Published 1990

Impact of Carbon Dioxide, Trace Gases, and Climate Change on Global Agriculture

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Proceedings of a symposium sponsored by Divisions A-3, A-6, S-6, A-5, C-3, S-1, C-2, S-3, and S-5 of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America with support from the USDA-ARS. The symposium was held in Anaheim, CA, 1 December 1988.

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ASA Special Publication Number 53

American Society of Agronomy, Inc.
Crop Science Society of America, Inc.
Soil Science Society of America, Inc.

1990

Cover Design: Patricia J. Scullion

Second Printing 1992

American Society of Agronomy, Inc.
Crop Science Society of America, Inc.
Soil Science Society of America, Inc.
677 South Segoe Road, Madison,WI 53711 USA

Library of Congress Cataloging-in-Publication Data

Impact of carbon dioxide, trace gases, and climate change on global agriculture : proceedings of a symposium / sponsored by divisions A-3 . . . [et al.] of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America with support from the USDA-ARS ; editorial committee, Bruce A. Kimball, chair . . . [et al.].
p. cm. — (ASA special publication ; no. 53)
"The symposium was held in Anaheim, CA, 1 December 1988."
Includes bibliographical references.
ISBN 0-89118-103-2 (paperback)
1. Climatic changes—Congresses. 2. Meteorology, Agricultural—Congresses. 3. Atmospheric carbon dioxide—Congresses. 4. Greenhouse gases—Congresses. I. Kimball, Bruce A. II. American Society of Agronomy. Division A-3. III. Crop Science Society of America. IV. Soil Science Society of America. V. Series.
S1.A453 no. 53
[S600.7.C64]
630 s—dc20
[632'.1] 90-37086
CIP

This book is printed on acid-free paper.

Printed in the United States of America

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FOREWORD

Global climate change is one of several important issues that will command the attention of policymakers and scientists in the 1990s. The evidence that concentrations of carbon dioxide (CO_2), and other gases are increasing in the atmosphere is irrefutable. This evidence, and the knowledge that CO_2 and trace gases may absorb thermal radiation sufficient to warm the atmosphere, has prompted much speculation that ensuing atmospheric warming may lead to changes in the distribution of precipitation, and of crop adaptation and productivity, that would alter the world supply of food and fiber. The implications of this speculation are compelling for agronomists, because agronomists are stewards of the world's food supply and of the natural resources that are used to produce food. Agronomists have a pivitol role in conducting the research needed to anticipate crop response to climate change, and in informing policymakers and the general public about the adequacy of our knowledge.

In this publication, leading scientists from the international community of agronomists assess the current status of scientific knowledge about the putative role of greenhouse gases in global climate change and report their findings. The information will be useful not only to scientists, but also to policymakers as background for deliberation on farm, environmental, and agricultural research legislation.

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PREFACE[1]

The concentrations of CO_2 and some other radiatively active trace gases are increasing in the global atmosphere, and these changes in composition have been predicted to significantly warm the Earth (the "greenhouse effect") and possibly to alter precipitation patterns, as described by Taylor and MacCracken (Chapter 1). Agricultural productivity is greatly dependent on climate and weather, so these predictions or projections of climatic change should be of concern to agronomists and other agricultural scientists. Moreover, Burke and Lashof (Chapter 3) indicate agricultural practices and changing patterns of land use affect the emission rates of greenhouse gases. So to some extent, agriculture not only is vulnerable to the effects of climate change, but it is a possible cause as well. Not everyone agrees with the prediction of warming (Idso, Chapter 2), but nevertheless, it is prudent that we begin to consider the possibility of climate change and to make our planning for the future of agriculture as flexible as possible.

Even if climate does not change, the increased CO_2 concentration will significantly affect the growth of plants and probably increase agricultural productivity (Acock, Chapter 4). If climate does change, however, significant interactions are likely to occur between the CO_2 and the climate variables in their effects on plant growth (Idso, Chapter 5; Goudriaan & Unsworth, Chapter 8). These growth changes will not only affect our crop plants, but they will also affect the weeds with which they compete; and of course, competitive advantages among species growing in the wild may shift, so that the composition of plant communities may be altered (Patterson & Flint, Chapter 7). If the climate warms, soil organic matter content is likely to decrease while total N may increase in the temperate zone, but no major changes in fertilization practices are predicted (Buol et al., Chapter 6). Yet, even while global CO_2 and climate changes may be affecting worldwide agricultural production, the availability of one important resource for coping with hotter and drier conditions, irrigation water, may be adversely affected (Goudriaan & Unsworth, Chapter 8). Thus, in this book we attempt to review what can reasonably be inferred from the scientific literature about the effects of elevated CO_2 and changing climate on crop production and to describe their possible consequences for the future of agriculture.

This book is a direct result of a symposium held on 1 December 1988 at the American Society of Agronomy Annual Meeting in Anaheim, CA. Each chapter has been written by an invited expert speaker to that symposium, with the help of coauthors they have enlisted. Early in 1987, when first elected to be the 1988 program chair for Division A-3, several colleagues urged me to organize a symposium on this timely topic. That it was timely proved to be an understatement when the Midwest drought of the summer of 1988 became headline news across the USA and raised the public consciousness level about the possibility that the greenhouse effect might be real and that the climate might already have changed. Only a few atmospheric scientists publicly attributed the USA drought of 1988 to the greenhouse effect.

[1] Contribution from the USDA-ARS.

Nevertheless, the interest in the topic and the symposium was high, and hopefully will also be high for this book.

In addition to the invited speakers (who, along with their coauthors, have produced the chapters in this book), the symposium also featured a session with 14 volunteered posters. Although the goal of the invited papers and this book was to review existing information and synthesize principles, the posters presented new research results, which also contributed to the interest in and success of the symposium. The abstracts of these poster presentations are in the 1988 Agronomy Abstracts (published by the American Society of Agronomy), but as an acknowledgement of their important contribution to the symposium and as an aid to the reader, a list of the poster presentations is included in Appendix A.

Several other acknowledgments are appropriate for contributions to the symposium and to this book. First, I thank the speakers and presenters who produced stimulating talks and posters that made the symposium a success. Similarly, I thank the authors and coauthors for writing their book chapters that provide an excellent compilation of current knowledge on this topic. Also toward this end, I appreciate the efforts of my colleagues on the editorial committee, Drs. Norman J. Rosenberg and Leon Hartwell Allen, Jr., who took their role seriously by rigorously and fairly reviewing and editing the manuscripts. Next, I wish to thank the 1988 program chairs of the several other divisions who cosponsored the symposium, particularly those who pledged financial support. The encouragement and the solicitations of financial support for the symposium by 1988 ASA program chair Dr. E.C.A. Runge are greatly appreciated. Similarly, the encouragement and suggestions of Dr. Roger C. Dahlman, Department of Energy, Carbon Dioxide Research Division, were helpful in shaping the symposium. Finally, the grant from the USDA-ARS, which provided travel expenses for the "non-society" speakers, is gratefully acknowledged.

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

	Mass		
2.20×10^{-3}	gram, g (10^{-3} kg)	pound, lb	454
3.52×10^{-2}	gram, g (10^{-3} kg)	ounce (avdp), oz	28.4
2.205	kilogram, kg	pound, lb	0.454
0.01	kilogram, kg	quintal (metric), q	100
1.10×10^{-3}	kilogram, kg	ton (2000 lb), ton	907
1.102	megagram, Mg (tonne)	ton (U.S.), ton	0.907
1.102	tonne, t	ton (U.S.), ton	0.907
	Yield and Rate		
0.893	kilogram per hectare, kg ha^{-1}	pound per acre, lb $acre^{-1}$	1.12
7.77×10^{-2}	kilogram per cubic meter, kg m^{-3}	pound per bushel, lb bu^{-1}	12.87
1.49×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 60 lb	67.19
1.59×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 56 lb	62.71
1.86×10^{-2}	kilogram per hectare, kg ha^{-1}	bushel per acre, 48 lb	53.75
0.107	liter per hectare, L ha^{-1}	gallon per acre	9.35
893	tonnes per hectare, t ha^{-1}	pound per acre, lb $acre^{-1}$	1.12×10^{-3}
893	megagram per hectare, Mg ha^{-1}	pound per acre, lb $acre^{-1}$	1.12×10^{-3}
0.446	megagram per hectare, Mg ha^{-1}	ton (2000 lb) per acre, ton $acre^{-1}$	2.24
2.24	meter per second, m s^{-1}	mile per hour	0.447
	Specific Surface		
10	square meter per kilogram, m^2 kg^{-1}	square centimeter per gram, cm^2 g^{-1}	0.1
1000	square meter per kilogram, m^2 kg^{-1}	square millimeter per gram, mm^2 g^{-1}	0.001
	Pressure		
9.90	megapascal, MPa (10^6 Pa)	atmosphere	0.101
10	megapascal, MPa (10^6 Pa)	bar	0.1
1.00	megagram per cubic meter, Mg m^{-3}	gram per cubic centimeter, g cm^{-3}	1.00
2.09×10^{-2}	pascal, Pa	pound per square foot, lb ft^{-2}	47.9
1.45×10^{-4}	pascal, Pa	pound per square inch, lb in^{-2}	6.90×10^3

(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 Unit	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^{-4}	joule, J	British thermal unit, Btu	1.05×10^{3}
0.239	joule, J	calorie, cal	4.19
10^{7}	joule, J	erg	10^{-7}
0.735	joule, J	foot-pound	1.36
2.387×10^{-5}	joule per square meter, J m^{-2}	calorie per square centimeter (langley)	4.19×10^{4}
10^{5}	newton, N	dyne	10^{-5}
1.43×10^{-3}	watt per square meter, W m^{-2}	calorie per square centimeter minute (irradiance), cal cm^{-2} min^{-1}	698
		Transpiration and Photosynthesis	
3.60×10^{-2}	milligram per square meter second, mg m^{-2} s^{-1}	gram per square decimeter hour, g dm^{-2} h^{-1}	27.8
5.56×10^{-3}	milligram (H_2O) per square meter second, mg m^{-2} s^{-1}	micromole (H_2O) per square centimeter second, μmol cm^{-2} s^{-1}	180
10^{-4}	milligram per square meter second, mg m^{-2} s^{-1}	milligram per square centimeter second, mg cm^{-2} s^{-1}	10^{4}
35.97	milligram per square meter second, mg m^{-2} s^{-1}	milligram per square decimeter hour, mg dm^{-2} h^{-1}	2.78×10^{-2}
		Plane Angle	
57.3	radian, rad	degrees (angle), °	1.75×10^{-2}

	Electrical Conductivity, Electricity, and Magnetism		
10	siemen per meter, $S\ m^{-1}$	millimho per centimeter, $mmho\ cm^{-1}$	0.1
10^4	tesla, T	gauss, G	10^{-4}
	Water Measurement		
9.73×10^{-3}	cubic meter, m^3	acre-inches, acre-in	102.8
9.81×10^{-3}	cubic meter per hour, $m^3\ h^{-1}$	cubic feet per second, $ft^3\ s^{-1}$	101.9
4.40	cubic meter per hour, $m^3\ h^{-1}$	U.S. gallons per minute, $gal\ min^{-1}$	0.227
8.11	hectare-meters, ha-m	acre-feet, acre-ft	0.123
97.28	hectare-meters, ha-m	acre-inches, acre-in	1.03×10^{-2}
8.1×10^{-2}	hectare-centimeters, ha-cm	acre-feet, acre-ft	12.33
	Concentrations		
1	centimole per kilogram, $cmol\ kg^{-1}$ (ion exchange capacity)	milliequivalents per 100 grams, meq $100\ g^{-1}$	1
0.1	gram per kilogram, $g\ kg^{-1}$	percent, %	10
1	milligram per kilogram, $mg\ kg^{-1}$	parts per million, ppm	1
	Radioactivity		
2.7×10^{-11}	becquerel, Bq	curie, Ci	3.7×10^{10}
2.7×10^{-2}	becquerel per kilogram, $Bq\ kg^{-1}$	picocurie per gram, $pCi\ g^{-1}$	37
100	gray, Gy (absorbed dose)	rad, rd	0.01
100	sievert, Sv (equivalent dose)	rem (roentgen equivalent man)	0.01
	Plant Nutrient Conversion		
	Elemental	***Oxide***	
2.29	P	P_2O_5	0.437
1.20	K	K_2O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602