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DRAINAGE FOR AGRICULTURE

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DRAINAGE FOR AGRICULTURE

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GENERAL FOREWORD

AGRONOMY—An ASA Monograph Series

The steadily increasing worldwide demand for food supplies makes this volume on drainage especially timely. Intensive farming of existing crop land and the farming of new land now limited in use due to poor drainage are urgently needed to achieve the great food requirements of the future. New developments in the field of drainage can do much to further these objectives. *Drainage for Agriculture,* Agronomy No. 17, presents these developments and their applications.

This new volume, Agronomy No. 17, is also noteworthy in that it is a complement to and not a replacement for Agronomy No. 7, *Drainage of Agricultural Lands,* edited by J. N. Luthin, and published by the American Society of Agronomy in 1957. The first drainage book underwent three printings and 4,200 copies were distributed worldwide. Incidentally, it was the first in the *Agronomy* series to be published by the society; the first six numbers were published by Academic Press, Inc., of New York. Only volumes no. 7 through 17 are available from the American Society of Agronomy, Inc., at 677 South Segoe Road, Madison, Wisconsin 53711.

As is the case with all of the volumes in this series, the society is indebted to many individuals who contributed much in the way of knowledge, time and patience in the production of this book. A number of authors are nonmembers of the American Society of Agronomy and several are from countries outside the USA. A list of the contributors appears on pages xxi-xxii.

Publication of the *Agronomy* monograph series represents a significant and continuing effort of the American Society of Agronomy to disseminate information to the public in the interest of human welfare. Since assuming the responsibility for development and publication of titles in the *Agronomy* series in 1957, there have been over 40,000 copies of numbers 7 through 16 distributed throughout the world. Other recent volumes are no. 16, *Soybeans: Improvement, Production, and Uses*; no. 15, *Alfalfa Science and Technology*; no. 14, *Turfgrass Science*; and no. 13, *Wheat and Wheat Improvement.* Several other topics are either in preparation or under consideration by the society for future monographs.

The society is associated with the Crop Science Society of America and the Soil Science Society of America. The three societies share many objectives and activities in promoting these branches of agriculture and scientific disciplines. The over 8,000 members of the associated societies are organized into 21 subject matter divisions and are located in over 80 countries around the world.

Drainage for Agriculture should be of great benefit to scientists, engineers, planners, contractors, and other workers who deal with land problems involving drainage of soil. From that standpoint the title could be considered a misnomer. The several chapters on theory offer information useful to a much broader audience than the agriculturists. Other chapters relating to soil properties and drainage principles provide information on numerous and broad types of applications. The American Society of Agronomy as an educational organization offers this book to the public in the hope that through the fundamental and applied material presented, it will help to solve many of the food production, land use, and environmental problems which face the people of the world today.

677 South Segoe Road
Madison, Wisconsin, 53711
March 1974

MATTHIAS STELLY
Editor-in-Chief
ASA Pulibcations

FOREWORD

This monograph is published at a very appropriate time. For the first time in this country, we are concerned that not enough land is available to meet our food, feed, and fiber needs and those of the overseas countries that have depended on the abundance from American agriculture. The era of agricultural surpluses has past and we are now striving to produce those agricultural products which used to be in super abundance.

With the goal of maximum production for American agriculture, comes the need to make every acre give its best level of production. Drainage is a limiting factor on many agricultural lands of this country. During the past two decades, there has been a host of scientific advances in the field of drainage. It is fitting then, that the state of the art be brought up to date. *Drainage for Agriculture* will make available more widely the newest knowledge, it will stimulate new research, and it will aid American agriculture and, indeed, world agriculture in helping to fulfill mankind's needs.

On behalf of the American Society of Agronomy, I wish to express thanks and appreciation to the members of the monograph committee, the authors, and to the editor, as well as to others who contributed to this book. Their efforts will stand as an important contribution to agriculture and to our profession.

Gainesville, Florida
April 1974

DARELL E. MC CLOUD
President
American Society of Agronomy

PREFACE

Why publish another book on the subject of drainage at this time? This question deserves a thoughtful answer.

Drainage for agriculture has been practiced for over 2000 years. In the second century B. C., the Roman Cato referred to the need for removing water from wet fields, stating that in low-lying areas, it is necessary to have many drains. The second half of the 19th century saw the beginning of the development of drainage theory, as well as the introduction of manufacturing processes for making drain tile and of mechanization for drain installation. The relationship between drainage, irrigation, and salinity was first placed into perspective in this country by E. W. Hilgard around the turn of the century. By the mid-1950's, the drainage industry was well established and a substantial body of knowledge had accumulated on both the practice and the theory. This led to Volume 7 of the present series, published in 1957.

Since that time, the rate of development has been rapid. New materials and new methods have revolutionized the industry while advances in theory, coupled with computer technology, have substantially broadened our understanding. The universal concern with water quality has focused attention on the interrelationships of water management practices and the constituents of drainage water. An expanding world population, together with a thrust towards improving living standards, has sharpened the awareness of the importance of rational water management for food production.

Thus the situation has changed sufficiently to warrant the compilation under one cover of many of the recent advances in drainage that should make possible significant progress in achieving the desired improvement in water management that will help feed the world population while maintaining values of environmental quality.

Within this framework, a small group of leaders in the field was convened in 1967 to delineate the scope of the volume that was to become *Agronomy* no. 17, *Drainage for Agriculture,* to develop an outline, and to identify appropriate contributors. This group consisted of J. W. Biggar, Herman Bouwer, Don Kirkham, and R. C. Reeve. The American Society of Agronomy and, especially, the editor, owe a debt of gratitude to these men for their important contribution to the planning.

The preparation of a book such as this requires the active participation of many individuals. The excellent cooperation of the many authors is gratefully acknowledged, as is the considerable assistance of a number of individuals who gave unstintingly of their time in reviewing various manuscript drafts.

Special thanks are due Thomas J. Thiel who accepted the task of preparing the index, using a computer program designed for information retrieval. His efforts represented a first for the American Society of Agronomy and, hopefully, the experience gained should lead to significant advances in reducing the time required for such a laborious task.

Riverside, California
March 1974

JAN VAN SCHILFGAARDE
Editor

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To convert column 1 into column 2, multiply by	Column 1	Column 2	To convert column 2 into column 1, multiply by
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in	2.54
	Area		
0.386	kilometer^2, km^2	mile^2, mi^2	2.590
247.1	kilometer^2, km^2	acre, acre	0.00405
2.471	hectare, ha	acre, acre	0.405
	Volume		
0.00973	meter^3, m^3	acre-inch	102.8
3.532	hectoliter, hl	cubic foot, ft^3	0.2832
2.838	hectoliter, hl	bushel, bu	0.352
0.0284	liter	bushel, bu	35.24
1.057	liter	quart (liquid), qt	0.946
	Mass		
1.102	ton (metric)	ton (English)	0.9072
2.205	quintal, q	hundredweight, cwt (short)	0.454
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp), oz	28.35
	Pressure		
14.50	bar	lb/inch^2, psi	0.06895
0.9869	bar	atmosphere,* atm	1.013
0.9678	kg(weight)/cm^2	atmosphere,* atm	1.033
14.22	kg(weight)/cm^2	lb/inch^2, psi	0.07031
14.70	atmosphere,* atm	lb/inch^2, psi	0.06805
	Yield or Rate		
0.446	ton (metric)/hectare	ton (English)/acre	2.240
0.892	kg/ha	lb/acre	1.12
0.892	quintal/hectare	hundredweight/acre	1.12
1.15	hectoliter/ha, hl/ha	bu/acre	0.87
	Temperature		
$\left(\frac{9}{5}\ °C\right) + 32$	Celsius	Fahrenheit	$\frac{5}{9}\ (°F - 32)$
	−17.8C	0F	
	0C	32F	
	20C	68F	
	100C	212F	
	Water Measurement		
8.108	hectare-meters, ha-m	acre-feet	0.1233
97.29	hectare-meters, ha-m	acre-inches	0.01028
0.08108	hectare-centimeters, ha-cm	acre-feet	12.33
0.973	hectare-centimeters, ha-cm	acre-inches	1.028
0.00973	meters^3, m^3	acre-inches	102.8
0.981	hectare-centimeters/hour, ha-cm/hour	feet^3/sec	1.0194
440.3	hectare-centimeters/hour, ha-cm/hour	U.S. gallons/min	0.00227
0.00981	meters^3/hour, m^3/hour	feet^3/sec	101.94
4.403	meters^3/hour, m^3/hour	U.S. gallons/min	0.227

* The size of an "atmosphere" may be specified in either metric or English units.

DRAINAGE OF AGRICULTURAL LANDS

AGRONOMY NO. 7

Edited by JAMES N. LUTHIN

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Agronomy Monograph no. 7 can be ordered from the American Society of Agronomy, 677 South Segoe Road, Madison, Wisconsin USA