IRRIGATION WATER MANAGEMENT

Training Manual No. 9

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DRAINAGE OF IRRIGATED LANDS

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A manual based on the joint work of
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Preface

This is one in a series of training manuals on subjects related to irrigation, issued in the period from 1985 to 1995. The manuals are intended for use by field assistants in agricultural extension services and irrigation technicians at the village and district levels who want to increase their ability to deal with farm-level irrigation issues.

The manuals contain material that is intended to provide support for irrigation training courses. Taken together, they do not present a complete course in themselves, but instructors may find them helpful when specific irrigation conditions are under discussion. The material may also be useful to individual students who want to review a particular subject without a teacher.

Following an introductory discussion of various aspects of irrigation in the first manual, subsequent subjects that have been discussed are:

- topographic surveying
- crop water needs
- irrigation scheduling
- irrigation methods
- scheme irrigation water needs and supply
- canals
- structures for water control and distribution
- drainage of irrigated land.

A further subject to be covered is:

- irrigation scheme operation and management.

At this stage, all the papers are regarded as being provisional because there is, as yet, little experience in preparing irrigation training material for use at the village level. After a trial period of a few years, when enough time has elapsed to evaluate the information and the methods outlined in the draft manuals, a definitive version of the series can be issued.

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ABOUT THIS PAPER

DRAINAGE OF IRRIGATED LANDS is the ninth in a series of training manuals on irrigation. It discusses the need for drainage in irrigated areas, focussing on drainage at the farm level. It reviews the systems that are available to drain irrigated lands and explains which factors of soils and hydrology influence drainage. It touches briefly upon the design, construction, operation, and management of field drainage systems.

ACKNOWLEDGEMENTS

The theory in this manual is based on the second, completely revised edition of ILRI Publication 16: *Drainage Principles and Applications*.

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Chapter 1

Introduction

In many irrigation projects, crop yields are reduced due to waterlogging and salinization of the land. In some cases, there is total loss of production and therefore the land is abandoned. Waterlogging may also cause human health problems, particularly malaria, because of ponded water. Of the estimated 235 million ha of irrigated land in the world, 10 to 15 percent has been affected by waterlogging and salinization.

Two important causes of waterlogging and salinization are: (a) excessive application of irrigation water; and (b) lack of adequate drainage. Thus provision of adequate drainage is a solution to the waterlogging and salinization problems of irrigated lands. However, it must be pointed out that improving drainage should not be a substitute for reducing excessive application and that improved drainage should not be implemented without first assessing whether waterlogging may be reduced by optimizing application. Figure 1 (a and b) illustrates waterlogging and salinization of irrigated lands respectively.

This manual will help extension officers and irrigation technicians to understand the relationship between irrigation and drainage. It will show them how to assess the need for drainage, and will help them understand how drainage systems function.

Chapter 2 presents the importance of drainage in crop production. It shows the need to control waterlogging and salinization and how this could be achieved by drainage.

Chapter 3 deals with the physical features of the drainage system. It explains the components of a typical drainage system. It also describes the different types of drainage systems and their appropriate applications.

Chapter 4 discusses the factors related to drainage, a good understanding of which is essential to design, construct and manage a drainage system. It also presents simple methods to determine the depth of the water table and hydraulic conductivity of soils which are important factors in the design of drainage systems.

Chapter 5 is concerned with drainage design considerations. It explains the layout of surface and subsurface drainage systems and the needs and requirements of drainage outlets.

Chapters 6 and 7 deal with the design and construction of surface and subsurface drainage systems respectively. In Chapter 7, special attention is given to the design, installation and supervision of construction of pipe-drainage systems.

Chapter 8 deals with operation, monitoring and maintenance of drainage systems.

The intention of the manual is to present a complete picture of drainage of irrigated lands in a simple form. Those who wish to obtain additional information are referred to the reading list suggested at the end of the manual.

FIGURE 1
Drainage can reduce or eliminate (a) waterlogging and/or (b) salinity

Chapter 2
Drainage and crop production

THE NEED FOR DRAINAGE

Figure 2 shows the water balance in an irrigated area. Before irrigation water can be applied to a crop, it has to be diverted from a river or lake (1) or pumped from the groundwater reservoir (2). The amount of water needed has to be greater than the quantity required by the crop because some of it will leave the area in various ways: not only will it be used by the crop as evapotranspiration (3), but some of it will be lost as evaporation (4), as seepage (5) and operational spills (6) from the irrigation canal system, as tailwater runoff from irrigated fields (7), and as deep percolation (8).

In the field, irrigation water, together with any rainfall (9), will be partly stored on the soil surface (10) and will partly infiltrate into the soil (11). If rain or irrigation continues for long periods, pools may form on the soil surface. This excess water on the soil surface is called ponded water. It needs to be removed.

Ponding is the accumulation of excess water on the soil surface.

Part of the water that infiltrates into the soil will be stored in the soil pores and will be used by the crop (3); another part of the water will be lost as deep percolation (8). When the percolating water reaches that part of the soil which is saturated with water, it will cause the water table to rise (12). If the water table reaches the root zone, the plants may suffer (Figure 3). The soil has become waterlogged. Drainage is needed to remove the excess water and stop the rise of the water table.

Waterlogging is the accumulation of excess water in the root zone of the soil.

Even if irrigation water is of very good quality, it will contain some salts. So, bringing irrigation water to a field also means bringing salts to that field. The irrigation water is used by the crop or evaporates directly from the soil. The salts, however, are left behind (Figure 4). This process is called salinization. If these salts accumulate in the soil, they will hamper the growth of crops.

Salinization is the accumulation of soluble salts at the soil surface, or at some point below the soil surface, to levels that have negative effects on plant growth and/or on soils.

FIGURE 2
Water balance in an irrigated area

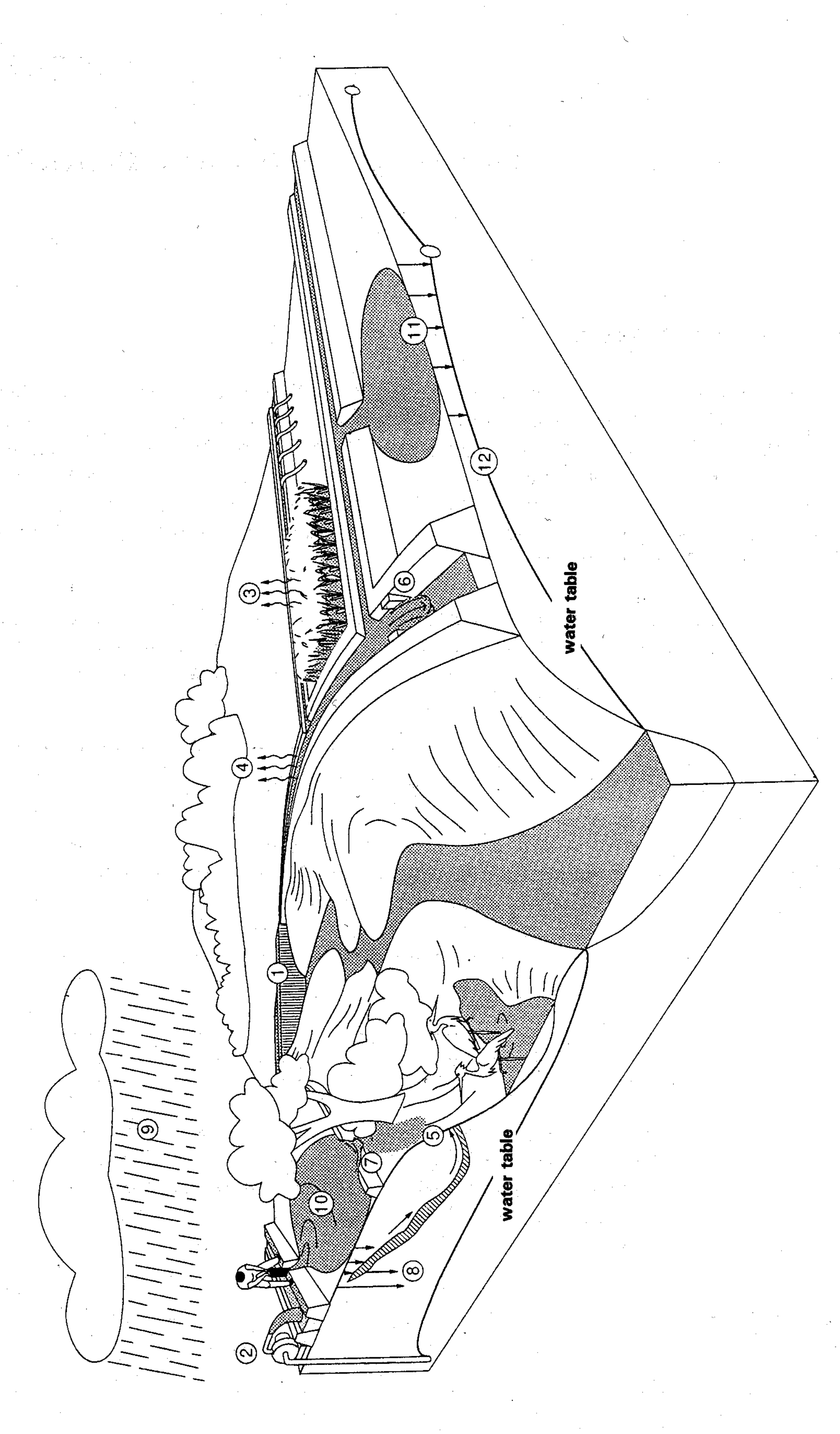


FIGURE 3
After irrigation or rainfall, the water table may rise and reach the root zone

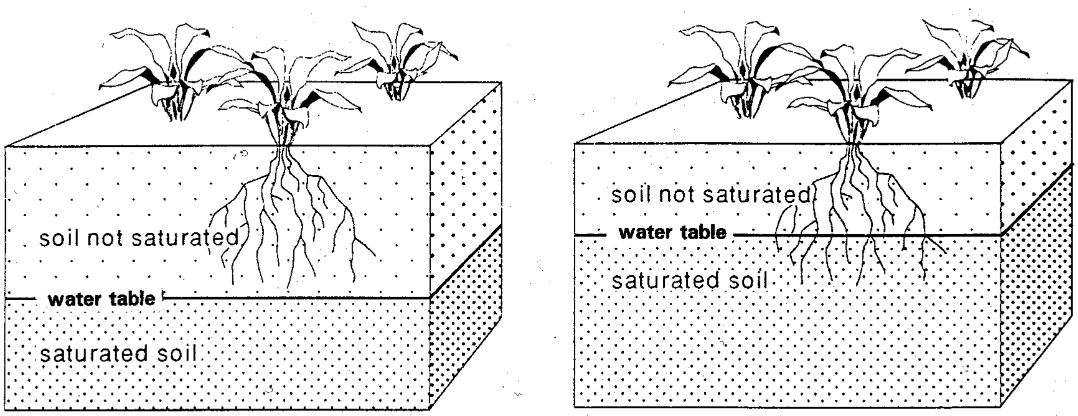


FIGURE 4
Irrigation water brings salts into the soil

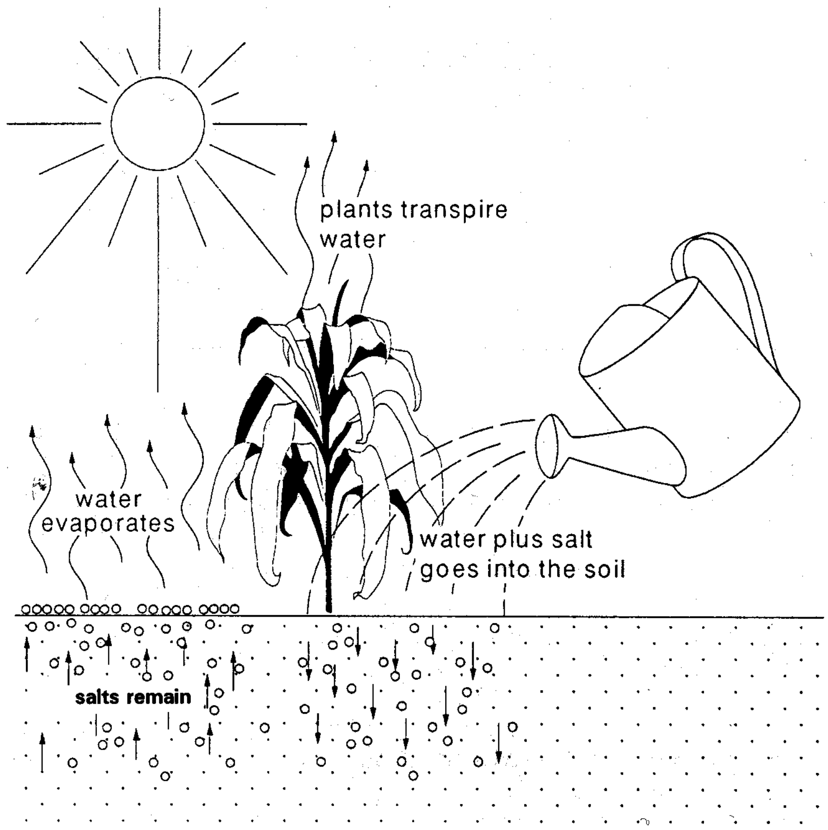
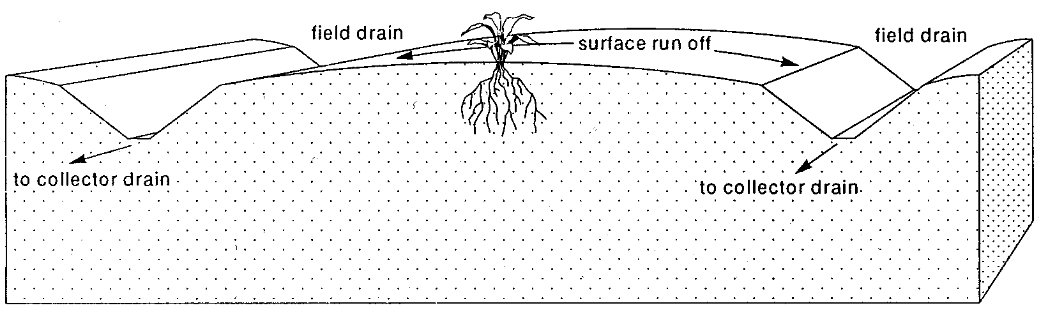


TABLE 1
Tolerance levels of some of the major crops

Highly tolerant (up to 10 g/l)	Moderately tolerant (up to 5 g/l)	Sensitive (up to 2.5 g/l)
Date palm	Wheat	Red clover
Barley	Tomato	Peas
Sugar beet	Oats	Beans
Asparagus	Alfalfa	Sugar cane
Spinach	Rice	Pear
	Maize	Apple
	Flax	Orange
	Potato	Prune
	Carrot	Plum
	Onion	Almond
	Cucumber	Apricot
	Pomegranate	Peach
	Fig	
	Olive	
	Grape	

FIGURE 5
Surface drainage to remove excess water from the land surface



Some crops are more tolerant to salts than others (Table 1). Highly tolerant crops can withstand a salt concentration up to 10 g/l in the saturation extract. Moderately tolerant crops can withstand up to 5 g/l, and sensitive crops up to 2.5 g/l. (For more information, see Training Manual No. 1 *Introduction to Irrigation*.) If sensitive crops are to be grown, drainage is needed to remove the salts.

So, drainage is used to control ponding at the soil surface, to control waterlogging in the soil, and to avoid salinization.

Drainage is the removal of excess water and dissolved salts from the surface and subsurface of the land in order to enhance crop growth.

Drainage can be either natural or artificial. Most areas have some natural drainage; this means that excess water flows from the farmers' fields to swamps or to lakes and rivers. Sometimes, however, the natural drainage is inadequate to remove the extra water or salts brought in by irrigation. In such a case, an artificial or man-made drainage system is required.

A man-made drainage system is an artificial system of surface drains and/or subsurface drains, related structures, and pumps (if any) to remove excess water from an area.

Therefore drainage is needed for successful irrigated agriculture because it controls ponding, waterlogging and salinity.

DRAINAGE TO CONTROL PONDING

To remove ponding water from the surface of the land, surface drainage is used. Normally, this consists of digging shallow open drains. To make it easier for the excess water to flow towards these drains, the field is given an artificial slope. This is known as land shaping or grading (Figure 5).

Surface drainage is the removal of excess water from the surface of the land by diverting it into improved natural or constructed drains, supplemented, when necessary, by the shaping and grading of the land surface towards such drains.

DRAINAGE TO CONTROL WATERLOGGING

To remove excess water from the root zone, subsurface drainage is used (Figure 6). This is done by digging open drains or installing pipes, at depths varying from 1 to 3 m. The excess water then flows down through the soil into these drains or pipes. In this way, the water table can be controlled.

Subsurface drainage is the removal of excess water and dissolved salts from soils via groundwater flow to the drains, so that the water table and root-zone salinity are controlled.

DRAINAGE TO CONTROL SALINIZATION

To remove salts from the soil, more irrigation water is applied to the field than the crops require. This extra water infiltrates into the soil and percolates through the root zone. While the water is percolating, it dissolves the salts in the soil and removes them through the subsurface drains (Figure 7). This process, in which the water washes the salts out of the root zone, is called leaching.

FIGURE 6
Subsurface drainage to control the water table and to remove excess water and dissolved salts from the root zone

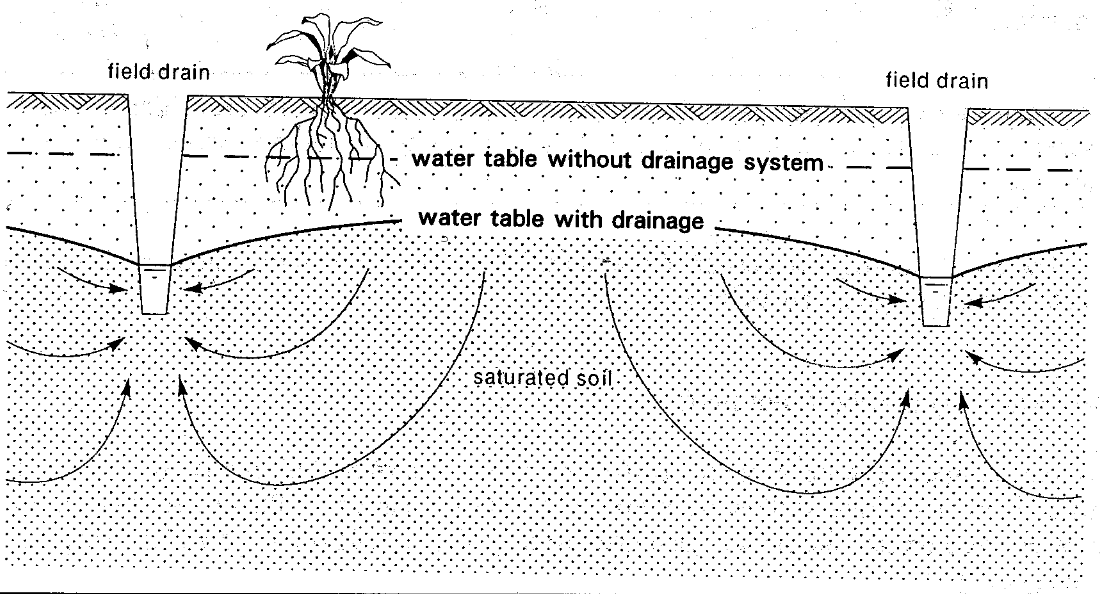
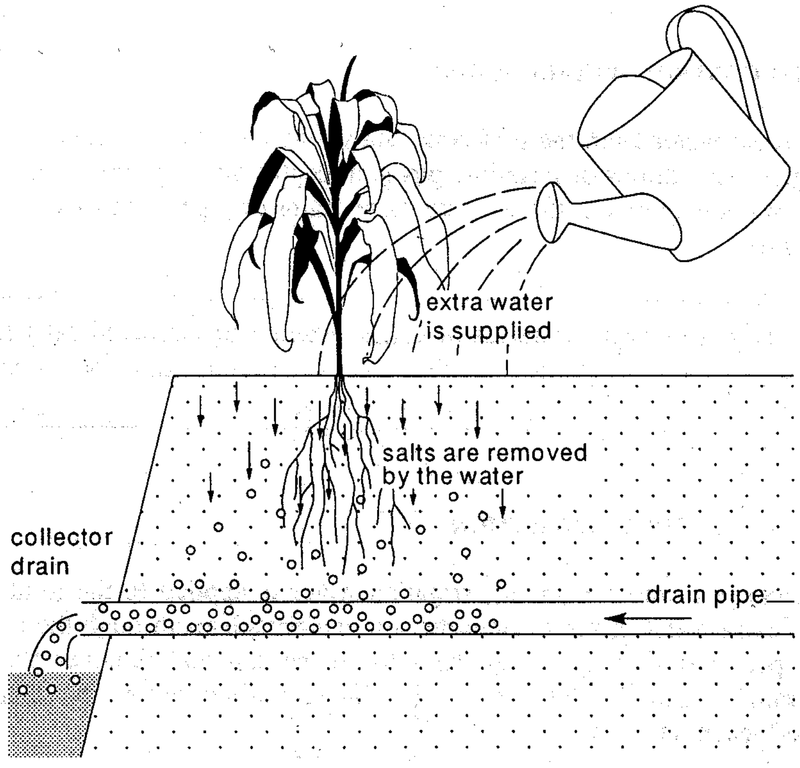


FIGURE 7
Extra irrigation water is applied to remove salts from the root zone



Leaching is the removal of soluble salts by water percolating through the soil.

The extra water required for leaching must be removed from the root zone by drainage, otherwise the water table will rise and this will bring the salts back into the root zone. Therefore salinity is controlled by a combination of irrigation and drainage.

BENEFITS OF DRAINAGE

One of the benefits of installing a drainage system to remove excess water is that the soil is better aerated. This leads to a higher productivity of crop land or grassland because:

- The crops can root more deeply.
- The choice of crops is greater.
- There will be fewer weeds.
- Fertilizers will be used more efficiently.
- There will be less denitrification.
- The grass swards will be better.

Other benefits of well-drained soils are:

- The land is more easily accessible.
- The land has a greater bearing capacity.
- The soil has a better workability and tilth.
- The period in which tillage operations can take place is longer.
- The activity of micro-fauna (e.g. earthworms) is increased, which improves permeability.
- The soil structure is better, which also improves permeability.
- Soil temperatures are higher, so that crops (particularly horticultural crops) and grasses can be grown earlier.

When drainage makes it possible to control the water table, the benefits that follow are:

- The root zone cannot become salinized by the capillary rise of saline groundwater.
- Leaching is made possible.

In its turn, the benefits of leaching are:

- It prevents increases in soil salinity in the root zone, thus making irrigated land use sustainable in the long term.
- By removing salts, it allows salt-sensitive crops, or a wider range of crops, to be grown.
- It makes it possible to reclaim salt-affected soils, thus bringing new land into cultivation.