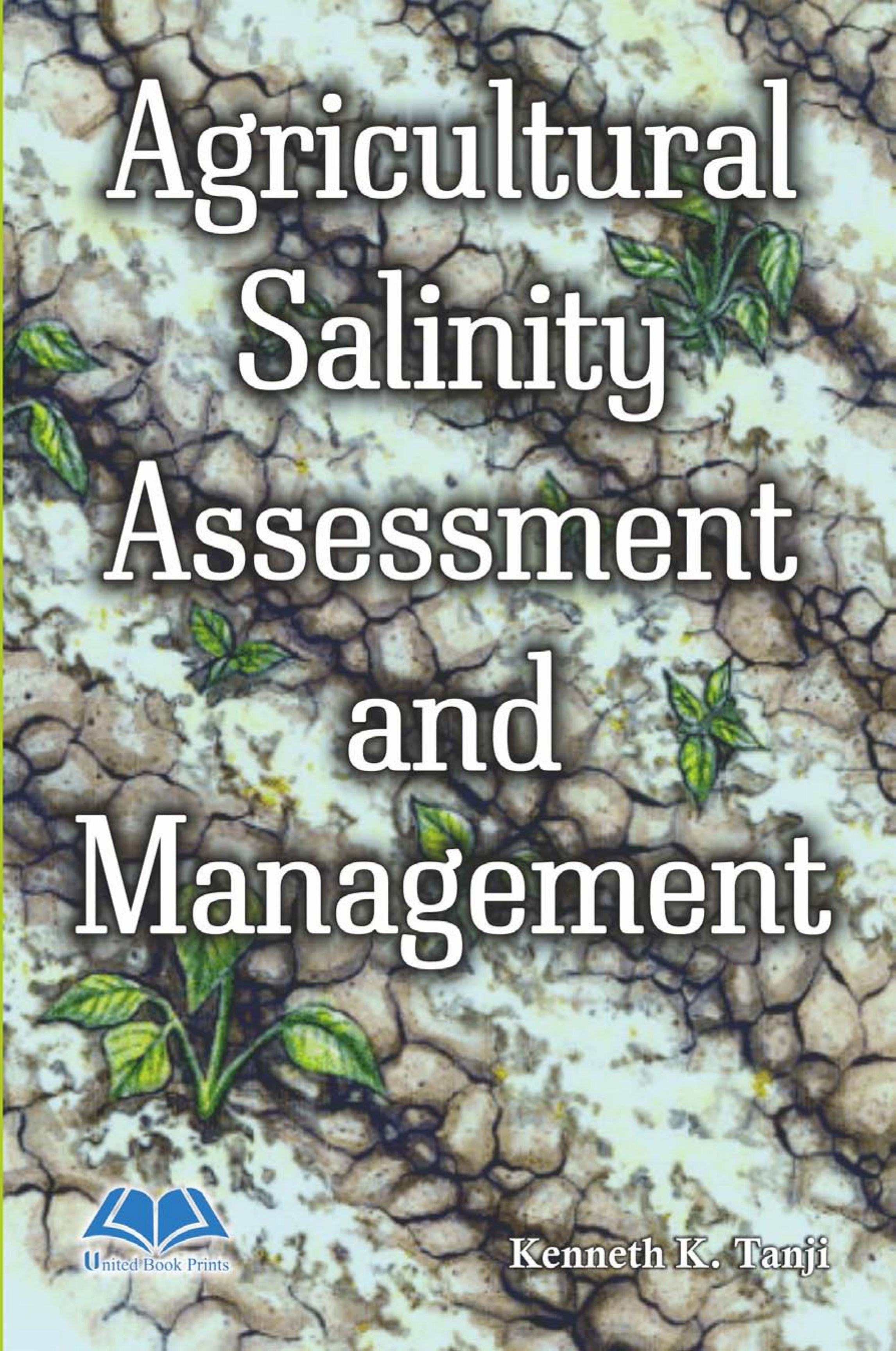

Agricultural Salinity Assessment and Management

Kenneth K. Tanji

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Agricultural Salinity Assessment and Management

Kenneth K. Tanji, Editor

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ABSTRACT

This manual, Agricultural Salinity Assessment and Management (Manual No. 71), integrates contemporary concepts and management practices for agricultural water and salinity problems. It consists of 28 chapters, written by 49 contributing authors, and covers not only the technical and scientific aspects of the topic but also the environmental, economic, and legal aspects. Some of the subjects discussed are: 1) The effects of salts on soil and plants, 2) the methods of sampling, monitoring, and measuring salinity; 3) the use of saline drainage water in irrigation; 4) the methods of managing salinity; and 5) the use of models in salinity assessment. Considering the topics covered, engineers, scientists, practitioners, and educators will find this manual to be a valuable resource on the mitigation of salinity problems in irrigated agriculture.

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Preface

In July 1984, Fred Hotes and Marvin E. Jensen suggested that ASCE produce a manual on agricultural salinity management. The Water Quality Technical Committee of the Irrigation and Drainage Division of ASCE accepted this challenge and appointed Kenneth K. Tanji of the University of California, Davis, as Project Coordinator to explore the development of such a manual.

After extensive consultations with colleagues in salinity research groups, cooperative extensions, universities, and regulatory and management agencies, Tanji submitted, in July 1986, a prospectus for a salinity manual. He outlined the needs for a manual that integrates contemporary concepts and management practices for agricultural water and salinity problems. He proposed that the manual be produced by an interdisciplinary team of authors and editors and that it contain engineering and scientific aspects as well as environmental, economic, and legal considerations. The principal objective was to prepare a manual that would be a valuable reference to a wide spectrum of users.

In September 1986, the Water Quality Technical Committee submitted a proposal to form a task committee for overseeing the development of the salinity manual. ASCE approved this proposal in February 1987. The task committee appointed an editorial committee in May 1987 to outline chapters, select contributing authors, and review outlines and manuscripts of chapters. In April 1988, as the draft of the manual was being developed, the executive committee of the Irrigation and Drainage Division appointed a peer review committee to independently review the manual. A complete draft of the manual was submitted to the Irrigation and Drainage Division in September 1989 for their approval and to the ASCE Board on Publications in October 1989.

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Division of Agriculture and Natural Resources, University of California for providing editorial and secretarial assistance and travel expenses for editorial committee meetings.

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Foreword

Salinity has plagued irrigated agriculture throughout history. Considerable progress has been made in managing and controlling salinity in irrigated lands on the basis that saline drainage waters would be disposed of somewhere. However, coping with salinity and drainage problems has become much more complex because of increasing environmental constraints on the discharge of drainage waters that contain salts and, in some instances, fertilizer and pesticide residues and naturally-occurring toxic trace elements.

The goal of this ASCE Salinity Manual is to bring together contemporary concepts and management practices addressing agricultural water and soil salinity problems that will be useful to engineers, scientists, practitioners and educators.

The manual consists of 28 chapters, written by 49 contributing authors. The manual is organized into ten sections: Introduction; Effects of Salts on Soils; Effects of Salts on Plants; Sampling, Monitoring, and Measurement; Diagnosis of Salt Problems; Salinity Management Options; Land Reclamation, Treatment and Disposal Of Drainage Waters; The Use of Models in Salinity Assessment; Environmental, Legal and Economic Issues; and The Future of Irrigated Agriculture.

This manual should be a valuable addition to earlier references regarding mitigation of salinity problems in irrigated agriculture, such as USDA Handbook No. 60, "Diagnosis and Improvement of Saline and Alkali Soils," published in 1954, and FAO Irrigation and Drainage Paper 29, "Water Quality for Agriculture," by R. Ayers and D. Westcot (1976, revised in 1985).

PART ONE—INTRODUCTION

CHAPTER 1

NATURE AND EXTENT OF AGRICULTURAL SALINITY[a]

INTRODUCTION

Irrigated agriculture has faced the challenge of sustaining its productivity for centuries. Because of natural hydrological and geochemical factors, as well as irrigation-induced activities, soil and water salinity and associated drainage problems continue to plague agriculture.

The problems have extended far beyond the farmlands, where saline soils and waters impair crop production. Practices based on the presumption that saline drainage waters will somehow, somewhere, be discharged are now being challenged. New and extended regulations on the discharge of nonpoint source pollutants in agricultural drainage waters are expected in the United States.

This chapter presents an overview of the nature of salinity in soils and waters, its extent from global to regional scales, the reactivity of salts and salt flows, and the concerns of agriculture and other sectors of society.

Nature of Agricultural Salt Problem

Salinity Constituents. Salinity is the concentration of dissolved mineral salts present in waters and soils on a unit volume or weight basis. The major solutes comprising dissolved mineral salts are the cations Na, Ca, Mg, and K and the anions Cl, SO_4, HCO_3, CO_3, and NO_3. Other constituents contributing toward salinity in hypersaline waters include B, Sr, Li, SiO_2, Rb, F, Mo, Mn, Ba, and Al.

Salinity Parameters. Salinity is expressed in a number of ways, depending on the method and purpose of the measurements. The salinity constituents listed above are frequently reported in terms of $mol_{(c)}/l$ (equivalents per liter) or mg/l (ppm) for major solutes and μg/l (ppb) for trace elements.

Salinity is often expressed as a lumped parameter, e.g., electrical conductivity (EC), an intensive parameter, total dissolved solids (TDS), an extensive gravimetric measure in mg/l, or total concentration of soluble cations (TSC) and anions (TSA) in $mol_{(c)}/l$. The EC of saline soils and waters are reported in decisiemens per meter (dS/m, which is equiv-

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alent to millimhos per cm) and the EC of lesser saline soils and waters in dS/m $\times$ 10^{-3} (or microsiemens/cm, which is equivalent to micromhos per cm).

No exact relationship exists between these measures of lumped salinity parameters, but TDS may be approximated by multiplying EC(dS/m) by a factor of 640 for lesser saline samples and a factor of 800 for hypersaline samples. To obtain TSC or TSA, multiply EC(dS/m) by a factor of 0.1 for $mol_{(c)}/l$ and a factor of 10.0 for $mmol_{(c)}/l$.

Salinity Measurements. The measurement of salinity in waters for EC, TDS, TSC, and TSA is straightforward. In contrast, soil-water contents significantly affect the measurement of salinity as a lumped parameter or dissolved mineral contents in soils. Soil salinity is typically measured (1) In a saturation soil extract; (2) in soil solutions extracted by vacuum in the field; or (3) by electroconductimetric methods. The concentration of salts in the soil solution does not typically change in proportion to change in soil-water contents because the major solute species participate in sink/source mechanisms, such as mineral precipitation and dissolution, cation exchange, and ion association (Tanji et al., 1967). Moreover, salinity is a dynamic property in soil-water systems, as it is highly mobile and related to water content.

Salinity Criterion. The criterion used for salinity hazard depends on the use of the water or soil. For instance, an irrigation water of EC < 0.7 dS/m poses little or no threat to most crops, while EC > 3.0 dS/m may restrict the growth of most crops (Ayers and Westcot 1985). A soil with an EC > 4 dS/m in the soil saturation extract is traditionally characterized as a saline soil (Richards 1954). Soil and water salinity decreases the availability of soil water and leads to reduced germination, growth, and yields.

Furthermore, certain constituents in waters or soils, such as B, may be toxic to plant growth. Others, such as Na, detrimentally affect the soil's physical properties, such as its infiltration rate. Therefore, characterizing a water or soil as saline is relative and may vary widely, since responses by plants and soils to salinity are highly variable.

Sources of Salts. The problem of salinity manifests itself in the environment in a number of ways: saline irrigation and drainage waters, saline and sodic soils, saline ground waters, seawater intrusion, brines from natural salt deposits or geologic formations, and brines from oil and gas fields and mining.

The primary source of salts in waters and soils is the chemical weathering of earth materials, i.e., minerals that are constituents of rocks and soils. Evaporative salinization, e.g., surface evaporation of water and transpiration by plants, and dilution, e.g., rainfall, snowmelt waters, and irrigation waters, affect the level of concentration of dissolved mineral salts. Mineral solubility principally regulates the extent to which salts accumulate or dissolve.

Natural secondary sources of salts include atmospheric deposits of oceanic salts along coastal areas, seawater intrusion into estuaries due to tidal events, seawater intrusion into ground-water basins in coastal