

**Irrigation management strategies
for improved
salinity and sodicity control**

Marcel Kuper

Proefschrift ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van de Landbouwuniversiteit Wageningen,
dr. C.M. Karssen,
in het openbaar te verdedigen
op 17 december 1997
des namiddags te 14.30 uur in de Aula.

CONTENTS

Abstract	i
Preface	iii
1. Introduction	1
1.1 Salinity and sodicity in the Indus Basin.....	1
1.2 Statement of the problem	4
1.3 Outline of the study	5
1.4 Limitations of the study	6
2. Research Locale	9
2.1 Description of the Chishtian Sub-Division	9
2.1.1 Physical environment	10
2.1.2 Irrigation system	13
2.1.3 Farming systems	19
2.2 Data collection and management	21
2.2.1 Data collection	21
2.2.2 Data management	25
2.2.3 Evaluation of the data collection and data management	25
3. Irrigation system management: from the main canal to the tertiary unit	29
3.1 The irrigation agency: objectives and decision-making processes	30
3.1.1 General principles of canal irrigation management	30
3.1.2 Irrigation management activities	31
3.1.3 Scope for interventions	34
3.1.4 Physical system constraints	38
3.2 Methodology	39
3.2.1 General framework	39
3.2.2 Developing a hydro-dynamic model (Step 1)	41
3.2.3 Developing a regulation module for operations at the main canal (Step 2)	46
3.2.4 Water distribution indicators	50
3.3 Improving operations at the main canal level	52
3.3.1 Analyzing the official and existing operational rules at the main canal level (Steps 3 and 4)	52
3.3.2 Simulating the existing operational rules (Step 5)	58
3.3.3 Simulating the impact of the official operational rules on the water distribution (Steps 6, 7, 8)	63

3.3.4	Identifying the scope for an equitable water distribution by changing the operational rules (Steps 6, 7, 8)	65
3.3.5	Identifying the scope for redirecting canal water supplies to areas with salinity or sodicity problems (Steps 6, 7, 8)	70
3.4	Improving water distribution at the secondary canal level	72
3.4.1	Analyzing the official and existing water delivery patterns: principles of water distribution (Step 3)	72
3.4.2	Management interventions in the outlet characteristics: analyzing the local impact on the offtaking discharge (Step 4a)	76
3.4.3	Management interventions in channel and structures: analyzing the global impact on water distribution in secondary canals (Step 4b)	79
3.4.4	Assessing the effect of management interventions on the water distribution at the secondary canal level	82
3.5	Analyzing the impact of interventions at the main and secondary canal level on water deliveries to tertiary units	87
3.5.1	Water deliveries to tertiary units as a function of the inflow of secondary canals	87
3.5.2	Combining and comparing the effect of main and secondary canal interventions on water deliveries to tertiary units	89
3.6	Conclusions	93
4.	Farmers' salinity and sodicity control: from the field to the tertiary unit	97
4.1	Salinity and sodicity processes: a brief description	98
4.1.1	Pathways leading to soil salinity and sodicity	98
4.1.2	Effects on soils and crops	102
4.2	Objectives and constraints of farmers dealing with salinity and sodicity	103
4.2.1	Farmers' classification of salinity and sodicity	104
4.2.2	Farmers' strategies and measures to cope with salinity and sodicity	107
4.2.3	Scope for irrigation management interventions to help farmers in dealing with salinity and sodicity	112
4.3	Methodology	114
4.3.1	Unsaturated flow of water and solutes: basic principles and description of SWAP93	114
4.3.2	Predicting the sodium hazard	120
4.4	Analyzing the effect of irrigation on soil salinity and crop transpiration	122
4.4.1	Calibration and validation of the model	122
4.4.2	Sensitivity analysis	129
4.4.3	The effect of irrigation quantity and quality on soil salinity and transpiration for existing conditions	132
4.4.4	The effect of farmers' irrigation practices on soil salinity and transpiration	136
4.5	Predicting the effect of irrigation on soil sodicity and soil degradation	139
4.5.1	Predicting the soil sodicity risk	139
4.5.2	The effect of sodicity on soil degradation	145
4.6	Predicting soil salinity and sodicity at the level of the tertiary unit	147
4.7	Conclusions	151



5.	Irrigation management for improved salinity control: towards an integrated approach	155
5.1	Developing a framework for the integrated approach	155
5.1.1	Introducing the economic component of the integrated approach	155
5.1.2	General framework to analyze the effect of canal irrigation management on salinity and sodicity	157
5.2	Methodology	158
5.2.1	Identification of relevant parameters /variables	159
5.2.2	Operationalizing the integrated approach	160
5.2.3	Performance indicators	163
5.3	Irrigation management interventions and their effect on soil salinity and sodicity: application to the Fordwah Branch and Distributary	165
5.3.1	Irrigation management and salinity control in the Fordwah Distributary: actual situation	166
5.3.2	Improving the salinity control for the Fordwah Distributary	170
5.3.3	Evaluation of the impact of canal irrigation management on cropping intensities, salinity and sodicity for the Fordwah Distributary	174
5.4	Evaluation of the integrated approach	176
5.4.1	Product evaluation	176
5.4.2	Process evaluation	182
5.4.3	Perspectives	185
6.	Summary and conclusions	191
6.1	Irrigation system management interventions for improved salinity and sodicity control: lessons from the case study in Pakistan	191
6.2	General application of the developed integrated approach to irrigation management	195
Appendices		
1	Structure equations used in the hydraulic model Simulation of Irrigation Canals (SIC), version 2.1 under DOS	199
2	Mathematical derivation of equation 3.15	203
3	Modifications in outlet dimensions for the Masood and Fordwah Distributaries for various simulation scenarios of Sections 3.4.4 and 5.3	205
References		209
Samenvatting		217
Resumé		225
Abbreviations and glossary		233
List of main symbols		235
Curriculum vitae		238



International Irrigation
Management Institute
Pakistan National Program
12 Km Multan Road,
Chowk Thokar Niaz Baig
Lahore 53700
Pakistan



Cemagref
Groupement de Montpellier,
Division Irrigation
361, rue J.F. Breton, BP 5095
34033 Montpellier cedex 1
France



Wageningen Agricultural
University
Department of Water Resources
Nieuwe Kanaal 11
6709 PA Wageningen
The Netherlands