

# Challenges and Strategies of Dryland Agriculture





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**Srinivas C. Rao and John Ryan, *co-editors***

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## FOREWORD

The world has made remarkable progress in maintaining adequate food supplies during the past quarter century by introducing yield-increasing technologies such as better genetics, crop protection products, and more efficient use of fertilizers and irrigation. Far more people depend on irrigation in the modern world than during the times of ancient Sumeria. The spread of irrigation has been the key factor in increasing global crop yields. But future water scarcity presents the single biggest threat to future food production. The shift of water from agriculture to the growing cities and industry almost certainly will impact global food production. This means that dryland agriculture will be increasingly important in meeting food requirement for the growing population. Advances in plant genetics and agronomic conservation technologies, when considered in concert, continue to provide the greatest opportunities to achieve sustainability and profitability in dryland agriculture and will continue to be the focus of the ARS research program.

The ARS is pleased to join the Crop Science Society of America and International Center for Agriculture Research in Dry Areas (ICARDA) in sponsoring a symposium “Challenges and Strategies for Dryland Agriculture” at the Tri-Societies Annual Meeting in November 2002 at Indianapolis, IN.

This special publication contains an impressive series of papers by an international group of experts on dryland agricultural production, conservation, and policy. The principles, philosophies, and technologies presented in this publication have the potential to contribute to improve food security and livelihoods for the people in dryland regions of the world.

Edward B. Knipling  
Acting Administrator  
USDA-ARS  
Washington, DC



## PREFACE

The world's population has more than doubled in the last half century, reaching 6 billion in 1999, and is projected to grow to 9.3 billion by the Year 2050. As a consequence of more people on this earth that need to be fed, in addition to rising incomes in some countries, the demand for food is expected to increase by 50% by 2015 and to more than double by 2050. It is this grim reality that agriculture as a profession faces—the challenge has to be met by everyone involved in the food production chain, from researchers to farmers, and all in between. Today, the world's population is better nourished than any time in history. The advances in global food production in the 20th century have dispelled, at least temporarily, the dire predictions of Malthus. Yet, despite such achievements, poverty and malnutrition, and their associated societal consequences, are the lot of numerous people in developing countries, especially in Africa and Asia.

In assessing modern agricultural practices and technology, it is important to distill both the limits and potential for sustaining global food supplies without degrading the resource base. Over the past three decades, expansion of irrigation, high-yielding varieties, and fertilizer input have been the major factors in achieving self-sufficiency in food grain production. On a worldwide basis, agriculture accounts for about 70% of all annual water withdrawals, and significant areas of irrigated lands are degraded to some extent by waterlogging and salinization. Another major pressure that leads to declining irrigation is high energy costs associated with delivering water to crops. With burgeoning populations, renewable fresh water resources are subject to severe competition between agriculture, industrial, and residential uses. Demand is increasing for all these uses. The shift of water from agriculture to urbanized societies and industry may hinder future global food production.

Given the pressure on the world's ecosystems, dryland agriculture, a sector that has been neglected in the past, will be increasingly important in meeting food requirements in the future. Globally, 90% of cropland is classified as dryland, and these lands provide 67% of all crop production and about half of the economic value of all crops. However, it is estimated that more than two-thirds of the potentially productive drylands are threatened by various forms of degradation. Therefore, it is essential that appropriate production technology be developed in the future to protect the fragile drylands in the process of meeting the needs of world's future population.

This timely symposium—the first major international meeting on the subject for many years—has brought dryland agriculture into the forefront of international agricultural research, as well as highlight the role of the world's major national and international research centers in addressing the problems of drylands. It was with this background, the Crop Science Society of America, the American Society of Agronomy, USDA-ARS, and the International Center for Agricultural Research in the Dry Area (ICARDA) sponsored a symposium addressing the wide array of issues associated with “Challenges and Strategies of Dryland Agriculture into the New Millennium” at the 2002 Annual Meetings of the Tri-Societies in Indianapolis, IN.

As Editors of this special publication, we express our gratitude to the authors who submitted their manuscripts in a timely manner to us. A particular thanks is due to those authors who, though not present or participating in the meeting itself, responded to the call for additional papers. Their contributions considerably complemented the subject-matter issues and undoubtedly widen the technical and geographical appeal of this volume. We also thank many scientists who served as reviewers for the chapters. In addition, we express our sincere appreciation to USDA-ARS Office of Technology Transfer, USDA-ARS Office of International Research Programs, USDA-ARS Grazing Lands Research Laboratory, and ICARDA for providing financial assistance for publication of this book.

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## **Conversion Factors for SI and non-SI Units**

Conversion Factors for SI and non-SI Units

To convert Column 1 into Column 2, multiply by	Column 1 SI Unit	Column 2 non-SI Units	To convert Column 2 into Column 1, multiply by
Length			
0.621	kilometer, km (10 <sup>3</sup> m)	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
3.28	meter, m	foot, ft	0.304
1.0	micrometer, μm (10 <sup>-6</sup> m)	micron, μ	1.0
3.94 × 10 <sup>-2</sup>	millimeter, mm (10 <sup>-3</sup> m)	inch, in	25.4
10	nanometer, nm (10 <sup>-9</sup> m)	Angstrom, Å	0.1
Area			
2.47	hectare, ha	acre	0.405
247	square kilometer, km <sup>2</sup> (10 <sup>3</sup> m) <sup>2</sup>	acre	4.05 × 10 <sup>-3</sup>
0.386	square kilometer, km <sup>2</sup> (10 <sup>3</sup> m) <sup>2</sup>	square mile, mi <sup>2</sup>	2.590
2.47 × 10 <sup>-4</sup>	square meter, m <sup>2</sup>	acre	4.05 × 10 <sup>3</sup>
10.76	square meter, m <sup>2</sup>	square foot, ft <sup>2</sup>	9.29 × 10 <sup>-2</sup>
1.55 × 10 <sup>-3</sup>	square millimeter, mm <sup>2</sup> (10 <sup>-3</sup> m) <sup>2</sup>	square inch, in <sup>2</sup>	645
Volume			
9.73 × 10 <sup>-3</sup>	cubic meter, m <sup>3</sup>	acre-inch	102.8
35.3	cubic meter, m <sup>3</sup>	cubic foot, ft <sup>3</sup>	2.83 × 10 <sup>-2</sup>
6.10 × 10 <sup>4</sup>	cubic meter, m <sup>3</sup>	cubic inch, in <sup>3</sup>	1.64 × 10 <sup>-5</sup>
2.84 × 10 <sup>-2</sup>	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	bushel, bu	35.24
1.057	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	quart (liquid), qt	0.946
3.53 × 10 <sup>-2</sup>	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	cubic foot, ft <sup>3</sup>	28.3
0.265	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	gallon	3.78
33.78	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	ounce (fluid), oz	2.96 × 10 <sup>-2</sup>
2.11	liter, L (10 <sup>-3</sup> m <sup>3</sup> )	pint (fluid), pt	0.473

Mass		
$2.20 \times 10^{-3}$	gram, g ( $10^{-3}$ kg)	pound, lb
$3.52 \times 10^{-2}$	gram, g ( $10^{-3}$ kg)	ounce (avdp), oz
2.205	kilogram, kg	pound, lb
0.01	kilogram, kg	quintal (metric), q
$1.10 \times 10^{-3}$	kilogram, kg	ton (2000 lb), ton
1.102	megagram, Mg (tonne)	ton (U.S.), ton
1.102	tonne, t	ton (U.S.), ton
Yield and Rate		
0.893	kilogram per hectare, kg ha <sup>-1</sup>	pound per acre, lb acre <sup>-1</sup>
$7.77 \times 10^{-2}$	kilogram per cubic meter, kg m <sup>-3</sup>	pound per bushel, lb bu <sup>-1</sup>
$1.49 \times 10^{-2}$	kilogram per hectare, kg ha <sup>-1</sup>	bushel per acre, 60 lb
$1.59 \times 10^{-2}$	kilogram per hectare, kg ha <sup>-1</sup>	bushel per acre, 56 lb
$1.86 \times 10^{-2}$	kilogram per hectare, kg ha <sup>-1</sup>	bushel per acre, 48 lb
0.107	liter per hectare, L ha <sup>-1</sup>	gallon per acre
893	tonne per hectare, t ha <sup>-1</sup>	pound per acre, lb acre <sup>-1</sup>
893	megagram per hectare, Mg ha <sup>-1</sup>	pound per acre, lb acre <sup>-1</sup>
0.446	megagram per hectare, Mg ha <sup>-1</sup>	ton (2000 lb) per acre, ton acre <sup>-1</sup>
2.24	meter per second, m s <sup>-1</sup>	mile per hour
Specific Surface		
10	square meter per kilogram, m <sup>2</sup> kg <sup>-1</sup>	square centimeter per gram, cm <sup>2</sup> g <sup>-1</sup>
1000	square meter per kilogram, m <sup>2</sup> kg <sup>-1</sup>	square millimeter per gram, mm <sup>2</sup> g <sup>-1</sup>
Density		
1.00	megagram per cubic meter, Mg m <sup>-3</sup>	gram per cubic centimeter, g cm <sup>-3</sup>
Pressure		
9.90	megapascal, MPa ( $10^6$ Pa)	atmosphere
10	megapascal, MPa ( $10^6$ Pa)	bar
$2.09 \times 10^{-2}$	pascal, Pa	pound per square foot, lb ft <sup>-2</sup>
$1.45 \times 10^{-4}$	pascal, Pa	pound per square inch, lb in <sup>-2</sup>
6.90 × 10 <sup>3</sup>		

(continued on next page)

Conversion Factors for SI and non-SI Units

To convert Column 1 into Column 2, multiply by		Column 1 SI Unit	Column 2 non-SI Units	To convert Column 2 into Column 1, multiply by	
Temperature					
1.00 (K – 273)		kelvin, K	Celsius, °C	1.00 (°C + 273)	
(9/5 °C) + 32		Celsius, °C	Fahrenheit, °F	5/9 (°F – 32)	
Energy, Work, Quantity of Heat					
9.52 × 10 <sup>-4</sup>		joule, J	British thermal unit, Btu	1.05 × 10 <sup>3</sup>	
0.239		joule, J	calorie, cal	4.19	
10 <sup>7</sup>		joule, J	erg	10 <sup>-7</sup>	
0.735		joule, J	foot-pound	1.36	
2.387 × 10 <sup>-5</sup>		joule per square meter, J m <sup>-2</sup>	calorie per square centimeter (langley)	4.19 × 10 <sup>4</sup>	
10 <sup>5</sup>		newton, N	dyne	10 <sup>-5</sup>	
1.43 × 10 <sup>-3</sup>		watt per square meter, W m <sup>-2</sup>	calorie per square centimeter minute (irradiance), cal cm <sup>-2</sup> min <sup>-1</sup>	698	
Transpiration and Photosynthesis					
3.60 × 10 <sup>-2</sup>		milligram per square meter second, mg m <sup>-2</sup> s <sup>-1</sup>	gram per square decimeter hour, g dm <sup>-2</sup> h <sup>-1</sup>	27.8	
5.56 × 10 <sup>-3</sup>		milligram (H <sub>2</sub> O) per square meter second, mg m <sup>-2</sup> s <sup>-1</sup>	micromole (H <sub>2</sub> O) per square centi- meter second, μmol cm <sup>-2</sup> s <sup>-1</sup>	180	
10 <sup>-4</sup>		milligram per square meter second, mg m <sup>-2</sup> s <sup>-1</sup>	milligram per square centimeter second, mg cm <sup>-2</sup> s <sup>-1</sup>	10 <sup>4</sup>	
35.97		milligram per square meter second, mg m <sup>-2</sup> s <sup>-1</sup>	milligram per square decimeter hour, mg dm <sup>-2</sup> h <sup>-1</sup>	2.78 × 10 <sup>-2</sup>	
Plane Angle					
57.3		radian, rad	degrees (angle), °	1.75 × 10 <sup>-2</sup>	

Electrical Conductivity, Electricity, and Magnetism

10	siemen per meter, S m <sup>-1</sup>	millimho per centimeter, mmho cm <sup>-1</sup>	0.1
10 <sup>4</sup>	tesla, T	gauss, G	10 <sup>-4</sup>

Water Measurement

9.73 × 10 <sup>-3</sup>	cubic meter, m <sup>3</sup>	acre-inch, acre-in	102.8
9.81 × 10 <sup>-3</sup>	cubic meter per hour, m <sup>3</sup> h <sup>-1</sup>	cubic foot per second, ft <sup>3</sup> s <sup>-1</sup>	101.9
4.40	cubic meter per hour, m <sup>3</sup> h <sup>-1</sup>	U.S. gallon per minute, gal min <sup>-1</sup>	0.227
8.11	hectare meter, ha m	acre-foot, acre-ft	0.123
97.28	hectare meter, ha m	acre-inch, acre-in	1.03 × 10 <sup>-2</sup>
8.1 × 10 <sup>-2</sup>	hectare centimeter, ha cm	acre-foot, acre-ft	12.33

Concentrations

1	centimole per kilogram, cmol kg <sup>-1</sup>	milliequivalent per 100 grams, meq 100 g <sup>-1</sup>	1
0.1	gram per kilogram, g kg <sup>-1</sup>	percent, %	10
1	milligram per kilogram, mg kg <sup>-1</sup>	parts per million, ppm	1

Radioactivity

2.7 × 10 <sup>-11</sup>	becquerel, Bq	curie, Ci	3.7 × 10 <sup>10</sup>
2.7 × 10 <sup>-2</sup>	becquerel per kilogram, Bq kg <sup>-1</sup>	picrocurie per gram, pCi g <sup>-1</sup>	37
100	gray, Gy (absorbed dose)	rad, rd	0.01
100	sievert, Sv (equivalent dose)	rem (roentgen equivalent man)	0.01

Plant Nutrient Conversion

<i>Elemental</i>		<i>Oxide</i>	
2.29	P	P <sub>2</sub> O <sub>5</sub>	0.437
1.20	K	K <sub>2</sub> O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602

