Irrigation Management in Latin America

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Present Situation, Problem Areas and Areas of Potential Improvement

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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Preface

THERE ARE NOW about 220 million hectares (ha) of irrigated land in the world, representing about 15 percent of the total cultivated area. Of the 220 million ha, 158 million ha, or 72 percent, are located in developing countries. The irrigated area in these countries make up 20 percent of the total cultivated area.

In production teams the significance of irrigated agriculture is even greater. In South Asia, for example, yields per hectare obtained from irrigated cereals average between 1.5 and 2.25 times as much as from those on unirrigated lands. More than half of the region's total food production comes from irrigated lands. In the 1960s and 1970s, when the increase of cereal output in these countries was running at an impressive 3.4 percent per year, more than two-thiids of this growth was attributed to irrigation.

Not surprisingly, the developing world has made massive investments in the development of new irrigation schemes and in the rehabilitation of older schemes. Several developing countries with irrigation potential have devoted over three-fourths of their public spending for agriculture to irrigation projects. Worldwide investment on the scale of US$ 10 billion per year is often cited by irrigation professionals. Overall the payoff for these investments has been high. In its absence, it is doubtful whether the tremendous gains in food production achieved over the past two decades would have been possible.

Despite the importance of irrigation in sustaining food production, most irrigation systems are performing far below their potential. This is true whether performance is measured in terms of achieving planned targets, or in terms of the production potential created by the physical works. In other words, most of the benefits of irrigation development have stemmed from the magnitude of the investment, not from efficient and productive systems.

In Latin America, some 11 million hectares or 8.1 percent of the total arable area is classified as irrigated. Three-fourths of this area is in northwest Mexico, the Peruvian coast, some parts of central and southern Brazil, the valleys of central Chile, and the Andean region of Argentina, in which irrigated agriculture has traditionally been the only viable form of crop cultivation. In contrast to other parts of the world, there has been little groundwater irrigation in Latin America, and water from the great river basins of the Amazon, the Parana, and the Orinoco is not used to any significant extent.

Although the total extent of irrigated agriculture in Latin America is relatively small compared to that of Asia and represents less than 5 percent of the total worldwide irrigated land, the potential for increasing the area under irrigation is great. Thus, within the last decade, several Latin American countries have proposed ambitious plans for expanding their irrigated areas. However, as a result of recent financial difficulties, it is unlikely that those plans will be fully implemented in the foreseeable future. This fact, together with the disappointing performance of existing systems, has led to increased interest in improving the management and performance of those projects already in place.

The International Irrigation Management Institute (IIMI) is an international research, training and information institute headquartered in Colombo, Sri Lanka which aims to strengthen national efforts to improve and sustain the performance of irrigation systems in developing countries. Through collaborative programs that involve national agencies responsible for irrigation and agriculture together with research and training institutions, IIMI assists countries in the identification of constraints to improved irrigation management and ways to alleviate these shortcomings. Over the next few years IIMI hopes to initiate such collaborative programs with Latin American institutions to complement similar activities in Asia and Africa.

As a first stage in developing these programs, IIMI and the International Commission on Irrigation and Drainage (ICID) are co-hosting a special session on Irrigation Management in Latin America during the 14th International Congress on Irrigation and Drainage in Rio de Janeiro, Brazil on 4 May 1990.

To prepare for this session, IIMI has invited seven selected experts from Latin America to write papers describing the present situation of irrigation management in their own countries in the context of overall irrigation management issues in the region. This volume contains the seven papers identifying problem areas and areas where the potential for improvement seems great. The first four papers deal with regional issues: Grassi has addressed the overall status of irrigation management in Latin America and the potential for social and economic benefit through management improvement; Bertranoux has studied the socioeconomic aspects of irrigation in five Latin American countries; Ciancaglini has reviewed the irrigation systems in five countries of the southern cone of Latin America, pointing out the systems' main characteristics. administrative organization and legal-support structure, level of farmer management and other relevant information: and Canelo identifies a number of constraints that result in lower than anticipated performance of irrigation systems. The remaining three papers by Novaes, Garcia and Palacios describe in more detail irrigation management and training issues in Brazil. Colombia, and Mexico.

Chapter 1

IRRIGATIONMANAGEMENT

Carlos J Grassi

SUMMARY

IN LATIN AMERICA, expansion of the irrigated am has slowed down, but food requirements have increased with the growing population. The economic and financial crisis is a serious limiting factor. The author analyses the factors that will improve economic and social conditions using management techniques that enable an efficient use of existing irrigation systems. The current status of irrigation systems is examined on the basis of the definition of irrigation management developed by IIMI. The analysis focuses on underutilization of irrigation systems, inadequacy of irrigation policies, slow institutional development, poor water management at field and system levels, performance parameters for irrigation systems, financing of irrigation services, infrastructure and institution management, and staff training.

INTRODUCTION

In Latin America the development of irrigation started with the establishment of perennial systems in the arid zones of Argentina. Chile, Mexico, and Peru where there was no possibility of agriculture without it. In the past 30-40 years, supplemental irrigation systems have been established in the tropics to alternate irrigated crops with rainfed crops.

The total irrigated area is 15 million ha, with an annual increase rate of about 0.25 million ha. Recently, however, this expansion has slowed down; efficiency of existing irrigation systems has also declined. Several factors have contributed to this situation: the economic and financial crisis, low market value of local agricultural products, and the high cost of irrigation development. In Mexico, for example, this has led to stagnant yields and the establishment of crops with low added value (Olivares, 1986).

These factors are partly responsible for a deterioration of the infrastructure and services, underutilization of irrigated land, inefficient use of resources, and the resulting dissatisfaction with and loss of interest in irrigation. There is a need to increase production through better system management, in order to improve the economic and social benefits for a growing population. But the much-needed investments in infrastructure can only be procured once irrigation is restored as a productive sector for public investment (Carruthers, 1988).

MANAGEMENT VERSUS ADMINISTRATION

An irrigation system is composed of a set of physical elements, people, and ways of using water, land and various inputs to produce crops under certain conditions and without adverse effects on the environment. The system has two components: the "hardware," including the natural environment and physical system (hydraulic infrastructure and network), and the "software," consisting of irrigation operations and services. The successful performance of a system depends as much on the "software," as on the "hardware." But the existing systems depend more on the magnitude of investment than on management.

Irrigation management has been defined by IIMI (1988) as "the process by which organizations or individuals set the objectives of a system; determine appropriate conditions; identify, mobilize, and use resources to attain the objectives; and ensure that all the activities are carried out without any adverse effects."

Irrigation-related activities are generally limited to two professions: civil engineering and agronomy. This is too restrictive to encompass what is defined as management. Other disciplines should be integrated to understand the system as a whole. with its various domains, dimensions, and linkages (chambers, 1988).

In Latin America the current situation stems from the fact that irrigation is administered not managed. Administration is mainly geared towards maintaining the status quo whereas management attempts to change it (Jayaweera, cited by Svendsen, 1988).

IRRIGATION MANAGEMENT AGENCIES

Following the land reforms in the older systems. focus was shifted from increased productivity to the greater social benefits. Project output was jeopardized by serious errors in the land reform operation. This suggests the need to reformulate the lend tenure and allocation system.

The structure of irrigation agencies varies according to their particular characteristics and legal framework. They range from public sector agencies that finance irrigation with state funds to water-user associations with their own resources.

The degree of decentralization -- and the concomitant rise in user participation -- increases from national to regional and local levels. In all cases, the agency at the national level is a public body attached to a ministry or state secretariat. At the local level (irrigation system or district) user participation through district committees and users' councils increases, although some central government agencies are still predominant, as in Venezuela

Usa participation helps to ensure better respect of users' rights for a more equitable distribution of water. It helps to maintain a certain independence from external influences. The system also benefits from users' experience and can count on their direct contribution to operations and maintenance. User participation thus guarantees a more efficient use of water resources.

Latin America has many cases of irrigation agencies that have been administaed by users. In Chile, an area of 0.5 million ha in the Central Valley was put under irrigation in the early part of this century. In Mendoza, Argentina the administration and financing of secondary canals by users was established by the Law of 1884. The area covered by the associations was recently expanded for greater financial and administrative efficiency (Chambouleyron, 1984). In Peru, responsibilities previously assumed by government agencies for the San Lorenzo irrigation and land settlement project are being gradually transferred to the users (Hotes, 1983). In the Dominican Republic, soil salinization and poor maintenance of a canal were dealt with by transferring responsibility for the irrigation system to a water-usex association (ODI-IIMI, 1989).

Organizational, economic. ecological (mainly rainfall), and human factors, and the extent to which they can satisfy water requirements influence the willingness of users to participate. For example, climatic conditions have to be considered for decisions concerning the suitability of perennial irrigation or supplemental irrigation.

User participation should be introduced where it does not exist and strengthened where it already exists. Nevertheless, such steps should be taken with caution and in stages, by starting in areas with the highest success potential. It is not realistic to expect farmers to participate in such projects unless they are sure to benefit from them (Lazaro et al., 1979).

WATER MANAGEMENT AT SYSTEM LEVEL

Irrigation systems range from sophisticated hydraulic works with accurate flow control to traditional structures with a low control level. The type of structure has a direct bearing on water conveyance efficiency which is based on water conveyance losses and flow characteristics. Management efficiency is expressed by the ratio of water delivered to users to that actually used by them (Palacios and Day, 1977).

Proper canal management implies several steps: formulation of a crop and irrigation plan for each cropping season, appropriate evaluation of water requirements, and distribution and delivery of water according to these requirements. In Latin America, this is unfortunately more theory than reality since it is rarely put into practice.

Properly managed operations can minimize the effects of hydraulic head variation along the canal. In Mendoza, Argentina. this is a very frequent problem and fields at the tail-reach have to use groundwater to supplement an insufficient surface water supply.

Operational flow measurement is a precondition for efficient canal management. Studies to improve water use conditions through reliable and equitable distribution require reliable data. Gauging sections are generally established along irrigation systems, but systematic flow monitoring is rare.

Automatic control systems ensure steady flows and are less dependent on personnel. Such systems are common in Mediterranean countries, but they have not produced satisfactory results in Latin America. For example, the flow control systems in Venezuela could not be used due to lack of qualified staff and inefficient operation and maintenance.

Timely and adequate application is essential for increasing crop yields; water supply should therefore correspond to the demands. Except in a few Mexican systems (Palacios, 1977), hardly any efforts are made to apply technology developed at research stations. These techniques can help improve system performance at farm level under adequate water distribution and delivery conditions.

In small irrigation systems, water is delivered only during the day. This is not possible in large and medium systems because of the time needed to fill and empty the canals and the stress imposed on structures due to frequent operation. Night irrigation often causes water loss and drainage problems at the tail-reach due to negligence of operations staff and water users.

WATER MANAGEMENT AT FIELD LEVEL

Irrigation efficiency in currently operating systems ranges from less than 20 percent to more than 70 percent depending on irrigation methods, crops, topography. soil, water management ability of water users, irrigation Services. etc. Application efficiency is. however, less than 40 percent.

Water use efficiency (measured in kilograms of crop harvested per cubic meter of water used) is generally low, with a few cases showing high capacity for resource use. Efficiency rates for irrigation and water use can be substantially increased through appropriate management The potential is higher in the supplemental irrigation systems compared with perennial systems.

A more efficient use of irrigation requires partial modification, and sometimes a complete change, of the farming system to meet the requirements of national and international markets. Monoculture or cultivation of a few crops with similar agroclimatic requirements does not fully optimize available water and climatic resources, labor, and equipment. A longer cropping season and guaranteed water supply offer more options in the choice of the cropping pattern for crop diversification, especially in the tropics. This may, however, require changes in existing irrigation systems.

PERFORMANCE PARAMETERS FOR IRRIGATION SYSTEMS

Studies on how to improve the performance of an irrigation system are based on the evaluation of certain parameters. However, such measurements are not considered to be objective because they are influenced by the professional bias of civil engineers and agronomists. The causes of poor management should be identified. Performance indexes should be established for decision making. Zhi (1989) suggests three types of technological and economic indexes: water use, irrigated area and engineering aspects of the system, and economic benefits. Poor performance could be expressed in terms of unattained employment and living conditions objectives (Chambers, 1988).

Long delays between the construction of the basic infrastructure and the development and start of irrigation initially produces an oversupply. The resulting incorrect irrigation practices Cannot be easily rectified. They hinder normal expansion with a consequent shortfall in irrigated area compared with the target figure.

UNDERUTILIZATION OF IRRIGATION SYSTEMS

In Latin America, inadequate optimization of water resources is due to low efficiency combined with underutilization of irrigation systems. The area that is actually irrigated represents a small percentage of the potential area Although underutilization is observed under different climatic conditions. it is most frequent when the drought period for which the system is designed is followed by a rainy period. The soil moisture reserves replenished by the rains can then support one or more cropping seasons.

Underutilization of irrigation systems implies a low rate of return on the project, and it is a common feature in Latin America. Three types of cases can be distinguished:

- Abundant supply of water that can be used to irrigate a larger area, using the same infrastructure, this is the case of Argentina (Leiva, 1986);

- Partial utilization by farmers located in an irrigation system; this is the case of supplemental irrigation in Venezuela and other tropical countries;

- Unused potential for cropping patterns that satisfy market demand for crops with higher yields under irrigation (based on the potential and actual value of water); this is found in many Latin American countries.

Underutilization and management problems usually occur in new irrigation systems, rather than rehabilitated systems. In the first case, rainfed or dryland crops are replaced by irrigated crops. As fanners have no previous experience of intensive cultivation, there is little possibility of user participation at the planning and design stages to avoid subsequent management problems.

FINANCIAL SUPPORT FOR IRRIGATION SERVICES

In Latin America, water is considered as a freely available natural resource. Regulations' on water charges are therefore not respected. Moreover, certain loopholes in the water laws make it difficult to enforce the regulations. Various methods are adopted to finance irrigation; they range from total state support to full financing by water users.

In both developed and developing countries, capital costs for constructing the infrastructure are either borne entirely by the state or are highly subsidized (Sagardoy 1982). With the exception of the structures built by the private sector in Chile and in some cases in Mendoza, Argentina, all Latin American systems were built through state subsidies, even when the original plan was to charge the costs.

The principle of charging users for operations, maintenance, and administration is, however, better accepted. But little progress has been made in this direction and charges are mostly nominal. For example, in Venezuela they represent no more than 20 percent of the actual service cost (Merea, 1983).

Irrigation services can be financed directly or indirectly. Rates for direct charges can be fixed according to the volume of water consumed (Brazil, Mexico, Peru) or based on the size of the irrigated area (Argentina, Venezuela and most of the other countries). The services are financed indirectly through tax revenues (direct and implicit).

Although the volumetric water rate is more equitable, it is technically difficult to measure and monitor flow fluctuations continuously for 24 hours. The type of soil also accounts for differences in rates, which are higher for sandy than for clayey soils. This is the general trend for water charges but progress is slow and the positive effects are dissipated by subsidies. The Brazilian enterprise, Companhia de Desenvolvimento do Vale de Sao Francisco, has established a volumetric rate based on an equation that includes cost of depreciation, administration, operations, and maintenance; physical life of the works; amount of water consumed; and coefficients for subsidizing the actual rate (Abreu and Barrionuevo, 1985).

Water fees are reduced to insignificant figures because of cost inflation, a common feature in Latin American economies. Seasonal and annual rate adjustments are very slow because of the bureaucracy and regulations. One alternative is to adopt the Southeast Asian system which uses the price of a basic crop like rice as a reference.

The volumetric water rate is an inadequate measure. It should be based on an updated real value that reflects the actual cost of supplying water to the users. It is impossible to apply a common financial policy as political goals and strategies differ with each country. According to the Asian Development Bank and IIMI (1986), financial policies for irrigation should be evaluated in terms of their effects on irrigation system performance, investment decisions, financial position of the government, and income distribution.

MANAGEMENT OF THE IRRIGATION INFRASTRUCTURE

Poor or delayed maintenance raises costs proportionally. It also affects the environment, reduces canal capacity due to weed growth that spreads to the fields, encourages proliferation of insect vectors. increases soil salinization, etc. Poor maintenance can then become a case for rehabilitation.

Improper maintenance is, without exaggeration, a common feature in most Latin American projects. This is generally due to poor organization and a lack of specific norms and procedures for carrying out such tasks. Moreover, professionals are interested in design and construction rather than operation and maintenance. Resource allocation is also low as such activities are considered to be a form of dispensable bureaucratic spending.

At least 60 percent of the irrigation services budget is earmarked for infrastructure and equipment maintenance. Any shortfall in funds therefore has a direct effect on maintenance operations. There is even a tendency to build more infrastructure instead: for example, relining of canals to reduce maintenance. However, good management by competent staff can compensate for the lack of funds.

Rehabilitation of irrigation systems in the arid zones (Mexico, Peru, Argentina) usually results in at least alleviating the problem of soil salinization and drainage. These problems are spreading rapidly and will require substantial adjustments in the techniques and organization of irrigation management. Poor management can aggravate drainage problems as it leads to a larger supply of water compared to demand, frequent and abrupt changes in water level in the canal. and reduced capacity of the drainage system.

MANAGEMENT OF IRRIGATION INSTITUTIONS

Management of an irrigation agency involves not only water resources but also people and information (IIMI, 1988).

In Latin American countries, irrigation agencies consider water as one among many factors of agricultural production. They limit their task to routine operations, but this does not help to attain the system's objectives.

Irrigation management covers many other factors besides these. It involves "monitoring the output of the system. the processes, and feedback. in order to make the necessary changes in real time in response to the feedback" (IIMI 1988).

The irrigation sector in Latin America does not operate according to this concept. However, efforts have been made in this direction, when the work of organizations indirectly related to the sector is taken into account. But irrigation management is a multidisciplinary operation that cannot be reduced to the sum of the partial and uncoordinated efforts of various organizations.

Irrigated agriculture involves various costs and services besides water. Major inputs are seed, fertilizer, herbicides, and pesticides. They are usually lied to other institutions that may depend on different ministries. Similarly, support services such as extension, marketing, and credit belong to different administrations.

Inputs and support services are of vital importance since the absence of any one of them would partially or totally compromise the results. The activities of different institutions therefore need to be coordinated, which is not an easy task in Latin America. It is for this reason that irrigation agencies have limited their efforts to the adminismuion of water resources.

Irrigation agencies should be dynamic enough to keep pace with advances in technology and management. They should also be able to adapt to changes in the objectives of irrigation and fanning systems which require adjustments at all levels. A significant impact can only be achieved through substantial changes in the operation of the agency, fiscal and financial aspects (mobilization of resources through water fees), interaction with other support agencies. tenure system, etc.

Opportunities for reorganization should be used to increase fanner participation in irrigation management. Such opportunities are provided by: total or partial replacement or improvement of the canal system, expansion of the canal system based on new water resources, and rehabilitation of irrigation systems and their integration into the production process.

STAFF TRAINING

Training programs should have a multidisciplinary (technology, socioeconomics) and holistic approach in order to provide staff with the necessary knowledge and skills. A serious constraint in Latin America is the absence of such an approach. There is also a critical shortage of trained staff to keep pace with ti chnological developments. They also lack the management skills needed to obtain the expected results.

The shortage of qualified staff in Latin America is aggravated by the lack of interest in field work. Consequently, qualified people are mostly concentrated in the main offices, whereas actual experience can only be acquired from the field. More and better-trained staff who work directly in the field would make a disorganized system function more effectively (Lazaro et al.. 1979).

The World Bank estimates that it takes 8-9 years for farmers to shift from traditional production methods to more intensive farming (Hotes, 1983). In Latin America, it may take longer and farmers may not change their practices without the necessary incentives.

Training. extension, and demonstration services can yield positive results if they are carried out well and with a certain amount of perseverance, and if users are receptive. Extension services have not been very effective in improving irrigation management. These problems which occur throughout the agricultural sector also affect irrigation, which requires special training. Results in demonstration plots are poor compared with the surrounding fields – they are a demonstration of what should not be done.

CONCLUSION

In the past few years expansion of the irrigated area has slowed down. Existing irrigation systems are underutilized, resulting in dissatisfaction and loss of interest. This is not very encouraging because the climatic characteristics of the region make agriculture dependent on irrigation to meet the needs of a growing population.

The irrigation potential is not fully utilized. More land can be irrigated because the infrastructure is not used to full capacity. Cropping patterns also do not make effective use of irrigation. The social and economic benefits that can help the region overcome the financial and economic crisis and low prices of agricultural commodities can only be gained through better management.

Irrigation policies should be defined more clearly. They should also be implemented more consistently. This is particularly relevant for the tropical and subtropical zones with alternate wet and dry periods, where several options exist Government irrigation agencies are predominant among irrigation institutions at national and regional levels. Although greater farmer participation is recognized as a legitimate need, at least for managing sections of irrigation systems, little progress has been made in this direction except for some successful cases.

Water management at field and system levels as evaluated by performance indexes is not adequate and needs to be improved. Professional bias of civil engineers and agronomists should, however, be avoided because of the higher priority on the technical aspects at the expense of others, particularly irrigation management

Little attention is paid to maintenance due to inappropriate organizational norms and procedures. lack of interest on the part of professionals, and shortage of funds. This leads to land salinization and degradation of the environment, and systems often have to be rehabilitated.

Except in certain cases, operations, maintenance, and administration are financed by the state. But this leads to a shortfall in funds and an unproductive use of financial resources. Self-supporting systems offer a solution for mobilizing funds to cover these costs.

Training programs should aim to encourage field work. They should provide the knowledge and skills - through a multidisciplinary and holistic

approach -- required to meet the challenge of obtaining social and economic benefits without further **capital outlay.**

References

Abreu F y A. Barrionuevo, 1985. "Tarifas de água para irrigacao - Experiencia brasileira", ICID, I Conferencia Regional Panamericana, p. 63-64.

Asian Development Bank (ADB) and IIMI (International Irrigation Management Institute). 1986. "Irrigation service fees", Proceedings of the Irrigation Regional Seminar, Manila, July 21-25. p. 82.

Carruthers, I., 1988. "Irrigation under threat: a warning brief for irrigation enthusiasts", in IIMI Review. April, v 2, n.1, p. 8-11.

Chambers, R., 1988. "Managing canal irrigation", Oxford & IBH Publishing Co. Chapter 2, p. 28-46.

Chambouleyron, J., 1984. "El riego en la provincia de Mendoza", Departamen to General de Irrigación, Mendoza, p. 1-34.

Hotes, F., 1983. "La experiencia del Banco Mundial en el subsector de reigo", Seminario Iberoamericana de Riego y Drenaje, Noviembre 10-21/1986, p. 1-15.

IIMI (International Irrigation Management Institute), 1989, "The Strategy of the International Irrigation Management Institute", IIMI September (draft). p. 21-23.

Lazaro R.. D. Taylor and T. Wickham, 1979. "Irrigation policy and management issues: an interpretative seminar summary", the Agricultural Development Council, Inc. Bangkok, p. 1-12.

Levia F., **1986.** "**La** agricultura **de** riego en Argentina: situación y perspec tivas", Seminario Iberoamericano **de** Riego **y** Drenaje, Madrid, Noviembre **10-21.**

Merea, **A., 1983.** "**La** autosufiencia **financiera de** los servicios **de administración,** operación **y** conservación de los **proyectos de** irrigación, **VI** Jornadas Venezolanas de Riego y Mejoramiento de Tierras, *Caracas*, Septiembre 28, **p. 1-8.**

ODI-IIMI, 1989. "Newsletter". **ODI/IIMI** Irrigation Management Network Paper **89/la,** p. **22-23.**

Olivares, J., **1986.** "**El desarrollo** del riego **en** América Latina", Seminario Iberoamericano de Riego y Drenaje, Madrid, Noviembre **10-21. p.1-9.**

Palacios, **E., 1977.** "Introducción **a** la teoría de la operación de distritos y sistemas de riego". Colegio de **Postgrado,** Chapingo. México, **p. 200-221.**

Palacios. E. and DAY, **1977.** "A new approach for estimating irrigation conveyance losses and their economic evaluation", Water Resources Bulletin. June, **V 13, n.3,** p. **1-11.**

Svendsen, M., **1988.** "The changing concept of management in irrigation". **IIMI Review, August, V 2, n.2, p. 15-17.**

Zhi, M. 1989. "Identification **of causes** of poor performance of a typical **large** sized irrigation scheme in **south** China", ODI-IIMI Irrigation Management Network, Paper **89/1b p. 1-20.**

Chapter 2

SOCIOECONOMIC ASPECTS OF IRRIGATION

Armando D Bertranou

CHARACTERISTICS OF IRRIGATION MANAGEMENT IN LATIN AMERICAN COUNTRIES

IRRIGATION IN LATIN AMERICA varies considerably with the climatic, geomorphological, technological, cultural, and economic conditions in the countries of the region[1]. In the mid-1980s, total irrigated area for the region was 15 million hectares (ha) – 7 percent of the world total–and presented a patchwork of situations that are difficult to summarize[2] (ECLA, 1985). Certain characteristics of irrigation in major countries should, however, be distinguished to understand the policies that were implemented. For example, it is useful to know the role of irrigation withii the farming system and its production objectives[3].

In Mexico, Peru, and Chile, irrigated agriculture plays a diistinct role in agricultural production and accounts for one-fourth and to one-thirds of the cultivated area.

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[1] It should be recognized that in this type of work. generalizations are hazardous, because each country or region ha6 specific characteristics that cannot be explained.
[2] Latin America is generously endowed with natural resources – land and water – but they are unequally distributed in both space and time. The data referred to have been extracted from FAO Yearbook - ECLA report.
[3] Many country reports have been presented at meetings of experts such as the 8th Latin American seminar on irrigation (Venezuela, 1984) organized by the IICA; and the Ibero-American *seminar* on irrigation and drainage (Madrid, 1986) organized by EDI, IICA. and IRYDA.

Table 1 presents information on the five countries with the largest irrigated area in the region. Together. they represent 70 percent of the total fa Latin America.

	Irrigation area ('000 ha)	Percent of total cultivated area	Main crops	Market orientation	Current situation
Argentina	1 600	4%	Fruit and vegetables	Domestic	Stagnant
Brazil	2 000	3%	Rice(60%), cereals, oilseeds, vegetables, sugarcane	Domestic Foreign	Strong expansion in early 1980s
Chile	1 300	25%	Fruit, vegetables, cereals	Foreign	Sustained growth
Mexico	5 900	25%	Cereals, oilseeds, vegetables	Domestic	Stagnant
Peru	1 100	35%	Rice, sugarcane, cotton	Domestic	Stagnant

Sources: FAO yearbooks, BID, ECLA, IICA reports.

In certain years, irrigated crops in Mexico and Peru can attain almost half the total agricultural production value. They are therefore of significant importance in satisfying the national food demand. In Chile, commodities from irrigated areas have become a major source of foreign-exchange income in recent years. A large part of the fruit production, especially table grapes, is destined for foreign markets.

Irrigation can be considered as a focal activity in these countries. It has a long tradition and benefits from substantial government support.

In Mexico and Peru where irrigation plans are implemented at national level irrigation institutions demonstrate a strong centralizing tendency. Planning, establishment, and operation of irrigation systems are responsibilities assumed by the central government. whereas regional institutions are responsible for the management of water resources.

Recently in Chile, under the new laws that came into effect in the early 1980s. the central government has taken on a subsidiary role. In practice, it is now limited to supervising the operation and development of irrigation systems.

Irrigation in Argentina differs widely from that of Chile, Mexico, and Peru. Irrigated agriculture is of secondary importance at national level. production (cereals, oil crops) from the humid zones provides the bulk of foreign-exchange earnings in the agricultural sector. But in the arid and semiarid zones, fruit and vegetable production in the irrigated oases is a focal activity that contributes substantially to regional development For example, in one province, 360 000 ha are irrigated with groundwater from 20 000 wells. Fruit and vegetable production and processing contribute 20 percent to the gross product of the province. Agricultural production is mainly intended for the domestic market

The case of Argentina is not unique; in many countries of the region, irrigation is closely linked to regional development

In Brazil, although agriculture is not based on irrigation, in the mid-1980s the government launched various irrigation programs: PHONE in the Nordeste region and PRONI in the rest of the country. The ultimate objective is to satisfy basic needs through self-sufficiency in staple crops and to increase production levels. The programs thus aim to meet the growing demand for food by reducing prices for consumers; they therefore provide an effective means to control inflation. The strategy is to develop irrigation for dryland agriculture. Incentives are offered for this purpose; they include tax cuts on establishment and acquisition of irrigation equipment, lower electricity charges, and easy access to credit

The programs produced very striking results right from the start. The irrigated area was expanded by an average of 150 000 ha/year during the period 1982-1986. The results clearly indicate that irrigation is now considered as an important alternative for investment, with the firm support of the government.

This brief description highlights the differences in irrigation among the five main countries with irrigated agriculture.

The following points should be considered while analyzing the irrigation situation in these countries:

* The significance of irrigation to the economies of some countries;

* The relevance of irrigation to regional development efforts in various countries; and

* The trend to direct production towards domestic or foreign markets as the driving force for future expansion of the irrigated area

SITUATION OF THE LATIN AMERICAN ECONOMIES AT THE END OF THE 1980S

The critical situation of the Latin American economies is a cause of deep concern to the countries of the region. Certain socioeconomic considerations therefore need to be examined because of their relevance to irrigation.

Socioeconomic development in Latin America over the past 40 years can be divided into the 1950-1980 period and the decade of the 1980s.

The 1950-1980 period was marked by an upward trend in per capita income. employment, investment, consumption, foreign trade, and capital income. The high rate of GDP growth in the countries of the Latin American region indicates the dynamism of the economies during this period. Significant benefits were achieved in terms of social progress. But this upward trend was interrupted in the 1980s, when per capita GDP and capital formation rates fell. Rising unemployment and drastic cuts in public spending have raised the poverty level.

The approach *to* the foreign debt problem explains the prevailing situation to a certain extent (IDB, 1989). Reduced imports and increased exports illustrate the fall in real pay.

In the 1980s, availability of goods and services in the countries declined as a result of the substantial increase in exports and drastic fall in imports. In 1987, it stood at only 87 percent of the 1980 level. Population grew from 347 million inhabitants to 414 million inhabitants during this period, with a resulting decline in real pay. In 8 years, per capita GDP fell by 7 percent. after having risen by 40 percent between 1970 and 1980[4].

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[4] The 3-point hike in interest rates between 1988 and 1989 signifies an increase in the annual foreign debt service charges (IDB, 1988.1989). IDB estimates this additional charge at US$10 billion. The current level of indebtedness is equivalent to four times the value of exports. IDB Report, 1989.

Relative prices of primary products have also deteriorated. The causes are: excess supply due to past investments; steady decrease in the use of raw materials for production in the industrialized countries; high inelasticity of demand for primary products; and high real interest rates.

With the drop in net capital entry into the region and cuts in public spending, investments have been the hardest bit by the foreign debt crisis [5].

The composition of national deficits has changed completely. During the 1970s. the deficits were financed with external funds, they are. now financed through internal capital.

There is a chronic shortage of entrepreneurs, because no social value is attributed to the role of the entrepreneur as a productive agent. The entrepreneur manages and optimizes production factors and technological coefficients. The function appears to be disappearing or is facing Serious problems in Latin America.

Population is the best indicator of the. Latin America of the 1980s. It represents 9 percent of that of the planet. But the regional GDP attains only 8 percent of world GDP. The industrial GDP stands at only 6 percent. For the creative professions – scientists and intellectuals – it is only 2 percent.

Since 1970. not a single Latin American country has achieved balanced growth (Bustelo, 1989). The 1980s are already reported as a lost decade for Latin America, especially in social terms.

IRRIGATION DEVELOPMENT: MACROECONOMIC CONTEXT

Irrigation development in Latin America is closely related to the economic variables of the region.

The rough division into two periods presented in the previous section can also be applied to irrigation. Irrigated area expanded at a sustained rate in the

[5] In absolute terms. the estimated level of investments in 1988 was US$40 billion less than in 1980, accounting for only 81% of the second mount in constant 1988 dollars. IDB Report, 1989.

1960s and 1970s, corresponding to the generally positive trends of the economic variables during this period. The average rate of annual expansion after 1965 was 250 000 ha. Between 1975 and 1980 the growth rate reached nearly 3 percent. Except for Brazil and Chile, expansion of the irrigated area recorded an abrupt down-turn in the early 1980s[6].

In countries where commodity supply from irrigated areas is mainly directed to domestic markets. irrigation development is closely linked to domestic demand, its characteristics. evolution, and persistence over time. One of the main characteristicsof domestic demand is that it is highly inelastic. This can, however, be an advantage for certain regions.

The tendency towards saturation of domestic markets during the period of irrigation expansion in the 1970s or, at the other extreme. the abrupt fall in internal demand in the 1980s. has impelled certain areas to reorient their production towards export markets. The Chilean and. to a certain extent. the Brazilian cases are the most striking, but not the only ones.

Reorientation implies that irrigated agriculture should focus on the complex problems of foreign markers in which it has to compete. It has to meet requirements of quality rather than quantity, unlike the domestic market, where the priority is to satisfy the demand for food.

The export orientation of irrigated areas has a positive impact through price stabilization - and sometimes increase.. Better prices are an incentive for adopting new production and irrigation technologies, which are often linked to more dynamic industrial sectors of the economy (Leiva et al).

Fluctuations in the economic system have a considerable influence on irrigation activities. Poor economic performance has been accompanied by slow development of irrigation. We must not only recognize the macroeconomic context of irrigation. but also analyze the specific problems caused by irrigation itself.

IRRIGATION PROBLEMS AND LIMITATIONS

Many authors have cautioned against the problems related to investments in irrigation (Carruthers, 1986; Horning, 1986). International funding agencies

[6] At the world level, the growth rate of irrigation between 1965 and 1975 was 5%, but fell to 1.5% between 1975 and 1987. See ECLA 1985, pp 50-54.

have acquired a vast experience on such investments (Hotes; Colmenares and Aguirre). Many lessons can be drawn from their experience. Current literature indicates a certain dissatisfaction and **loss** of confidence regarding irrigation. The arguments in favor **of** irrigation are well-known, mainly increased productivity which significantly reduces food problems. But it is also true that the projected rates of return from irrigation investments were overoptimistic.

Irrigation development projects have generally exceeded estimated costs for construction and for operation and maintenance.

Irrigation performance has **been** explained on the basis of certain observations on the status of irrigation in Latin America. the main constraints to its consolidation and expansion, and the framework of the characteristics mentioned in the first section.

The observed facts are as follows:

* Excess supply of imgated land due to a marked recession **of** economic activity. Water and soil resources are underutilized. Groundwater use is also very low.

* Unused dammed water capacity in large-scale projects built for gravity irrigation systems. This contrasts with the relatively low capacity for water conveyance and **drainage** in associated irrigations ystems. The infrastructure is also underutilized.

* Poor maintenance of irrigation systems. Water use efficiency **for** irrigation is therefore low, so that water appears tobeamorescarcethanitisinreality.

* Slow spread of agricultural production and of irrigation and drainage technology. The exception is that there exist pockets of efficiency, which **per**petuate a great number of hectares with low technological level and in a state of deterioration.

* Expansion of irrigation projects from exclusively infrastructure systems to integrated projects. Integrated projects include socioeconomic infrastructure, subsidized services to farmers, and output marketing, **all** of which inflate considerably the cost of these projects.

The economic crises have an unequal impact on different types of producers. The small and medium farms are the hardest hit. The situation favors a bipolarization of many regional economies with irrigated lands. At one extreme are the small and medium farms that predominate in primary production and use low levels of production and irrigation technology. They are inadequately integrated into the regional and national economic context and exposed to erratic markets for perishable commodities. At the other extreme are the large integrated producers, highly technical and well-informal, who benefit from economies of scale and adequate economic and political integration (Llop, 1987).

Although these situations developed during 1965-1980, no efforts were made to rectify them. They have persisted and contributed to the discreditation of irrigation.

But investments in irrigation projects with uncertain rates of return continue, leading to situations described earlier (Pascuchi et al, 1977: Fiorentino et al, 1986). Some of the possible reasons for this are:

* Projects that are supposed to help small and medium farmers. This reason is often given to justify support for projects with low rates of return. Socio-political considerations can. in certain cases, have a high degree of rationality. But if these projects have no assurance of a corresponding subsidy, they become a misleading aid for the weakest which is expropriated by the strongest.

* In several instances, vicious cycles have developed that are difficult to reverse, and bring negative feedback on irrigation investments. Through misleading signals (subsidized prices for inputs and/or products for agriculture) communicated to the market and to decision makers, unreasonably high expectations of the profitability of investments in irrigation have been maintained. In turn, these have generated greater output levels. which have a depressive effect on prices. But the political pressures generated to raise prices for agriculture (for reasons of income distribution or regional development) have reinforced the feedback loop of this vicious cycle.

* The unwieldiness of the multiple–purpose and gravity irrigation projects is one of the causes which explains the existence of an excess supply of irrigated land and the relatively underutilized capacity of water stored for

irrigation purposes. It is not unusual that this type of project with large economies of scale should be fundamentally justified by the energy it generates. But at the same time, they are. not marginal projects in terms of an evaluation from the point of view of irrigation. The subject of the unwieldiness of gravity irrigation projects - as contrasted with the use of groundwater (wherever this exists) - should be analyzed.

* In general, there is a bias among administrators and politicians in favor of large engineering projects. They display a lack of understanding of less impressive investments in operations and maintenance, and tend to underestimate their value. The appeal of the newly completed grandiose public works project and the crowning bronze plaque which immortalizes it are weighty factors difficult to overcome.

* The pressures of the companies involved in the construction of large infrastructure works can also influence decisions. Thii is less true in periods of economic recession.

The panorama presented in this complex activity known as irrigation, gives the impression of a lack of coordination among the components of the system and the agents of those institutions responsible for irrigation activities.

In the evaluation of complex and multifaceted projects. such as irrigation, numerous errors have ben committed, due to an inability to judge the integrated operation of the system. For example, an isolated evaluation of one component of a system which operates closely with other components, necessarily requires a joint assessment from the standpoint of economic evaluation (Major and Lenton, 1979). In spite of the obvious convenience of coordinated operation. management organizations have shown a reticence towards such systems as discussed in a later section.

The response given to these problems during the 1960s was the development of various experiments with water planning. The examples of Mexico, Venezuela, Peru, and Brazil in particular, followed by Ecuador, Colombia. Honduras, El Salvador, and the Dominican Republic, were studied in depth by Dourojeanne (1985). He affiis that such plans have been useful in countries where they were adopted. Among the main benefits are.: better knowledge of water availability, greater interinstitutional collaboration for water use, better knowledge and identification of alternatives for calculating water supply and demand, better perception of the current and potential conflicts in water delivery, better possibility for integrating environmental considerations, and more options for improving the operation of irrigation systems.

Planning has definitely helped improve irrigated systems. In Latin America, however, it is concerned with the physical and operational dimension of water resources management, rather than the administrative and institutional dimension (Scelza Cavalcanti, 1988).

Action-oriented recommendations were proposed for irrigation management at the United Nations Conference on Water held at Mar del Plata, Argentina. in 1977. The recommendations stressed the need to improve existing irrigation systems and their administration, before undertaking new irrigation projects. Efforts in this direction should focus on: funds earmarked for operation and management, participation of small groups of water users in experiments, better training and extension services, and political priority to irrigation (ODI, 1976). These recommendations are still relevant today.

INTEGRATED IRRIGATION MANAGEMENT KEY TO THE FUTURE OF IRRIGATION

Concern for improving irrigation system efficiency has been expressed at international and national levels. Recently, this preoccupation has been directed towards the management of water resources.

A project for cooperation in the management of water resources was undertaken by ECLA through its natural resources and energy unit, and with support from the West German government (ECLA, 1989). At present, it is continuing this effort through its project for training in irrigation project and system management[7].

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[7] Participating in these projects are researchers and administrators of relevant water system at relevant institutes in Latin America. such as the CIDIAT. Venemela: INCYTH-CELA. Mendoza, Argentina; Dirección General de Aguas, Suelos e Irrigación, Peru; INCAE. Costa Rica; and DNAEE. Brazil.

The International Irrigation Management Institute (IIMI), which was founded only 5 years ago, is a valuable response for addressing irrigation management issues (IIMI, 1988).

There is a general consensus that efficient management and identification of innovative technologies are the main bases for irrigation development.

Management is the decision-making process for guiding a complex organizational system (formed by individual parts and interactions among agents) towards a set of objectives, within a given environment which provides resources, but also offers advantages and constraints.

The complexity of the institutions increases with that of the environment. Analysis and management of institutions, and that of the total organizational system in which they operate, should consider relations between and within institutions and their relations with the environment (Correa de Pavón, 1985).

Irrigation institutions as organizational systems should function as social systems and interact with the environment. But in reality they are isolated, with little communication between them (Bertranou).

These institutions tend to adopt an oversimplistic view of reality by considering it exclusively on the basis of their area of concern and objectives. They become obstacles to the solving of problems which transcend their scope. of action.

Water authorities in Latin America have not kept pace with the object they administer, whereas infrastructure, technology. and management techniques have developed in both quantitative and qualitative terms (Braceli, 1980).

We shall now examine certain management factors and processes which may offer better possibilities for improving the efficiency of irrigated systems.

Integration and Coordination

Integration consists of the processes designed to achieve greater coordination, to avoid duplication of efforts, and to control unproductive competition among different organisms (Bustelo, 1988).

Earlier sections on irrigation development and constraints describe certain situations resulting from a lack of coordination in decision making. The most typical case are: inadequate integration of economic, irrigation, and social policies and lack of coordination between administrative units.

Administrative units find it more difficult to accept the benefits of better co-ordination than the costs generated by coordination within each organization. The benefits of better coordinati'on should compensate for the costs of those involved. The basic problem is that, the application of the compensation principle requires some form of centralized accounting. In turn, the problem which impedes centralization is the limited vision which people hold of all the possible alternatives from a central point of view. Obviously. there is no question of suggesting compulsory programming through a central coordinating body. But the existence of a coordinating organism is of crucial importance in irrigation. Such an organism will be effective only if it conveys confidence to the rest of the system.

In conclusion, the possibility of integration of the decision-making process largely depends on changing the type of irrigation institutions (Pascuchi et al, 1977; Correa de Pavón, 1985).

"Finally, authorities need to be persuaded that only political will can overcome traditional bureaucracies and create greater scope for cooperation. Pluralism should be combined with coordination if efficiency has to prevail over fragmentation and duplication of efforts" (Bustelo, 1988).

Budget

One of the main factors that impedes rational decision-making is the lack of an adequate information system. Coordinated action depends on the quality, quantity, and timeliness of information. In this respect. the budget is the best information-laden planning instrument for the administration as it reflects the final allocation of resources according to predetermined political priorities (Braceli et al, 1987).

In Latin America the budgeting process. and ultimately establishment of water charges, have serious shortcomings (Bustelo, 1988). There is a lack of budget programming for the medium and short terms. Inflation and, more recently, hyperinflation have obvious erosive effects.

The budgetary structures of the past are perpetuated in the present There are no buget planning mechanisms that operate between sectors and within each administration. Budgets are constructed by simply adding a heterogeneous set of demands.

It is difficult to predict incomes in an inflationary context. The execution phase is beset by difficulties because of a lack of systems for consolidation.

Few mechanisms exist for evaluating the financial situation and project results. As the costs of different activities cannot be determined, it is difficult to establish the cost-benefit ratio and impact of the activities.

The budget is therefore. not a legitimate. instrument for planning between administrators and politicians. Water users should be integrated in decisions on the budget and establishment of water fees, and in its day-today implementation.

Manpower Development

According to an ECLA report (1989a): "One of the basic conclusions of a broad study by the ECLA of the major issues that confront the exercise of water management in Latin America is the need to improve the quality of management, as thii would seem to offer an adequate solution to many existing inefficiencies." Good management would thus seem to be an ample solution to many shortcomings.

This indicates that one of the most pressing needs in terms of realizing improvements in management quality is the presence of a training system for civil servants from public organisms linked to the management of water resources.

Various countries of the region have agreed that efforts should be undertaken and coordinated in this area through research on the demand and supply of training in management (Bandes. 1989; Llop et al, 1989) and the creation of an integrated manpower development program for Latin America.

IIMI has proposed similar objectives for itself, thus opening up a broad range of possibilities for coordination which we have the obligation to implement, if we mean to practice what we preach.

References

Bandes, T. 1989. Estudio sobre la oferta y demanda de capacitación en gestión de recursos hfdricos en Venezuela.

Bertranou. A. Undated. Manejo de sistemas de oasis.

Bustelo, E. 1989. Encuentros y desencuentros. Paper presented at the Latin American Seminar. Mendoza, Argentina. Mimeo.

Braceli. O. 1980. Análisis de las administraciones de riego: aspectos presupuestarios y tarifarios. INCYTH-CELA. Mendoza, Argentina. Pp 1 - 25.

Braceli, O.; Tomba, A.; Fellinger, E. 1987. Estudio presupuestario para la administración de riego de. Mendoza. INCYTH-CELA, Mendoza. Argentina.

Bustelo, E. 1988. Politica social en un context0 de crisis. Paper presented at Seminario Alto Nivel: Como recuperar el progreso social en América Latina. Santiago, Chile, page 13.

Carruthers, I. 1986. El nego amenazado. Una advertencia a sus partidarios. **informe de la consultoria de expertos en tarifas de agua para riego. FAO, Rome.**

ECLA. 1985. Los recursos hidricos de América Latina y el Caraibe y su aprovechamiento. ECLA Study No. 53. Santiago, Chile.

ECLA. 1989a. Capacitación en gestión de los recursos hidricos en America Latina y el Caraibe: diagnóstico y propuestas. Santiago, Chile.

ECLA.1989. La gestión de los recursos hidricos en América Latina y el Caraibe. Estudios et Informes no. 71. Santiago. Chile.

Colmenares, J.. and Aguirre, J. Inversióne riego pasado y futuro. Seminar...", as cited in Note 2, pages 67-105 and pages 143 - 173.

Correa de Pavón E. 1985. Las organizacionesde recusos hídricos y el mecanismo de toma de decisiones. INCYTH-CELA. Mendoza, Argentina.

Dourojeanne, A. 1985. La formulacióndе los planes de ordenamiento de recursos hídricos en America Latina y el Caraibe. ECLA, Santiago, Chile.

Fiorentino, R.; Biondolillo, A.; Bertranoux, A. 1986. Lineamientos para una estrategia de la agricultura en riego. UNDP Project ARG 85/020. September.

Homing, H.M. 1986. Tendencias del dessarrollo del riego. Informe de la consultoria de expertos en tarifas de agua para el riego ego. FAO. Rome. Page 19.

Hotes, F. La experiencia del Banw Mundial en el subsector. Seminar ...'', as cited in Note. 2, pages 67-105 and pages 143 - 173.

IDB (International Development Bank). 1988. Progreso económico-social en America Latina. Pp 4, 13, 31, and 37.

IDB (International Development Bank). 1989. Informe Económico-Social.

IIMI. 1989. The strategy of the International Irrigation Management Institute.

Leiva, F.; Biondolillo, A.; Bertranou, A. Undated mimeo. Apertura de la economia y crecimiento de la agroindustría regional. INCYTH-CELA. Mendoza.

Llop, A. 1987. Estrategias y politicas de desarrollo regional. Fundación América.

Llop, A.; Correa, E.; and Gorri, A. 1989. Relevamientode la oferta y demanda de capacitación en Argentina. INCYTH-CELA.

Major, D., and Lenton, R. 1979. Applied water resource systems planning. Prentice-Hall, New Jersey, USA, page 248.

ODI (Overseas Development Institute). 1976. Irrigation management in developing countries: A suggested action programme. Canterbury, UK.

Pascuchbi. J.: Manuelli, R.. and Marcu, D. 1977. Sobre la programmación de las inversiones en riego. CONFAGUA, Mar del Plata, Argentina. March.

Scelzy Cavalcanti, B. 1988. Notas sobre capacitacao em gastao de recursos hidricos de Brazil. Rio de Janeiro. ECLA project on Training in Water Resource Management. Chile.

Chapter 3

SELECTED COUNTRIES OF THE SOUTHERN CONE

Nicolas C Ciancaglini

SUMMARY

THE CURRENT SITUATION of irrigation and drainage is described for selected countries of the southern cone of Latin America The countries chosen are Argentina, Bolivia, Chile, Peru, and Uruguay. For each country. there is a review of the irrigation systems, with their main characteristics, administrative organization and legal support structure. level of farmer management, and other relevant information. The most important factors that promote and condition irrigation development in each country are indicated. The case of Argentine is described in greater detail.

Irrigation-related training and research activities in Argentina are described, with special reference to the Instituto Nacional de Ciencia y Técnica Hídricas (INCYTH). The Institute could support IIMI's efforts in the southern cone of Latin America. General guidelines are suggested for IIMI's strategy for a future cooperative program at a regional level and in the different countries.

INTRODUCTION

This paper was prepared at the request of the International Irrigation Management Institute (IIMI), with the objective of describing the current irrigation situation in selected countries of the southern cone of Latin America. Argentina is treated in greater detail, while Bolivia, Chile, Peru, and Uruguay are discussed in more general terms. The major irrigation and drainage management problems detected in these countries are described and possible lines of action are recommended for successfully and rapidly alleviating the constraints.

Problems with a significant effect on the irrigation and drainage situation in Latin America, especially in those countries of the southern cone, are identified. The paper does not deal with Brazí - the host country of this conferenc - as its situation will be discussed with greater depth and understanding by other speakers.

The research and training activities of the National Institute of Hydraulic Science and Technology, Instituto Nacional de Ciencia y Técnica Hídricas (INCYTH), Argentina, are also reviewed. These activities are carried out by its two centers that specialize in this area: the Andean regional Center, Centro Regional Andino (CRA), and the Center for Water Economics, Legislation, and Administration. Centro de Economía, Legislación y Adminstración del Agua (CELA). INCYTH could serve as a base for IIMI's future activities in Latin America, in the same manner as it already assists FAO, UNESCO, ECLA, and other international organizations.

ARGENTINA

Background

In Argentina, irrigation was practised before the arrival of the Spanish conquistadors. The local population grew several indigenous crops such as maize, potato, zucchini, etc. Irrigation systems were mainly developed in the northern part of the country (Jujuy, Salta, Santiago del Estero) and in the Cuyo region (Mendoza, San Juan). After the Spanish conquest, irrigation systems became more important with the inflow of immigrant fanners, who arrived towards the end of the last century. The appointment of the engineer Cesa

Cipolletti in 1898 and the benefits derived from the National Irrigation Law of 1909 were instrumental in the expansion of the hydraulic infrastructure.

The provinces promulgated their own water laws to manage water resources. In the 1950s, the deep-well pump was introduced and widely disseminated. This development initiated the use of groundwater, which extended the irrigated area and enabled the application of modern techniques such as trickle and spray irrigation. Mendoza, for example, has 18 000 bore holes sites, which are the equivalent of having access to another river.

Water resources are not evenly distributed in the country. The arid and semiarid zone which covers 66 percent of the continental territory (185 million ha) has only 18 percent of the surface water resources. Annual rainfall varies between 100 and 500 millimeters (mm), whereas annual evaporation exceeds 2 000 mm. Ninety percent of the surface water resources are used to satisfy the demand for irrigation water in the arid zones. Although 50 percent (95 million ha) of thii region has a high irrigation potential, only 3.7 percent (3.5 million ha) of the *area* can be irrigated due to lack of water.

Current Situation of Irrigation and Drainage

Out of a total cultivated area of 178 800 000 ha (1982), the area under irrigation fluctuates between 1.2 and 1.3 million ha. The irrigated regions are as follows:

* Northeastern zone: provinces of Jujuy, Salta, Tucuman, Catamarca, and Santiago del Estero. About 380 000 ha are irrigated (35.5 percent of the total irrigated area, [TIA]), using 14 percent of the surface water resources of the arid and semiarid zones (WRAS). Some crops, such as sugarcane, occasionally require supplemental irrigation.

* Central zone: La Rioja, San Luis and Córdoba. About 57 000 ha (5.3 percent of TIA) are irrigated, using 3.4 percent of WRAS.

* Andean zone: San Juan and Mendoza. About 442 000 ha (41.5 percent of TIA) are irrigated, using 6.5 percent of WRAS.

* Comahue zone: Buenos Aires, Río Negro. La Pampa, Neuqun. and Chubut. Abut 188 000 ha (17.7 percent of TIA) are irrigated, using 73 percent of WRAS.

* Other zones: Entre Ríos, Santa F, and Chaw. These include small rice-growing areas, particularly in Entre Ríos.

Overall irrigation efficiency is estimated at 33 percent. It is the ratio of water consumption at national level, 6.18 billion cubic. meters (m3), to the amount of water captured (20.26 billion m3). This efficiency level is typical of all the irrigation systems in the country, which signifies a generally low-level of water use efficiency.

Except for the expansion of certain systems with supplemental irrigation for growing vegetable crops (e.g. potato in subhumid areas), there is a general tendency to reduce irrigated area in some regions with traditional irrigation (Mendoza, Santiago del Estero, to a lesser extent in Rfo Negro). The irrigated area could therefore be easily doubled with the promotion of export-oriented crops.

An estimated 584 000 ha of land are affected by soil salinization and another 550 000 ha by poor drainage. Among the provinces with serious drainage related problems are: Mendoza (45 percent), San Juan (12 percent). Tucuman y Salta (10 percent), Río Negro (9 percent). The percentage may be actually higher for Tucuman y Salta and Rfo Negro, where fewer studies were carried out than in Mendoza and San Juan.

Irrigation and Drainage Infrastructure at Zone and Field Levels

The 1950s and 1960s saw a considerable expansion of the irrigation and drainage infrastructure, in terms of dam construction, lengthening of canals and drainage channels, and establishment of other structures. The construction of dams for hydroelectric power projects contributed greatly to this expansion. But the percentage of lined canals at national level is low (10 percent). The drainage infrastructure is incomplete in 390 000 ha and nonexistent in 62 000 ha.

The lack of adequate maintenance, due to insufficient funds for the purchase or repair of maintenance equipment or both. is leading to an increasing deterioration of the irrigation infrastructure. Increased funding and the replacement of obsolete equipment would definitely improve water use efficiency at district level and lead to a rapid expansion of the cropped area

Farmers are unaware of the basic - how, how much. when - of irrigation application. They tend to use too much water as they have no means to measure the quantity to be applied. They do not have a clear idea of the time of application. In addition, due to the rigid water delivery procedures (rotation), it is impossible to synchronize irrigation schedules with water deliveries.

Irrigation Legislation and Administration

In *Argentina* the use of water for irrigation is governed by provincial laws. But the laws are only established in those provinces where there is a need for them. Even when they do exist, the laws are not effective, because the institution that is supposed to apply them has insufficient power to enforce them.

Except in certain systems, irrigation administration is the responsibility of the provincial government. Performance of irrigation institutions varies widely. Some have succeeded in achieving an acceptable level of irrigation management by organizing water users into groups or associations that take on the responsibilities of operating, maintaining, and managing a portion of the network (Mendoza, San Juan). At the other extreme are areas where poor management by the province and water users has become yet another limiting factor to water use. Part of this undesirable effect may be attributed to the basic assumption of improvement project evaluations that competent authorities exist to manage the projects. Investments in the irrigation sector are almost exclusively directed toward the creation of an irrigation infrastructure. This generates a disequilibrium, since improvement of administrative institutions has lagged behind the growth of the object they administer. Consequently, operation. maintenance, and management of the new infrastructure becomes inefficient.

Before establishing water-user associations. preliminary studies should be conducted on the infrastructure and the system's social, economic. and legal characteristics. For example, the results obtained by grouping associations into unitsof 10 000-12 000 ha in Mendoza cannot be directly transplanted into other advanced regions, such as of San Juan.

Few administrative agencies are financially self-sufficient Two major causes of this problem are the economic crisis and the failure of agroeconomic development models in provinces with irrigated crops. Other drawbacks also contribute w the financial constraints. but to a lesser degree. One of them stems from the accounting norms of the provinces which do not distinguish between operation, maintenance. and administration costs. As the real costs are not known, it is virtually impossible to determine when one of these activities is incurring higher than normal costs.

At present, the main objective of most irrigation agencies is equitable water distribution according to the area of lands with irrigation rights. Although some information is available on water distribution in major irrigation systems, it is not processed nor used as feedback for planning. Such feedback is indispensable for improving related activities in the district.

Operation and Maintenance of Irrigation Systems

The technico-administrative procedure used for water delivery is a rotation system. Such rigid allocation is probably suitable for some zones (e.g. La Rioja. Catamarca, San Luis) where the development of irrigated crops is in its early stages. However, in provinces with a long irrigation tradition, such as San Juan, Mendoza, and Alto Valle del Río Negro, it is a constraint to greater application efficiency because water delivery times and quantity are the same, regardless of the type of cmp or irrigation method (furrow irrigation, border irrigation. etc.). Any program that aims to improve irrigation efficiency at the regional or district level should seek to modify this system.

In the more advanced zones. the application of modern techniques is clearly needed to optimize the use of both surface and groundwater resources. to reduce the general costs of irrigation systems, and to conserve the quality of groundwater aquifers. The necessary technology is already available at INCYTH; its application requires a concerted effort in collaboration with the irrigation agencies.

High fuel costs and obsolete equipment - sometimes more than 15 years old - affect maintenance of irrigation and drainage systems. Information is needed on weed control techniques and time of weeding operations. The use of inappropriate equipment widens earthen channels, resulting in higher water conveyance losses and other problems. The costs of chemical treatments are prohibitive and no other techniques of integrated pest management are known (e.g. mechanical and biological methods, use of fish to destroy diploid or triploid plants) by which costs could be reduced.

All these difficulties tend to lower water conveyance and distribution efficiency. As a result, irrigation requirements cannot be satisfied as planned.

Crop Production and Marketing

The main irrigated crops are: vine, fruit and vegetables, sugarcane, cotton, tobacco, rice, etc. production is mostly directed towards the domestic market, with the exception of pip and stone fruits. In recent years, there is a strong trend towards large- and medium-scale production of all types of irrigated crops for export.

production increase has been generally slower than the establishment of irrigation infrastructure. Installed capacity is high compared with current use levels. The current infrastructure therefore. offers a high potential for extending the irrigated area and growing export crops.

Crop Production Technology

Argentina has vast areas with irrigation 'potential. The major obstacle is, rather, the low level of production technology because farmers do not have the necessary means. The two main reasons for this are a shortage of funds and market uncertainty. Input use (fertilizers, pesticides, herbicides) is low and farmers tend save on labor and capital required to improve water conveyance and application and removal of excess water on and below the surface. This leads to low irrigation efficiency, loss of soil nutrients, soil salinization and waterlogging, and other adverse effects, which, in turn, reduce crop productivity.

The knowledge required to solve these technical problems is available and can be easily transferred to farmers. Technical improvement programs should integrate the economic preconditions for technology adoption, as well as suitable training programs for farmers. Even moderate efforts in this direction will increase irrigation efficiency substantially from 30 percent at present to 50 percent, improve soil quality, and expand the am for growing export crops.

Factors Influencing Irrigation Development

The main factors that limit or promote irrigation development in Argentina are listed briefly.

* Abundance of underutilized natural resources (land and water) which can support a further expansion of the irrigated area to more than 2.2 million ha, without the need to construct new infrastructure.

* Underutilized irrigation infrastructure, which has sometimes deteriorated.

* Absence of an institution that plans irrigation development, especially for the long term.

* Inadequacy of administrative agencies in teams of training programs and introduction of new management techniques, as well as equipment and information processing capacity.

* Low farmer participation in irrigation management at district level. Farmers should be encouraged to participate more actively.

* Deficiencies in irrigation operations and in technico-administrative procedures for water delivery.

* Inadequate maintenance and obsolete equipment which raise maintenance costs.

* Need for province-level irrigation programs that would assign priorities to projects and establish administrative rules for executing the projects.

* Need for baseline studies; evaluation of surface water and groundwater resources (for rice. in humid zones); and studies on drainage, agricultural potential of soils, etc.

* Need to improve technical assistance to farmers.

* Imbalanced development of cmp production, with moderate expansion for certain crops (pip fruits, rice. sugarcane) and decline for others (vine, tobacco).

* Inadequate level of technology for irrigated crops and for irrigation and drainage.

* Sufficient know-how for irrigation and drainage is available with various national organizations such as INCYTH. A vigorous program of technology transfer to farmers and irrigation management agencies is needed. The program would rapidly increase irrigation efficiency.

Irrigation problems essentially stem from socioeconomic and political conditions. Technological problems appear to be a result rather than a cause. The crisis of irrigated agriculture arises from the same causes as the region's economic crisis. The most obvious signs are stagnant production, underutilization, and technological drag. They result from a poor economic integration of many of these activities into the national and international context. The new economic policies and increasing awareness among large-scale and some medium-scale producers tend to promote export crops with protitable future perspectives. This should serve as an incentive for increasing technology adoption and developing training programs for farmers.

National Policies to Improve Irrigation and Drainage

In 1977, the Argentine government created an interministerial commission, Comisión de Tierras Aridas, to address the problems affecting irrigation and drainage. The Commission is an interface between the Secretariats of Agriculture, Water Resources, Water and Electric Power, Economic Affairs, and Internal Affairs and Planning. Its objective is to coordinate the development of the dryland investment program, Programa de Inversiones en Tierras Aridas, by considering the interdependence of the different irrigation projects in the region. It is assisted by a technical secretariat made up of officials from the institutions that make up the Commission.

The criteria adopted by the Commission will be applied to existing irrigation systems including those with incomplete or deteriorating infrastructure. Priority will be given as follows:

1. Maintenance costs for existing systems, with funding from public agencies and through incentives given to the private sector.

2. Completion of the construction of unfinished irrigation infrastructure, as distinct from the initiation of new projects.

3. Rehabilitation projects. mainly construction of drainage works and lining of canals.

4. Promotion of projects that will lead to crop diversification in existing irrigation systems.

5. When the preceding four criteria cannot be applied to two or more projects. preference will be given to those where the social and economic infrastructure is more developed.

The drylands investment program is not automatically funded from national or provincial budgets. One of the objectives is to replace this traditional funding source by specialized local or international agencies that have specific criteria and qualified staff for an appropriate evaluation.

BOLIVIA

Bolivia has an area of approximately 1.1 million square kilometers (km^2 – approximately equal to the combined areas of France and Spain – and a population of 6.4 million people. The country has a wide range of physical features – forests, large rivers, vast plateaux. and high mountains.

The total cropped area is 30 375 000 ha (1982). About 150 000 ha are irrigated, of which 10 000 ha are located in national irrigation systems; the remainder are irrigated privately or by organized groups of water users. The systems are usually small and only cover a limited area.

The country is generally divided into three regions according to the physical, population, and production characteristics:

* The high plateaux region, situated in one of the highest parts of the Andes range with peaks up to 3 500 meters above sea level, accounts for 16 percent of the total area and 38 percent of the population. The region is located in the department of La Paz, with its capital by the Same name. Annual rainfall is 400-600 mm, most of which is received between December and March. The agriculture of the region is essentially subsistence farming based on potato, tobacco, maize, and quinoa. Livestock includes llamas and some cattle; wool is also produced. Approximately 10 000 ha are irrigated, 2 800 ha of which are covered by the Tacagua irrigation project in the center of this region.

* The region of the valleys, situated between 1 200 meters and 3 500 meters above sea level, accounts for 42 percent of the total area and 30 percent of the population. The rainfall pattern varies with the altitude. In the valleys of Cochabamba, Sucre, and Tarija, rainfall is the same as in the plateaux; it is higher in the north and towards the Amazon Basin. Agricultural production varies from cocoa to maize, using traditional techniques including irrigation. Fruits such as peach. apricot. and grape are grown and there are industries (wine cellars, factories) to process the produce. About 48 700 ha are. irrigated. Among the major irrigation projects is the La Angostura project on the Sulqui river. It is located in the department of Cochabamba. with an irrigated area of 6 000 ha. The project operates under state administration.

* The lowlands, which cover 65 percent of the total area with only 20 percent of the population, include the departments of Santa Cruz, El Beni, and Pando, as well as the eastern part of the department of Tarija. Total irrigated area is 15 000 ha. This region has two distinct climatic zones:

  - The subtropical semiarid Chaco region is located to the south of Santa Cruz. Temperatures range between 0°- 40°C, and rainfall is only re between December and March. Crops include cotton, maize, and soybean. The irrigated area does not exceed 4 000 ha, but a series of infrastructural works were built to cover 30 000 ha supplied by the Pilcomayo river. The region has the highest potential for expanding irrigation in Bolivia, given its climatic conditions, fertile soils, and river water resources.

- The Amazon river watershed situated to the north of Santa Cruz, has high temperatures and rains throughout the year. Major crops are cotton, rice, and sugarcane. The region of Santa Cruz de la Sierra has a hydrographic network that forms part of the Amazon basin; the topography is quite even, as is typical of the plains and annual rainfall is 700 mm in the south and 2 000 mm towards the northwest. Cropped area exceeds 200 000 ha, and the main crops are cotton. sugarcane, rice, maize, soybean, etc. Apart from the indigenous farmers them are colonies of Japanese settlers (Okinawa) and Mennonites. Estimated irrigated area is 11 000 ha; access to the major surface water and groundwater sources is an asset for rapid expansion of irrigation. Some areas face problems of soil quality and poor drainage.

Farmers are usually responsible for operation, maintenance, and administration of the irrigation network. They only pay for maintenance. Once or twice a year farmers put in a day to clean the irrigation network together.

Irrigation efficiency is low. Water is distributed according to ancestral customs and supply is usually meager at field level. For example, in the Cinti valley, located in the department of Chuquizaca, water is distributed over 700 ha according to a rotation system established in 1980, which is scrupulously respected.

The most important irrigation and drainage problems are:

* In the high plateaux region:

  - Establishment of irrigated crops on terrains with steep erosion-prone slopes.

  - Poor knowledge of farmers about correct irrigation practices (flow management, duration and time of irrigation, etc.).

- Inadequate water conveyance infrastructure (network and fields).

- Need to integrate microirrigation techniques that use local materials and respect local customs.

* In the valleys:

  - The same problems as in the high plateaux region, particularly the subsistence agriculture area Erosion control is of crucial importance; crop diversification and mtation are needed to maintain soil fertility.

  - In areas where cash crops are grown. there is a need to increase the level of technical assistance to farmers, through dissemination of technical information on cultivation, health, plot levelling for irrigation, improvement of the irrigation infrastructure at the zonal and field level, etc.

* In the lowlands:

  - Need for integrated studies. including irrigation and drainage aspects, for developing the Chaco and tropical and subtropical regions to the north of santa Cruz.

  - Need for technical assistance to farmers in terms of irrigation, drainage, cropping techniques, etc.

CHILE

The climatic characteristics of Chile make a considerable part of its agriculture dependent on irrigation, at least during six months of the year. It has four distinct seasons, with a wet winter and hot, almost dry summer throughout most of the country.

The 13 administrative regions are divided from north to south. They are grouped as follows:

* The northern desert provinces (Regions I, II, and III) receive no rainfall. Agricultural activities are limited to the valleys or along rivers, with very little water available for irrigation; water quality is also poor.

* Region IV requires irrigation in Spring and summer and dams have to be constructed to provide water for crops during these seasons.

* Regions V, VI, and VII offer adequate conditions for irrigation, since the rivers are fed by snow melt from the Andes.

* Regions VIII, IX, and X have higher rainfall and crops only require supplemental irrigation during certain periods of the year.

* Regions XI and XII have abundant rainfall and temperatures range. from medium to low. Livestock production and winter farming are the main agricultural activities.

Total cropped area is 17.4 million ha Total irrigated area (1982 figure) is 1.26 million ha, with perennial irrigation in 59.39 percent of the area and supplemental irrigation in 40.61 percent. Only 4 000 ha have a drainage network.

Among the irrigation institutions, the Irrigation Directorate (Dirección de Riegos) was created in 1915 and placed under the control of the Ministry of Development Its function is to plan, construct, and administer the water works for a temporary period. The Directorate General for Water (Dirección General de Aguas), under the Ministry of Public Works, is responsible for enforcing the water laws (Código de Aguas). The new water law that came into effect in 1981, led to the creation of the National Irrigation-Commission (Comisión Nacional de Riego), under the Ministry of the Economic Affairs. Its role is to advise the Irrigation Directorate on the integrated studies conducted in the valleys. The current water law recommends reduced involvement of government agencies and more private initiative.

Farmers manage irrigation systems through water communities (comunidades de aguas), canal associations (asociaciones de canalistas), and vigilance councils (juntas de vigilancia). These are all autonomous entities governed by an assembly and a chairman. Irrigation administration has thus been sufficiently decentralized. Moreover, since the 1970s, the state has been transferring responsibility of a large part of the infrastructure (dams, canals, and other structures) to the private sector. The transfer is made through sale to existing private companies and issue of shares that the state allocates to the water users.

Among the most important irrigation projects in the country are:

* The multipurpose Conchi dam in Antofagasta (Region II), with a capacity of irrigating 1 400 ha.

* Rio Claro de Rengo project in the Central Valley, including a dam and 20 groundwater wells, for irrigating 8 000 ha.

* Digua project in Region VII (Parral for supplemental irrigation over 65 000 ha.

* Coihueco dam in Region VIII, covering 6 500 ha.

* Convento Viejo dam, expected to irrigate between 78 000 and 160 000 ha.

Through its aggressive export poky for agricultural products, the government has established subsidies for introducing innovative irrigation technology. In 1980.1 500 ha were under trickle irrigation. which was established through private initiative. But certain problems related to poor water quality have emerged as a result; insufficient removal of salt deposits is also observed. Studies and advice are needed to solve the problems.

Rice is grown between the latitudes of 34°10'S and 36°20'S, covering parts of Regions VI, VII, and VIII. Two-thirds of the national rice production is concentrated in Region VII. Cropped area is 36 860 ha (1985 figure); it is mainly located on clayey soils that are considered as marginal for other crops. Rice could be potentially grown over 250 000 ha on alluvial or lake soils.

Irrigation problems identified in Chile are:

* High cost of irrigation projects due to the generally mugh topography which requires the construction of siphons, tunnels, drop structures, etc.

* Limited soil resources for the future expansion of irrigation; the maximum area that can be economically irrigated with current technology is not more than 2.5 million ha.

* Poor quality of water and insufficient flow capacity that cause problems in areas with trickle irrigation in the northern part of the country.

* Conveyance and distribution losses due to infiltration.

* Oversupply of water to some crops, especially rice.

* Location of cropped areas (except for rice) on steep slopes and soils that are not adequately levelled for irrigation. Fields are shipped of topsoil, with subsequent loss of soil fertility.

* For rice crops, lack of knowledge of economically appropriate methods, equipment, and layouts for constructing minor irrigation and drainage structures. These include land levelling according to soil characteristics and limitations (e.g. heavy texture, impermeable horizon, high water table, etc.).

* Limited crop rotation.

* Unsuitable plowing equipment (e.g. plows with nonreversible moldboards for rice crops).

* Lack of knowledge of farmers abut irrigation techniques.

* Need to reline field-drain pipes over 1000 ha in a system irrigated by the Lluta river (northern Chile) and a comparatively smaller area in the Camarones valley.

PERU

In Peru agriculture is an occupation that dates back to very early times. By the time the Spanish arrived; there were more than 700 OW ha of irrigated land, with sophisticated systems of water supply from surface water and groundwater sources. During the next 350 years, however, the irrigated area was considerably reduced. In the late 19th century, interest was renewed in expanding the cultivated area under irrigation. Currently, irrigated area covers 2 587 OW ha of cropped area (1986 figure), which represents 34 percent of the total cropped area.

The terrain is very rough, with the Andes range which crosses the country from north to south. Three natural regions can be distinguished:

* The coastal region, with 1522 000 ha (55 percent of total irrigated area) of irrigated land. Annual rainfall is less than 25 mm. The region's 52 rivers are the main source of water supply: they are fed by the rains in the central Peru. Rainfall is concentrated during January-April (75 percent), with the remaining 25 percent falling between May and December. Large projects are under way to deliver surface water and to reclaim lands affected by salinization and poor drainage (40 percent of the total). More than 12 000 wells were dug to draw on groundwater. Among the most important projects are: Chira-Piura project (35 000 ha), Tinajones project (96 000 ha). Majes project (60 000 ha), and Chavimochic project (138 000 ha).

* The Sierra region, with 990 OW ha (33 percent) of irrigated land. Rainfall varies widely between 44 mm and 1 200 mm; the temperatures fluctuate between hot and cold. due to the uneven topography. Rational planning of agriculture. is therefore difficult. The main irrigation project., are: Linea Global project (30 000 ha) extending into the coastal region and Jequetepeque-Zaña project (46 000 ha).

* The forest region, with 258 000 ha (9 percent) of irrigated land. The region has abundant water resources. Annual rainfall varies between 700 mm and 4 500 mm. Supplemental irrigation is required during dry periods due to the high evaporation levels.

The institution responsible for irrigation administration in Peru is the Directorate General for Water (Dirección General de Aguas). Irrigation districts were created for better management of water resources; there are currently 76 districts (coastal region, 31; Sierra region, 32: forest region, 13). The water-user associations (comits de regantes, comisiones de regantes, juntas de usuarios) work with the Water Authority (Autoridad de Aguas) for system operations, but participate more directly in maintenance. The National Water Users' Council (Junta Nacional de Usuarios) was constituted recently; it groups together water users from all the irrigation districts. Activities related to water use and delivery by the state and water users are governed by the General Water Law (Decree No. 17752 of 1969).

Inadequate use of irrigation water in the new irrigated areas of the coast has led to land salinization and flooding due to poor drainage in the lower parts of the valleys. These problems affect 34 percent of the area. In the Sierra region, surface and underground drainage problems are caused by excessive rainfall and by filtration to lower terraces, valleys, and areas surrounding lakes and lagoons. About 1 500 ha are affected by these drainage problems. The forest region mainly faces surface drainage problems due to heavy rainfall, river overflow, and almost zero slope of the soils.

A land drainage and rehabilitation center, Centro Nacional de Drenaje y Rehabilitación, was established in 1968 to control and prevent drainage and soil salinization problems. It is the result of a collaborative effort between the Peruvian Agricultural University and Government of the Netherlands. A national plan for rehabilitating coastal land, Plano Nacional de Rehabilitación de Tierras Costeras, was started in 1974, and a program fox land drainage and reclamation, Pmgrama Nacional de Drenaje y Recuperacin de Tierras (PRONADRET), began recently in 1988.

URUGUAY

Uruguay lies in the southern temperate zone between the latitudes 30-35 S. Average annual rainfall is 1071 mm, with 10 percent more in the northern part of the country and 10 percent less in the south. Between December and

February, due to a rainfall deficit of 300 mm. supplemental irrigation is required to satisfy crop water requirements.

The rural areas are practically uninhabited, with an average population density of 15 people/km2. The major crops for the past several decades have been rice and sugarcane. The cropped area totals 15 million ha, of which 88 000 ha are irrigated (1982 figure). Rice covers about 60 percent of the cropped area and sugarcane slightly more than 15 percent The current rice and sugarcane areas could be increased through irrigation, since production is less than the processing capacity.

Only 2 percent of the total surface water resources are used for irrigation; 95 percent of the irrigation resources are used for rice crops. Surface water is usually supplied by directly pumping water from rivers, streams. and lagoons. Winter runoff is collected in dams for use during October-March.

The government has established several irrigation projects. The India Muerta dam (department of Rocha) has a holding capacity of 116 million cubic meters (m3). It irrigates 8,000 ha of rice crops, with the participation of two large groups of rice farmers. It also enables the expansion of livestock production in the dryland area covered by the project Another project is located in the Merin lagoon basin, on the border with Brazil. Seventy-eight percent (1988 figure) of the total rice-growing area in Uruguay is concentrated in this project.

Three agricultural settlements (colonias agrccolas) have also been established:

* The Espaa settlement (Bella Unin), with 2 000 ha of sugarcane crops that are processed by the CALNU sugar refinery. The CALPICA cooperative in this colony has 1500 ha of sugarcane crops, divided into three irrigation sectors, each with equipment to pump water from the Uruguay river.

* The Berreta settlement (Fray Bentos), with a project for 2000 ha of citrus, sugarbeet. and maize. Water is pumped from the Uruguay river.

* The Molinelli settlement (San Jacinto) is located 55 km from the capital. It has 500 ha of gardens and orchards for market crops and is supplied by a reservoir.

Rice crops are flooded. Surface irrigation (rivers. 70 percent; reservoirs, 30 percent) supplies 90 percent of this water, while the remaining 10 percent is obtained from groundwater. Seventy-eight percent of Uruguay's rice-growing area is concentrated in the Merin lagoon basin, 17 percent in the Río Negro basin, and 5 percent in the department of Artigas (1988 figures).

Furrow irrigation (surface water, 60 percent; groundwater, 40 percent) is used for sugarcane crops. The methods used for market crops are furrow irrigation (60-80 percent) and sprinkler irrigation (20- 40 percent). The main source is groundwater: 85 percent for market crops (approximately 2 500 ha) and 70 percent for fruit crops.

Various organizations deal with crop production in irrigated areas. The Ministry of Livestock Production and Agriculture conducts studies, research, and experiments and disseminates findings on soil, climate, water, and crops. The Ministry of Public Works is responsible for planning and constructing the infrastructure for collective irrigation and drainage systems. The Instituto Nacional de Colonización, an institute for land settlement. operates. develops, and administers irrigation works; it also offers technical assistance and credit to settlers.

Fanner participation in operation, maintenance, and administration of irrigation systems is still in its early stages. Cooperatives in the large systems handle marketing and irrigation services. In certain rice-growing areas, irrigation services are provided by private companies, who are paid in kind (a certain number of sacks of rice/ha).

Major irrigation problems are as follows:

* The soils where rice is grown have a medium texture and are not well drained. They are characterized by low fertility and poor permeability with excess moisture in winter and a deficit in summer. Crops need to be. constantly rotated, with fallows of 2-3 years, to overcome these problems and that of weeds.

* Rice crops need carefully levelled soils. This is a cost-intensive operation because of the extremely uneven topography.

* Water consumption is very high, resulting in low irrigation efficiency. It also creates problems among fanners during water scarcity.

* Higher pumping costs reduce crop profitability.

* The water conveyance and distribution infrastructure in sugarcane crops is inadequate. It lacks gauging structures, standardized hydraulic gates, etc.

* Maintenance of the irrigation infrastructure in sugarcane crops is inadequate. The insufficient canal gradient is favorable to weed growth, control measures for which are not based on rational techniques.

* Farmers cannot improve water use as they lack basic knowledge about efficient irrigation practices (e.g. appropriate type of irrigation. irrigation methods based on soil characteristics, land levelling. timely application of water, etc.).

TRAINING AND RESEARCH ACTIVITIES

In Argentina, various organizations conduct teaching and research activities related to irrigation and drainage. Among these the most important are the universities; the Institute of Agricultural Technology, Instituto Nacional de Tecnología Agrícola (INTA), and INCYTH.

The universities primarily focus on basic research and postgraduate training. Irrigation and drainage are either taught as part of the agricultural sciences program, where the subject is studied in detail, or as part of the hydraulic engineering program, where the topic is considered as a secondary activity. The creation of a Master-level postgraduate course in irrigation and drainage has been approved, and it will begin in 1990 at the Faculty of Agricultural Sciences of the National University of Cuyo. situated in the Mendoza province.

INTA's research activities are mainly conducted in Mendoza, with smaller teams at experiment stations in the provinces of San Juan and Río Negro. In the remaining stations throughout the country, the staff is mainly involved in irrigation-related extension activities and research is limited to on-site. testing of techniques developed at the centers of excellence. The results obtained by INTA are directly transferred to fanners.

INCYTH conducts its irrigation and drainage work at its two centers, CELA and CRA in Mendoza. CELA - as its name suggests - focuses on water economy, legislation, and administration. CRA deals with mountain and urban hydrology, and irrigation and drainage throughout the country. Mendoza was selected as the site for the two centers as it offers a natural laboratory for studying existing conditions and testing new methods. It has 500 000 ha classified as appropriate for irrigation and adequately organized water-user associations.

INCYTH is concerned with applied research and development on new themes that require more in-depth research or the development of innovative technology. Fanners are involved only when the new methods are being evaluated. The results of the evaluation are then transferred to the universities, INTA, and national and provincial institutions. who are responsible for disseminating them among farmers and other water users.

INCYTH's activities are oriented toward three aspects: a) applied research and technology development; b) advice to provincial, national, and international institutions; and c) manpower development and dissemination of knowledge squired in the field.

Applied research programs on irrigation and drainage conducted by INCYTH-CELA and INCYTH-CRA, include:

* Optimization of the operation of irrigation systems: models for operating reservoirs used for irrigation, models for optimum water use at regional level, combined use of surface water and groundwater resources, methods for inventory of the irrigation and drainage infrastructure, and information storage in data banks.

* Design and evaluation of irrigation systems and engineering works: guidelines for designing new irrigation projects, including operation and maintenance aspects; standardization of the design of field-level irrigation structures.

* Automatization of irrigation at field and distribution network levels, based on local conditions.

* Measurement of water deliveries at field and distribution network levels, in order to assess irrigation efficiency and efficiency of irrigation administration in the area.

* Optimization of irrigation system maintenance, through studies on maintenance equipment performance; weeds and their effect on the hydraulic performance of canals; and weed control by mechanical. manual, and biological means.

* Determination of parameters for irrigation application and of evaluation techniques, with the objective of improving irrigation efficiency.

* Study of drainage at zone and field levels. through an extensive network to monitor water-table levels in the province of Mendoza.

* Use of remote sensing for: study of actual and potential evapotranspiration rates, monitoring of cmp water requirements, charting of cmps. inventory of the irrigation and drainage infrastructure, determination of the extent and rate of salinization, etc.

* Planning of agricultural development through the combined use of techniques such as remote sensing and on-site information collection (implementation stage).

* Formulation of water codes and laws.

* Analysis of the legal, economic, and organizational features of water administration.

* Sociological analysis of the water-usex associations.

* System of fee establishment and a budgeting system for irrigation administrations.

* Development of models, criteria, and methods for planning investment projects for irrigation and drainage.

* Analysis of technological needs.

* Studies on the socioeconomic effect of contamination on irrigated areas.

* On-site treatment of effluents and re-use of water for irrigation purposes.

INCYTH offers advisory services to other organizations on the application of the research results, preparation of manuals on the tasks of irrigation administration staff, drafting of irrigation rules, regulations for water-user associations, organization of water user censuses, etc.

The two INCYTH centers organize manpower development seminars and international and national workshops on operation, maintenance, and administration; integrated management of water resources; reservoir and barrage management; irrigation fees; drainage problems at regional level, etc. For this, they collaborate with major international organizations such as FAO, UNESCO, and ECLA.

INCYTH plans to develop the facilities at Mendoza with: conference rooms with simultaneous interpretation facilities and different types of amphitheaters of variable capacity; library; printing facilities; various types of computer equipment (micro-VAX II, PCs), equipment for digitalization of plans and digital processing of satellite images and neutron probes for soil moisture determinations; laboratory for irrigation and drainage, automatization of irrigation, and electronics; vehicles for transporting course participants; etc.

Each year, INCYTH receives 5-10 visitors from other countries (the Netherlands, FRG, USA, other Latin American countries) who come for specific training in certain areas of its activity. Specialists from Europe and USA regularly visit the Institute for periods of 2-8 weeks in order to apply and test various mathematical models in the region.

SUGGESTED LINES OF ACTION FOR IIMI

Lines of Action at Regional Level

* National and regional training and development programs for operations, maintenance, and administration staff. They should be similar to the INCYTH-CRA courses. Professional, technical, and support levels should all be covered. The most appropriate techniques should be studied in each case and they should be in line with irrigation development in the region.

* Courses on the design of irrigation structures, based on future operations, maintenance, and administration needs.

* Workshops on operation, maintenance, and administration for decision makers from different countries, in order to familiarize them with new techniques and to discuss applicability of the techniques.

* Courses on management of irrigation services in the districts, similar to those organized by INCYTH-CELA. These courses should include strategy establishment, management techniques, and monitoring and evaluation of results. The courses should be organized every two years for qualified staff.

* Workshops on policies for rehabilitation or maintenance of irrigation systems or both, with presentation of case studies.

* Production of publications in Spanish and Portuguese to communicate the new techniques to irrigation district staff, to comment on the results obtained in other regions of Latin America, and to receive their input

* Implementation of a regional research program, directed by IIMI and in collaboration with other international organizations. Four areas are proposed for launching the program:

  - Application of techniques to design, operate, maintain, and administer irrigation projects in less developed rural areas and in valleys with steep slopes. A valley in Cochabamba, Bolivia, could be selected, or a location with similar conditions in Peru. The results would be useful for similar regions in Mexico, Ecuador, Colombia, and other countries.

  - Application of modern techniques related to irrigation canal management, maintenance methods, and forms of administration. Case studies could be selected from Argentina (Mendoza or San Juan), Brazil (projects in the northeast), Chile (Central Valley), or Peru (coastal region).

  - Application of models to optimize combined use of water resources and use of other techniques (for example, satellite images, GIS) for programming and management of irrigation at zone or district level. A possible case would be that of Mendoza, where a study was conducted on this aspect and yielded a rich information base.

- Selection of appropriate integrated techniques for maintaining irrigation and drainage systems. especially in terms of weed control. The location of the study area should be determined according to the type of climate where the project will be conducted. as it has a direct effect on weed development.

Lines of Action Specific to Individual Countries

* Advice on preparation of irrigation guidelines, including manuals on the tasks of operation, maintenance, and administration staff.

* Organization of courses on the techniques for information management and communication between irrigation agencies and farmers, using case studies.

* Assistance in organizing courses given by staff from each country, for a thorough understanding of operation, maintenance, and administration techniques. A specific case could be developed during each course. These courses would train staff who would serve as "multipliers" of these techniques in the other areas of the country.

* Advice on computerization of planning. execution, and control for operation. maintenance, and administration of irrigation systems.

* Organization of workshops to discuss case studies to identify the most suitable methods for payment of irrigation services.

* Assistance in the organization of a program informing farmers on various irrigation. levelling, and drainage techniques, using mass communication, group communication, demonstration plots, etc. The program would be executed by national staff.

* Organization of a national and regional program to encourage farmer participation in operation, maintenance, and administration of irrigation

systems, according to the laws and socioeconomic conditions in each country.

* **Advice to each country** on **the process of transferring responsibility from state agencies to water users.**

Chapter 4

PROBLEMS OF IRRIGATION SYSTEM MANAGEMENT

Augustin Merea Canelo

INTRODUCTION

Role of Irrigated Agriculture in Latin America

LATIN AMERICA, LIKE other developing regions of the world, experiences serious and very varied limitations m attaining the short- and medium-term socioeconomic objectives set out in national, sectoral, and regional development plans.

One of the major problems *facing* Latin *America* as a whole. is that of substantially increasing its current levels of agricultural production and productivity, particularly for food and fiber crops.

In recent years, there has been a general consensus at conferences attended by agricultural development officials and *specialists* that the actual and potential irrigated areas could and should contribute significantly to an alleviation or solution of the production problems.

The report of the Independent Commission on International Development Issues under the chairmanship of ex-Chancellor Willy Brandt is a relevant indication of the consensus expressed at major meetings *such* as the World Food Conference (1974), United Nations Conference on Water (1977), Inter-American Conference on Agriculturel, the Latin American Seminars on Irrigation.

In chapter V on Hunger and Food, the Brandt report states that investment is better than food aid and recommends that: "The biggest single amount of investment quired is for irrigation and water management.

The implementation of the first part of the recommendation is rendered difficult by the economic crisis faced by most countries of the region. Due to scarce. financial resources, the countries have to seek loans from the Inter-American Development Bank, World Bank, and other funding agencies for the construction of new irrigation projects.

The second part of the recommendation, however, is feasible as it requires an optimization of water administration and an optimum utilization of irrigation pmjects.

Water and Land Availability for Agricultural Production

Latin America is a privileged region as regards the availability of water and land resources. The problems facing agriculture are in fact those of "scarcities in abundance."

Many studies concur that the region has the most abundant water resources in the world. Average annual rainfall is 1 500 millimeters (mm), 60 percent higher than the world average. Average annual water flow is 370 000 cubic meters per second (m^3/s) which represents 30 percent of the world total.

In reality, these averages conceal marked differences among countries. a situation that belies the earlier statement. Most of the Peruvian coast and northern Chile have virtually no effective rainfall, while in the Choco region of Colombia, and the Darien region of Panama, average annual rainfall is approximately 8 000 mm. Large seasonal and annual variations in intensity and frequency are recorded in zones with an average annual rainfall of 1,200 mm. Yields of rainfed crops, particularly annual (duration < 100 days) and perennial crops, are unpredictable because of excess or insufficient rainfall.

Seasonal and annual rainfall variations are reflected in the irregular water flow in the basins. Although the upper basins of the Andean rivers south of latitude 28° S are fed by glaciers and melting snows, water flow in many cases is still not regular.

The river network is also not evenly distributed throughout the area. A few major rivers like the Amazon, Plate, Orinoco, and Grijalba-Usumascinta account for 70 percent of all rivers. Although these river basins cover 45 percent of Latin American territory, they only account for a b u t 10 percent of the total population.

This situation explains why water for agricultural purposes is a scarce resource.

Latin America has a potential of approximately 700 million hectares (ha) of arable land. But the actual cultivated area (annual and perennial crops, prairies with crops, fallow land) according to recent national and FAO statistics only totals approximately 170 million ha. of which 15 million ha are irrigated (8.8 percent of total cultivated area).

Irrigated Areas

The total irrigated area, with perennial or supplemental irrigation, is estimated at approximately 15 million ha, which is significantly little compared with the available potential.

In South America alone, excluding the humid tropics, the potential irrigated area is calculated to be 160 million ha. Nearly all the Latin American countries have areas under irrigation; countries with the largest irrigated areas are Mexico, Argentina, Chile, Peru. and Brazil.

But in practice, no more than 80 percent of the potential area can be irrigated annually because of flow fluctuations in the rivers that supply the irrigated areas. In several countries, the infrastructure constructed over the last 15 years, particularly the water distribution and delivery network, does not cover all the fields that could be supplied by the main reservoir and conveyance network. This reduces the total irrigated area to less than the 80 percent indicated earlier. The average area that is actually irrigated annually is reduced even further due to other problems, which are discussed in the next section.

Approximately 85 percent of the region's irrigated area is composed of irrigation systems, projects, or districts established with state funding. Gravity irrigation is used in about 95 percent of the total irrigated area, but it is not found to be very efficient. In Mexico, the efficiency levels are: water use, 46 percent; conveyance and distribution, 70 percent; application at field level, 65 percent. In Argentina, overall efficiency is no more than 30 percent in major irrigation systems. This level is also observed in most other Latin American irrigation systems.

CONSTRAINTS TO BETTER USE AND MANAGEMENT OF IRRIGATION SYSTEMS

The problems affecting use and management of irrigation systems vary according to the situation in individual countries. This has been confirmed at recent conferences attended by officials and specialists involved in this effort. It must be acknowledged. however, that considerable p r o p s has been made in certain countries.

The conferences have contributed to a large extent in the identification of the causes and effects of these problems. But the policies, lines of action, and methods recommended to alleviate or overcome the problems have yet to be adopted and implemented.

The general problems can be grouped as follows: legal and regulatory; institutional; technical, administrative, and methodological; and socioeconomic and cultural.

Legal and Regulatory Problems

The fundamental legal aspects concern regulatory laws which define and establish the procedure to be followed; in this case they govern water and land resources. They also concern regulations. which are general and specific rules for facilitating the interpretation and implementation of basic laws. In practice, regulations can be more easily modified as they are normally formulated and put into effect by different echelons of the executive branch.

Legal and regulatory problems arise from various aspects.

Outdated water and land laws or codes. Bolivia, Brazil, Honduras, and the Dominican Republic are among the countries where basic water laws have been in force for at least 25 years. although there are plans to update them. On the other hand, Colombia, Guatemala, Nicaragua and Venezuela do not have specific laws for water, although they have been drafted.

Since 1969, the national laws on water have been updated in the remaining countries: Peru (1969), El Salvador (1970), Ecuador (1972), Mexico (1972), Uruguay (1979). and Chile (1981).

Fundamental incongruities between laws for water and other natural resources. In certain countries, varying degrees of antinomy are observed among basic laws. Different laws consider water as a public utility or as a public utility that may be used freely by riparian farmers for natural irrigation, thus ceasing to be public. Laws or decrees on minerals and some other natural resources refer to water as public or private property. Such conflicting views invalidate the legal safeguards, creating serious problems for the administration of water resources.

Inadequate general or specific regulations to facilitate the interpretation and implementation of water laws. In many Latin American countries, there are insufficient general and specific regulations which could clarify the laws for easier interpretation and implementation. without

departing from the basic principles established in the laws. The regulations should define the "rules of the game" to be observed and respected by both public servants responsible for their implementation and by water users.

Delays by legislative and executive bodies in promulgating updated bills for water laws and general and specific regulations. This problem which exists in several countries in the region is related to their particular situation, and affects optimum use and development of various resources available in irrigated areas.

Lack of flexibility on the part of the normal judiciary in handling litigations. Except for the few countries with special courts, disputes involving the use of water are resolved very slowly by the normal judiciary. Such delays have an create serious problems for users and public or private institutions responsible for developing irrigated agriculture, particularly management of irrigation systems, projects, or districts.

Institutional Problems

The following institutional problems have been identified.

Poor organization, operation, and mobilization of human and financial resources by irrigation agencies. The recent budgetary restrictions in many countries are becoming even tighter. This has affected the organization and normal operation of agencies responsible for developing the existing irrigated areas.

The repercussions are seen at different levels and have led to: a lack of qualified professional and technical staff; too many underemployed junior staff; limited travel expenses: lack of materials. equipment. and manuals on operations and procedures, etc. There are not many specialized units to collect, process, and analyze information on the different responsibilities of the institutions, which would enable a realistic assessment of their performance. There is also a shortage of units to carry out activities such as agricultural research and extension.

Lack of coordination between government and other institutions. National and regional organizations often share the responsibility for studies, construction, and management, but without coordinating their activities. In Argentina and Brazil. the size of the territories and federal system of government justify such situations. But they are also found in countries with centralized governments such as Ecuador, Peru, and Bolivia, exceptions being the Dominican Republic, Colombia, Costa Rica, Mexico, and Guatemala.

Poor *coordination between irrigation agencies and organizations responsible for support services and action program.* Very few countries in the region have institutionalized coordination mechanisms to ensure optimum concerted efforts between agencies that are directly responsibility for operations, maintenance, and administration of irrigation systems, and organizations responsible for support services and action programs (research and development of irrigated agriculture. marketing, agroindustries, land tenure, training, credit, input supply, storage and transport). They should as a single entity and contribute to a more rational use of all available resources in these areas.

Lack of organized participation of water users in operations. maintenance. administration, and development of irrigation system. Water users in Chile, Mendoza and the CORFO-Río Colorado region in Argentine, and the irrigation districts of Coello and Saldaña in Columbia provide an excellent example of farmer management of irrigation systems.

Such organized participation by water users is found to a lesser extent in Mexico, Peru, the remaining irrigated districts in Colombia, and certain systems in Ecuador, Brazil, Uruguay, the Dominican Republic, and Honduras. But in the other countries, user participation is either negligible or nonexistent.

Inadequate training of irrigation agency staff. The current economic and financial situation has led to a serious lack of training for all levels of irrigation agency staff. Mexico has made considerable efforts in this direction, through its training programs for SARH officials. Training programs are also conducted in Brazil, Peru, Argentina, the Dominican Republic, and Colombia, with support from IICA, FAO. AID, BID, and other organizations.

Technical, Administrative, and Methodological Problems

In most countries, operations, maintenance, and administration are the tasks of centralized or independent agencies, mainly from the agricultural sector. They confront a variety of problems in providing these essential services.

Inappropriate subdivision of irrigation districts. Subdivision of the irrigation districts should correspond to existing structures, canal networks, and land tenure system. Water distribution can then be rationalized, as well as the work of service officials.

Nonexistent, insufficient or underutilized gauging structures. More gauging sections and devices are needed to monitor and measure water catchment, conveyance, distribution, and delivery.

Outdated registers of water users. Proper records are needed to identify owners and/or water users in the irrigated districts: location of total and cropped areas of farms with irrigation rights; location, number, and maximum capacity of field-level intakes and of natural or artificial channels for draining excess surface water or groundwater.

Inattention to the original design norms. Little or no attention is paid to norms for a correct operation of the major structures such as regulating weirs, diversion weirs, regulators, pumping stations for irrigation and drainage, maintenance equipment).

Unsuitable water distribution methods and norms. Water distribution methods do not often correspond to soil characteristics and crop water requirements (time of application and amount); application, conveyance, and distribution efficiencies: water availability: and catchment, distribution, and delivery capacities.

Low overall irrigation efficiency. In many cases the efficiency rate is less than 30 percent. Factors responsible for the low rate include: inefficient operations and maintenance, inadequate. extension services and credit facilities for training water users in better irrigation practices for a rational and sustainable use of land resources.

Lack of coordination between operations and *maintenance.* Poor coordination makes it difficult to cut off water supply to carry out inspections and maintenance.

Lack of coordination between institutions managing regulating reservoirs and irrigation agencies. Regulating reservoirs are managed by agencies other than those responsible for managing irrigation systems. The lack of coordination between these institutions affects irrigation services.

Lack of information and methods for monitoring and evaluating management of irrigation system. Such information includes: checklists for operations: water data; derived and delivered volumes; conveyance. distribution. and application losses; specific and overall efficiencies; area, average water requirements, average unit yields, total production, and value of different crops: production costs and net income of farmers; etc.

Inefficient planning and execution of maintenance and improvement programs. Routine and preventive maintenance of the hydraulic infrastructure, roads, equipment, and buildings, is often delayed and carried out inefficiently. Maintenance specifically involves: removal of sediment and vegetation from irrigation and drainage canals, proper operation of gates for control and distribution of water; rehabilitation of canal beds and embankments, drainage network, bridges, and service roads; repair of pumping stations; maintenance of buildings. and passenger and heavy-duty vehicles; etc.

Unsuitable maintenance norms for maintenance equipment. Norms for routine and preventive maintenance either do not exist or are unsuitable. This mainly applies to heavy or any other equipment used by maintenance services.

Nonavailability of essential spare parts. Equipment is out of commission for long periods because of the rigid procedures for procuring spare parts.

Excessive dependence on mechanical removal of sediment and weeds from canals. Such work can be suitably done by local field labor which is available during the land preparation season. The laborers could be. paid either daily wages or by quantity of material removed

Nonevaluation of Operations and maintenance costs. Operations and maintenance costs are rarely assessed. This applies to output, materials, and cost of maintenance and rehabilitation of the infrastructure.

Lax enforcement of regulations. Sanctions are not strictly imposed in cases of water theft, willful damage to intake or control structures, damage to roads though negligent handling of surface water, construction of unauthorized intakes, etc.

Absence of demonstration plots. There is a need for fields or plots for demonstrating irrigation and cropping techniques for local crops.

Lack of coordination between agencies providing support services. There is a lack of coordinauon between the different agencies responsible for credit, marketing, extension services. research and training, agroindustries, and agricultural development.

Lack of communication with water-user associations. Little effort is made to integrate the active participation and collaboration of water-user associations in programs and activities aimed at a better use of resources.

These problems are to some extent common to many irrigation systems in Latin America. However, some countries with more experience in irrigation such as Mexico, Peru, Argentina, and Colombia, have largely overcome the problems in some of their irrigation systems. Other countries are attempting to solve them.

Socioeconomic and Cultural Problems

In many countries, landless peasants were collectively or individually allotted land with irrigation and drainage facilities, in accordance with national land reform or settlement laws. But in many instances. for political reasons, the beneficiaries had no experience of cultivating even dryland or rainfed crops.

Socioeconomic problems are mainly related to the implementation of land reform policies in irrigated areas.

Beneficiaries are passive subjects. Decisions on land reforms were taken at higher levels, without organization of training and motivation programs.

Lack of motivation of beneficiaries. The beneficiaries prefer to be sole owners of their land. With very few exceptions, those on collectively allotted land have no incentive to collaborate and commit themselves to the success of the operation.

Lack of responsibility of leaders of collective lands. Leaders of collective lands do not often fulfill their responsibilities for certain tasks such as delivery of harvest, credit payment, acquisition of inputs.

Delays in execution of the final deeds. Delays in awarding the deeds to beneficiaries creates difficulties for certain procedures such as credit applica-

Slow action by authorities for revoking land allocations. Despite relevant clauses in the laws, authorities are slow in revoking individual or collective land allocations in cases where peasants abandon their holding or portion of land without justification or do not exploit it rationally.

Unsuitable land. In some cases, the land expropriated or acquired for land reform in irrigated areas is unsuitable for growing irrigated crops.

CONCLUSION

This paper does not claim to examine in detail all the problems that constrain better and more rational use of irrigation projects, systems, or districts in Latin America. Its aim is to provide for an exchange of views and ideas on this serious problem.

Chapter 5

FORMATION OF WATER-USERS ASSOCIATIONS AND TRAINING

Fabio de Novaes

INTRODUCTION

AGRICULTURAL DEVELOPMENT DEPENDS entirely on the management of production factors including technical and financial factors. inputs, equipment, and labor. The availability or shortage of any of these factors determines the pattern and degree of development and intensification.

One of the main characteristics of Brazilian agriculture is its diversity which is based on different geographic, cultural, and settlement conditions and on the form of crop or livestock production. Another characteristic is fragmentation due to the high cost of land and division of property through the line of inheritance. Farm size is often reduced to an area that can no longer be exploited productively.

FARM MANAGEMENT

Extensive livestock production does not raise major management problems. Such activities are usually located in remote. low-cost areas where traditional pastures can still satisfy production needs. Labor requirements are also low and can be met by local manpower. The only inputs used are those necessary to maintain natural growth. The most important problems concern animal health and protection of property.

Large extensive, nonirrigated farms do not quire much management Risks are higher, but the magnitude of production also yields profits in the long term. Investments in crop protection and price stabilization guarantee good results but require a more complex administrative structure.

In both cases the producer-owner generally lives in the city, and the farm is left in charge of a manager or administrator. Big farms are sometimes managed by a single person living on site. while the owner takes care of "weekend management".

Such situations are also common in large irrigation systems. In this case. the owner's presence is vital because of higher investments and the need for better technology.

Management of small and medium private irrigated farms is more complex. More intensive fanning implies more assistance and inputs, larger support structure, more technical know-how, and better processing of produce to supply more demanding markets. Water management becomes an important factor in overall management.

MANAGEMENT OF MINOR IRRIGATION IN GOVERNMENT PROJECTS

In Brazil, irrigation systems of farms developed through government projects are hampered by poor management. The most important causes for this constraint are:

* Settlers have little experience of irrigated agriculture. For cultural reasons they do not respond favorably to technological innovations. They also lack the financial and technical support to carry out their activities successfully. These new fanners do not share common interests and are therefore not mentally prepared to form groups. By imposing a cooperative model on reticent farmers, the government has contributed to the discredition of an otherwise efficient system for marketing fann produce.

* Excessive intervention of government agencies in decisions of rural communities. without duly considering their aspirations. The agencies presume that they have sufficient know-how to organize water-users associations and tend to issue regulations that are often inappropriate or ill-timed. But the technical and financial support given rarely covers even minimum needs for development because it is either inadequate or untimely.

* Disproportionate emphasis on civil engineering vis-a-vis agricultural know-how. The cost of hydraulic structures makes them economically unfeasible. The agricultural and human elements are overlooked in implementing government irrigation projects.

The current policy of decentralizing government projects in the northeast should make them cost-effective by eliminating the damaging effects of public administration. The success of this policy will largely depend on the method of implementation. But decentralization is not an easy task. One risk is that farmers who are unprepared to manage their farms will be left out of the production process unless they are given efficient technical, administrative, and financial support.

MANAGEMENT OF PRIVATE IRRIGATION PROJECTS

Private small and medium irrigated agricultural projects are of great economic importance because they form the largest group and they are the most productive in the agricultural sector.

The national program PROVARZEAS has promoted the development of more than 65000 such projects throughout the country.

Efficient management and perseverance invariably yield good results within a reasonable period. Despite a lack of experience, the farmers have been able to fully amortize their loans, thus showing a high management capacity. They form a progressive group that is anxious to improve living conditions through an efficient use of irrigation. The farmers would therefore be receptive to and benefit from practical training programs that improve their irrigation management capacity.

Although the farmers share. a common production goal they have different cultural backgrounds and motivations for joining an association. The training program should take these differences into account. It should provide information on the principles and organization of associations and on the administrative and financial aspects.

In heterogenous communities, the more educated groups are those most likely to form associations. They are usually better informed about market mechanisms and their higher social status also lends itself to the process.

In Brazil, the establishment of cooperatives without the spontaneous and willing support of future members has often been a disastrous experience. However, water-users associations in southern Brazil have proved to be socioeconomically viable and serve as an encouraging example for establishing others.

The cases of Turuo and Torres are examples of such successes.

* In Turuo, Santa Catarina state, farmers formed a water-users association 6 years ago. Members paid the equivalent of 12 percent of production value for water use. At present, the association charges only 2 percent. Per hectare water consumption has been reduced and more users are supplied with water, with obvious economic benefits.

  In 1980, rice yields in the area were a meager 1 500 kilograms per hectare (kg/ha). Low production even forced some farmers to migrate to cities. But the PROVARZEAS program changed the situation. In 1981.28 experimental projects were established over an area of 110 ha. They served as pilot projects for developing rice crops in 1 325 projects covering 8 975 ha Cropped area increased by 50 percent and production by 310 percent. Average yields rose from 1 500 kg/ha to almost 6 000 kg/ha and system-level production increased from 12 000 tons per hectare (*) to 49 000t / ha. Yields exceeding 9 000 kg/ha are now frequent. Rice quality also improved, 90 percent of the rice which used to be mixed to facilitate marketing, is now of grade 1 quality.

* In Torres, Rio Grande de Sul, the farmers association for farm mechanization services in irrigated areas, APSAT, was instrumental in rapidly transforming the economy of the irrigation system. An important factor for its success was the perseverance and able leadership of a local farmer.

PROVARZEAS initially provided funds for purchasing basic equipment and constructing a community storehouse. The impact on crop production was so positive that each fanner now has an individual storehouse.

But it was not an easy task. A simultaneous training program on irrigation management would have facilitated the work.

At present there are many APSATs in Brazil. But any effort to support farmers would be hitless without favorable economic conditions.

Another target group for such training programs are the farmers who are geographically isolated. They lack training and the appropriate cultural background. They hope that associations organized by philanthropic bodies or responsible leaders will provide the support they need.

A typical case is that of the Igarepé-Arzú cooperative in Pará state, where fanners were in a state of poverty 3 years ago. They were incapable of producing crops, but after 1 year of moderate, well-managed support from PROVARZEAS, they were able to produce 10 000 sacks of rice, using only traditional techniques.

Training in management would greatly benefit group leaders. Each year, 1000 such persons could be trained. Although they constitute a comparatively small number, they would have a multiplying effect by disseminating information which would be useful for future programs.

Chapter 6

IRRIGATION MANAGEMENT IN COLOMBIA

Enrique Sandoval Garcia

SUMMARY

AFTER A BRIEF review of land development in Colombia, the author presents the current status of irrigation in the country and analyzes the socioeconomic context.

Two programs were established; one for the modern, large-scale irrigation sector and the other, for the traditional, small-scale irrigation sector.

The program for large-scale irrigation is divided into two phases for rehabilitating 15 of the 23 systems administered by HIMAT. The establishment of 12 projects is planned; they will cover 181 300 ha and benefit 114 000 families.

For the small-scale irrigation program, 236 projects were completed; they covered a total area of 18 800 ha (6600 families). Others are under way.

The programs are mainly financed from the national budget. An investment recovery plan is expected to reduce this dependence on government funds.

INTRODUCTION

Colombia, situated in the extreme northwest of South America, has an area of 114 million hectares (ha), 54 percent of which is mainly covered by natural

Figure 1. Map of Colombia.

forest. The remaining 46 percent is classified as agricultural land for crop and livestock production.

Analyses of the agricultural lands show that only 10.6 million ha (20 percent of the area under study) have an irrigation potential. Lands with irrigation potential include 6.6 million ha that can be directly irrigated and 4.0 million ha with some limitations that need to be overcome before they can be irrigated.

At present, 841 600 ha have an irrigation and drainage network, indicating that Colombia has developed only 12.6 percent of the directly irrigable area, or only 7.9 percent of the total potential area.

The Instituto Colombiano de Hidrología, Meteorología y Adecuación de Tierras (HIMAT) is the official hydrology, meteorology, and land development organization with a mandate. to promote. irrigation and drainage programs and technological development in the agricultural sector.

HIMAT is conducting various studies in different parts of the country, they include reconnaissance studies (258 000 ha), identification of potential areas (53 000 ha). prefeasibility studies (645 000 ha). feasibility studies (178 000 ha). and project planning (39 000 ha).

The efforts undertaken to date by the government for developing new areas (from identification of potential areas to project execution) cover 30 percent of the total directly irrigable area. The current irrigated area will therefore be expanded by 140 percent on completion of the projects.

Agriculture is the most important economic activity in Colombia and the sector accounts for 23 percent of the gross domestic product (GDP). It also represents more than 70 percent of the country's total exports in terms of value.

Approximately 20 million ha of land are currently devoted to agriculture. The degree of intensification and technological level vary considerably. Colombia's agriculture can therefore be classified into two distinct sectors: the modem, large-scale sector and the traditional, small-scale sector.

THE MODERN SECTOR: LARGE-SCALE IRRIGATION

Background

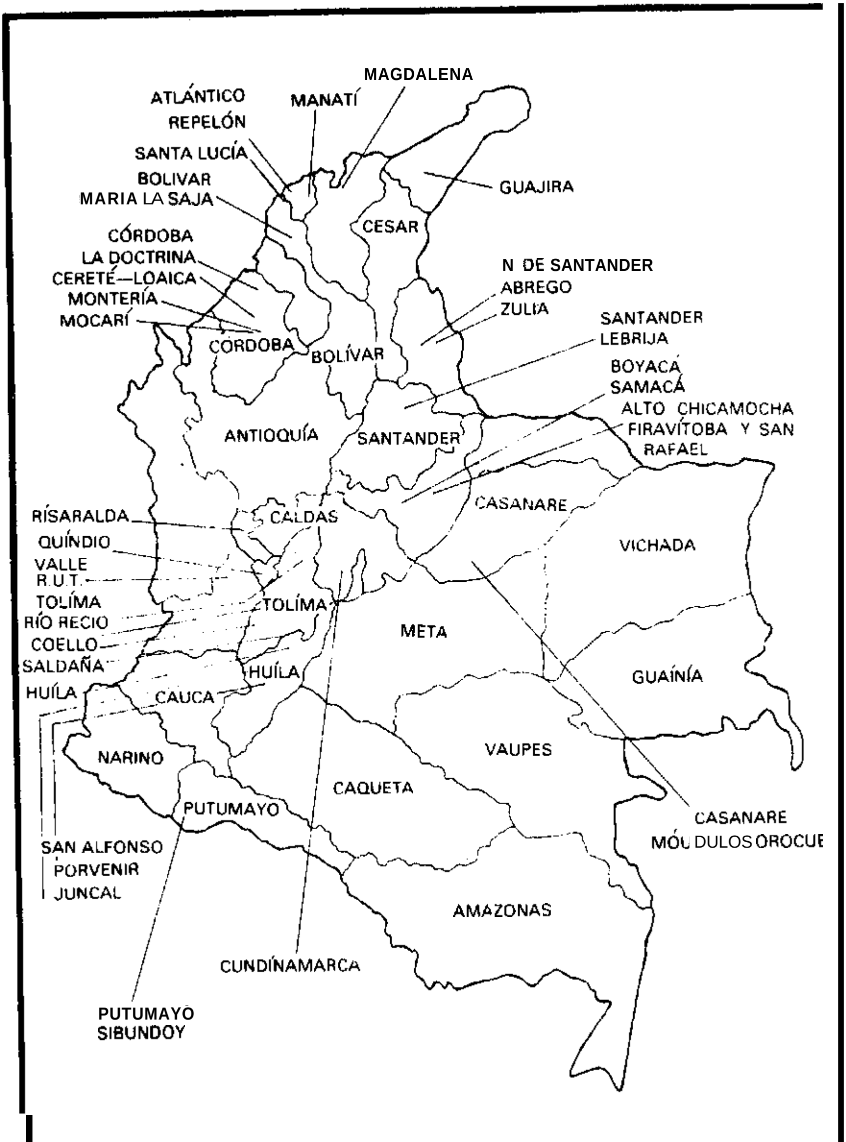
Large-scale land development began in the late 19th century with the construction of the irrigation system in the banana-growing zone on the Atlantic coast by the United Fruit Company. Fifty years later, Electraguas, a government organization no longer extant, completed development of the systems in the upper Chicamocha, Firavitoba, and Samacá valleys (department of Boyacá) in central Colombia. Subsequently, the newly appointed Ministry of Economic Affairs undertook the development of the La Ramada system in the plains of Bogotá.

The 1940s marked the start of a period of intense development of irrigation in Colombia. A diversion barrage, commissioned by the Ministry of Economic Affairs enabled the development of the Río Recio system (department of Tolima). The irrigation systems of the Coello and Saldaña rivers (department of Tolima) were established with support from the agricultural credit bank, Caja de Crédito Agrario. In 1960, the autonomous regional corporation, Corporación Autónoma del Valle del Cauca, initiated the development of the Roldanillo-La Unión-Toro system in the department of Valle del Cauca.

The agrarian reform institute, Instituto Colombiano de la Reforma Agraria (INCORA), was founded in 1961. It undertook the largest integration operation of irrigated lands with the establishment of 15 irrigation systems: Manatí, Repelón, and Santa Lucía (department of Atlántico); María La Baja (Bolivar); Montería-Mocarí, Cereté-Lorica, and La Doctrina (Córdoba); San Rafael (Boyacá); Abrego and Zulia (Norte de Santander); Lebrija (Santander); San Alfonso, El Porvenir, and El Juncal (Huila); and Sibundoy (Putumayo).

In the 1970s, the government commissioned an evaluation of the current status of irrigation systems. It reckoned that rehabilitation of the deteriorating systems would entail large investments and that such an evaluation should be carried out before undertaking new projects. The rehabilitation operation began in 1982.6 years after HIMAT was given the responsibility for administration and establishment of land development operations.

Figure 2. Location of irrigation in Colombia.



Rehabilitation, Completion, and Expansion of Irrigation System

In 1979-1980, the FAO-World Bank Cooperative Program collaborated with the Colombian government in the identification and proposal of an investment project. Its objective was to rehabilitate existing irrigation and drainage structures and establish supplementary infrastructure. The operation would be carried out in 15 of the 23 irrigation systems administered by HIMAT, that were. only partially developed. The proposal was adopted as a land development strategy in the 1979-1982 national development plan.

The project consisted of two phases:

* Phase I (BIRF 1996-CO loan). Priority was given to the rehabilitation of *existing structures and replacement* of *electromechanical* equipment. Phase I covered eight systems (86 000 ha) and was expected to benefit 13 000 families. The duration of this phase which was started in 1982 is 8 years. The total investment amounted to US$50 million. Additional tasks included preliminary studies for Phase II, and extension and technical support services.

* Phase II (BIRF 2667-CO loan). This phase began in 1987. The objectives were rehabilitation, expansion, and completion of the infrastructure in the remaining seven systems (of the 15 selected for the project). Phase II covers 150 000 ha and is expected to benefit 59 000 families; its duration is 6 years. Estimated investment amounts to US$174 million. of which US$114 million are provided as loans. To date. US$20 million have been spent on irrigation and drainage infrastructure, erosion control, small hydraulic structures, machinery and equipment. maintenance, and consulting and training services.

On completion of the two phases, an additional 136 000 ha will be sufficiently developed to produce two crops annually. Annual production is expected to increase by approximately 830 000 tons (t). The main commodities are sorghum, soybean, oil palm. sesame. cotton. banana, rice, beef, and shrimp.

Contribution of Irrigation System to National Production

In 1988, the total area devoted to agricultural production was 20 million ha. Distribution according to sector is: livestock production, 79 percent; food crops for processing, 10 percent; food crops for direct consumption, 8 percent; non-food crops, 3 percent.

In the systems administered by HIMAT (directly or through water-users associations), 347 000 ha (1.7 percent of national cropped area) were cultivated in 1988. District production was 1.18 million t, representing 5.5 percent of national production.

The share of the HIMAT systems in national production of food crops for direct consumption was 3.2 percent, which corresponds to 1.6 percent of total national production.

The systems account for 4.4 percent of national area and 8.2 percent of national production of *food* crops for processing.

Grazing lands in the systems make up 0.9 percent of national area and 5.5 percent of national production for the sector.

Construction of Large-scale Irrigation Projects

HIMAT is striving to procure the funds required for constructing large-scale irrigation projects that have been approved as economically and socially feasible. The objective is to guarantee food supply up to the year 2000, decrease dependence on imported raw material, sustain the GDP growth rate, and generate new employment opportunities.

Twelve urgent projects will be proposed to the World Bank *for financing*. The projects will cover a total area of 181 300 ha and benefit a population of 114 000 people. The estimated cost of development is US$2 500/ha; half of this would be financed through foreign loans and the rest from the national budget.

TRADITIONAL SECTOR SMALL-SCALE IRRIGATION

In contrast to the modem sector, the traditional sector is characterized by a lack of capital; low level of technology; difficulty in the transport, storage, and marketing of produce; and complete dependence on rainfall. Production is limited to basic subsistence crops, with an occasional surplus for local or regional markets.

The small-scale irrigation program was established by the government to address these problems. It concerns the majority of Colombia's smallholders. The government hopes that the efforts will have a multiplying effect and improve the welfare of the farmers.

The program aims at a more intensive and rational use of soil and water resources in systems on slopes and those fed from lakes. It has the following objectives:

* To settle farmers in rural areas.

* To guarantee water supply (for agricultural and domestic use) to the largest possible number of people in these areas, in order to improve living conditions.

* To counter dry spells in summer which have an adverse effect on agricultural production, and to intensify land use..

* To stagger planting dates in order to vary cropping schedules.

The small-scale irrigation projects use permanent water sources. Reservoirs are created by building low dams where topographic and hydrological conditions are suitable.

The program will mainly benefit regions with small holdings. Each project will cover a maximum area of 300 ha to facilitate the organization of the community for efficient administration and production.

Twenty percent of the total infrastructure cost and the total cost of farm-level irrigation structures will be borne by the water users.

Program Execution

The small-scale. irrigation program, which was completed in June 1989, undertook 236 projects covering an area of 18 800 ha and benefited 6 600 families. Investments in the projects to date amount to approximately US$8.5 million.

At present, an additional 138 projects are under way. They cover 10 500 ha and benefit 5 900 families; the approximate investment amount is US$9.5 million.

Construction of Small-scale Irrigation Systems

During the next 6 years, HIMAT plans to invest US$80 million in small-scale irrigation, with funding from the World Bank (Phase III) and US$40 million from other sources. Phase III will cover 90 000 ha and benefit 55 000 families.

FUNDING POLICY FOR IRRIGATION SYSTEMS

Operation Costs

Administration, operation, and maintenance of the systems are primarily financed from the national budget because irrigation service charges have remained at a low level. A policy of self-supporting services would eliminate government subsidies, and thus release funds for additional investments to rationalize water use.

In keeping with this policy. water charges are being gradually increased starting from January 1990. Twelve of the 23 systems will become self-supporting by 1993, and the rest, by 1995.

The policy is also applied to large-scale systems. Administration of two large-scale irrigation systems (Coello and Saldaña) was handed over to water-users associations and the districts are now self-supporting. Two more systems will assume responsibility for administration by late 1990.

Investment Recovery

Recovery on investments made for irrigation projects is still very limited. Regulations are being drafted to define procedures for paying off and recovering the original investment.

Recovery for Phase I of the rehabilitation program, which was completed in 1989, is expected to start in the second half of 1990. Rehabilitation of the systems in Phase II will be completed in 1993.

The funds generated by water users' contributions to HIMAT for realizing the full economic potential of the projects, will be held in a national fund for land development and irrigation systems, Fondo National de Adecuación de Tierras y Distritos de Riego. It will be administered by HIMAT, and will enable the Institute to expand its activities.

The two policies, gradual increase of water charges and users' contributions, will significantly reduce dependence on the national budget.

HIMAT should thus be able to provide part of the funds to supplement external loans by 1993, and the entire national contribution by 1998.

Chapter 7

IRRIGATION SYSTEMS IN MEXICO

Enrique Palacios Velez

INTRODUCTION

IN THE REPUBLIC of Mexico. approximately 20 million hectares (ha) of land are cropped each year. This figure can, however, vary significantly; it can reach 21 million ha with adequate rainfall, and decrease to only 18 million ha in a dry year. But on the 5.5 million ha of irrigated land. crops can be grown irrespective of agroclimatic conditions. Of this irrigated area, 3 3 million ha are located in irrigation systems (distritos de riego) and 2.3 million ha in about 27 000 small irrigation units.

Cropped area in the irrigation systems represents only one-sixth of the total arable area, but the production is approximately 30 percent of national production; it is 50 percent of the total value if the output of the small irrigation units is also considered. These systems produce slightly more than 70 percent of Mexico's wheat and rice, 75 percent of oilseeds, 82 percent of cotton, 30 percent of sugarcane and sorghum, and a high percentage of the market and fruit cmps. Figures 1 and 2 depict the percentage distribution of these crops by

Figure 1. Distribution of irrigated crops by area.

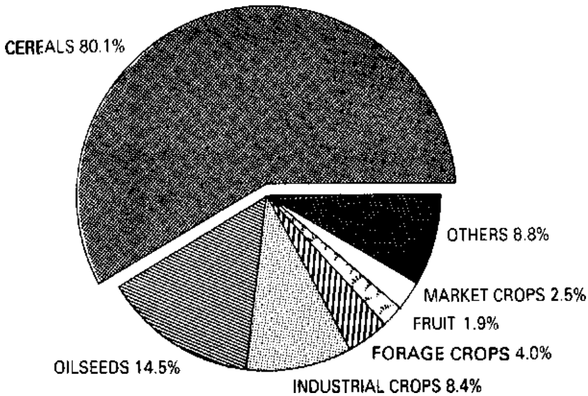
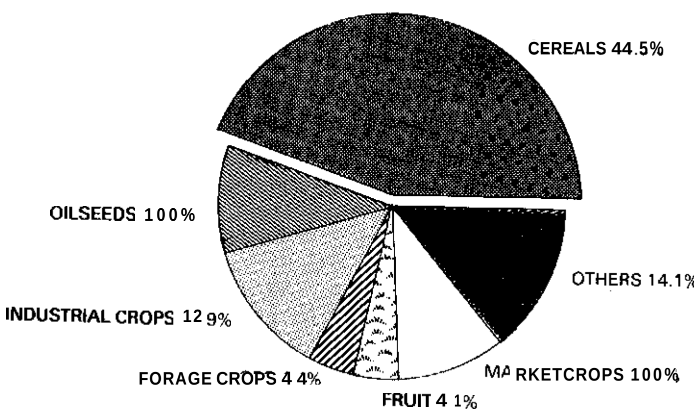


Figure 2. Distribution of irrigated crops by production.



cropped area and production. It is generally estimated that irrigated areas are 2.5 times more productive than rainfed areas.

The irrigation infrastructure in the systems covers about 3 million ha, approximately 10-15 percent of which produces two crops annually. About0.5 million water users are. established in the system and the average size of the holdings is about 6 ha. It is estimated that these lands directly generate about 100 million person days (8-hour) of work and probably three times as much indirectly. Of the water users benefitting from the program, about 73 percent are ejidatarios[1] occupying about 56 percent of the area, and 27 percent are smallholders who farm the remaining 44 percent of the land. Table 1 summarizes the characteristics of the 77 administrative units of the systems.

Table 1. List of irrigation systems in Mexico.

No.	NUMBER	NAME OF SYSTEM	STATE	COMMAND AREA(ha)	IRRIGATED AREA (ha)	WATER USERS (NUMBER)	AVERAGE AREA/USER (ha)
1	41	RIO YAQUI	SON	225009	294594	34190	6.58
2	10	CULIACAN-HUMAYA	SIN	224718	276661	18934	11.87
3	14	RIO COLORADO	BCN	207121	208255	14395	14.39
4	75	RIO FUERTE	SIN	259474	192588	18067	14.36
5	25	BAJO RIO BRAVO	TAM	232688	170840	10861	21.42
6	17	REGION LAGUNERA	D-C	126580	121804	51557	2.46
7	51	COSTA HERMOSILLO	SON	144915	121109	2501	57.94
8	11	ALTO RIO LERMA	GTO	102089	97745	20826	4.90
9	38	RIO MAYO	SON	91000	90251	11062	1.23
10	26	BAJO RIO SN JUAN	TAM	78086	78995	3082	25.34
11	97	LAZARO CARDENAS	MCH	68916	75158	12968	5.31
12	63	GUASAVE	SIN	78030	73537	6065	12.87
13	5	DELICIAS	CHI	59557	72810	10970	5.43
14	37	ALTAR-PITIQUITO	SON	57577	59685	3872	14.87
15	66	STO DOMINGO	BCS	54600	54570	709	77.01

[1] Landholdings created as a result of a major land reform conducted in Mexico

No.	NUM BER	NAME OF SYSTEM	STATE	COMMAND AREA(ha)	IRRIGATED AREA (ha)	WATER USERS (NUMBER)	AVERAGE AREA/USER (ha)
16	13	EDO. JALISCO	JAL	69523	52418	42138	1.65
17	3	TULA	HGO	42843	5 m 9	25129	1.67
18	19	TEHUANTEPEC	OAX	50807	40771	8494	5.98
19	20	MORELIA-QRENDARO	MCH	46296	39868	8929	5.18
20	76	VALLE DEL CARRIZO	SIN	41587	39612	4087	10.18
21	92	RIO PANUCO	TAM	138821	36734	2874	48.30
22	16	EDO. DE MORELOS	MOR	33694	36412	15438	218
23	43	EDO. NAYARIT	NAY	42373	34586	7284	5.82
24	87	ROSARIO-MEZQUITE	MCH	33476	27307	7405	4.52
25	86	SOTO LA MARINA	TAM	29824	27260	2092	14.26
26	4	DON MARTIN	N L	23829	26064	2316	10.29
27	30	VALSEQUILLO	PUE	34735	25364	12385	2.80
28	84	GUAYMAS	SON	23938	22090	2207	10.85
29	29	MOCORITO	SIN	26585	21993	1995	13.33
30	24	CIENEGA-CHAPALA	MCH	22341	21771	7056	3.17
31	53	EDO. DE COLIMA	W L	24435	20492	1733	14.10
32	9	CD. JUAREZ	CHI	18940	19923	11445	1.65
33	33	EDO DE MEXICO	MEX	17423	19253	22406	0.78
34	52	EDO DE DURANGO	DGO	15443	18128	4226	3.65
35	100	ALFAYUCAN	HGO	22995	17780	15675	1.47
36	18	COLONIAS YAQUIS	SON	25000	17340	2312	10.81
37	61	ZAMORA	MCH	16309	16271	3610	4.52
38	89	EL CARMEN	CHI	15922	14188	nD	20.68
39	57	AMUCO-CUTZAMALA	GRO	13500	14083	3978	3.39
40	82	RIO BLANCO	VER	13140	13487	1309	10.01
41	35	LA ANTIGUA	VER	23997	12224	2271	10.57
42	6	PALESTINA	COA	11600	12140	1392	8.33
43	23	SN JUAN DEL RIO	QRO	10566	11114	34%	3.06
44	93	TOMATLAN	JAL	8999	10719	1548	5.81
45	34	EDO DE ZACATECAS	ZAC	16786	9332	4553	3.69
46	85	LA BEGOÑA	GTO	11483	9085	2336	4.92
41	45	TUXPAN	MCH	8472	8820	3602	2.35

No.	NUMBER	NAME OF SYSTEM	STATE	COMMAND AREA(ha)	IRRIGATED AREA (ha)	WATER USERS (NUMBER)	AVERAGE AREA/USER (ha)
48	98	JOSE MA MORELOS	MCH	8453	7994	494	17.11
49	1	PABELLON	AGS	11879	7660	924	12.86
50	48	EDO DE YUCATAN	YUC	8732	7583	49M	1.78
51	50	ACUÑA-FALCON	TAM	6413	7195	303	21.17
52	42	BUENAVENTURA	CHI	7718	6916	1296	5.96
53	59	RIO BLANCO	CHIS	6500	6210	1410	4.61
54	49	RIO VERDE	SLP	5850	5978	2645	221
55	103	RIO FLORIDO	CHI	8634	5963	734	11.76
56	29	XICOTENCATL	TAM	14551	5760	538	27.05
57	88	CHICONAUTLA	MEX	4401	5218	1959	2.25
58	107	SAN GREGORIO	WS	11400	5050	N h	N h
59	8	MEZTITLAN	HGO	5454	4651	3335	1.64
60	90	BAJO RIO CONCHOS		10456	4411	968	10.80
61	96	ARROYOZARCO	MEX	19049	4258	6458	2%
62	46	CACAHOATAN-SUCHI.	CHIS	8443	4168	332	25.43
63	83	PAPIGOCHIC	W	4799	3783	413	11.62
64	56	ATOYAC-ZAHUAPAN	TLX	4067	3659	5208	am
65	104	COAJINICUILAPA	GRO	2810	3580	132	21.29
66	95	ATOYAC,105:NEXPA	GRO	1693	2505	593	2.85
67	99	QUITUPAN-MAGDALENA	MCH	5120	2470	497	10.30
68	31	LAS LAJAS-A.SJUAN	N L	4408	2380	136	3241
69	44	JILOTEPEC	MEX	5968	2109	907	6.58
70	60	EL HIGO	VER	2144	1922	258	8.31
71	68	TELECOACUILCO	GRO	3468	1841	746	4.65
72	28	TULANCINGO	HGO	1178	1401	399	a95
73	81	EDO DE CAMPECHE	CAM	2518	1323	537	4.69
74	73	LA CONCEPCION	MEX	903	830	495	1.82
75	94	SUR JALISCO	JAL	11312	588	291	38.87
76	102	RIO HONDO	Q R	6336	544	201	31.32
77	101	CUXTEPEQUES	CHIS	9950	500	N.A	N.A.
TOTAL				3150650	2854981	494195	6.40
AVERAGE				40918	38178	6335.8	6.40

NOTE: *Area in ha and volume in* hm^3.

BACKGROUND

The climatic conditions make it necessary to irrigate crops to satisfy the growing demand for food. The national irrigation commission, Comisión Nacional de Irrigación (CNI), was established by the Decree of 9 January 1926. CNI initiated the construction and organization of the national irrigation systems (sistemas nacionales de riego), which were called distritos de riego after 1935. A resolution passed on 20 December 1935 brought the systems under the control of the national agricultural credit bank, Banco Nacional de Crédito Agrícola. But after 10 years, due to operating difficulties, they were ceded back to CNI by the Decree of 30 November 1944. The Ministry of Water Resources was created in 1947, but the irrigation systems remained attached to the Ministry of Agriculture and Livestock production. In February 1951. however, because of operating difficulties, the systems were integrated with the Ministry of Water Resources. The Decree of 2 January 1953 led to the formation of governing committees to rationalize the management and development of the irrigation systems.

By 1960, many of the irrigation systems were visibly deteriorating due to the lack of an adequate drainage system which led to increased land salinization. For this reason, a rehabilitation program was launched the following year, with funding from the World Bank and financial commitment of the water users. It was started in four systems in the northeast and subsequently extended to others. In the mid-1960s, the national plan for field improvement. Plan Nacional de Mejoramiento Parcelario (PLAMEPA), was implemented, also with external support. Its objectives were to improve system management in order to reduce water conveyance losses and to provide technical assistance to fanners for better yields and application efficiency. By the end of this plan in the mid-1970s. irrigation efficiency and cropped area increased significantly. Annual rates of production increase in the systems were observed to be greater than 5 percent during this period. By 1975, total cropped area was 1.3 times the physical area of the systems.

In December 1976, the Ministry of Water Resources and the Ministry of Agriculture and Livestock production were merged. Thereafter, the Directorate General of Irrigation Units for Rural Development was united with the Directorate General of Irrigation Systems; in addition, a Directorate General of Rainfed Areas was created. Technical assistance to the irrigation systems was reduced to cover all aspects of production, including rainfed crops.

In 1985 it was decided to merge the 77 irrigation systems and the 150 rainfed areas (disuitos de temporal) to form 192 integrated rural development areas (distritos de desarrollo rural). This arrangement was finally legalized by the Law of 28 January 1988 on Rural Development Areas by which measure the technical assistance was further reduced.

The directors of those rural development areas where irrigation systems were located had the added responsibility of lands not requiring the same type of water management. The increased burden combined with reduced financial resources affected the maintenance of the irrigation and drainage infrastructure and crop yields declined. To overcome the problem, the new government elected in December 1988 created a national water commission, Comisión Nacional del Agua (CNA). Irrigation operations and maintenance were separated for the irrigation systems and rural development areas and transferred to the new Commission.

WATER AND IRRIGATION INFRASTRUCTURE USE

The volume of water used for irrigation in the systems depends on supply from barrages and other supply sources, but annual average consumption exceeds 30 billion cubic meters (m^3). Of the total water supply, 53 percent is derived from storage reservoirs, 33 percent from surface flows, and 14 percent from deep wells.

Average conveyance losses due to infiltration and surface runoff are estimated at 40 percent. Part of the water can be reused, however, because. it returns either to surface flows or to aquifers from where it can be pumped. but a substantial portion evaporates or reaches the sea without being used. Water is also lost during application in the fields. CNA is undertaking operational measures and improving the water conveyance infrastructure to reduce these losses, Technical assistance is provided to farmers so that they can use water and land resources with greater efficiency.

The irrigation and drainage infrastructure in the systems was mainly constructed by the federal government following the creation of CNI in 1926. The work was continued by the Secretaria de Recursos Hidraulicos and the Secretaria de Agricultura y Recursos Hidraulicos. It is now undertaken by CNAA.

Table 2. The irrigation and drainage infrastructure m Mexico.

Sources of water supply		
Storage reservoirs	134	
Diversion barrages	399	
Deep wells	3 141	
Water conveyance		
Main channels (total):	11464	km
Lined with concrete	4022	km
Lined with masonry	910	km
Unlined	6532	km
Secondary channels (total)	28350	km
Lined with concrete	8723	km
Lined with masonry	873	km
Unlined	18754	km
Control structures *(total)*	175 194	km
concrete	146412	km
Masonry	28782	km
Drainage network		
Length of drains (total)	25297	km
Main drains	8 008	km
Secondary drains	17289	km
Service roads		
Total length	47102	km
Graveled	17282	km
Dirt	26 046	km
Paved	3 228	km
Buildings	1416	

In recent years, funds for operation and maintenance of irrigation systems have decreased due to reduced cost-sharing by water users and lower government subsidies as a consequence of the economic crisis in the country. The deteriorating physical infrastructure has led to increased conveyance losses and reduced productivity of water and soil resources.

Considering the production deficits for food and raw materials and the budgetary restrictions imposed by the federal government, the most economical way to augment agricultural productivity is to rehabilitate the existing irrigation systems.

CNA's main objective is to raise the productivity of the existing irrigation and drainage infrastructure and that of water and soil resources. This program, which aims to contribute to food self-sufficiency, depends upon the concerted efforts of water users and state governments.

The second objective is make irrigation systems self-supporting through increased user participation in operations, maintenance, and administration. According to the guidelines of the national development plan, the responsibility of administering those systems that have reached an adequate socioeconomic level will also be turned over to the fanners. The following interventions have been planned to attain the objectives:

* Modernization of 20 irrigation systems, located mainly in the north and covering a total of 1.9 million ha. Operation, maintenance, and administration of these systems will be transferred to the water users.

* Rehabilitation of 40 other systems which total 850 000 ha. Production is expected to increase substantially. Greater user participation in operating costs and administrative activities should lead to financial self-sufficiency.

* Rehabilitation and other measures in the 17 remaining systems, which cover 410 000 ha. These measures which aim to optimize the infrastructure and thus improve productivity will be carried out in collaboration with those involved in the sector, including the state governments and waters users.

These interventions should increase cropped ares in the irrigated systems by 500 000 ha (370 000 ha in the 20 systems undergoing modernization and 130 000 ha in the other 57 irrigation systems) by the end of the current 6-year presidential term. Productivity of soil and water resources is expected lo improve by about 5 percent compared with the current level. Operating subsidies granted to most systems will be reduced, except in the least developed systems.