in the state of Sonora.

The results obtained with the use of subsurface pipe drainage and the decision to buy specialized installation equipment significantly increased demand for private companies to design and install the drainage networks. Since 1995, the area under subsurface drainage increased to 35,000 ha in 2001 (figure 4). This technology has been used mainly in the northwest irrigation districts of Río Colorado in Baja California state, Valle del Carrizo, Río Fuerte, Culiacán-Humaya in Sinaloa, Río Yaqui and Río Mayo in Sonora, and in the northeast districts of Bajo Río Bravo and Bajo Río San Juan.

In the Irrigation District of La Barca near Lake Chapala, surface drains are also used for subirrigation. In this case, in dry periods, surface water is introduced into the drain, and the water table is raised. Moisture moves upward by capillary action to the root zone. Subirrigation is regarded as a highly energy- and water-efficient method of irrigation.

Figure 4 Subsurface drainage, by region



Source: Pulido, et al. 2001.

Vertical drainage by means of tubewells is also used to control waterlogging and salinity in about 1 million ha in the north and northwest irrigation districts. Tubewells serve the same primary purposes as horizontal drains but, in addition, extract groundwater for irrigation. Pumping lowers the water table, and capillarity minimizes salinization. This situation is ideal where the groundwater is not very brackish or saline and is therefore suitable for irrigation. In districts where the groundwater is highly saline as in Río Colorado, or saline as in Río Yaqui or Río Mayo, the pumped water is mixed with fresh water.

Methods of improving the internal drainage of low permeability soils include: subsoiling, deep tillage, mole drainage, and biological practices, cropping with deep-rooted legumes (e.g., alfalfa) and crop rotations. In some cases, the additional need of water for leaching generates conflicts between users in drought prone areas. This problem has to be properly addressed during the planning and decisionmaking process before installing subsurface drains.

Typology

Drainage is a regional and national water element of the water cycle and therefore needs recognition in the planning process. Planning at basin level should recognize drainage functions as a means of improving productivity of irrigated areas, especially those with high water tables and excess salinity, and of discharging excess water from flooding, rainfall, or overirrigation (table 2). Vertical drainage and reuse of drainage water from agriculture, industries, and cities is an important provider of water for beneficial uses in the basin. The control and monitoring of water quality thus becomes an important function in integrated water management strategy. The interaction between users in the upper part of the basin and those at the discharge end of the system are critical to sustain balance among the different economic activities.

The functions and relations summarized in table 2 need to be identified and integrated in the current basin-planning process, not only to calculate water balances or identify projects or remedial actions but also to further integrate the general obligations stated in the concession titles of the different users. These aspects also have to be incorporated in specific regulations for the operation and maintenance of the district. Drainage needs a chapter of its own in concession titles, like the one used for irrigation operations. Obligations and services between users, the service provider, and the NWC need to be explained and agreed with farmers at different project levels.

Table 2 Drainage typology factors

Factor	***Río Mayo***	***V. Carrizo***	***Centro de Veracruz***	***Zanapa Tonala***	***Tesechoacan***
Climate	Arid	Arid	Subtropical	Humid tropical	Tropical
Physiography	Coastal lowlands	Coastal lowlands	Coastal lowlands	Coastal lowlands	Coastal lowlands
Topography	Flat	Flat	Flat	Flat	Hills-flat
Flood control	Dam	Dam	None	Dams and dikes	Dams and dikes
Soils	Clay and loam	Clay	Loam	Heavy clay	Clay
Water quality	Good; groundwater inadequate	Good; groundwater inadequate	Medium; groundwater good	Good; groundwater good	Good; groundwater good
Agricultural technology	Highly developed	Highly developed	Developed	Potential high	Medium development
User objectives	Export and national	National market	National market	Local export	Regional
User organization	Highly centralized	Strongly democratic	Incipient	Very incipient	Good
Coordination with other sectors	Food subsidies	Good, support of Agricultural Alliance	Urban development	State government	Sugar mill estate; government
Equipment and materials	Adequate and sufficient	Adequate and sufficient	Need for on-farm development	Need for on-farm development	Need for on-farm development

Source: Author.

It is particularly important to observe, as an example, the area curves graph for Yaqui ID. After The construction of a surface drainage system initially lowered the water table, but waterlogging and high salinity returned due to poor maintenance between 1980 and 1990. With improved maintenance after transfer of responsibility to user associations, the waterlogged, high-salinity area was reduced, but it increased in lower areas and pocket zones. These results show the importance of installing subsurface drainage systems. This experience is particularly important as justification for the land reclamation program in 415,000 ha of high-salinity and high–water table land.

With the development of the Mexico drainage typology, areas could be identified where vertical drainage is present in large and small systems and another where the availability of underground water is not significant and surface drainage is the principal means of eliminating excess water (table 3). In the tropical areas, surface drainage is linked to flood control and is basically designed to eliminate local runoff from storms. Subsurface drainage systems have been developed in some districts in the north, but its influence is still small. Last, some hurricane- and storm-prone regions have flood control structures.

With the information available in the NWC, drainage density per hectare and soil and water productivity were analyzed for the 13 hydrological regions. From figure 5, we can conclude that the density of the drainage infrastructure has a bearing on land and water productivity, but it is not clear that more infrastructure raises productivity.

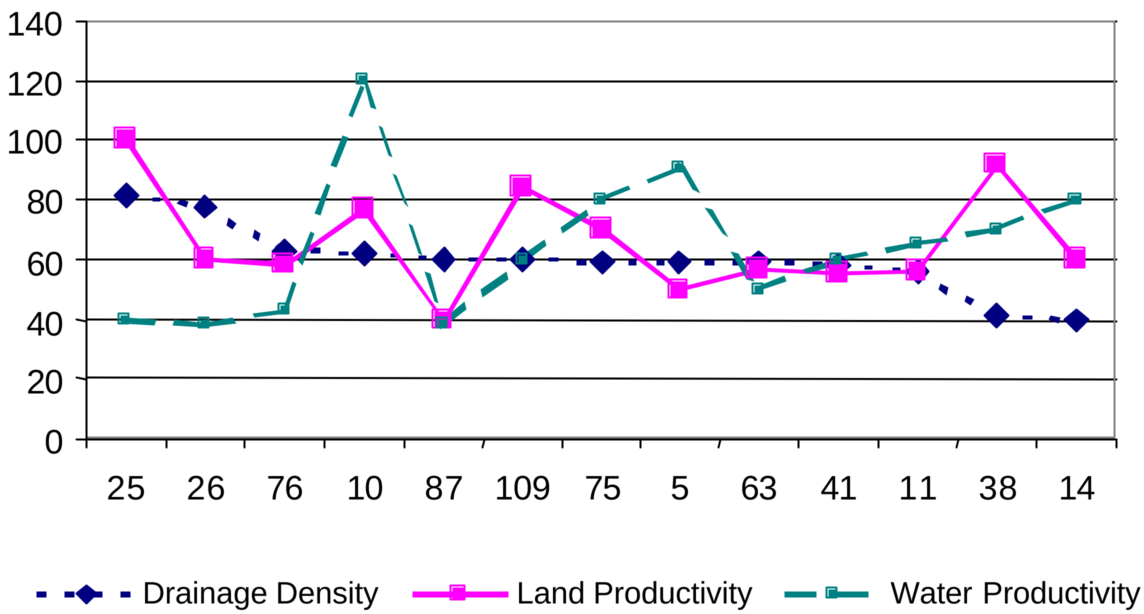
Table 3 Mexico's drainage typology agroclimatic drainage types

Type drainage for	*Arid*	*Semiarid*	*Temperate*	*Subhumid*	*Humid tropics*
Large systems with vertical drainage	Cuencas Cerradas, Baja California, Northeast	n.a.	Lerma	n.a.	n.a.
Large systems without vertical drainage	n.a.	North Pacific, Bravo	Balsas, Valle de México	North and Central Gulf, South Pacific	South Border
Small systems with vertical drainage	n.a.	n.a.	Lerma	n.a.	Yucatan Peninsula
Rainfed agriculture	n.a.	n.a.	n.a.	n.a.	n.a.
Flood control	All regions	All regions	All regions	All regions	All regions
Land reclamation	n.a.	n.a.	n.a.	Central Gulf	South Border

n.a. Not applicable.

Source: Author.

Figure 5 Drainage density and soil and water productivity



Source: Author.

The role of the WUAs in the system operation is important for analysis of the relation between physical structures and society's interests in the country's drainage systems (table 4). A water council in each district helps administer water allocation, irrigation scheduling, and drainage maintenance programs as well as coordination with other sectors involved in agricultural production. At basin level, basin councils have important functions in the coordination of programs and water allocation at basin level. At the national level, the National Association of Irrigation Users and the National Advisory Council, representing different users and interest groups, have a strong voice in national policy. Congress has a special Committee for Water Affairs that approves budgets, laws, and regulations for the water sector and reviews multisectoral relations.

Table 4 Physical structure and societal interests

Level	*User*	*Beneficiaries*	*Other stakeholders*
Farm	Farmers	Rural organizations	Rural sector
Tertiary	Farmers	Rural residents	WUAs
Secondary	Farmers	Rural and urban residents	WUAs, SRLs, industry, and state government
Main	Farmers	Rural and urban resident industry	Fishery, tourism, water councils, NWC, and state government
Outlet	Farmers and SRLs	Rural and urban industry	Fishery, tourism, water councils, NWC, and state government
Dams	Farmers, WUAs, and SRLs	Rural and urban industry	Fishery, tourism, water councils, NWC, state government, federal government

WUA water user association; SRL federation of water user associations; NWC National Water Commission.

Source: Author.

User participation and the proliferation of water conflicts are strong drivers for the ongoing decentralization of water functions at the regional level. The institutional transformation of the NWC will strengthen the policy voice of nongovernmental associations, water user associations, and local and state governments at basin level.

4. Irrigation and Drainage Institutions

Water institutions have played a prominent role in Mexico's development. Starting with the Irrigation with National Waters Law, through the Federal Waters Law, to the present Mexican Waters Law, Mexico has designed a complex system for managing water (NWC 1991). According to the Mexican Constitution of 1917, water is a national good, administrated by the state. The National Water Law authorizes concession of water for private and collective use; establishes rights and obligations for the different users of water; creates a water registry for water entitlements; provides for enforcement of water market law; promotes efficient use of water and private investment; establishes regional basin councils for participatory management of water resources; provides for formation of water user associations to manage the irrigation and drainage systems; and defines conflict-resolution procedures to reduce costly, time-consuming judiciary procedures.

Like the legal instruments, water institutions have also evolved with the needs and requirements of the country's development (table 5). In 1926, the National Irrigation Commission (CNI) started the development of irrigation systems. So successful was this intervention that CNI was transformed into the Water Resources Ministry (SRH) and the integrated water resources management (IWRM) concept was institutionally adopted. Later on, this entity was merged into the Ministry of Agriculture and Water Resources, and some of its functions were transferred to other ministries. To handle Mexico's growing water problems, the NWC was created in 1989.

Table 5 Irrigation and drainage institutions

Institution	*Year initiated*	*Legal mandate*	*Planning level*
National Irrigation Commission (CNI)	1926	Constitution 1917 Irrigation Law	Project
Water Resources Ministry (SRH)	1946	National Law for Federal Waters	Basin
Water Resources Ministry (SRH)	1970	Federal Water Law	National Water Plan
Ministry of Agriculture and Water Resources (SARH)	1977	Federal Water Law	National Water Plan
National Water Commission (NWC) in SARH	1989	National Water Law	Water Program
NWC in the Ministry of Environment, NR and Fisheries	1995	National Water Law	Water Program
NWC in the Ministry of Environment and Natural Resources	2000	National Water Law	Water Program

Source**:** Author.

Today the NWC is the sole authority in water. It has four distinct functions: it is the guardian of water resources and user concessions; it collects water charges and taxes; it plans, designs, and constructs water infrastructure; and promotes decentralization of its use at the basin and local levels. In 1985, the Planning Commission, responsible for developing regional and national water plans, was transformed into IMTA to strengthen research, training, and development of specific water programs mainly to protect water quality and secure efficient use of water. Water planning was decentralized at the regional basin level.

The right to use water is granted by concessions to individuals or groups, and discharges into water bodies are regulated. An important feature in water administration is the creation of water and drainage user associations. This process, devised to cope with inefficient maintenance and water delivery services in the agricultural sector, has changed the country's way of looking at these services. Practically all the irrigation and drainage district systems have been transferred to 440 WUAs, 11 SRLs (formed by WUAs to operate the main irrigation canals and drains), and 26 drainage user associations (DUAs). These associations collect water fees, operate and maintain systems, and keep water user records. They have received from the government the water concessions, infrastructure, machinery, equipment, and office space to perform these obligations. They also participate in the programs to rehabilitate and modernize the systems (World Bank 1991).

According to different external evaluations, farmers consider the transfer successful; irrigation and drainage services have improved, and water is used more efficiently and productively (Colegio de Postgraduados 2000). Nevertheless, this process needs careful monitoring and supervision to cope with second-generation problems. Principally, it is important to keep water charges at sustainable levels.

Transparency and accountability are other important issues facing the associations, together with modernization of irrigation and drainage to help farmers diversify and compete in the global economy. Environmental concerns are also emerging as local issues.

To integrate the Mexican experience in drainage, as part of the integrated water management system, field studies were conducted in two distinct regions of the country. They helped to up-date the results obtained by the user associations with the support of both the NWC and IMTA. This was an opportunity to validate the results obtained, develop a drainage typology, and make recommendations for future development of the irrigation and drainage program. For the purposes of the field study, visits were made to the arid northwest of the country to the Río Mayo Irrigation District, ID 038 (97,000 ha); to the Valle del Carrizo ID 076 (42,000 ha); and to the Improved Rainfed Districts, Centro de Veracruz (75,000 ha), Tesechoacan (18,000 ha.), and Zanapa Tonalá (106,900 ha), which were developed by the Program for Integrated Rural Development for the Humid Tropics (PRODERITH). Drainage has been integrated into regional development strategy, linked to irrigation in the north and to rural development and flood protection in the south **(**NWC 1998**)**. The main conclusions are presented below.

5. Drainage and Integrated Water Resources Management

To keep up with its growing population, Mexico applies the concept of integrated water resources management to organize its interventions to transform the hydrological cycle. This policy has been particularly influenced by its relations with United States, across the world's largest common border formed by a river bed, as well as by its own hydroelectric potential and the frequent droughts and floods. Since the creation of the Ministry of Water Resources in 1946 and the Water Basins Commissions in 1948, Mexico has developed a comprehensive approach to water resources development.

The National Water Plan

The planning process, originally done on a project basis, was scaled up to include the different uses in basins and, at the beginning of the 1970s, was integrated into regional planning in the formulation and implementation of the National Water Plan. The Mexican Water Plan of 1975 is one of the most innovative water plans that has ever been done.

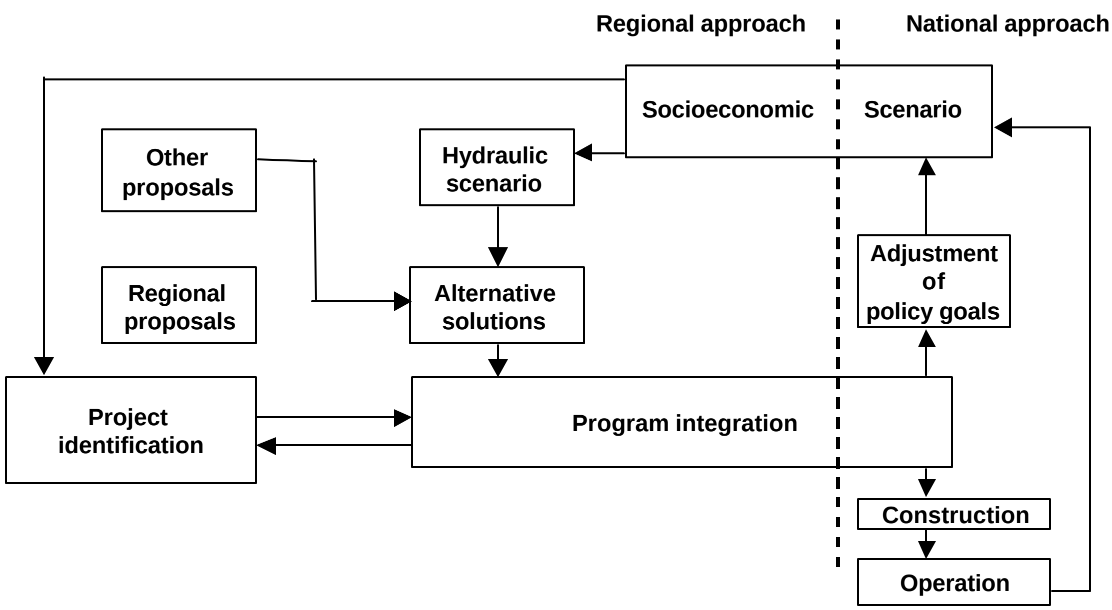
The objectives of the plan were to formulate and institute a systematic process for planning water resources development and for the rational selection of programs, projects, and policies. Its institutions included, besides the Planning Commission, a Managerial Council consisting of the president of Mexico and the ministry secretaries for water resources and treasury; a Consultative Council made up of three Mexican experts and three international experts, and a Coordinating Committee with representatives from agencies involved in water and its use. To achieve a balance among the physical, technical, social, economic, and institutional aspects relative to water management, the Planning Commission was made up of an interdisciplinary group of 82 people. This group, because of its professional competence, was responsible for implementing the main conclusions derived from the National Water Plan.

Methodology

The methodology developed for the National Water Plan (PNH), depicted in figure 6, was the starting point for all the different processes involved in planning water resources in Mexico at different times. The socioeconomic aspects were studied at both national and regional levels, thus allowing identification of the objectives, policies, and development goals that, together with other technical factors, determine demand for water. The supply of water resources in the form of precipitation, surface runoff, and groundwater storage and permanent yield was compared with demand. In this way, water balances were calculated. The problems thus identified derived mainly from water shortages, lack of control, or inadequate quality.

Alternative solutions to these problems were identified, including proposals by different water-related agencies. A catalogue of existing projects, served as a basis for formulating and integrating regional programs for water resources development.

Figure 6 Methodology for developing the national water plan



Source: SRH 1976.

The regional programs were integrated at the national level in order to analyze the compatibility of supply with demands derived from the socioeconomic scenarios and with financial and human requirements. On the basis of this analysis, some adjustments were made in the policies originally formulated. Adjustments complete the planning cycle. Feedback from program implementation and operation then leads to the identification of new goals.

In each cycle, policies and goals for water resources development are set up. New projects are identified, and recommendations are made for obtaining and analyzing basic data. For the first time in Mexico, population projections, economic growth scenarios, and basic socioeconomic goals were analyzed and used to define water policies and programs in an integrated system. A new institutional development process was initiated: the technical interdisciplinary personnel responsible for developing the plan later became responsible for its implementation and eventually took over leadership of water development policy for the country.

This interdisciplinary group evolved with the experience gained in developing the plan and in implementing different programs as PRODERITH, the design of alternatives for the water supply of the country's metropolitan areas, the efficient use of water, the transfer of the irrigation districts to user associations, and finally produced the new water law, the water register, the financial water system, and the main water programs Mexico is now implementing. This process laid the basis and gave political impetus for the creation of the National Water Commission and the Mexican Institute for Water Technology. This institutional development process has received international recognition and has been cited as an example of sound water management. Today, Mexico has 13 water programs, covering every region and a planning period of 2001–2025 (NWC 2001).

Agricultural, Environmental, and Socioeconomic Benefits of Drainage

The primary benefits of drainage go beyond controlling excess soil water and excess salts in the crop root zone. The coincident environmental and socioeconomic benefits associated with disease vector control and public health must be fully recognized. A major environmental benefit of drainage is its positive impact on improving the health of humans, plants, and farm animals. The effect has been a drop in the incidence and prevalence of important water-related and mosquito-transmitted diseases such as malaria, yellow fever, and filariasis. Through the ability to grow high-value food crops in well-drained soils, health, nutrition, employment, income, and economic diversification of rural populations have been improved.

Where used to reclaim saline and waterlogged lands, drainage is an environmentally beneficial practice, because the land is restored to its full productive potential. The adaptation of subsurface drainage systems to serve as subirrigation or controlled drainage systems leads to other benefits such as the reduction of nitrate pollution. ICID-FAO (1997) summarized the field-scale benefits of drainage as follows:

- Drainage promotes beneficial soil bacteria activity and improves soil tilt.
- There is less surface runoff and soil erosion on drained land.
- Improved field machine traffic ability reduces soil structural damage.[2]
- In general, land value and productivity are increased.
- Farm income is increased and income variability reduced.

[2] Soil compaction is reduced, and less energy is required for field machine operations. Drainage also allows for timelier field operations. Consequently, the growing season can be lengthened and crops can achieve full maturity. Crop yields are increased because of improved water management and uptake of plant nutrients. Higher value crops can be planted, and there is flexibility to introduce new and improved cropping systems.

- Drainage maintains favorable salt and air environments in the crop root zone

Environmental Impact Assessment

To comply with the environmental law and regulations, an environmental impact assessment (EIA) is prepared prior to construction activities associated with new projects or rehabilitation. The objectives are to identify potentially adverse environmental effects and their magnitude and to develop mitigating measures. Positive benefits are also identified. In cases where the adverse impacts far outweigh the expected benefits, the project may be completely redesigned or suspended. This is also the case where mitigating measures would be either too costly or technically unfeasible. The EIA is conducted during the preparation of feasibility studies, while crucial decisions are still being deliberated. According to Ochs and Bishay (1992), environmental effects can be classified as:

- *Direct and indirect, or first order and higher order.* These are chain effects, felt throughout a catchment and possibly downstream.

- *Secondary*. The primary activity of a drainage project may he extended to include secondary activities.

- *Synergistic*. These effects include an increased threat to the survival of certain species of wildlife that are under pressure in several ways as a result of the project.

The International Commission on Irrigation and Drainage has developed an environmental checklist to identify environmental impacts of irrigation, drainage, and flood control projects. The World Bank has prepared an Environmental Assessment Sourcebook (World Bank 1991). FAO has produced a paper on the steps in the EIA process and the major environmental impacts of irrigation and drainage projects (Gonzalez and Contijoch 1992). The purpose of these documents is to enable detailed environmental impact assessments of irrigation and drainage projects. The ICID checklist provides a comprehensive list of environmental parameters that must be evaluated in an EIA. Ochs and Bishay (1992) list the main steps in the EIA process as:

- Scoping, a public process involving the participation of all parties. It results in specific guidelines for inclusion in the environmental impact study (EIS). EIS refers to the document, whereas EIA refers to the entire process.

- Drawing up the EIS. Potentially adverse and beneficial impacts are identified. Proposed actions with alternatives are indicated, and mitigating measures are presented.

- Submitting the EIS for public review.

- Receiving advice from the reviewing agency.

- Accepting the EIS.

- Choosing project components. The decisionmaker chooses the project option to be implemented and the mitigating measures.

- Implementing the project.

- Monitoring the actual environmental impacts during and after project implementation monitored and comparing them with the EIS predictions. This is useful for improving future predictions and project designs.

Water-Quality Issues

The installation of drainage systems may result in changes in the associated ecosystem. These changes may be either beneficial or adverse. The positive environmental benefits were listed earlier. However, it is very important to notice the potentially adverse effects.

Concentrations of salts, nutrients, and other crop-related chemicals in drainage discharge vary with time and discharge rate. The use of fertilizers and pesticides in intensive agricultural production has sometimes led to damage to downstream aquatic ecosystems (ICID-FAO 1997).

On-farm source control is the most efficient method of minimizing environmental problems. In irrigated areas, improved irrigation water management can achieve this. Higher irrigation efficiencies and lined irrigation conveyance structures will reduce the amount of drainage water that has to be removed. Applying fertilizers and pesticides only when needed and in the smallest amounts needed will reduce chemical leaching. Research has shown that intercropping with a legume or ryegrass reduces the amount of nitrates found in drainage water. In the Mexican experience, different programs have been used to improve the efficiency of water use at farm level such as, in tropical areas, water and soil conservation practices.

Reuse of Drainage Water

In the northwest districts where irrigation water is scarce, drainage water is used to meet crop water requirements. Reuse is feasible because drainage water is of sufficiently good quality, 4,000 ppm of salts, and it can be mixed with good quality water from the irrigation channels. In Mexico, drainage water can be contaminated with trace elements, toxic organic substances, industrial waste, and municipal waste in open main drains. Contaminated drainage water could cause various problems including impairment of the soil's physical and chemical properties, water-related health problems, and contamination of food products.

Interest is increasing in the utilization of natural and constructed wetlands to manage drainage water. Wetlands are particularly effective for removing sediment and nutrients such as nitrates and phosphates. Plant, soil, and hydrologic parameters interact in complex ways to filter and trap pollutants and recycle nutrients. Certain tree and plant species can absorb pollutants. In Mexico, coastal irrigation districts were planned to stop intensive cultivation at the 4m curve above sea level, leaving a space for natural vegetation and pastureland. This buffer zone helps in the removal of pesticides and other chemicals that would otherwise be discharged into the sea. In some districts, aquaculture has been introduced, using irrigation district facilities, mainly roads, and some water. Shrimp farmed in these areas is in high demand and fetches a high price. Around 20,000 ha have been reclaimed for aquaculture production in Sonora and Sinaloa states.

One of the most severe water problems in Mexico is the increasing contamination of both surface and underground water. Studies by the NWC in 2000, using water-quality indicators, show severe restrictions on use in many basins because of the low water-quality standards prevailing especially in the central and north regions.

The NWC water-quality network numbers 403 measurement and monitoring stations, 215 of them located in rivers and canals, 45 in coastal zones, and 143 in lakes, lagoons, and other water bodies. There are also 227 semiportable stations for use in the secondary network.

The availability of surface and underground water is connected to changes in the environment and pollution. These aspects have to be considered in the implementation of programs to improve water irrigation efficiency and develop drainage solutions. The overuse of water in irrigation, in some basins, exceeds their capacity to regenerate resources, absorb pollutants, and satisfy the population's needs. Moreover, overuse has impoverished and disequilibrated the ecosystems. A reduction has been noticeable in the cropped area in the last few years, and pollutants have shown up in streams and in rivers. As discussed above, agriculture is both cause and victim of its own pollution. By using water for irrigation, agriculture became a source of pollution through runoff of organic and chemical substances into water bodies and through erosion, producing a net loss of soil, salinization, and waterlogging. Agriculture is a victim, because reuse of agricultural water and municipal and industrial wastewater pollutes soil and crops and transmits disease to consumers and workers.

In Lake Chapala, pollution associated with the deterioration of water quality has invited the growth of algae and aquatic weeds. The Ministry of Health reported 5,620 deaths from waterborne diseases in 1999. The most frequent bacteria are coliforms of human origin, which reflect poor sanitation in Mexico. Nitrate levels in underground water have increased, and 10 out of 100 Mexicans drink water that does not meet the country's lowest acceptable quality norm for drinking water (10 mg of pollutants per liter). In Mexico's tropical areas, the aggressive development of livestock production and deforestation is causing changes in flow patterns in most basins and siltation in riverbeds and dams is aggravating flooding.

The loss soil fertility is a complex problem related not only to erosion but also to a combination of vegetative and nutrient factors. In the tropical areas, once biodiversity is lost and the land is still used for agriculture, the use of fertilizers has to increase to provide nutrients artificially. The incorporation of agricultural land for intensive production therefore has to be carefully considered and planned to prevent ecological repercussions and loss of biodiversity.

An important issue affecting relations between Mexico and the United States is the high level of pollution along the Río Bravo/Río Grande border and in the Río Tijuana and Río Nuevo in Baja California. The director of the International Boundary and Water Commission told the local press that 352 million liters of inadequately treated sewage is dumped into the Río Grande every day. Nuevo Laredo alone dumps 3.2 million liters of untreated water into the river daily, and Laredo, its neighbor on the U.S. side, contributes another 2 million liters(David Negrete, personal communication). Mexicans, as well as Americans, use the river for irrigation and energy generated by two hydroelectric plants (Sally Spener, personal communication).

Water Reuse Experiences

Agricultural water reuse in Mexico is a consequence of insufficient precipitation, low availability of clean water, and the existence of a low-income population requiring water for agricultural production. The most outstanding case is the Mezquital Valley. For almost a hundred years, this region has used residual water from Mexico City in a constantly expanding irrigation system. At present, the 18 million residents of the metropolitan area produce 1.35 billion m^3 a year, equivalent to 43,000 l/s of wastewater, with which 90,000 ha are irrigated.

Some favorable aspects derived from this ongoing experience include:

- An increase in cropped areas with enriched soils and available irrigation water
- An increase in yields, as these irrigation waters contains nutrients
- An increase in income-yield capacity by including crop patterns with higher value agricultural products
- Strengthening of family and regional economies
- Enhanced social development and improved public services.

The most important risks and costs of agricultural irrigation include:

- *Public health*. Higher incidence of gastrointestinal diseases among farmers and their families and slightly greater incidence among consumers of vegetables and similar produce
- *Aquifers*. Increased concentrations of heavy metals and chemicals in water
- *Cropped soils*. Increased concentrations of heavy metals and salts
- *Water bodies*. Increased concentrations of heavy metals and seasonal eutrophication of reservoirs. The organic pollution content of the Pánuco River, where these waters are discharged is higher than in any of Mexico’s 218 hydrological basins.

The inventory of areas irrigated with wastewater carried out in 1990 identified 252,000 ha. According to more recent studies by the IMTA, 344,000 ha are irrigated with mixed wastewaters.

Internationally, wastewater-irrigated areas amount to 1,873,000 ha (González and Contijoch 1994). The country with the greatest such area is China (1.33 million ha). In second and third place, respectively, are Mexico (340,000 ha) and India (95,500 ha). There are also large wastewater-irrigated surfaces in Saudi Arabia, Chile, the United States, Kuwait, Australia, Israel, Tunis, Peru, Germany, Argentina, Sudan, and South Africa.

Potential for agricultural reuse

On the national level, domestic users in Mexico generate nearly 150 m^3 of wastewater. Streams where municipal drainage is discharged also receive industrial liquid wastes, so a calculated flow volume of 200 m^3 of mixed wastewaters is reused for agricultural irrigation (Calderon 2002).

In relation to outflow from treatment plants, an inventory indicates there are a total of 808 installations, including 416 stabilizing ponds, 174 plants with activated sludge, 59 with imhoff tanks, and 32 with biological filters. In the 615 plants in operation, installed capacity is 55m^3, and treated flow volume is 35.3m^3, producing an annual volume of 111 billion m^3.

The scenarios for reuse potential obtained from a broad analysis are the following:

- *Short term.* From treatment plants in operation, 30m^3 of outflow
- *Medium term.* From plants budgeted or under construction, 16m^3 of outflow
- *Long term.* From 200 idle plants that could be rehabilitated, 20m^3 design-outflow equivalent
- *Very long term.* From cities with a population greater than 50,000, an additional 100m^3 of potential discharge flow but requiring the construction of treatment plants.

Specific projects identified can be grouped in the following categories:

- *Control of groundwater pollution.* By delivering treated water to producers now using raw sewage in agricultural reuse
- *Control of aquifer overexploitation.* By delivering treated water to farmers in exchange for closing down water wells now used for agricultural irrigation
- *Water reuse in agricultural irrigation.* By delivering treated water to producers interested in participating in agricultural reuse
- *Control of water pollution in irrigated areas.* By treating residual water now discharged into water bodies supplying irrigation districts
- *Water interchange*. By delivering treated water to producers in zones with balanced aquifers in exchange for allowing water from wells now used for agricultural irrigation to be allocated to other uses.

There are now 33 treatment plant projects, all of them with studies and executive projects, and some others are under construction. Institutional arrangements are being made for use of the outflow for several purposes.

Public Health

To achieve economic and social benefits from agricultural reuse, public health must be protected. The use of raw wastewater brings risks associated with the presence of intestinal nematodes *(helminthes),* bacteria, and viruses from human excrement. Worms present the highest risk, viruses the least, and bacteria, low risk.

Health guidelines recommended by the World Health Organization (WHO) proposed values for estimating potential risks (qualitative pathogen presence and unrelated to illness detection), which resulted in very stringent regulations, often difficult to comply with in developing nations. Epidemiological studies have recommended less rigorous criteria. There is no evidence indicating higher illness rates when treated waters are reused in agriculture, but they do indicate a greater incidence of illnesses (gastrointestinal) when untreated waters are used. In Mexico, regulations are based on WHO criteria, but more recent studies suggest that the Mexican official norm for the use of residual water should be modified to set stricter limits for helminthes and less restrictive ones for fecal coliforms. The new standard could be met through the use of stabilizing ponds and retention reservoirs to store water.

Four groups of people face potential risks in agricultural reuse of untreated residual water: producers and their families; personnel handling agricultural products; consumers of raw produce, and persons who live near areas irrigated with wastewater. To protect their health, four actions are recommended:

- *Water sanitation*. Only sanitary, treated water will be used.
- *Adequate agricultural practices*. The technical assistance system will give training on handling irrigation waters so as to minimize health risks to the irrigators.
- *Crop restriction*. Compliance with regulations will be reinforced.
- *Prevention and medical treatment*. The health sector will carry out epidemiological studies, and preventive and medical services will be strengthened.

According to the new norms now in effect, most cities and industries need to treat their water to comply with the Water Law and the Ecological Law. Because of social pressures and Mexico's economic conditions, however, the application of the law has been postponed for five years. During this time, cities and industries have to develop water treatment projects to comply with the new legal requirements. This reprieve gives them an opportunity to develop alternatives to reuse in agriculture. These possibilities have to be sufficiently analyzed. In some districts, this solution may lead to a reengineering of the present distribution of water and to changes in cropping patterns.

6. Policy Recommendations

Based on these considerations and field visits, policy recommendations can be tailored for each region.

Northwest and Pacific North Regions

In the Northwest, although Río Mayo and Valle del Carrizo are neighboring districts, the availability of water in the Río Mayo aquifer gives different characteristics to drainage solutions in the two districts. In the case of Río Mayo, the use of tubewells to meet demand for irrigation and lower the water table has played a fundamental role in reducing pressure from salinity and high water table problems. The Valle del Carrizo, a much younger development area, presented more serious problems of salinity due to overirrigation. Within the region, the Valle del Carrizo had the lowest benchmarking indicators in terms of water and soil productivity despite its better climate for crop diversification (Contijoch 2002).

In both districts, salinity and high water table severely impaired agricultural output over 37 percent of the Río Mayo district and 72 percent of the Valle del Carrizo district. Both presented an opportunity for massive testing of the alternative of installing subsurface irrigation. In both cases, studies were conducted using the available information and the support of satellite imaging, GPS technology, and field samples (Pulido, et al. 2002). IMTA is responsible for carrying out the initial designs, day-to day methodologies to determine solutions, and pilot projects to test them. The results in both cases, but particularly in the Valle del Carrizo, have being impressive. The introduction of subsurface drain lines at distances between 23 m and 50 m, with diameters starting at 3 inches discharging into 6-inch collectors have been installed in a total area of 15,000 ha at an average cost of less than US$1,000/ha (Namuche, Pulido, and IMTA 1991).

This reclaimed land has now returned to its former productivity, because farmers have followed the recommended practices for water leaching, soil improvement, and irrigation. In Valle del Carrizo, property values have multiplied tenfold since the introduction subsurface drainage.

Several recommendations were identified during the field visit.

- Volumetric delivery of water is essential for controlling overirrigation practices, and it can be introduced as in the neighboring Río Yaqui district north of the perimeter. IMTA has devised a tool kit for this purpose, which can be used in most districts in this region.

- Maintenance of the discharge system to the lagoons is important to guarantee the correct functioning of the irrigation district as a whole. In Río Mayo, this work requires further attention to solve some of the existing waterlogging problems.

- Improved water use per unit of output can be obtained by pursuing the modernization program now being developed. Priority should be given to on-farm irrigation systems, using the matching grants provided by the Agricultural Alliance Program.

- To improve the design criteria, "reference sectors" must be developed, integrating water and salt balances in the different subareas within the districts. Based on these results, subsurface drainage systems could cover the entire salinity-affected area, an estimated at 25,000 ha in both districts.

- Fertilizer use must be reduced, and agrochemical use must be limited, based on the results of environmental studies to identify the main impacts of the drainage discharge to the coastal lagoon.

- Formal integration of aquaculture farms into the water user associations is of great importance to prevent future conflicts. Some problems have been identified: obstruction of natural drainage, eutrophication of lagoons, and, most important, backflows in the drains.

- Promoting water user associations has proven its worth as a functional strategy for all future irrigation development. The results already significant obtained can be improved if self-sufficiency in system operation and maintenance is retained as a major objective.

Southeast Tropical Region

The tropical lands of Mexico represent the future frontier of the country's rural development. The present status and promising future of these drainage units have recently been emphasized. The present government gives high priority to the development of the tropical areas within its overall plans for future economic growth.

Investment in the improved rainfed districts is relatively low, around US$1,000/ha, compared with investment of between US$5,000 and US$10,000 in the irrigation districts. The amount of institutional work involved in planning, monitoring, technical support, and supervision of the improved rainfed districts is lower than in the irrigation districts, but the economic returns are similar (internal rate of return of 14.4 percent for PRODERITH versus 13.8 percent for the Irrigation and Drainage project). Social returns on government interventions in the tropical areas have also proved the feasibility of the government intervention following a participatory approach like the one used in PRODERITH (World Bank 1994).

The systems were designed specifically for each set of natural conditions and the agricultural interests of area farmers. Design deliberately preserved wetland areas and incorporated conservation works to protect them. The use of pesticides and fertilizers is still minimal, and it is not affecting the watercourses. There are, however, some health problems, mainly with water supplied to the rural population, which is not always disinfected, and some waterlogging in the drains.

From the projects visited, the drainage typology could be tailored in terms of the following factors:

- Protection of the drainage area by major infrastructure works (dams and levies), or its lack of protection

- Potential use of land to satisfy farmer interests and agroeconomic conditions in the project area.

- Managerial capability and possible external interventions from private investors, considering also relations with agribusiness

- Possible interference of the drainage infrastructure with future development of highways and oilfields

- Opportunity or need to develop on-farm systems

- Level and continuity of governmental interventions at different phases of project life

- Organization of the farmers for the maintenance of drainage works
- Coordination with agricultural research activities and the possibility of encouraging their work for the consolidation process.

The maintenance system observed during the field visit in the Center of Veracruz and Tesechoacan Districts is appropriate and is providing good results. The maintenance system in Zanapa Tonala needs more funding, which might come from the local government. The formation of associations is impressive, and the role and responsibility accepted by the elected leaders is commendable. Some associations have established formal agreements "contracts" with local governments and agricultural companies in the project areas, allowing them to surmount the implicit problem of collecting fees for drainage system maintenance and amortization of debt on machinery.

The collection of fees for infrastructure maintenance depends on the particular arrangements established by the associations in each project. They are, however, doing a much better job than the government did. The procedures for performing maintenance work are economical and competitive. The average rate of around US$3.00/ha complies with the program requirements formulated by the NWC. The money collected has been used efficiently and provides for both asset accumulation and amortization of equipment. The NWC is helping to facilitate this process and has authorized agreements "contracts" between the associations and the local governments or private companies with agricultural interests in the area to derive funds for the conservation works. This flexibility has helped drainage user associations assume their responsibilities. For the expansion of on-farm drainage systems, new funds are needed, and technical assistance from district offices or the UCT is required.

The organization of the associations corresponds to the typology of the drainage infrastructure and the agroecological zones defined in the feasibility studies. This aspect was fundamental in the integration of the associations with different farm groups in their communities. For the purpose of defining the micro-typology, the following aspects were considered: soil type, agroecological zone, infrastructure, and land tenure. The average drainage unit is between 400 ha and 1,600 ha.

The type of machinery provided to the associations was well selected (mainly motor graders, agricultural tractors with light equipment, compactors, Dondi trenchers, D-5 tractors, and water excavators), and the work implemented has been done properly. This system is affordable for the farmers and can reduce deferred maintenance problems that plague drainage infrastructure, especially in the humid tropics.

The associations have started to become involved in the construction of on-farm and soil conservation works, which can help to materialize the benefits of the systems. Now that some innovative farmers realize the importance of such investments, it is time for the government to fully support these initiatives. The National Water Commission still plays a major role in constructing new infrastructure, taking care of some works that need a high level of expertise, and providing new machinery required by the associations for their on-farm works. The general recommendation is to consolidate the development of the improved rainfed districts, preparing detailed plans for each project in a third phase of development.

In some projects, as anticipated, supplemental irrigation is been developed. The introduction of pressurized systems is helping to solve the technical problems of providing this service to farmers. New commercial crops have been developed with excellent results.

According to the project completion report of PRODERITH II, an internal rate of return of 14.4 percent and the original major objectives were substantially achieved. These objectives, as stated in the initial evaluation, were poverty alleviation, expansion of rational land use, increase in agricultural production and productivity, and strengthening of farmer institutions. The production impacts could still be increased substantially, if new on-farm investments are promoted. The associations could be a good vehicle for introducing this type of coordination between the agricultural programs and the drainage systems in the improved rainfed districts.

The Technical Committee of PRODERITH, which provided the linkage between the different agencies involved in the program, could be reestablished. It should, however, be slightly reorganized, probably in each state, and with representatives at the level required to assume responsibilities and follow up on their implementation. In the agricultural sector, SAGARPA, INIFAP, and FIRA are basic for the support of productive activities.

A new stage of PRODERITH, or a Program for the Consolidation of the Improved Rainfed Districts, could be studied and implemented. This project could probably have the support of the World Bank. Competition between irrigation projects and drainage system projects is detrimental to drainage results, but mainly because of the difficulties in assessing development in the tropical areas, not because projects in the tropics suffer from comparison of impacts and results. In the tropical regions, diversification of the landscape, poverty, the lower level of investment and productivity per hectare, the rate at which development takes place in this region, and the specific objectives of the farmers and rural communities, demand specific approaches and flexibility for implementation.

Conclusions

The following lessons and recommendations can be drawn from the previous chapters, analysis of the information, and discussion with stakeholders. They are presented by the functions of the irrigation and drainage sector as institutionally organized in Mexico

Most drainage interventions fit into general basin planning on the assumption that it encompasses: correct application of integrated water resources management principles; representation of stakeholders and their active participation in implementation; and availability of financial resources, both within the system and from external sources.

Integrated water resources planning

In terms of the first assumption, Mexico has a National Water Law and regulations, a sole authority for water, a systematic planning process, a water tax law, clearly defined water rights and concessions integrated in a water register, and organization of water users at different levels. These conditions, seldom found in other countries, are a big asset for the application of IWRM principles. The findings of this study suggest that some additional activities should be included, considering the importance of damage in the functioning of the hydrological cycle.

The methodology and the information available are sufficient to arrive at a general framework for water planning at basin level. More information is necessary about water quality to analyze interrelations within the system. The integration of policies and strategies is coherent. The analysis of alternatives to solve high water table and salinity problems is limited, but, in the case of irrigation and drainage in the arid areas, the basic issues stem from the present conditions of the surface drainage system and farmers' decisions to incorporate the new alternatives in their investment choices to improve the productivity of their fields.

In the case of drainage in the humid tropical areas, where drainage demonstration modules have not been expanded to cover the entire agricultural area in the projects, more demonstrations and specialized equipment are needed. Government interventions in drainage have to utilize fully the incentives available (e.g., the Agricultural Alliance) to encourage users to choose alternatives proposed by the government for use at subbasin level.

From experience with drainage development, particularly in the tropical regions, there is a general consensus on the importance of looking at drainage at basin and subbasin level. Projects and alternatives have to be integrated in the general planning process for the basin. The basic rule is to guarantee discharge conditions at system outlets and provide the infrastructure needed to operate under normal conditions as well as to deal with predictable events such as storms and flooding. Usually flood protection has not been properly addressed, and users have not observed nonstructural measures.

From the economic results obtained in the development of drainage projects in the tropical areas, the following conclusions have been drawn.

- Drainage areas in Mexico have been developed exclusively for land served by surface drainage systems where pumping excess water is not necessary.

- In terms of risk management, the 5-year frequency probability of storms has provided good protection as a predictor. For levies, a 10-year frequency is also a valid assumption. For rural towns of 2,500 to 20,000 inhabitants, the period should be 20 years. Larger towns need return periods of 50 years and a complete hydrological analysis.

- Most outlets to rivers and lagoons pass thorough open structures or flap gates. The systems do not include subsurface drainage installations. The economic rationale for the choices made relates to the potential production expected. This strategic decision is coherent with the farmers' production objectives and has helped reduce the operational costs of infrastructure and system maintenance and sustainability.

In the case of the 35,000 ha of irrigation districts with subsurface drainage, the positive productive and economic results obtained show that this technique can be introduced in the 400,000 ha identified as being able to improve their productivity. The handbook developed by SARH and IMTA (1986) from this experience, together with the proposed "reference sectors" and "FAO monitoring plots," are good tools for assisting the extensive application of subsurface drainage systems in Mexico's irrigation districts.

From experience in Mexico's planning process, the projects were conceived starting at the basin and working down to the subbasin and micro-basin to define basic units for on-farm drainage. These drainage units are blocks of between 400 ha and 1,600 ha. In the case of the irrigation districts, drainage units were defined in terms of micro-basins, drains, roads, and collectors. The average block is around 400 ha. The road system associated with drainage and irrigation projects serves both drainage and communication objectives. Experience in both irrigation and drainage projects suggests that communication circuits should be established to connect rural communities with their agricultural areas. Special attention was given to the location and construction of bridges, culverts, fords, and side water inlet facilities. Land tenure and holding size require detailed discussions with farmers to prevent future conflicts.

To improve the planning process for subsurface drainage, the experience acquired by IMTA in the use of remote sensing can be applied in the determination of the areas in four irrigation districts affected with saline and high water table problems (IMTA 1998). The methodology is cost effective (US$0.40/ha) and gives a fast and accurate evaluation of drainage needs. This work was presented in the Expert Consultation Meeting in Ede-Wageningen in May 2001 (IMTA 1998).

IMTA has proposed that the NWC and the water user associations should be responsible for monitoring drainage compliance with reference sector provisions in the districts that have installed subsurface drainage systems in order to calibrate the design parameters and optimize investment costs. Potential yield of 100 percent was set for a spacing of 28 m, the calculated technical spacing. However, it can be observed that, if a 15 percent yield decrease is accepted, the cost of the system decreases 50 percent with a spacing of 50 m. With the support of FAO, several monitoring units will be implemented in the Río Yaqui Irrigation District. This practice should be used extensively in cooperation with the water user associations and the NWC.

An important decision must be made about irrigation and drainage practices at farm level. Right now, the technical personnel and the laboratories still belong to the NWC as part of its technical assistance and supervision activities. The NWC and the SRLs have to work closely together to strengthen the functioning of these groups, which are important for the districts' future development. In addition to keeping records on the evolution of water tables, soil analysis, and technical assistance. These groups can supervise subsurface drainage system construction and monitor water quality in drainage systems and lagoons. In the tropical areas, the UCT could be contracted to do the monitoring. In the future, the UCT could also be enlisted to promote, organize, and develop on-farm drainage units.

From experience in Valle del Carrizo, IMTA could contract with the NWC for the implementation of environmental impact studies of the effects of agrochemicals on coastal lagoons and water bodies for the irrigation and drainage districts. This activity will become more important once the on-farm drainage systems expand, as foreseen.

Stakeholder participation

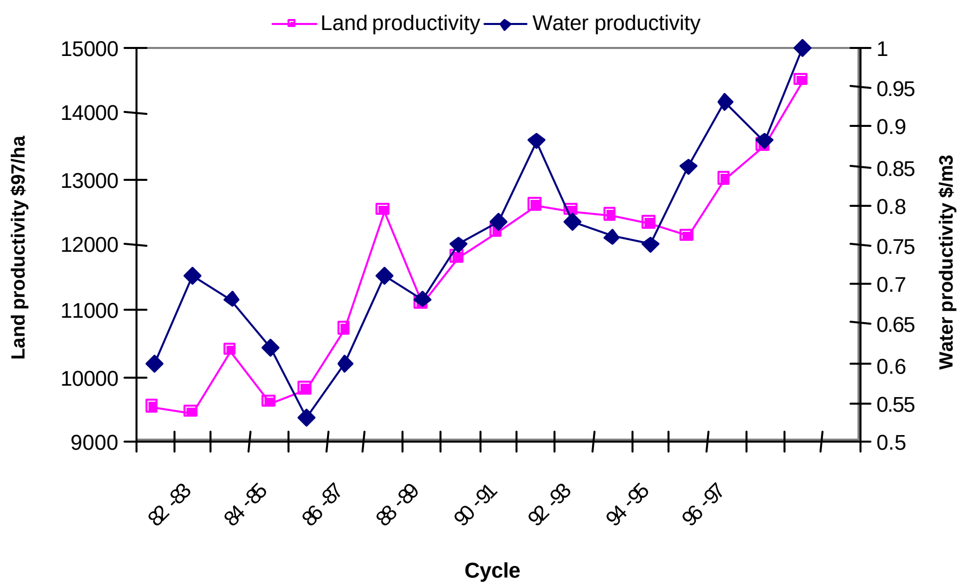
As a second assumption, appropriate stakeholder participation mechanisms are essential to guarantee the implementation of the proposed plans and solutions. The experience of the basin councils is still inconclusive regarding how far down decisionmaking should be decentralized. The councils have not managed to reach a consensus on the general sustainability of the basin. Tradeoffs are not easily identified, and the role of the NWC in transferring water allocation and program definition to the councils has not yet been implemented. The role of the NWC as Mexico's "sole authority for water" is being challenged every day by state governments. This is not an isolated process; it relates to the new democratic era the country is living. With the experience, information, and expertise in conflict resolution that the NWC personnel now have, water could become a sector where consensus among the different stakeholders could be built.

Some important experience has been acquired at the district level, where users play an active role in the administration of water, assets, and responsibilities. In both irrigation and rainfed districts, the users participate actively in day-to-day decisions on operation and maintenance of the infrastructure and the ongoing modernization programs.

Mexico's strategy for decentralizing these functions to the user associations has proven very successful (ICID 1992). In the inquiries conducted by independent institutions, users have expressed satisfaction and given high ratings to the transfer process. For instance, 96 percent of the users consider that the WUAs implemented the irrigation program correctly. The increase in soil and water productivity and the reduction in the irrigation water table are positive, as can be observed in figure 7, developed for the NWC by the Colegio de Postgraduados in an unpublished study.

The future role of the National Association of Irrigation Users (ANUR) requires strong support from the agencies involved, not only in irrigation but also in agriculture, rural development, credit, and organization. The government has to support the decentralization process to improve performance. The ANUR is conducting training courses for district managers, administrators, and technical personnel with the support of IMTA and the NWC, in the National Training Center for Irrigation and Drainage located in the Valle del Carrizo Irrigation District. This program can and should be reinforced to cover drainage-related aspects.

Figure 7 Evolution of water and land productivity in the irrigation districts



Source: Colegio de Postgraduados 2001.

Funding and investment

Concerning the third assumption, the government has little funding available for irrigation and drainage, especially for investment in the tropical areas. At a time when agriculture is trying to deal with food surpluses on world markets, Mexico still imports basic crops, mainly for animal feed. This shortage in

Mexico is one argument for increasing productivity, and the best place to do it economically and with least cost to the ecology is in the current irrigation and drainage projects. It would also have positive economic and environmental effects, because it entails more rational use of past investments and lower use of agricultural inputs.

Farmers consider water their most vital resource and basic agent of production, not an additional cost of agricultural production. Nevertheless, maintaining self-sufficiency in operation and maintenance costs incurred in delivering the resource is crucial. However, farmers consider installation of subsurface drainage infrastructure an investment that has to prove profitable in the long run for each project. Therefore, the experience gained with the 35,000 ha test is important and should be given the widest possible public exposure to prove the economic and financial value of these type of projects.

Preparing new strategies and options is very important to convince the NWC to promote productivity increases in the irrigated and drainage areas now under production. The importance of giving priority to this decision should be properly presented to obtain the administration's commitment to it. Drainage could be the government's "motto" for its interventions in the tropical areas. At the same time, the economic and social results needed to minimize poverty must be produced. This strategy has to shape a climate for private investment and incorporate strategies for agribusiness activity.

Irrigation and drainage users received valuable assets through concessions of water and infrastructure. Market mechanisms can be used to transfer or rent this asset to the most productive activities so as to get a collective benefit for modernization of all the districts as a whole. For instance, if farmers could provide bulk water to the city of Hermosillo, they could compete with suppliers of new water from a desalinization plant. The margin could help stabilize the aquifer through the introduction of drip irrigation, saving water and increasing productivity and income per cubic meter. The district, which now has an agricultural area of 50,000 ha, could save 50 million m^3 of water a year and sell it to the city. In return the city could help users save water from agriculture, increase productivity, and improve cropping patterns.

Irrigated areas could now perform an environmental service for the cities by reusing water and sludge. This could reduce pressures for additional sources of water. The supply of reuse water does not fluctuate throughout the year as do other sources because of the climate changes reported in the last decade. These new functions could improve the irrigation sector's financial footing.

Besides influencing water-quality issues, WUA federation ands SRLs can also influence the future role of drainage in the irrigation districts. The SRLs need technical specialists in drainage to improve their effectiveness in maintaining drainage infrastructure, identifying the best areas to include in programs for subsurface drainage installation, and supervising the private companies responsible for construction. These activities could improve the WUAs' financial results.

Construction. The drainage works inspected were well constructed and are performing the functions they were designed for. However, some aspects need further improvement:

- Planting groundcover on the slopes and berms with guidance under the Cooperation Agreement with the U.S. Department Agriculture for PRODERITH. Sowing Bermuda or Pensacola grass seed during drain construction can reduce O&M costs.

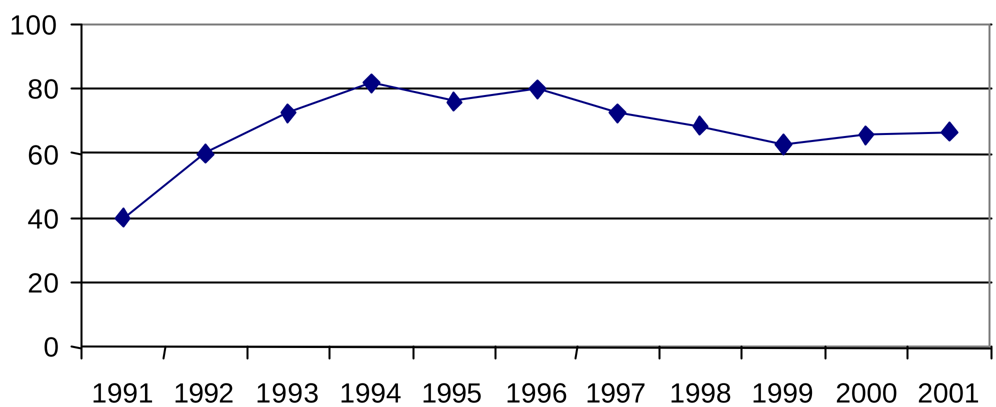
- Adding side inlets along the drains to prevent erosion. Pipe or rock-lined chutes should help to minimize direct erosion of the channels.

- In subsurface drainage, the availability of pipes of the design diameter could restrict optimal operation. Only two factories in Mexico, both in the northwest region, produce corrugated pipes with bores of 3 inches to 6 inches. For some projects 2-inch and 8-inch pipes are needed. This problem has to be solved economically once the program is fully operational in other parts of the country to reduce the costs of transportation. District or SRL personnel should supervise construction.

Operation and Maintenance. The sustainability of irrigation and drainage development hinges on the adequacy of resources for O&M provided by water users now that they are responsible for upkeep of their irrigation and drainage networks. Government intervention is required to monitor the process, supervision, and technical assistance, especially at farm level. Because water-quality monitoring and development of the area-curve graphs are important elements of the systems, the government should invest in this part of systemic information and analysis.

Among the second-generation problems facing water user associations, the most import one is the level of O&M self-sufficiency in the districts. As can be seen in figure 8, because of the economic crisis and the drought in recent years, the water fees have not covered the costs of recommended infrastructure maintenance. This serious problem deserves prompt attention from the authorities, the ANUR, and the users. If this situation continues, service could deteriorate, and the positive results obtained could be lost. In the present situation, the NWC has provided funds to partially offset the deficit. This situation has a negative effect on sustainability in the irrigation sector.

Figure 8 Self-sufficiency trends in operation and maintenance costs



Source: NWC 2001.

Districts where subsurface drainage systems have been installed must be provided with specialized maintenance equipment to unclog the pipes. Obtructions in the pipes are not a substantial problem, but the SRLs could start this maintenance and provide farmers with this service. In the improved rainfed districts, drainage users have made a remarkable effort, and farmers throughout the region should receive more support to reduce deferred maintenance problems and help the development of SRLs. Investments in the vicinity of US$177 million can be incorporated in the NWC budget, but a good case has to be presented to obtain these funds from the Treasury Department. In parallel, the UCT system has to be enforced, especially to cover expansion of on-farm drainage projects.

Efficient water management and expedited technology transfer are needed for increased productivity and crop diversification. Ample technology is available and in use by the better farmers countrywide, but extension services have to be improved to accelerate its distribution, especially to small farmers in irrigated areas. In this respect, the WUAs could perform an important role, perhaps with assistance from existing government programs. For instance, the WUAs could apply for funds from the Agricultural Alliance Program to finance technical assistance activities in an integrated organization, following the principles existing for the UCT.

Coordination with agricultural and rural development

Agricultural policy must be coordinated with water policy operations in irrigation and drainage, within an integrated approach for the productive transformation of the rural sector. This integration could be analyzed by the water committees in each irrigation district. To prevent this activity from turning into a burocratic coordination exercise, the WUAs could take the lead. They could begin some studies, works, and activities to integrate the various proposals to restructure the productive orientation of their systems, with an eye to increasing competition and expanding their role in building regional and local niches. An example of this work can be seen in the Río Yaqui ID where farmers are working on a proposal to modernize their market system. To increase their competitiveness, the district has to diversify from wheat into citrus, oilseed, and milk production. This means changes in the operation of the irrigation service to allow more flexibility in dealing with the requirements of their new agricultural and livestock activities.

For this strategy to work, agreements and consensus have to be reached at the state and local levels and in each irrigation and drainage district and improved rainfed district. Farmer organizations and WUAs have to become more actively involved in the strategy as a whole so that all actors understand internalize the objectives in specific programs and activities and coordination and competition can be improved. This aspect has been properly addressed in the preparation of the ongoing project for modernization of the irrigation and drainage sector.

Program and budget

Mexico is starting a second phase of the Irrigation and Drainage Program to increase productivity and efficiency of water use in agriculture through the newly approved Irrigation and Drainage project. The recommendations outlined in this report are in line with this process. The NWC, with the support of the World Bank, analyzed the different components of the strategy and evaluated proposals in each district for incorporation in the program.

Planning. The following activities would improve the position of drainage in integrated water resources planning and management:

- The use of remote sensing methodology to identify precisely the areas affected by salinity and high water tables. This could be initiated in the 10 most affected districts.

- Implementation of "reference sectors" (for 400 ha farms) as proposed by IMTA in the four districts that have installed subsurface drainage systems and also the implementation of "reference plots," as agreed with FAO (for 20 ha farms) for the monitoring and calibration of the design criteria for subsurface drainage. Some of these ideas could be extrapolated to the tropical areas to improve surface design criteria, still missing in Mexico.

- Integrating information on the evolution of the water tables in every district, using the same procedures used in the Río Yaqui Irrigation District for the area-curves graphs

- Conduct the Environmental Impact Assessment of the effects of agrochemical use in the coastal lagoons in the northwest region of Mexico for the following irrigation districts: Colorado, Yaqui, Mayo, Carrizo, Fuerte, Guasave, Sinaloa, San Lorenzo y Piaxtla Elota.

Operation. From the field visits and the different conversations with farmers and technical personnel from the WUAs, and the farmers we can recommend:

- Strengthening the UCT concept for agricultural technical assistance and expand the demonstration modules of on-farm surface drainage in the tropical areas.

- Up-dating the evolution of the cropping pattern and the economic evaluation of the improved rainfed districts now in progress.

- Developing procedures for drainage practices and operations in the concession titles, so the roles and responsibilities of the government and the associations are clearly stated.

- Integrating maintenance of the subsurface drainage systems as part of the SRLs' normal activities and charge the cost to the users.

- Fostering the development of the coastal lagoons by having the NWC regulate development of aquaculture farms and coordinating water concessions and infrastructure maintenance with the user associations. This would help prevent congestion of the drainage outlets. At the same time, it is important to monitor the water quality at the discharge to the lagoons.

Implementation. The NWC is working to integrate drainage into the future development plans of the irrigation sector in Mexico. We suggest the following actions for the implementation process.

- Integrate a program for the development of subsurface drainage for the reclamation of 400,000 ha identified affected by salinity and high water table. The program should identify the specific land affected, evaluate the impact, and promote user participation in program implementation. Specific designs and terms of reference should be developed for the installation of subsurface drainage systems as agreed with the users, associations, SRLs, and the corresponding agencies. These activities are expected to be implemented by the new Irrigation and Drainage project supported by the World Bank. The activities proposed to improve water use efficiency and reduce the initial problem of overirrigation are important parallel activities under this project.

- Integrate the third phase for the consolidation of the improved rainfed district This project can strongly stimulate the south and help address poverty and fragmentation. The project could include institutional development of drainage user associations, rehabilitation of works, and on-farm and technical assistance components in a total area of 2.2 million ha of existing drainage infrastructure.

- Improve coordination at the district level between the agricultural and the water programs to improve the social and productive results of the government interventions.

Appendix A Meetings and Field Visits

Date:	May 15–18, 2002
Place:	Wageningen, the Netherlands.
Organization:	World Bank and University of Wageningen
Contact person:	Sawfat Abdel-Dayem and Peter Mollinga
Position:	Principal Irrigation Advisor
Subject:	Preparation of drainage study

Date:	May 23, 2002
Place:	Mexico City
Organization:	National Water Commission
Contact person:	Cesar Ramos Valdez
Position:	General Subdirector of Operations
Subject.	Presentations of study objective and support for field visits

Date:	May 27, 2002
Place:	Mexico City
Organization:	General Direction of Drainage Districts
Contact person:	Isidro Gaytán
Position:	General Director
Subject:	Drainage district information and coordination of field visits

Date:	August 6, 2002
Place:	Xalapa Veracruz Mexico
Organization:	Papalopan Basin Council
Contact person:	José Miguel Moto del Hoyo
Position:	Executive President, Rural Development Institute
Contact person :	Juán Manuel Irigoyen
Position:	General Coordinator of the Council
Subject:	Irrigation and Drainage programs in the state of Veracruz

Date:	August 7, 2002
Place:	Xalapa , Atoyac Centro de Veracruz, Tres Valles.
Organization:	Centro de Veracruz Drainage District.
Contact persons:	Tomas Valenzuela, NWC. Central Offices
	Guillermo Herrnández Viveros, Regional Manager
	Jorge Camacho Gaxiola, Subregional Manager Operations
	Farmer Drainage User Association of Medellín and Jamapa.
	President's Board of Directors and Ing. José Luis Barocio Esquivel, Chief Engineer Drainage District 007.
Subject:	Field visit to the drainage district

Date:	August 8, 2002
Place:	Villa Azueta Veracruz
Organization:	Drainage District 003 Tesechoacán Veracruz

Contact persons:	Hugo Toscano Sarabia and administrative managers of the user association
Position:	Chief Drainage District 003
Subject:	Field visit to the drainage district
Date:	August 9, 2002
Place:	Cardenas Tabasco
Organization:	Drainage District 002 Zanapa Tonala
Contact person:	Adan Palavicini Evia.
Position:	Regional Manager, Frontera Sur Region
Subject:	Field visit to the drainage district
Date:	August 10, 2002
Place:	Cardenas Tabasco
Subject:	Field visit to Chontalpa and return to Mexico City.
Date:	August 29–30, 2002
Place:	Cd. Obregón Sonora
Organization:	Regional Office, National Water Commission Northwest SRL, Río Yaqui.
Contact person:	Alejandro Elías Calles
Position:	President, SRL Río Yaqui
Subject:	Meeting with representatives of Irrigation District 041 Field visit to subsurface drainage projects
Date:	August 30–September 1, 2002
Place:	Los Mochis Sin.
Organization:	Irrigation District 076 SRL Valle del Carrizo
Contact person:	Hermenegildo Castillo Cruz
Position:	President, SRL Valle del Carrizo
Subject	Field visit to drainage systems
Date:	September 3–27, 2002
Place:	Cuernavaca Morelos
Organization:	Mexican Institute of Water Technology (IMTA)
Contact person:	Benjamin de León Mojarro Arturo Gonzalez
Subject:	Discussion of field visits and integration of report
Date:	October 21–28, 2002
Place:	Wageningen, the Netherlands
Organization:	World Bank and University of Wageningen
Contact persons:	Sawfat Abdel-Dayem Peter Mollinga
Subject:	Drainage Workshop

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