ILRI SYMPOSIUM "TOWARDS INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT"
PREFACE

The Earth Summit held in Rio de Janeiro in 1992 emphasized the need for integrated irrigation development and management (United Nations Conference on Environment and Development/UNCED). The Jubilee Symposium at the occasion of the fortieth anniversary of ILRI and the thirty-fifth anniversary of our International Course on Land Drainage (ICLD) looked at the possibilities and potential benefits of better integration of irrigation and drainage management. ILRI selected this theme because of its belief that the integration of irrigation and drainage management represents an opportunity to alleviate many of the problem issues in irrigated agriculture. As irrigated agriculture is by far the largest consumer of freshwater, these issues are highly relevant for the water sector as a whole and for rural communities, particularly in developing countries of the arid and semi-arid regions where environment, employment and food security depend on irrigated agriculture.

For these reasons, the highlights and conclusions of the Jubilee Symposium were presented to an international audience of policy and decisionmakers in the water sector, on 28 November, 1996.

The proceedings before you provide a complete account of what was presented and discussed at the Jubilee Symposium.

I wish to thank all those who were active in planning, organizing and participating in the Jubilee Symposium and also those who assisted in preparing the proceedings.

Wageningen, April 1997

M.J.H.P. Pinkers
Director ILRI
ACKNOWLEDGEMENTS

The first meaning of symposium according to The Concise Oxford Dictionary, is "1. Ancient-Greek after-dinner drinking party with music, dancers, or conversation." While our symposium involved a certain amount of 'wining and dining', this was not a primary objective. A more suitable description is given in The Longman Dictionary of Contemporary English: "sym-po-si-um / a meeting between scientists or other people experienced in a particular subject, in order to talk about a certain area of interest." The names of the scientists and other interested people who took part in our symposium are listed in these proceedings, as a speaker, author, session chairman, rapporteur or participant. Their contribution is greatly appreciated. There are other persons who are not mentioned elsewhere in these proceedings, and without whom there would have been neither symposium nor proceedings. These are the ILRI support staff, whose contribution is hereby acknowledged. In particular, we wish to thank Mrs. Elizabeth Rijksen for handling most of the logistics, Mr. Joop van Dijk for doing all the artwork, and Mrs. Dorethé Kulijpers for processing and finalizing the text and lay-out of the proceedings.

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PROCEEDINGS OF ILRI SYMPOSIUM: TOWARDS INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT

Introduction by the editor

ILRI organized a symposium, entitled TOWARDS INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT, on 25 and 26 November 1996 on the occasion of its 40th anniversary and the 35th International Course on Land Drainage (ICLD).

The main objective of the symposium was to identify research needs that promote integration of irrigation and drainage management and contribute to a sustainable water, salt, and financial balance.

To achieve this objective, first a background paper was prepared which 1. Explains why this theme was selected, 2. Describes the organization of the symposium, and 3. Provides guidelines for presentations. The background paper is included in these proceedings as Annex A. It was sent to potential guest speakers, who were asked to prepare a presentation if they were interested in the topic. Fortunately, the response was adequate to prepare a programme with 15 speakers. Subsequently, this programme was considered interesting enough for some 100 participants who not only gave two days of their valuable time, but who also contributed examples from their own experience.

The symposium consisted of four sessions:
1. Examples of situations that call for integration of irrigation and drainage management;
2. Technical innovations towards integration of irrigation and drainage management;
3. Institutional innovations towards integration of irrigation and drainage management;
4. Identification of research needs.

In the first three sessions, 15 presentations were given by speakers representing FAO, IIMI, IPTRID, IWASRI (Pakistan), DRI (Egypt), Euroconsult, The Waterboard of Schieland (Netherlands) and ILRI. The contents of their presentations and a summary of the discussions are given in these proceedings.

In addition, 89 participants from 16 countries contributed examples from their own experience on standard forms. On the basis of these forms, participants were divided into 6 sub-groups, who in the fourth session discussed research needs in their specialized fields. The results of these discussions are also presented in these proceedings.

Wageningen, April 1997

W.B. Snellen
Session 1 Practical examples that call for integration of irrigation and drainage management

Dr. Ir. W. Wolters (ILRI) and Dr. M.N. Bhutta (IWASRI). Need for integrated irrigation and drainage management, example of Pakistan

Dr. J.M. Beltran (FAO). The need for integration of irrigation and drainage management; some examples and proposals

Dr. N.K. Tyagi (CSSRI). Salinity management: the CSSRI experience and future research agenda

Dr. Ir. L.K. Smedema (IPTRID) and W.J. Ochs (World Bank). Integrated water management for the humid tropics

Ir. H.W. Denecke (ILRI). Towards integration of irrigation and drainage management in the Aral Sea basin

Chairman: Prof. Dr. Ir. R.A. Feddes (Wageningen Agricultural University)
ILRI rapporteur: Ir. K.J. Lenselink
NEED FOR INTEGRATED IRRIGATION AND DRAINAGE MANAGEMENT, EXAMPLE OF PAKISTAN

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Abstract

Pakistan has the largest contiguous irrigation system in the world, 16 Million ha. Lack of well-defined natural drainage in the Indus Basin has caused a surface drainage problem that has been further aggravated by construction of roads, railways, flood embankments and the irrigation system, while the existing surface drainage system is inadequate. The agricultural sector of Pakistan suffers dearly from this drainage problem, which is among the causes leading to waterlogging and salinity. About 75% of the population is dependent on agriculture, and about half of the Gross National Product is related to the agricultural sector.

The irrigation system is simple in set-up, with continuous flow all the way down to the Mogha (tertiary unit offtake), from where the farmers take over management of the water. Formally, operation and maintenance of drainage systems is to be taken care of by the Provincial Irrigation Departments, a few years after completion of the systems. However, these Departments do not receive additional funds when they are presented with the additional charge of O&M of the drainage systems, and therefore, the systems could not be operated and maintained as necessary. The administrative structure of the Provincial Irrigation Departments was established around the extensive canal irrigation system. With the installation of the drainage systems, separate sections were simply added to the administrative structure, but not integrated in the existing set-up. This resulted in diffused responsibilities for the operation and maintenance of the entire system. Integration of irrigation and drainage management is very necessary because the irrigation management and drainage problems are strongly inter-linked through: (i) irrigation as a cause of waterlogging; (ii) relationship between irrigation management and drainage effluent. Since irrigation and drainage are closely interrelated, research on these aspects should also be interrelated.

Introduction

Irrigation, waterlogging & salinity, and socio-economy

Pakistan has the largest contiguous irrigation system in the world: 16 Million ha. Irrigation in Pakistan is very old; the Indus Basin has witnessed one of the early 'hydraulic civilizations' about 5,000 years ago. Construction of the contemporary system started about a century ago, and the design of the system was based on the principle of thin spreading of available
Figure 1. Pakistan and some features of its irrigation system
water over a large area. The main purpose of the system was to prevent crop failure in dry years, as there is not enough water to supply the full crop irrigation water requirements. Figure 1 shows Pakistan and some features of its irrigation system.

The introduction of irrigation has resulted in an impressive production capacity. Although the average yields are low in terms of production per area, they are among the highest yields per unit of water in the world (Bhatti et al., 1991). However, the introduction of irrigation has also resulted in widespread waterlogging and salinity. Figure 2 shows the rise of the watertable after introduction of irrigation in the Punjab. For Pakistan, the area of lands (Tarar, 1996) with a water table depth in April-June (pre-monsoon) within 5 ft (1.5 m) of the soil surface varies between 1.5 and 3 million ha, whereas Pakistan has almost 6 million ha salt affected lands, of which about half is found in the canal irrigated area. An estimated 2 million ha is abandoned due to severe salinity.

Figure 2. Rise of the water table after the introduction of irrigation

Editors note: This figure is based on Fig.14.4 in ILRI Publication 16 (Ritzema, H.P. 1994. Drainage Principles and Applications). By request of the author, the groundwater profiles for the year 1920 and the pre-irrigation period have been modified. In the earlier figure, these profiles connected with each of the riverbeds, which in the author’s present view is not correct.

The salt balance of the Indus Basin is known in rough figures only, but an estimate can nevertheless be made. The salts are brought in by the rivers and their tributaries. The total salt load entering Punjab is about 15.8 Mton of which 2.2 Mton can be disposed of into evaporation ponds. Of the remaining 13.6 Mton, about 2.5 Mton goes below Panjnad mostly during high flow and the remaining 11.1 Mton is stored within the Punjab (NESPAK/MMI, 1993). This implies that, annually, an average of one ton of salt is added to each hectare of irrigated land.
The agricultural sector suffers dearly from the waterlogging and salinity. About 75% of the population is directly or indirectly dependent on agriculture, and about half of the Gross National Product is directly or indirectly related to the agricultural sector. These facts illustrate that problems of waterlogging and salinity are not just agricultural problems, but that they do affect the country as a whole and ultimately the social fabric of Pakistani society.

Waterlogging and salinity remain a hazard for the Indus Basin and threaten the livelihood of farmers, especially the smaller ones. Drainage rather than additional water continues to be priority number one for the sustainability of the system. While this may be understood by planners and researchers, the farmers individually and collectively often appear pre-occupied primarily in securing additional irrigation water.

**Drainage in Pakistan**

**SCARP Tubewells**

In the 1950s detailed surveys were made of groundwater tables and salinity in the Punjab with collaboration of the US Geological Survey. These surveys formed the basis for the SCARP (Salinity Control And Reclamation Project) program and for the decision to go ahead with the public tubewell program. About 14,000 such wells, producing approximately 80 l/s (3 cfs) average were constructed in the 1960s and 1970s. The main purpose of the public tubewells was to combat waterlogging and salinity, but where the water was not too saline, it was used for irrigation. This demonstration led to a proliferation of private tubewells of about 28 l/s (1 cfs) and less by the farmers in the 1970s and 1980s, and resulted in a reduction in plans for public tubewell installation particularly in fresh ground water (FGW) zones, where a SCARP transition program is attempting to hand over the pumping of ground water to the farmers. However, in saline ground water (SGW) areas, where tubewell effluent cannot be used for irrigation, the tubewells remain in the public sector but these are plagued with technical and institutional problems effecting O&M. Excessive private tubewell pumping, while increasing the cropping intensity in an environment of scarce canal water and lowering the water table, will deplete the FGW and result in encroachment of poor quality ground water.

**Surface drainage**

Lack of well-defined natural drainage in the Indus Basin has caused a surface drainage problem that has been further aggravated by construction of roads, railways, flood embankments and the irrigation system. The existing surface drainage system is inadequate, although over the years more than 9,000 miles have been constructed, but not well maintained.

**Sub-surface drainage**

The technical performance of operated sub-surface drainage systems is good, although the costs may be too high:
**IWASRI** has reviewed the performance of drainage systems in Pakistan for a number of years now, and there is ample evidence that the variety of systems (tubewell drainage, pumped and gravity pipe drainage) is capable of controlling the water table at lower levels. Moreover, the soil salinity status, area cultivated, and cropping intensity has improved in many systems also (Bhutta et al., 1995, 1996a, 1996b);

**Costs of drainage.** The Government of Pakistan (GoP) cannot continue to fund the operation and maintenance of the entire irrigation and drainage system, in conditions where, for instance, in the fiscal year 1992, the operation of tubewells in the Punjab absorbed more than 50% of the available O&M funding, even though the wells were operated on a very limited basis (SAR, 1992). Also in Sindh, cost of operation of the LBOD drainage system is more than the Government can budget: the annual cost for O&M Rs 600 million (1993 prices, equivalent to about US$ 20 M), with a construction cost of Rs 24,000 million (US$ 800 M).

**Present irrigation and drainage management**

**Irrigation Management**

The size of the Pakistan irrigation system becomes clear when realizing that water released from one of the main reservoirs Mangla or Tarbela in the North travels about 20 days to reach fields in the south of Punjab, and more than 20 days for Sindh. Fortunately, the system is simple in set-up, with continuous flow all the way down to the **mogha** (tertiary unit offtake), from where the farmers take over management of the water. In times of water shortage, the water has to be rotated between secondary canals: the minors and distributaries. Theoretically, there is a system of requesting for water also. A main or branch canal is called a Division, split up into Sub-divisions. The 'lowest' Sub-division submits its indent to its upstream Sub-division, and so-on. The accumulated indents will reach the Executive Engineer at the Head-works, and water will be supplied accordingly. Extra water allowance can even be requested for reclamation purposes.

However, actual practice differs considerably. Water, once released from the reservoirs, will flow and will continue to flow. Canals will usually not be allocated more than their design capacity, of which a typical value is equivalent to about 2 mm/d, in a climate with an ET in May-June of about 15 mm/d. Moreover, many canals can even no longer convey their official design capacity, due to siltation and erosion of banks.

**Drainage Management**

Formally, operation and maintenance of drainage systems is to be taken care of by the Provincial Irrigation Departments, a few years after completion of the systems. However, these Departments do not receive additional funds when they are presented with the additional charge of O&M of the drainage systems, and therefore, the systems can not be operated and maintained as necessary. This is one of the main problems of drainage management in Pakistan.

The administrative structure of the Provincial Irrigation Departments was established around the extensive canal irrigation system. With the installation of deep tubewell-, surface- and sub-surface-drainage systems, separate sections were simply added to the administrative
structure and not integrated in the existing set-up. This resulted in diffused responsibilities for the operation and maintenance of the entire system (Bandaragoda and Firdousi, 1992).

**Need for integration of irrigation and drainage management**

Integration of irrigation and drainage management is very necessary because the irrigation management and drainage problems are strongly inter-linked through: (i) irrigation as a cause of waterlogging, and (ii) relationship between irrigation management and drainage effluent.

**Irrigation as a cause of waterlogging**

There are several examples of where irrigation causes waterlogging, often unnecessary as it seems:

- By law, neither the Irrigation Department nor farmers are allowed to close a tertiary canal. Once farmers do not need water, it is diverted away from their fields, and collects in the lower areas. Field observations in the Fordwah Eastern Sadiqia system confirm that operational spills collect in depressions, in times of low water demand. The lack of a well-defined surface drainage system, furthermore impeded by infrastructure (as roads, railways, flood embankments, and the irrigation system) causes the water to stagnate, thereby making use of the lower-lying lands impossible. Prevention of spills would undoubtedly lead to less need for drainage;

- The *punchoo* (or *panchoo*) system of Sindh operates differently from the *warabandi* system. *Warabandi* means 'time-sharing'. The water is turned over from farmer to farmer. In the *punchoo* system, however, water is supplied to all farms at the same time. This results in very low application efficiency, as the aquifer is just allowed to fill up;

- By law, outlets for tertiary canals cannot be installed on a main or branch canal. In practice, however, many such off-takes exist, which gives the possibility to take any excess water, for an area for which already a share is included in the secondary canal. This excess does not help in reducing the drainage requirement.

**Relationship between irrigation management and drainage effluent**

The volume of drainage effluent can be reduced by:

- Increasing irrigation efficiency. Wolters (1992) presents a list of positive and negative effects of increased irrigation efficiencies. Among the negative effects: (i) increased soil salinity because of reduced leaching. The increase of soil salinity due to reduced leaching was studied for Pakistan by Smedema et al. (1992), who conducted rainfall/salinity simulations. The results agreed with the field experience that irrigation-induced soil salinization is not an acute hazard when the annual rainfall is more than 400-500 mm/year. Although there are claims of 'uneducated' farmers who over-irrigate, field observations also show that farmers use water sparingly. The canal supply is by far short of the crop irrigation water requirement, which forces many farmers to cultivate only a part of their lands; (ii) need for more sophisticated operation and more accurate monitoring, leading to more expensive infrastructure and management (if at all possible). The latter point is cost related, and, as the greater part of the farmers are without resources, government investment will be necessary to improve the efficiency of
irrigation. Wolters (1992) also presents conditions that favour the efficient use of irrigation water, including: medium or heavier textured soils; control over water flow to the system and within it; sophisticated field application methods; and data availability. These conditions are not always encountered in the Indus basin irrigation system;

- Re-use of drainage water. The volume of drainage water available for potential reuse in Pakistan varies considerably in both space and time, and in addition to salts and trace elements leached from the soil, drainage may contain domestic sewage, industrial effluent and chemicals, such as fertilizers and pesticides. Data on trends and patterns in drainage quantity and quality is a prerequisite for any proposed re-use scheme. Although some limited spot sampling has been undertaken in this regard, no long-term, comprehensive data exist. Available data is scattered having been collected at different times by different organizations using a variety of methods at sometimes ill-defined locations. The direct use of untreated effluent for irrigation, which is being practiced by some farmers in Pakistan, frequently leads to damage to crops and could be a danger to public health.

Related to the desired reduction of drainage effluent are salt disposal problems. Evaporation ponds are a means of disposing of saline drainage water for a number of command areas in the middle reach of the Indus plain, Punjab. Evaporation ponds are already in operation in two commands (Pat Feeder on the Indus right bank and SCARP VI on the Indus left bank). Other ponds are in an advanced stage of planning for another command (Fordwah Eastern Sadiqia South). Evaporation ponds may eventually serve a total area of 1 to 2 million ha. Data on their performance and environmental impacts is scarce. Monitoring of the existing ponds has been limited. However, these ponds have created waterlogging of nearby agricultural lands through groundwater seepage.

Problems of salt disposal are experienced all over the world where there is no environmentally acceptable means of drainage waste disposal. Research is now yielding unconventional solutions to many of the traditional problems with re-use. Ochs et al. (1995) present an example of 'agro-forestry', where drainage water is re-used for increasingly salt-resistant crops and trees, with the drainage water becoming more concentrated in the process, but reduced in volume. Ultimately that water is disposed of into a solar evaporator, where the salt is converted into a crystalline form.

The future

To tackle the urgent problem of waterlogging and salinity - which is the result of a multitude of factors, including: human intervention in nature, financial neglect, mismanagement, decay of institutions, lack of planning and learning from research, exclusion of the end-users as active stake holders in the management of the system - a mid-term strategy emerges from the National Drainage Program. This strategy essentially relies on drainage, implemented along-side long-term measures, as the single most important operation to bring the Indus System back into balance that can then be maintained by the adoption and institutionalization of the measures of a long-term strategy. Environmental impact mitigation of the negative effects of drainage should form an essential part of the surface and subsurface drainage schemes, as well as of the small schemes to alleviate localized drainage and public health problems.
The Government cannot continue to inject huge amounts of money in drainage projects forever. The users will have to take their share as well. Preferably, and that seems to be a growing consensus now in Pakistan, the main systems of irrigation and of drainage should both be managed by the Government. Somewhere in between, the users of the system should become involved in the management. The GoP has plans and policies ready in this direction, outlined in the National Drainage Programme (NESPAK/MMI, 1995). In this programme, PIDA's, Provincial Irrigation and Drainage Authorities, will become autonomous bodies to manage the system. The conceptual framework of the National Drainage Programme mentions as three specific objectives to be achieved through the programme:

- Participation of farmer's organizations and private sector in construction, operation and maintenance of drainage facilities;
- Targeting government investment on areas in greatest need of drainage;
- Quicker returns by targeting drainage investments on smaller scale, quicker yielding interventions.

The NDP proposes to directly involve farmers in the planning, design, construction, operation and maintenance of on-farm drainage systems. It presents modes for setting-up and operating farmers organizations and stipulates that research should develop instruments to involve the farmers. NDP admits that there is limited experience with direct farmer participation in on-farm drainage in Pakistan and states that the technical capacity will initially be weak. During a transition stage farmers could learn, thereby assisted and guided by professionals, directly or through Non-Governmental Organizations (NGO's).

However, we should not expect too much of this 'social approach' in a short time, because:

- Farmers might be ready to pump for irrigation, but they will not pump 'continuously' for drainage;
- The resource base of the small farmers is very narrow. About 45% of the farm land in Pakistan is cultivated by small farmers, with a farm size of less than 5 acres. They have virtually no own resources. Moreover, they are even offered lower than market prices for some of their produce, or have to pay water cess when not even receiving canal water;
- Sincere involvement of farmers takes time. This is what we experience in the recent IWASRI/NRAP 'Participative Approach to Drainage' work. Several current, hurried, attempts to promote 'participative' approaches in on-farm drainage stand little chance of real success quickly. Even with a functioning main drainage system, and a favourable attitude of users and bureaucracy, it would be time-consuming;
- There still is, at decision-taking level, a serious lack of understanding of what it takes to involve farmers, especially with the objective to involve farmers in the planning, implementation and ultimately transfer for O&M of drainage systems.

Need for integration of irrigation and drainage research

Since irrigation and drainage are closely interrelated, research on these aspects should also be interrelated. For example, the recharge of the aquifer due to seepage from the (canals of the) irrigation system is considered as the main cause of drainage problems. Therefore, several recharge reducing measures are being studied. This includes: (i) improved field irrigation management; (ii) seepage interceptor drains along canals; and (iii) lining of distributaries.
SESSION 1 PRACTICAL EXAMPLES THAT CALL FOR INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT

The 'drainage' research will show the impact of installation of interceptor drains, and 'irrigation' research will show the impact of the lining work. But, these results cannot be seen on their own. Their impact has to be integrated for use in recommendations for final drainage plans for the area. For the Fordwah Eastern Sadiqia (South) area, IWASRI studies the combined impact of all proposed measures in a groundwater model.

Much data has been collected in Pakistan, by the SCARP Monitoring Organization, as well as many others. Also, a lot of research has been completed on problems of waterlogging, salinity, drainage and irrigation. However, it appears that the research results are either not extracted from the data, when data is not critically analyzed, or that research results just do not reach the users. For IWASRI, this last group includes: (i) farmers; (ii) planners and designers; (iii) policy makers; and (iv) construction industry.

It is here that the urgent requirement for mobilization and dissemination of research results meets with the task and mandate of ILRI. ILRI is unique in the world, is well-known through its publications as well as its other work, and there is enough scope for another 40 years!

References


Discussion

The rapporteur for this session summarized the discussion as follows:

- Dr. Wolters stressed that the farmer orientation must not be considered a panacea: it will not lead to quick results for various reasons, such as the small resource base of the farmer, little experience with the process, and lack of understanding.

- Accepting that irrigation and drainage management should be integrated, research on irrigation and drainage should be integrated as well. The International Waterlogging and Salinity Research Institute (IWASRI) in Lahore follows this approach. The IWASRI also realizes that its research should yield practical results and offer 'value for money'. Potential benefits from a number of research items were calculated, showing that a multiple of the IWASRI budget could possibly be saved. In addition, IWASRI sees an urgent need for mobilizing the vast amount of data that have already been collected, e.g. by the SCARP Monitoring Organization, so that these data become available to the potential users, be they farmers, planners, policy makers, or the construction industry.

- In remarks from the audience, better application of known research results was stressed. Also, available technologies are not so easily accessible/adaptable. The point of groundwater management in relation to drainage problems was also stressed, although it is sometimes difficult to find data for groundwater models.
THE NEED FOR INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT; SOME EXAMPLES AND PROPOSALS

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In irrigated lands lacking or with insufficient natural drainage, artificial drainage systems are needed to capture irrigation water losses. The conveyance losses can be intercepted either by a subsurface drainage system of parallel drains or by interceptor drains. The operational losses are discharged into the main drainage system and the application losses at the field level are captured by the surface and subsurface drainage systems.

In many rehabilitation projects of areas currently under irrigation, waterlogging and salinization problems must be solved. To do that, a choice has to be made among possible options:

(i) Modernization of the irrigation system.
(ii) Improvement of the water management at the project level.
(iii) Improvement of the water management at the field level without changing the irrigation method.
(iv) Improvement of the water management at the field level by changing the irrigation method.
(v) Intensification of the drainage system.

The following goals can be achieved by investing in modernization of the irrigation network and by improving the irrigation water management:

(i) Water savings.
(ii) Diminishing the drainage recharge.
(iii) Diminishing the drainage requirements.
(iv) Reducing the volume of the drainage water to be disposed.

However, sometimes the costs of modernization of the irrigation systems are so high that a compromise must be reached between investments in irrigation and drainage.

In this paper two examples are described showing the need for integration of irrigation and drainage. The first example comes from the Lower Tunuyan Irrigation Scheme, Mendoza, Argentina. There, alluvial soils situated in a large alluvial fan are irrigated by means of unlined canals on a rotational basis. In the upper and middle parts of the fan vineyards are irrigated with surface water. The overall irrigation efficiency is low and water losses recharge the aquifer. Groundwater flows towards the lower part of the fan, where farmers pump groundwater to irrigate because surface water is insufficient. Soil salinization occurs locally because of the salt content of the groundwater. In the adjacent fan formed by the river Mendoza, the low-lying lands need subsurface drainage to avoid waterlogging. Therefore, the best solution from a technical, economic and environmental point of view calls for integration of irrigation and drainage management.
Similar cases are common in the irrigation districts of northwestern Mexico, such as the Carrizo district in Sinaloa. There, seepage from unlined irrigation canals and application losses due to surface irrigation recharge the water table, which is close to the soil surface in the low-lying areas. In developing a solution to these problem, a comparison must be made of the benefits and costs of modernization of the irrigation network, improvement of the irrigation water management at the field level, and drainage intensification.

A case study on the integration of irrigation and drainage management is the Bajo Guadalquivir irrigation project. It is situated in southern Spain, where heavy clay and saline soils were reclaimed by means of irrigation and drainage. At the very start of the project, irrigation water was poorly applied. To solve the waterlogging and salinization problems, farmers asked for intensification of the subsurface drainage system by installing a new drain between two consecutive laterals. From monitoring the drainage system and the water management, it was concluded that by improving the irrigation management without changing the irrigation model no new investments in drainage works were needed.

To achieve the integration of irrigation and drainage management some research needs are proposed:
(i) Development of simulation models.
(ii) Introduction of environmental effects in the cost-benefit analysis.
(iii) Evaluation of areas with integrated irrigation and drainage management.

The improvement of the productivity of the areas already under irrigation per unit of water used is an element of a strategy defined in the context of FAO's Special Programme on Food Production in Support of Food Security. To achieve this goal, there is a need for integration of irrigation and drainage in the currently irrigated lands.

In the Waterlogging and Salinity Control activity of the FAO-AGLW Regular Programme for 1997, a proposal has been submitted which include two objectives:
(i) Review the existing simulation model for integration of irrigation and drainage management.
(ii) Review recent experiences in drainage design factors for a revised edition of FAO Irrigation and Drainage Paper no. 38.

To achieve these objectives international cooperation is necessary.

**Discussion**

On the issue of more efficient water use, a question was raised on how to determine the amount of water which is just adequate. Fixing the right amounts of ET and leaching is indeed difficult, but experience will help. Another question addressed the integration of saturated regional models with unsaturated one-dimensional models as one of the difficulties in the development of appropriate simulation models. A final remark was made on the absence of water pricing in the Argentina case. It appeared that the Water Users Association is now being involved in making farmers aware of the cost of irrigation water.

1 Drainage design factors, 1980.