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Agricultural drainage water management in arid and semi-arid areas

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Foreword

Irrigated agriculture has made a significant contribution towards world food security. However, water resources for agriculture are often overused and misused. The result has been large-scale waterlogging and salinity. In addition, downstream users have found themselves deprived of sufficient water, and there has been much pollution of freshwater resources with contaminated irrigation return flows and deep percolation losses. Irrigated agriculture needs to expand in order to produce sufficient food for the world's growing population. The productivity of water use in agriculture needs to increase in order both to avoid exacerbating the water crisis and to prevent considerable food shortages. As irrigated agriculture requires drainage, a major challenge is to manage agricultural drainage water in a sustainable manner.

Up until about 20 years ago, there were few or indeed no constraints on the disposal of drainage water from irrigated lands. One of the principle reasons for increased constraints on drainage disposal is to protect the quality of receiving waters for downstream uses and to protect the regional environment and ecology. Many developed and developing countries practise drainage water management. This study has brought together case studies on agricultural drainage water management from the United States of America, Central Asia, Egypt, India and Pakistan in order to learn from their experiences and to enable the formulation of guidelines on drainage water management. From the case studies, it was possible to distinguish four broad groups of drainage water management options: water conservation, drainage water reuse, drainage water disposal and drainage water treatment. Each of these options has certain potential impacts on the hydrology and water quality in an area. Interactions and trade-offs occur when more than one option is applied.

Planners, decision-makers and engineers need a framework in order to help them to select from among the various options and to evaluate their impact and contribution towards development goals. Moreover, technical expertise and guidelines on each of the options are required to enable improved assessment of the impact of the different options and to facilitate the preparation of drainage water management plans and designs. The intention of this publication is to provide guidelines to sustain irrigated agriculture and at the same time to protect water resources from the negative impacts of agricultural drainage water disposal.

This publication consists of two parts. Part I deals with the underlying concepts relating to drainage water management. It discusses the adequate identification and definition of the problem for the selection and application of a combination of management options. It then presents technical considerations and details on the four groups of drainage management options. Part II contains the summaries of the case studies from the United States of America, Central Asia, Egypt, India and Pakistan. These case studies represent a cross-section of approaches to agricultural drainage water management. The factors affecting drainage water management include geomorphology, hydrology, climate conditions and the socio-economic and institutional environment. The full texts of the case studies can be found on the attached CD-ROM.

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- PC with Intel Pentium® processor and Microsoft® Windows 95 / 98 / 2000 / Me / NT / XP *or*
- Apple Macintosh with PowerPC® processor and Mac OS® 8.6 / 9.0.4 / 9.1 / X
- 64 MB of RAM
- 24 MB of available hard-disk space
- Internet browser such as Netscape® Navigator or Microsoft® Internet Explorer
- Adobe Acrobat® Reader (included on CD-ROM)

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Acronym/ symbol	Description	Dimension
ψ	bulk density (kg m^{-3}, g cm^{-3})	M L^{-3}
σ	drainable pore space (m^3 m^{-3})	-
ζ	empirical shape parameter (cm^{-1})	L^{-1}
ς	empirical shape parameter depending on dK/dh	-
χ	volumetric water content (m^3 m^{-3})	-
χ_{fc}	volumetric water content at field capacity (m^3 m^{-3})	-
$\div h$	drop in groundwater table (m)	L
$\div M_{ss}$	changes in storage of soluble soil salts (kg, t)	M
$\div M_{xc}$	changes in storage of exchangeable cations (kg, t)	M
$\div S$	change in salt storage in the rootzone (ECmm)	$T^3I^2M^{-1}L^{-2}$
$\div W$	change in moisture content in the rootzone (mm)	L
$\div W_{rz}$	change in water storage in the rootzone (mm)	L
$\div W_{sz}$	change in water storage in the saturated zone (mm)	L
$\div W_{vsz}$	change in water storage in the vadose and saturated zone (mm)	L
$\div W_{vz}$	change in water storage in the vadose zone (mm)	L
A	salinity threshold (bars)	$ML^{-1}T^{-2}$
a	salinity threshold (dS/m)	$T^3I^2M^{-1}L^{-3}$
AW	applied water (mm)	L
B	slope expressed in percent per bar	-
b	slope expressed in percent per dS/m	$T^3I^2M^{-1}L^{-3}$
B_I	boron concentration in irrigation water (mg $litre^{-1}$)	M L^{-3}
BOD	biochemical oxygen demand (mg $litre^{-1}$)	M L^{-3}
B_{ss}	boron concentration in the soil solution (mg $litre^{-1}$)	M L^{-3}
B_{ss0}	initial boron concentration in the soil solution (mg $litre^{-1}$)	M L^{-3}
B_{sst}	desired boron concentration in the soil solution (mg $litre^{-1}$)	M L^{-3}
C_{dw}	salt concentration of drainage water (kg m^{-3} or mg $litre^{-1}$, g $litre^{-1}$)	M L^{-3}
CEC	cation exchange capacity (meq $100g^{-1}$ or mMol (c) $100g^{-1}$)	N M^{-1}
C_{gw}	salt concentration of groundwater (mg $litre^{-1}$ or kg m^{-3})	M L^{-3}
C_I	salt concentration of irrigation water (kg m^{-3} or mg $litre^{-1}$, g $litre^{-1}$)	M L^{-3}
CIMIS	California Irrigation Management Information System	-
C_{IW}	salt concentration of the infiltrated water (mg/litre)	M L^{-3}
C_k	solute species (mMol $litre^{-1}$)	N L^{-3}
COD	chemical oxygen demand (mg $litre^{-1}$)	M L^{-3}
C_{R^*}	salt concentration of the net percolation water (mg/litre)	M L^{-3}
CVRWQCB	Central Valley Regional Water Quality Control Board	-
$\overline{C}_k$	exchangeable form of solute species(mMol (c) $100g^{-1}$)	N M^{-1}
$\overset{\%}{C}_k$	mineral form of solute species (mMol (c) $100g^{-1}$)	N M^{-1}
D	dispersion coefficient (m^2 d^{-1})	L^2 T^{-1}
D_{rz}	depth of the rootzone (m)	L
D_L	depth of leaching water (mm)	L
D_r	drainage water reuse (mm)	L
D_{ra}	artificial subsurface drainage (mm)	L
D_{rn}	natural drainage (mm)	L
D_s	depth of soil to be reclaimed (mm)	L
E	evaporation (mm)	L
e_a	irrigation application efficiency	-
EC	electrical conductivity (dS m^{-1}, mS cm^{-1})	$T^3I^2M^{-1}L^{-3}$
e_c	water conveyance efficiency	-
EC_0	EC_e at which the crop yield is reduced to zero (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{50}	EC_e at which the crop yield is reduced to 50 percent (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{Dra}	EC of subsurface drainage water (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$

Acronym/ symbol	Description	Dimension
EC_e	*EC* of soil water of the saturated paste (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{e0}	initial EC_e (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{et}	desired EC_e (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{fc}	*EC* of soil water at field capacity (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{frR}	*EC* of percolation water mixed with soil solution (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{gw}	*EC* of groundwater (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_I	*EC* of the irrigation water (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{IW}	*EC* of the infiltrated water (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{IWi}	*EC* of the infiltrated water mixing with soil solution (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_R	*EC* of the percolation water (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{Si}	*EC* of S_i intercepted by subsurface drains (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{SW}	*EC* of the soil water (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
EC_{ts}	threshold *EC* of the extract from saturated soil paste (dS m^{-1})	$T^3I^2M^{-1}L^{-3}$
e_d	distribution efficiency	-
ESP	exchangeable sodium percentage	-
ET	evapotranspiration (mm)	L
ET_{crop}	crop evapotranspiration (mm)	L
ETo	reference crop evapotranspiration (mm)	L
f	leaching efficiency coefficient	-
f_i	leaching efficiency coefficient of water mixing with soil solution	-
f_r	leaching efficiency coefficient of the percolation water	-
G	capillary rise (mm)	L
H	hydraulic head (m)	L
h	soil pressure head (m)	L
I	total applied irrigation water (mm)	L
ICUC	irrigation consumptive use coefficient	-
IE	irrigation efficiency	-
IFDM	integrated farm drainage management	-
I_g	groundwater irrigation (mm)	L
I_i	infiltrated irrigation water (mm)	L
IS	irrigation sagacity	-
I_s	surface irrigation (mm)	L
IW	infiltrated water (mm)	L
K	hydraulic conductivity (m d^{-1})	L T^{-1}
K_c	crop coefficient	-
$K(\chi)$	unsaturated hydraulic conductivity (m d^{-1})	L T^{-1}
K_s	saturated hydraulic conductivity (m d^{-1})	L T^{-1}
LF	leaching fraction	-
LF_i	leaching fraction of water mixing with the soil solution	-
LR	leaching requirement	-
LR_i	leaching requirement of water mixing with soil solution	-
M_c	mass of salts removed by harvested crops (kg)	M
M_d	mass of salts dissolved from mineral weathering (kg)	M
M_f	mass of salts from fertilisers and amendments (kg)	M
M_p	mass of salts precipitated in soils (kg)	M
MPN	most probable number of faecal coliform	-
M_{Se}	mass of selenium (kg)	M
n	dimensionless empirical shape parameter	-
OP_{fc}	osmotic potential at field capacity (bar)	$ML^{-1}T^{-2}$
O&M	operation and maintenance	-
P	precipitation (mm)	L
P_e	effective precipitation (mm)	L
q	soil water flux or specific discharge (m d^{-1})	L T^{-1}
R	deep percolation (mm)	L
R^*	net deep percolation (mm)	L
RO	surface runoff (mm)	L
S	salts in rootzone (ECmm)	$T^3I^2M^{-1}L^{-2}$
SAR	sodium adsorption ratio (meq^{½} litre$^{-½}$)	$N^{½}L^{-1½}$
S_c	seepage from canal (mm)	L
SCARP	Salinity Control and Reclamation Project	-

Acronym/ symbol	Description	Dimension
S_e	water extraction sink (m^3 m^{-3} d^{-1})	T^{-1}
Se_{hp}	maximum selenium concentration in harvested product (mg kg^{-1})	-
Se_I	selenium concentration in irrigation water (σg $litre^{-1}$)	M L^{-3}
S_{end}	salts in the rootzone at the end of the period (ECmm)	$T^3I^2M^{-1}L^{-2}$
S_p	lateral seepage (mm)	L
Se_{ss}	selenium concentration in soil solution (σg $litre^{-1}$)	M L^{-3}
Se_{ssm}	maximum selenium concentration in soil solution (σg $litre^{-1}$)	M L^{-3}
S_i	seepage inflow (mm)	L
S_{IW}	salts in infiltrated water (ECmm)	$T^3I^2M^{-1}L^{-2}$
S_R	salts in percolation water from the rootzone (ECmm)	$T^3I^2M^{-1}L^{-2}$
S_{start}	salts in the rootzone at the start of the period (ECmm)	$T^3I^2M^{-1}L^{-2}$
S_v	vertical seepage (mm)	L
t	time (d)	T
TDS	total dissolved solids (mg $litre^{-1}$, g $litre^{-1}$)	M L^{-3}
TSS	total suspended solids (mg $litre^{-1}$, g $litre^{-1}$)	M L^{-3}
V_{dw}	volume of drainage water (m^3)	L^3
V_{gw}	volume of groundwater (m^3)	L^3
V_i	volume of irrigation water (m^3)	L^3
Y	empirical correction factor	-
Y_r	relative yield	-
W_{fc}	moisture content at field capacity (mm)	L
WT	water table depth (m)	L
z	vertical coordinate (m)	L