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The role of drainage for sustainable agriculture[1]

Die Bedeutung der Entwässerung für eine nachhaltige Landwirtschaft

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Stichworte
Entwässerungsbedarf, institutionelle Optionen, Investitionen und Management der Entwässerung, Wiederverwendung von Entwässerungswasser, Beteiligung der Bauern, Entwässerung und Süßwasser-Ökosysteme, Milderung und Ausgleich negativer Aspekte entwickelter Länder, Entwicklungsländer

Keywords
Drainage needs, institutional options, drainage investment and management, farmers' participation, reuse of drainage water, drainage and freshwater ecosystem, mitigation and compensation of negative aspects, developed and developing countries

Zusammenfassung
Auf 10 bis 15 Millionen Hektar bewässerter landwirtschaftlicher Flache in ariden und semi ariden Gebieten, aber auch in den Tropen, fehlen jegliche Art von Entwässerungssystemen, da die öffentliche Hand bisher keine oder nur unzureichende Investitionsmittel bereit stellte. Untersuchungen über die Ausbreitung von versalzten und vernässten Flächen, Ertragsdepressionen etc. verweisen auf einen hohen Investitionsbedarf in die Entwässerungsinfrastruktur und auf die Notwendigkeit neue Wege bei der Verbesserung des Management von Entwässerungssystemen zu beschreiten.

Erfahrungen in einzelnen Länden zeigen, dass Investitionen in die Entwässerungsinfrastruktur und ein gutes Management einen volks- und betriebswirtschaftlichen Nutzen versprechen, der ein stärkeres Engagement der öffentlichen Hand und eine Kostenbeteiligung der Nutznießer rechtfertigt Entwässerung schützt die Ressource Land landwirtschaftliche Ertrage bäuerliche Einkommen und die Investitionen in Bewässerungssysteme; Entwässerung schützt ländliche und städtische Einwohner und Immobilien vor Überschwemmungen und verbessert - ganz allgemein - die Lebens und Gesundheitsbedingungen.

Während in den letzten Jahren erhebliche Fortschritte beim Bewässerungsmanagement erreicht wurden, u.a. durch die Übertragung von öffentlichen Bewässerungssystemen an Wassernutzer-organisationen, blieb die Entwässerung weitgehend unbeachtet Es zeigte sich dass partizipative Optionen im Betrieb und der Unterhaltung der Entwässerungssysteme nicht in gleicher Weise Erfolg versprechen wie in der Bewässerung Die von der Entwässerung ausgehenden negativen externen Effekte sowohl innerhalb als auch au-

1 This paper is based on a study (commissioned by the German Ministry of Economic Co-operation and Development (BMZ) and written under the supervision of the German Development Institute (GDI) in Bonn.

ßerhalb eines Bewässerungssystems. z B wenn Flüsse und Feuchtgebiete als Vorfluter dienen, bedürfen anderer institutioneller Losungen als die, die für Bewässerungssysteme erfolgreich angewendet wurden.

Die Autorinnen gehen davon aus dass staatliche Regulierung und größeres Engagement bei Investitionen erforderlich sind um negative Auswirkungen zu minimieren Die Verwendung von Entwässerungswasser von landwirtschaftlichen Flachen zur Bewässerung und die Auswirkungen von Entwässerung auf Feuchtgebiete und Flüsse stellt weitere Anforderungen an die Gestaltung von effektiven Institutionen.

Abstract
Due to persistent neglect by the public sector, the need for land drainage[2] has developed for 10-15 million hectares in arid and semi-arid countries, as well as in the humid tropics. Data on land with high salinity levels, land removed from production, yield depressions, and waterlogged and flooded land indicate the immense need for investment and improvement of drainage management.

While change has been impressive in improving irrigation performance by transferring the management of irrigation systems to farmers organizations, this option can be applied to drainage only under very restrictive conditions. Drainage is a more difficult task for transfer because of its public-goods characteristics, production aspects and the externalities associated. There is no one institutional solution, but instead a wide range of options moving along a continuum, - from government department, parastatal, service and management-contracting, cooperative and communal arrangements etc. However. the authors argue that the state has to play a prominent role in investment and in the setting ot an institutional framework.

Although difficult, a review of effective practices that some countries have experimented shows that drainage pays if suitable models are applied: drainage protects the resource base for food production, it sustains and increases yields and rural incomes, protects irrigation investment, it serves rural and urban residents and protects human lives and assets against flooding and high groundwater levels, and, finally, improves health conditions - success stories that are rarely recognized. Issues of particular concern are the reuse of drainage water for irrigation, and the relation and effects of drainage on natural areas and habitat (wetlands) which requires approaches both technical and institutional in nature that serve for the mitigation and balance of negative aspects.

1. Introduction

Growing environmental awareness has contributed to the very negative image that irrigation projects and irrigated agriculture have. Reports on poor system performance, soaring costs, social inequity, etc. have led to even greater suspicions and given rise to the one-sided call that irrigation development be abandoned. However, rain-fed agriculture interferes with nature in much the same way as irrigation does, albeit to a lesser extent, in subsistence farming as well as commercial agriculture, on small farms as well as in large enterprises. Since there is no substitute for irrigated agriculture in terms of its production volume, drainage has a role to play here. The slogan of engineering science "No irrigation without drainage" can be extended: no sustainable

[2] The term 'land' and 'agricultural' drainage are used synonymously.

agriculture without drainage. Irrigation must be reinvented - with drainage taking due consideration of its *effects on nature and the environment.*

Irrigated agriculture inevitably produces emissions, i.e. agricultural effluents, and if drainage infrastructure is lacking or poorly maintained, these causes waterlogging and soil salinity. Areas inundated by excessive rainfall and high groundwater levels have negative impacts on agricultural production and call for efficient water use, drainage infrastructure, and management to mitigate the effects. While the need to improve water use efficiency is generally recognized, land drainage has not yet been clearly incorporated into the *concept of integrated water resources management.*

The positive effects of agricultural drainage on the land resource base as well as its impacts on agricultural productivity and farm income are as well known as are the various techniques available. However, drainage infrastructure and drainage services entail *investment and maintenance costs* that are difficult to meet.

During the last decade, new institutional arrangements for irrigated agriculture have been put in place: many developing countries have successfully transferred state-managed irrigation systems to various kinds of water users organizations. Unlike the case of irrigation management, no such approach has been worked out for drainage, and a review of country experiences[3] (Freisem and Scheumann 2001) shows that *institutions for managing agricultural drainage, waterlogging, and salinity* are still lacking.

The article is an attempt to further the discussion on how institutional development must take due consideration of all aspects of land drainage.

2. Seven good reasons for drainage

The basic objective of agricultural drainage is to provide for a root zone environment that facilitates plant growth and optimizes crop production. In arid and semi-arid regions, drainage is linked with irrigation to make it possible to dispose of excess irrigation water and allow for the leaching of soils; in temperate regions and the humid tropics drainage facilitates the control of high groundwater and the discharge of heavy rainfall.

Since the 1950s, land drainage has been a technique well-established and elaborated in engineering science; it has attracted increasing attention in connection with the development of water resources for agriculture. On the political international scene, however, many events that took place during the 1990s suggest that land drainage should have become an essential issue in the global dialogue on food security

3 The study was financed by the International Water Management Institute (IWMI), Colombo, Sri Lanka.

and strategies for the sustainable use of water resources. This, however, has not been the case.

A review of international events shows that 'land drainage' has been recognized as an essential technique (Scheumann and Freisem 2001). Drainage needs have been roughly identified and quantified for many countries; a network exists for applied research (ICID, IPTRID), and, for instance, the World Bank provides assistance and credit for drainage development. Like irrigation system management, **drainage management** is a core element for the sustainability of irrigated (and partly also for rain-fed) agriculture, though it has only recently been the subject of a conceptual development that has as yet not attracted much attention.

The Convention on Biological Diversity (1992) suggests that greater emphasis should be given to drainage. Protection of freshwater and marine ecosystems will restrict the reclamation of wetlands; this requires Environmental Impact Assessments (EIA) aimed at mitigating negative impacts from land drainage and the disposal of drainage effluents and calls for the 'wise use' of wetlands, which means potentially that wetlands provide ecological functions for the purification of drainage water.

It is assumed that 50 percent of the world's irrigated land has developed drainage problems and that about 25 million hectares have become unproductive due to irrigation inefficiencies and lack of adequate drainage (UMALI. 1993). SMEDEMA (2000) has estimated the drainage needs for the next 25 years, and he estimates that about 10-15 million hectares will require drainage, including 2-3 million hectares for which subsurface drains are necessary. The corresponding annual rate would be 400-600 000 hectares (ABDEL-DAYEM, 2000b). Assuming the costs for drainage development to be US$ 200 per hectare in South East Asian countries and US$ 1,000 per hectare in arid and semi-arid countries, drainage investment would be in the order of US$ 900 million per year (SMEDEMA and OCHS, undated).

In the face of other pressing development priorities and fiscal constraints, these high investment needs are not very attractive for decision-makers. However, drainage provides benefits, and there are, at least, **seven good reasons** that support the idea of putting greater emphasis on land drainage in the context of integrated water resources management.

First reason: Drainage protects the resource base for food production

Irrigation significantly contributes to meeting basic food requirements in that it is used to produce e.g. 60 percent of the rice and 40 percent of the wheat grown in developing countries as well as the bulk of food supplies in the developing countries in which the majority of the world's population lives. However, soils are the ultimate natural resource required for crop production. Reports indicate that close to 0.5 to 1.0 million hectares of irrigated land are lost annually due to soil deterioration caused by waterlogging and salinity. The FAO estimates that of the 250 million hectares currently under irrigation, about 30 million hectares are severely affected by salinity and an additional 60 to 80 million hectares are affected to some extent (FAO, 1994). In Mexico, salinity is encountered in 10 percent of the total area irrigated, in India the figure is 11 percent, in Pakistan 21 percent, in China 23 percent, in the United States 28 percent, and in some Central Asian republics it is over 50 percent.

In India e.g., 7 million hectares of land have been abandoned because of salinity.[4] Waterlogging is a threat on its own in the humid tropics, but there are no corresponding estimates on the extent of land that has developed high water table levels or is flooded.

Reclamation of saline and waterlogged soils and development of new land entails costs so high that it is financially more attractive to prevent land from becoming salinized. This is all the more the case because land that could easily have been brought under irrigation has, as a rule, already been developed, the more expensive and economically less favorable areas being left over. The provision of drainage infrastructure and services helps to sustain favorable soil conditions and ...

Second reason: Drainage sustains and increases yields and rural incomes

... agricultural productivity. The effects of saline and waterlogged land on farm economics are detrimental because they cause land to be removed from production and often result in significant yield depressions. Saline and waterlogged conditions severely limit crop choice, diversification, and intensification, adversely affect crop germination and yields, and can make soils difficult to work. Although it is difficult to give general figures on overall yield depressions - they vary with salt concentration, water table depth, soil and the crops cultivated - the *no-drainage case* leads to income losses, reduces job opportunities, may induce migration, and has negative effects on overall food production. Ghassemi et al. report an annul agricultural loss in Punjab and North-West Frontier provinces (Pakistan) of US$ 300 million from decreased farm production due to soils affected by salinity; US$ 208/year in the Murray-Darling Basin (Australia), and US$ 31.2 million/year, or a 10 percent yield decline, in the San Joaquin Valley (USA) (1995). Paddy and wheat yields were 41-56 percent lower on degraded soils, and net incomes from salt-affected lands were 82-97 percent lower than those from unaffected land. Production efficiency losses are manifested by increased costs of production: per unit paddy costs rise by about 60 percent, while per unit wheat costs increase by about 85 percent in saline lands. For cotton, the average net returns per hectare in salt-affected areas were 42 percent of the income in the unaffected areas in Menemen, Turkey (UMALI. 1993).

Salinity costs the world's farmers US$ 11 billion annually in terms of reduced income - almost 1 percent of the total value of agricultural production (WRI 2000).

[4] SCHERR and YADAV (2001) assume that salinization will be a major threat in the irrigation systems of the Indus, Tigris and Euphrates river basins, in northeastern Thailand and China, in the Nile delta, in northern Mexico and in the Andean highlands.

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By comparison, the *case with drainage* indicates that the net contribution of drainage is rising production. In Indian canal commands e.g. the figure is about 35 percent (DATTA et al., 1997). In Egypt, the average yield of wheat, broad bean, cotton, maize and rice increased after drainage, raising annual farm incomes and gross production value. Wheat yields increased by 14 percent, maize by 25-40 percent, and rice by 7-20 percent (ALI et al., 2001). In addition, there are clear indications, e.g. in Pakistan and Egypt, that land value and leasing rates increase with drainage:
in Punjab/Pakistan from 30-50,000 rupees to Rs 150-300,000; Rs 100,000 to Rs 1,750,000; Rs 80,0000 to Rs 1.250,000; lack of livestock improvement due to shortage of fodder was no longer an issue. For Egypt, ALI et al. (2001) report that farmer perception is that drained land is highly rated and that land prices have often increased considerably after installation of a drainage system.

Third reason: Drainage protects irrigation investment

Irrigation has been the largest recipient of public agricultural investment in the developing world. The gross area served by irrigation increased from 95 million hectares in 1940 to 250 million hectares in 1989 (WR1 1994). Over the last 30 years, billions of dollars have been spent to safeguard water supplies, raise yields, and increase rural incomes. Since the 1950s, the World Bank alone has invested some US$ 31 billion in irrigation, leveraging an additional US$ 53 billion from co-financiers and borrowing countries (Dinar 2001).

During the last decade, irrigation spending decreased because of increasing costs for developing new water supplies. Today, the costs of repeated irrigation projects are typically 2 to 3 times higher than the previous project. On average, the real capital costs of new irrigation projects has risen by between 70 and 116 percent per hectare since the 1980s, because well-sited and low-cost options were no longer available. The average cost to develop a hectare for irrigation is between US$ 8-10,000 for surface schemes; in India and Indonesia, real costs of new projects have doubled over the past 25 years: in Thailand and the Philippines costs have increased by 40 and 50 percent respectively (Dinar 2001). Costs of new irrigation projects will increase further when adequate drainage is included.

Assuming an annual loss of between 0.5 and 1.0 million hectares that cost between US$ 8,000 or 10,000 for surface irrigation schemes, overall losses amount to US$ 4/ 8 to 5/10 billion. Hence, if we consider returns on irrigation investment and the high costs of developing new water and land resources, investment in drainage[5] becomes a financially attractive option.

[5] Investment in e.g. canal lining too; it saves water and reduces drainage requirements.

Fourth reason: Drainage infrastructure serves rural and urban residents as well as industry

In many countries, off-farm drainage infrastructure is also used by rural settlements, cities, and industry to dispose of wastewater - a benefit rarely considered in planning drainage projects.

In the Lower Seyhan irrigation system in Turkey e.g., almost all industries, e.g. textiles, paint, plastic bottles, grease, oil etc., discharge untreated wastewater into the main drains that were constructed for agricultural effluents. Slaughterhouses, chicken factory-farms, and wholesale vegetable markets use the main drains as dumps. The untreated wastewater of half a million residents of a major city is also released into a main drain (SCHEUMANN and VALLENTIN, 1999).

While the volume discharged does not create a capacity problem and does not diminish the system's function for agricultural beneficiaries, non-agricultural usage causes a considerable increase in maintenance requirements and requires hazardous maintenance work in the drains for the working personnel and seasonal workers who live near such drains. Near Faisalabad (Punjab/Pakistan), a fertilizer plant releases its effluents into a main drain that provides water directly used for irrigating vegetables, and in all canal commands main drains are used by industry and settlements for wastewater disposal. This obviously creates health and environmental problems and requires regulation, though it is undoubtedly beneficial to non-agricultural users.

Fifth reason: Drainage protects human lives and assets against flooding and high groundwater levels

Well-drained areas and drainage infrastructure provide a buffer (retention area) for torrential rainfall. In the humid tropics monsoon flooding and waterlogging are part of natural conditions, but irrigation has altered the hydrology of the soils and thus aggravated the problem. Agricultural land no longer has the capacity to cope with the high, and highly intense, rainfall. Tremendous losses of human lives and damage to assets occur periodically through uncontrolled floods e.g. in India and Bangladesh.

Due to dampness, high water tables in rural areas can have a devastating effect on rural housing. This can lead to the abandonment of houses and entire settlements such as in the waterlogged areas along the river Indus (KAMAL et al., 1999). Properly functioning drainage systems considerably reduce damage to built-up property and improve living conditions during high-intensity rainfall. Damage to archaeological monuments due to high groundwater tables are well-known in Egypt. This could be reduced significantly by the installation of drainage infrastructure, especially in areas where monuments are surrounded by farmland (ALI et al., 2001).

It is worth mentioning that the Asia Drainage Program for the Humid Tropics combines land drainage for irrigation with flood control. In the Mekong Delta, Vietnam, a substantial level of flood control including land drainage has been achieved at low cost, with farmers contributing towards construction cost (WOLTER, 1996).

Sixth reason: Drainage services improve health conditions

The FAO (1997) estimates that five million people die annually from water-related diseases, i.e. water-related vector-borne diseases (malaria: schistosomiasis. or bilharzasis; Guinea worm infection; lymphatic filariasis, or elephantiasis): water-borne diseases that are of a gastro-intestinal nature (diarrhea), caused by fecal matter, and orally transmitted, as well as diseases related to the transmission of pesticides and pesticide residues in drainage water (non-communicable). Stagnant water on inadequately drained land and in poorly maintained, silted-up drains contributes to the transmission of diseases and escalates their incidence, causing human suffering, health costs, and incalculable costs in terms of unavailable or weak labor forces.

In the absence of domestic water supply and sanitation facilities, drainage water is often used for drinking purposes, washing, bathing, etc.; drainage infrastructure transports untreated wastewater, waste, and human excreta. It is estimated that access to safe water and adequate sanitation could result in two million fewer deaths from diarrhea among young children. With properly designed and maintained drains, vectors could be controlled. Sanitary conditions improve when stagnant water in and near villages is reduced, and pit latrines may work properly if the surrounding area has low water tables.

Apart from the positive effects on human health, land drainage is also beneficial to animal health. In a study on the impact of improved land drainage in Pakistan, the reduction of a number of water-related animal diseases was substantial (KAMAL et al., 1999).

Seventh reason: Drainage and protection of water quality

Irrigated agriculture inevitably produces emissions, and in many countries agriculture is the largest polluter of water bodies as a result of unsustainable land management practices. Even if water is used efficiently, irrigation uses entail a leaching fraction which contains salt. Water quality problems increase with repeated reuse, disposal in closed basins, and injections and percolation into deep wells, where groundwater is contaminated.

The supply of drinking water e.g. in the West Bank and Gaza has become critical because of high application levels of pesticides, and nitrate concentrations in some domestic wells exceed, in some instances, four times the drinking water standards set by the World Health Organization. In some areas, groundwater is no longer potable and 5 million cubic meters of drinking water has to be imported (UNEP 2000). On the other hand, in saline groundwater zones in Punjab/Pakistan vertical drainage has lowered groundwater table depth, and a small layer of freshwater has developed on the top that can be used as drinking water.

Properly designed and maintained drainage facilities contribute towards controlling effluents from agricultural land. Pollutants like pesticides and fertilizer are conveyed through the drainage systems to receiving water bodies such as rivers or lakes. Water quality problems can be minimized if drainage water is channeled to large open surface water systems with significant dilution or assimilative capacity. However, conveyance may not be the ultimate solution: while it may reduce health and environmental costs on-site, it externalizes problems entailing social costs off-site. These costs can only be reduced and internalized if drainage becomes a part of integrated water resources management. [6]

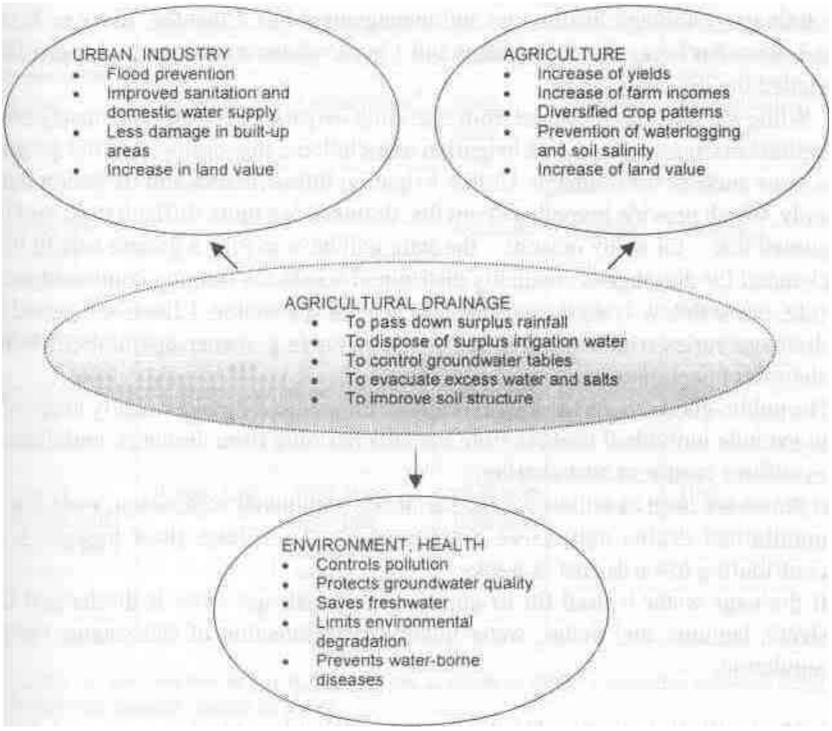

Figure 1:
Positive effects and impacts of agricultural drainage

[6] The authors would like to thank Frank van Steenbergen and RensVerstappen who stressed this point (2001).

3. Institutional arrangements for drainage, and 'good drainage practices'

Irrigation system management and provision of irrigation services has undergone impressive institutional changes that got underway in 1976 in the Philippines when the National Irrigation Administration was created as a semi-autonomous agency;
this continued with the transfer of large-scale public irrigation systems to irrigation associations in Mexico in 1988. a move which was followed by many countries. Both institutional changes have shown that the key to success is accountability to stakeholders, which forces management units to respond in time to local demands, technical requirements, natural circumstances, and economic and operational conditions of farming. Performance improves if irrigation management units depend for a substantial portion of their funding on fees paid by farmers (MERREY, 1996).

This success in improving irrigation management performance has no counterpart in drainage. Drainage institutions and management has remained, more or less, a black box. An exception is Pakistan and Egypt, where institutional changes have included the drainage sector.

While the state has refrained from operating irrigation systems, and management functions are now assigned to irrigation associations, this option will not promise the same success for drainage. Unlike irrigation infrastructure and irrigation water supply, which provide immediate benefits, drainage is a more difficult task, and it is assumed that - for many reasons - the state will have to play a greater role in it:

- Demand for drainage is unequally distributed across the farming community: as a rule. farms in low-lying areas are prone to under-provision. Effective demand for drainage varies with economic and social status (e.g. owner-operators of farms, share-croppers, tenants);
- The public-goods characteristics of drainage infrastructure make it nearly impossible to exclude individual farmers from benefits deriving from drainage, and difficult to enforce recurrent cost-sharing;
- If drains are used as outlets for industrial and communal wastewater, even poorly maintained drains may serve their purpose. Therefore, their incentive for contributing towards cost is weak;
- If drainage water is used for irrigation, and if drainage water is discharged into rivers, lagoons, and deltas, water quality and protection of ecosystems require regulation.

3.1 The institutional menu for drainage goods and services

One central issue is whether drainage infrastructure and drainage services are considered a public good to be financed by the general public, whether there are approaches that lead to beneficiaries taking full responsibility, or whether other options are feasible. A tentative approach for selecting institutions responsible for drainage functions is to work out whether drainage infrastructure and drainage services share characteristics with public or private goods and services (see Table 1). For instance, on-farm drains may be private goods if they can be managed by individual farmers and if decisions not to maintain the pipes or surface drains, for instance, affect individual farms only. In Turkey, due to the large size of farms, subsurface drains can be considered private, but since the collectors link and serve several farm units, maintenance for the most part requires collective efforts. In Egypt and Pakistan, for example, on-farm subsurface drains already connect more than one farm unit, and this makes exclusion difficult and requires enforceable rules for the sharing of maintenance costs.

Table 1:
Characteristics of drainage infrastructure and services[7]

Drainage infrastructure / service	Nature of goods / services		Production aspects		Provision aspects
	Rivalry or congestion[a]	Excludability[b]	Sunk costs	Economies of scale	Co-ordination necessary
On-farm drains	Congestion	Low	Low	Low	Low
Tertiary and secondary drains			Moderate	Moderate	Moderate
Main drains			High	High	Moderate
Regional outlets (river, sea)	Neither	Low			High
Reuse of drainage water (common pool resource)	Rivalry high	High at the operation outlet; low within irrigation system	High with treatment		High

a Rivalry, i.e. consumption by one reduces the use available to others. Congestion problems occur if the technical capacity reaches its limits.
b Excludability, i e a user can be prevented from consuming goods and services.

7 KESSIDES (1993) concept is applied for drainage infrastructure The original table (SCHEUMANN and FREISEM, 2001, p 14) has been modified following comments made by Jan MONSEES.

Following the infrastructure from tertiary to main drains, we find that an increasing number of farm units use and benefit from drainage systems, or are negatively affected by poor maintenance services. Once provided, collectively used drains make difficult both exclusion from benefits and enforcement of financial contributions. In some cases, exclusion may technically be possible from farm outlets to tertiary drains, but it is almost impossible to exclude individuals at the basin level. When non-agricultural users (industry, communities) discharge their wastewater into the drainage network. exclusion is feasible if effective institutional arrangements are in place.

If drainage water, or groundwater from vertical drainage infrastructure, is used to supplement irrigation water (e.g. Pakistan, Egypt and other Middle East North African countries) and is fed into a common pool, high incentives are given for farmers to share in development and management costs. Farmers organizations can then rely on already established common property regimes to allocate resource units by adhering to jointly agreed-on allocation patterns and financial commitments. But the setting, monitoring, and enforcement of water quality standards should be the state's responsibility.[8]

If vertical drainage is provided in saline groundwater areas (Pakistan) to lower groundwater table depths and serves to rehabilitate waterlogged land, and if this water is unsuitable for usage, co-operative management is more difficult; once provided, exclusion from benefits that accrue to a wide range of farm land is almost impossible.

There is no one institutional solution, but instead a wide range of options moving along a continuum, - from government department, parastatal, service-contracting, management-contracting, leasing, concessions, co-operative / communal arrangements to private entrepreneurship. Production aspects may help in defining policy options: for instance, capital with high sunk costs relies on *public* planning, policy-making, public financing and ownership. *For private firms,* building and operating drainage facilities is not profitable due to the non-excludability character of the services. Though a tax-based and regulatory solution might promise more success (LASLETT, 1997), it would require appropriate institutional arrangements for assessment. A *co-operative* solution is also difficult because individual farmers may be unwilling to pay even though they benefit as a collective entity.

However, cooperative solutions (Box 1) may be achieved if drainage services are linked with services which permit exclusion (i.e. supply of irrigation water). Farmers organizations can manage off-farm drainage infrastructure, but heterogeneity of demand for drainage and unequally distributed costs - due to location - must be balanced.

[8] If the common pool groundwater comes under a common property regime, or is regulated by the state, this requires that rights to groundwater bede-linked from land ownership, which is a sensitive issue

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Box 1:
Drainage infrastructure under common property regimes

- Small tube wells in fresh groundwater zones by Community Tubewell Groups (India. Pakistan, Turkey).
- Subsurface drainage schemes by Collector Users Associations which may become formally integrated into the water boards (Egypt).
- Off-farm tertiary surface drains by Drainage Beneficiary Groups (Pakistan) and Irrigation Associations (Turkey).
- Main drains by Area Water Boards (Pakistan) and Umbrella Associations (Turkey) - including non-agricultural beneficiaries and the state.

In addition, negative externalities such as water-related diseases, deterioration of water quality etc. call for state regulation or fiscal transfers. However, the 'menu of institutional options' is in need of conceptual development: how it can be applied to the varying facets of drainage as well as during the phases in which relevant decisions are made, i.e. planning, investment, execution, financing, operation, maintenance, and use. But here the conclusion may already be that private-sector involvement is feasible for limited aspects only (Box 2).

Box 2:
Private sector involvement

In most countries	Design and construction of drainage schemes (under state supervision).
Egypt	Drainage plastic-pipe production facilities undergo a gradual commercialization and transition from public authority to private companies.
Pakistan, Egypt	Contracting out maintenance works under the supervision of state agencies.

3.2 Investment in drainage infrastructure

While other goods and services with public-goods characteristics are in effect provided by governments, e.g. security, provision of agricultural drainage ranks low on the political agenda. One exception is Egypt, where investment in surface and subsurface drainage infrastructure is significant. India is a country that is in great need of investment in subsurface drains and - in many States - main surface drainage infrastructure. However, investment in subsurface drainage without previous investment in improving the main system will not prove sustainable. In the Philippines on-farm and off-farm drainage facilities can be considered inadequate, and system design for land drainage and flood control is poor. In Pakistan, most of public spending has gone to vertical drainage schemes, i.e. the Salinity Control and Reclamation Projects (SCARP), which effectively lowered groundwater table depth until operation and maintenance broke down. The main surface drains are in need of rehabilitation because maintenance has been neglected. Off-farm surface drainage infrastructure and on-farm subsurface drainage is still inadequate, though investment is part of on-farm water management projects and the National Drainage Program.

With the exception of Egypt, the tendency has been to allocate public resources to new irrigation projects instead of improving existing ones. But more recently attempts have been made to address drainage needs: e.g. the Indian Water Resources and Consolidation Projects; the Egyptian First and Second National Drainage Program; Pakistan's National Drainage Program; the Asia Drainage Program for the Humid Tropics.

Generation of funds from beneficiaries has proven to be difficult: in some countries, e.g. Turkey, farmers pay uniform capital charges based on the area opened up for irrigation, but contributions are negligible since charges are not adjusted to inflation. In Egypt, beneficiaries contribute about 50 percent in nominal terms towards capital costs for subsurface schemes. In the Philippines, farmers in National Irrigation Systems are required to contribute labor and material, donate land, and cover 10 percent of construction costs, while in Communal Irrigation Systems they are responsible for immediate repayment of 10 percent of construction costs and required to pay the balance within 50 years at 10 percent interest. In Pakistan, major drainage investment is undertaken by the federal Water and Power Development Agency (WAPDA), and beneficiaries contribute towards costs of subsurface and small-scale surface drainage schemes. Investment costs of small surface drainage schemes located in areas prone to floods are shared between the government and the farmers most affected by waterlogging, although all farms within a sub-basin or irrigation command 'produce' this externality (seepage from canals that transport water to their fields, irrigation water inputs). In India, contributions towards initial costs of surface drainage infrastructure are marginal (Box 3).

Since investment costs vary considerably from country to country and in terms of technical systems (higher for subsurface than for surface drainage infrastructure), feasible cost-sharing arrangements mean per unit costs that are within the farmers' ability to pay (net return). A further crucial point is that farmers in irrigation commands usually can only realize the benefits from drainage if they receive irrigation water. Since governments and international creditors want farmers to share in the drainage costs, irrigation system improvement is essential.

Non-agricultural beneficiaries usually do not contribute towards capital costs, and these expenses are borne by the general public. The same applies for flood control.

Box 3:
Sharing in drainage investment costs

Egypt	Farmers pay the balance of 50% of subsidies within 20 years, 5 years grace, interest free.
India	Public investment in surface drains, small contributions from farmers.
Pakistan	Public investment in large drains; contributions from farmers in subsurface and small surface schemes (e.g. donation of land without compensation, provision of material, removal of silt, 10% up-front payment of construction cost).
Philippines	National Irrigation Systems: farmers contribute labor, material, land, 10% of construction costs; Communal Irrigation Systems: farmers pay 10% of construction cost, 10% interest, 50 years.
Turkey	Subsidies for on-farm drainage schemes; repayment for off-farm drainage schemes.

3.3 Organizational features of drainage

The central question for drainage management is whether there are identifiable variables that facilitate 'good drainage management.' Organizations responsible for managing drainage infrastructure vary considerably with respect to their relation to the state on the one hand (including e.g. regulatory and supervisory functions) and the beneficiaries on the other. Countries are involved in some measure of experimenting with agricultural and non-agricultural beneficiaries in drainage affairs:

- **Egypt** has a financially dependent drainage agency (Egyptian Public Authority for Drainage Projects. EPADP) under the Ministry of Water Resources and Irrigation with Drainage Centers and Drainage Sub-centers, irrigation being the responsibility of another department of the same Ministry. In pilot schemes, Egypt is looking into whether Collector Users Associations are able to manage subsurface drainage schemes. The intention is to establish Water Boards - with representatives from agricultural and non-agricultural user groups - that are projected to operate irrigation systems at the secondary level and also assume responsibility for subsurface drainage.
- **India** has financially dependent state irrigation departments, in some States with separate drainage units in their technical departments. User participation in drainage

management is under consideration for subsurface drainage schemes (HOOJA et al., 2000).

- The State Hydraulic Works in **Turkey** depend on central budget allocations for operation and maintenance (O&M) of irrigation and drainage systems; the regional and project-related O&M units are also responsible for drainage. Irrigation management transfer is successful, but does not include drainage.
- In **Pakistan,** planning, investment, and construction are under the responsibility of the federal government (WAPDA), but smaller schemes come under the responsibility of the water unit of the Provincial Departments of Agriculture. O&M of drainage (vertical, main and secondary drains) is under the Provincial Irrigation Departments, which have separate units for SCARP, regular drainage, and flood control. The intention of the reform is to establish Area Water Boards with irrigation Farmers' Organizations that will assume responsibility for land drainage as well.
- The National Irrigation Agency of the **Philippines** is semi-autonomous and its Operation Divisions share responsibility with Irrigators Associations in National Irrigation Systems. Communal Irrigation Systems are managed by either Irrigators Associations or local governments.

All operating units are embedded in an institutional hierarchy in which a number of parties at multiple levels simultaneously share decision-making power concerning sector and project planning, investment, execution, operation, maintenance, and financing. Both their quality and the way in which they perform is shaped, among other factors, by these institutional hierarchies, though there is no clearly defined setting.

Responsibilities are fragmented and would require coordination either among or within units:

- **Planning, investment, and construction** of drainage infrastructure is separated from **management** (Pakistan).
- **Off-farm** and **on-farm drainage investment** comes under two agencies in Turkey, the General Directorate for State Hydraulic Works and the General Directorate for Rural Services, respectively.
- **Reclamation of saline land** and **regular drainage** comes under different agencies in Egypt. In Pakistan, two separate units exist within the provincial irrigation departments.
- Drainage is the joint management responsibility of **farmers organizations** and **public agencies** (the Philippines; experiments in Egypt and Pakistan).
- **Drainage management** is separated from **irrigation management** within a state irrigation agency (India, Pakistan). It is separated at the implementation level in Egypt, but coordinated at the Ministry and Central Governorate Irrigation Depart-

ment levels[9]. Drainage water use comes under EPADP and the irrigation units of the Ministry of Water Resources and Irrigation.
- Drainage for **flood control** is separated from **land drainage** (Pakistan, the Philippines).

Whether drainage system performance can best be improved by integrating several functions in one unit or by means of institutionalized coordination based on effective procedures is an open question (Table 2). An interesting approach has got underway in South Africa, where District Councils - a new third level of government - are responsible for development and implementation of infrastructure projects in local communities, including e.g. irrigation and drainage, which effectively means that District Councils define development tasks and co-ordinate funding.

Table 2:
Advantages and disadvantages of fragmented drainage responsibilities

Fragmentation	Advantage	Disadvantage	Country
Flood control - drainage		Flood control has priority	Philippines
Drainage - irrigation -reuse of drainage water	Strength of managerial capacity	No incentive for reducing drainage requirements, enforcement of water quality standards	Egypt, India, Pakistan
Farmers organization - public agency	Costs are shared, in-time response to local needs	Uncoordinated: drainage in tertiary drains depend on functional main drains	Philippines, Egypt, Pakistan
Reclamation of saline land - drainage -irrigation		Reclamation activities only * if regular drainage systems exist. * if additional water is made available from irrigation units	Pakistan, Egypt
Off-farm - on-farm drainage investment	Strength of technical capacity	Uncoordinated planning and implementation	Turkey
Investment/construction - management	Financial strength and institutional capacity	Management unitshave no control over design and construction quality	Pakistan

9 These are departments for coordinating the decentralized regional operation and liaison the ministry's mandate with the local governments and legislators.

3.4 Maintenance of drainage infrastructure and financing

In general, maintenance of drainage infrastructure is, at the very least, inadequate, though in most developing countries it is totally neglected, a state of affairs which often gives rise to the need for rehabilitation. In India, surface drainage infrastructure is heavily silted up and weed-infested, and in the Philippines maintenance is very poor. In Egypt, maintenance of the main system is contracted to companies according to a plan which requires that each open drain or the main system itself be de-weeded or de-silted every two years. Insufficient budget allocations have led to extension of the cleaning period to once every 3-4 years, which is inadequate due to increased growth rates of weed caused by relatively low-salt water, agricultural and municipal nutrients, and warm weather. In Turkey, maintenance, in particular of the main drains, is poor, and some are cleaned less than once in 10 years. Therefore, irrigation associations have refused to assign responsibility for drainage since drains are cleared by the state In Pakistan, the maintenance of SCARP tube wells has been most problematic ever since they were installed. Operation costs have tremendously increased, and major shares of the O&M budgets were directed towards O&M of SCARP tube wells leaving little over for maintenance of surface drainage and irrigation systems. The drainage wings of the irrigation departments that own machinery stores and have fully-fledged excavation divisions for O&M of surface drains, suffer from paucity of funds to maintain and repair the machinery.

Inadequate financial allocations for drainage maintenance[10] are prevalent in all countries where maintenance responsibility comes under state agencies, be they dependent or semi-autonomous. A common feature is that the major shares of O&M budgets are spent on personnel costs (up to 80 percent), leaving little over for the physical works component, e.g. fuel, spare parts, and contracting out maintenance. However, inadequate funds and lack of (qualified) staff are seldom sufficient to explain poor operation and maintenance performance. It would be useful to evaluate e.g. labor productivity, existing equipment, procedures for monitoring and supervision, as well as whether drainage works improve when they are contracted out.

As a rule farmers are not charged, and the provision of drainage services is highly subsidized. Egypt is an exception: farmers contribute towards maintenance costs for surface schemes through land taxes and provision of labor for maintaining collector-pipe schemes. However, land taxes are paid to the general tax department, and there is no traceable and intended link with subsequent expenditures for drainage. If charges or taxes are channeled into national treasuries, budget allocations tend to be dissociated and inadequate, and accountability towards clients is weak. If farmers are charged for the supply of drainage services, collection is the fundamental problem, one which gives rise to notorious deficits in the operating budgets.

[10] For financing maintenance services in irrigation systems, see VERMILLION, 1999.

In addition, if drainage infrastructure serves as outlets for industrial and domestic wastewater, non-agricultural beneficiaries are not charged, although e.g. industry could afford to pay both a drainage cess and, as far as water quality is concerned, pollution charges based on their higher rate of return from a unit of water compared with agriculture.

3.5 Participatory drainage management

Unlike participation in irrigation management, participation of agricultural and non-agricultural users in drainage *management* is more difficult to achieve (Box 4). Empirical evidence suggests that participation can be initiated in *investment* decision-making as well as in financing (Egypt, Pakistan, India).

The task of designing and implementing institutional arrangements for management calls for due consideration of technical features, the specific user/ beneficiary structure, and ability and willingness to pay: Water Users Associations (WUA) in e.g. Turkey have either refused to assume responsibility, or in cases in which responsibility for off-farm drainage infrastructure has been transferred, maintenance has been neglected due to the high maintenance costs involved for the aged drainage systems. However, if main drains serve an area greater than the command area of one association, WUAs may enter into contracts and form umbrella organizations. Or when industry and municipalities use main drains to discharge wastewater. it is possible to establish water boards that include representation of all stakeholders, including the state. This calls, in addition, for regulation in e.g. the setting of emission standards and balancing of costs.

Box 4:
Critical issues for farmer participation in drainage management

Boundaries of irrigation commands are not identical with drainage catchments. The group of farmers that 'produce' the externality is not identical with the groups negatively affected.
Exclusion from benefits is difficult but possible if this can be linked to the provision of e.g. irrigation water supply.

Management models for drainage must recognize that boundaries of drainage basins (or sub-basins) do not coincide with irrigation commands. However, this fact does not automatically lead to the conclusion that drainage institutions should be set up separately from irrigation institutions. Pakistan's concept of Drainage Beneficiary Groups (DBG) provides a good example[11] : DBGs include the farmers who are most

11 Based on field research conducted by W. SCHEUMANN (1999, 2000) that was co-financed by IWMI, Pakistan Piogram and Tethnical University Berlin.

affected by waterlogging and receive irrigation water from more than one watercourse. The number of individuals that cause drainage needs and the number of benefiting individuals is even larger than the number of DBG members. In the absence of a mechanism that guarantees that all polluters and beneficiaries contribute to defraying costs, only DBG member-farmers bear the costs of providing and maintaining the infrastructure. Such a mechanism could be effectively introduced only by irrigation organizations that control the important input 'water.' since DBGs have no power to collect charges and a drainage cess from farmers outside their area of jurisdiction.

If drainage then comes under irrigation management units, a question of major concern is how to overcome their bias against drainage, since their priority will as a rule be irrigation, not drainage. A possible solution would be to give additional voice in the representative units to the farmers affected most by e.g. waterlogging.

3.6 Reuse of drainage water

The reuse of low-quality water such as drainage water has become a viable option to meet part of the agricultural sector's water demand. In Israel, the Middle East, and North African countries, this has become a widespread practice and is supported by water-resource policies and agricultural policies. Here, drainage effluents have turned from a 'bad' resource that creates on-site and off-site costs into a "good', a new resource, that provides benefits. The reuse objectives are to control water quality (on the source side) and to increase agricultural production (on the delivery side). Whether this proves financially attractive or not depends on water quality requirements, the treatment necessary, the possibility of developing new water resources, and the costs entailed by both options.

Water reuse in most middle-income and low-income countries, however, is fraught with institutional difficulties. Sustainable use of drainage water calls for a strong knowledge base, sound policies, proper management practices, sufficient financial resources, the development of cost-effective technologies, and public awareness (ABDEL-DAYEM, 2000a). It first and foremost requires coordination between the ministries and institutions involved, in particular between those responsible for irrigation, monitoring of drainage water quality, and health and the environment (Box 5). Legal regulations could be used to define water quality standards and differentiated water prices with regard to water quality and uses.

3.7 Drainage and freshwater ecosystems

Land drainage changes the hydrological function of the surrounding areas and alters their ecology. Wetlands are converted into agricultural land; they dry up if water **is** removed from rivers and streams for irrigation; and wetlands lose their functions if water is contaminated with pesticides and other chemicals (MOSER et al., 1996). Degradation of freshwater ecosystems, e.g. wetlands, lakes, rivers, by salts and other chemicals has reached a critical state. In the Western United States, for instance, it is

Box 5:
Controlled use of drainage water (Egypt)

In the 1960s, the use of drainage water in irrigation began to satisfy the increasing water demands for food production. The *strategy* developed by the Ministry of Water Resources and Irrigation (MWRI) comprises e.g. the use of freshwater for germination; usage of diluted water for leaching and different growth stages;
reduction of the use of chemical fertilizers, pesticides and herbicides; use of drainage water only for salt-resistant crops; use of different water pipes for animal and human consumption.
A *regional network* has been established in the Nile Delta to monitor the quantity and quality of drainage water. Field studies are being conducted to determine the short- and long-term impacts involved in using drainage water in irrigation on soil and crops.
Legal regulation requires that if drainage water is used without treatment, salt concentration must be less than 700 mg/l; this water is mixed with Nile water if the salt concentration is higher. If the salinity exceeds 3,000 mg/l, the water is discharged into the sea (Amer 1996). While the official projects control drainage water quality, unofficial reuse does occur, and this leads to increased salt concentrations in irrigation water and soil.
Responsibility is fragmented among many agencies: the MWRI's Drainage Research Institute is supposed to monitor water quality and conduct research; it works closely together with EPADP. The Ministry of Health and MWRI has main responsibility for managing and preserving the quality of the country's water bodies. The Ministry of Interior is responsible for executing the law and stopping violations. If water quality standards for irrigation are violated, EPADP gives notice to the police. But it has no mandate or responsibility to prevent pollution. Enforcement is poor, and cases are pending (KfW 2001).

estimated that 90 percent of wetlands has been lost to agriculture (LEMLY et al., 2000). In Turkey, 190,000 hectares of swamps and marshes were drained by 1986 and reclaimed for agriculture and malaria control. However. Harmancioglu et al. (2001) estimate that only 35 percent of the land reclaimed has actually become useful for farming because parts of these areas are unsuitable for agriculture or have become unproductive due to salinization, burning of peat and wind erosion. Agricultural surface run-off and non-point source pollution significantly contribute to high levels of salt, pathogens, and heavy metals in surface water bodies (Ongley 1996); and if rivers or coastal ecosystems are contaminated by the inflow of poor-quality water, heavy metals and pesticides affect fish production and cause mass death of fish, frogs and waterfowl (Box 6).

Box 6:
Private fishing rights versus drainage (Turkey)

A main drain in the Lower Seyhan irrigation system was discharging into a lagoon where rights for fishing are held by a private party. Due to negative impacts on the fish stock caused by highly contaminated water, the title holder filed suit against the Regional Directorate of State Hydraulic Works, which owns and operates the drainage infrastructure. The court decided in favor of the lease holder, and the State Hydraulic Works have had to change the course of the main drain. The drain was rebuilt and now discharges directly into the Mediterranean Sea (SCHEUMANN. 1997).

However, the issue is not 'drainage' but the fact that industrial and domestic wastewater is not treated before it is disposed off. Concerning agricultural effluents, the most effective method to minimize environmental problems would be to implement source control at the on-farm level, i.e. reduced and efficient use of agro-chemicals combined with improved irrigation management. But the difficulties involved in controlling non-point sources are enormous.

Controlled drainage has proved to be an adequate technique to control the outflow of a drainage system and thereby the amount of soluble nutrients and pollutants. The technique involves using different rider heights in the drain outlet and allows a certain degree of outflow control (WESSTRÖM et al.. 2001).

Drainage water can be used for wildlife or wetland habitat irrigation, provided that a certain level of water quality is ensured that does not negatively impact on wildlife and the environment. In addition, creation of artificial wetlands entails the possibility to directly treat agricultural drainage water as a means of improving water quality (Box 7).

One comprehensive approach that balances conflicting issues, i.e. agriculture, industry, and the environment, is the Murray-Darling Basin Initiative, Australia (Box 8). It is the largest integrated catchment management program in the world and covers the watersheds of two rivers, drainage being one component.

4. Recommendations

Land drainage is an essential means for achieving worldwide food supply, and provides benefit for the agricultural and non-agricultural sectors. For realizing these benefits, the many as yet not addressed issues are in need of conceptual development.

The crucial points are the "who and how" of drainage investment and management. What role should the state play and what functions can be decentralized to "whom"?

Box 7:
Improving drainage wafer qualify by means of artificial wetlands (Aral Sea Basin, Central Asia)

The intention of the wetland program which is part of the World Bank's Aral Sea Program (1994) is to mitigate the desiccation of the Aral Sea. It will create a wetland buffer zone between the Aral Sea and the hinterland with the aim of closing off and restoring its Northern part. The buffer zone includes two new wetland zones: a freshwater wetland and a brackish water wetland which is fed by drainage water and. possibly, by the overflow from the freshwater wetland. To prevent salt concentrations from accumulating, the wetlands need a flow-through system (natural depression areas) to direct the water through vegetation. These systems will have the potential to reduce the pollutant concentrations. Moreover, part of the secondary functions of flow-through systems is that they provide a habitat for wildlife and offer potential for fish and shellfish production - depending on the concentration of the remaining pollutants (Ochs and Smedema 1996).
It is expected that the creation of artificial wetlands will provide relief for the ecological disaster. However, implementation requires institutional capacity as well as financial means to operate and maintain the system and monitor water-quality parameters (POST and OCHS, 1996).

"Who" can assure that drainage is no longer the forgotten factor? "How" is accountability achieved and to "whom" is it due?

Finding partners for drainage investment
Drainage investment means costs, and, in political terms, mobilizing sufficient public resources has not been very attractive But as drainage infrastructure undoubtedly provides benefits to identifiable agricultural and non-agricultural beneficiaries, the latter could contribute towards investment costs.

Cost-sharing arrangements between farmers and the state have been successfully used in e.g. Egypt, Pakistan, and India, and there are few reasons why industry and cities should not share in the cost of infrastructure investment. If all users participate, per unit costs decrease. Capital charges for agricultural beneficiaries may be assessed in relation to the area opened up for irrigation or the value of land. Financial contributions from beneficiaries can be ensured by means of up-front payments, commitments to land donation, in-kind contributions, etc. The task of mobilizing financial resources from the various groups of beneficiaries, however, calls for due consideration of **social and developmental aspects.**

Box 8:
Salinity management in the Murray-Darling Basin (Australia)

Salt is a natural feature in the Murray-Darling Basin, where groundwater is often as salty as the sea, but salinity has been exacerbated by changes in land and water use. Drainage may provide short-term relief from soil salinity, but it adds to river salinity. In addition, changing the river's flow regime had significant effects on its health: wetlands diminished, fish stocks declined, river water reached high salinity levels, and algae blooms increased.

A basin-wide framework providing for the sustainable management of water, land, and other natural resources has been established by the Murray-Darling Ministerial Council with the Ministers of the State Governments and the Commonwealth Government; it is responsible for water, land, and the environment in the basin.

A Basin Salinity Audit (1999) has shown that the threat of salinity could cause costs up to US$ 1 billion per year and would also cause significant environmental damage. The Basin Salinity Management Strategy's objectives for 2001-2015 are to secure the quality of water resources for all uses (i.e. agricultural, environmental, urban, industrial, and recreational); to control the rise in salt loads; to control land degradation; and to maximize net benefits from salinity control across the basin.

Two conflicting strategies - salt interception works and land drainage - are balanced through financial transactions known as 'salinity credits'. These are negotiated on the common understanding that the upstream states would provide financial support for salinity reduction works to the downstream states. Each state government is accountable for actions which impact on river salinity. Actions that would increase salinity are not allowed unless they are offset by works to ameliorate them (BLACKMORE et al.. 1999; Murray-Darling Basin Ministerial Council 2000).

Different uses and their conflicting objectives can be harmonized, at least to some extent, by developing and using new technologies and economic instruments. Drainage must lose its image as a merely end-of-pipe technology. If land and water are managed comprehensively, negative effects on the environment and nature can be mitigated in part from the outset.

Finding partners for drainage management, and strengthening the role of the state

Drainage system management is largely neglected. To improve the provision of drainage services, several issues are crucial:

- How do all beneficiaries share in recurrent costs, and how are payments assessed? A uniform drainage cess per unit (irrigated or drained) would be advantageous in terms of billing procedures because this reduces administrative costs. If socially desirable, small land holdings could be granted reductions. Charges for wastewater from industry and cities can take into account the volume of wastewater or be based on pollutants, or combine both factors. If land drainage infrastructure provides flood protection and reduces dampness etc., charges borne by house owners and residents should take account of the value of assets.
- What are the appropriate levels for decentralization of the various drainage tasks, and what services might be privatized?
- What role does the state play with respect to planning, investment, and management? What kind of regulation is needed and how should it be enforced?
- What are the comparative advantages of separate drainage organizations or of irrigation institutions dealing with drainage? How can their bias be overcome? Does it serve the purpose if the individuals that are most affected by waterlogging and salinity have a greater voice in management decision-making?

There is no blueprint model, and national agencies should be encouraged to develop country-tailored approaches in a joint effort with farmers organizations.

International lending institutions can assist borrowers, and irrigation management transfer programs may include drainage management as one component. The research institutes of the Consultative Group for International Agricultural Research (CGIAR) may extend their research programs to include issues related to drainage management.

Identifying priority regions and hot spots for investment, and install M&E systems
Investment needs are huge, and decision-making at the national level should focus on 'hot spots' that are based on hydrological and social criteria. Low-cost monitoring and evaluation systems (water table depth, groundwater and soil salinity) as well as data-processing systems should be developed. Close cooperation between political/ administrative decision-makers and research institutes would improve investment planning.

In a way similar to the Asia Development Program for the Humid Tropics, a program could be developed for arid and semi-arid regions, including e.g. Iran, Syria, Turkey, and the Northern African countries.

Institutionalizing procedures for coordination
Drainage investment and management requires coordination with sector policies and stakeholders:

- With irrigation management: guarantees reliable and predictable water supply incl. leaching, and suitable water quality if drainage water is used;
- With public health: reduces health hazards if involved in design and planning;
- With flood control: improves capacity of regular land drainage and flood control;
- With infrastructure development: prevents e.g. road construction from interrupting natural land drainage capacity;
- With agricultural policies: induces lower usage of agro-chemicals;
- With industry and cities: treats wastewater to reduce pollution and drainage maintenance needs;
- With environmental policies: sets and monitors standards for water quality.

Promoting the use of drainage water in irrigation, and risk alleviation

The use of drainage water in irrigation is an attractive option, but regulation and effective institutions, and their co-ordination, are crucial to controlling water quality. Producers and users of effluents could find cost-sharing arrangements to the benefit of both: the disposal costs incurred for producers of effluents may decrease, and users of drainage water may pay a lower price for drainage water than for high quality water.

Mitigating the negative off-site effects of drainage

There is no doubt about the conflict between protection of the environment and nature and drainage of agricultural land. Use conflicts can be harmonized, mitigated, or compensated for, at least to some extent, by developing new technologies and implementing economic instruments. The slogan is: **Reduce potential negative impacts at the outset, and not at the end of the drain.** Improvements in land and water management and wastewater treatment prior to its disposal in drains reduce negative effects on freshwater ecosystems and health and facilitate drainage management. Wastewater treatment should be considered an integral aspect of drainage - and not something that will be dealt with at a later stage of development; wastewater treatment involves costs that need to be financed by those who benefit.

Abbreviations

ADPHT	Asia Drainage Program for the Humid Tropics
DBG	Drainage Beneficiary Group (Pakistan)
EPADP	Egyptian Public Authority for Drainage Projects
O&M	Operation and Maintenance
SCARP	Salinity Control and Reclamation Project
WAPDA	Water and Power Development Authority (Pakistan)
WUA	Water Users Associations

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