Conservation Agriculture
Muhammad Farooq • Kadambot H. M. Siddique
Editors

Conservation Agriculture
Foreword

Conventional agriculture has largely been characterized by tillage, which leaves soil vulnerable to erosion. Continuous use of conventional farming practices with conventional tillage and burning crop residues has degraded the soil resource base and intensified soil degradation, with concomitant decreases in crop production capacity. Soil loss is expected to be a critical issue for global agricultural production under conventional farming practices. For instance, global erosion rates from conventionally ploughed agricultural fields averaged one to two orders of magnitude greater than erosion under native vegetation, long-term geological erosion and rates of soil production. Likewise, conventional tillage has also made agriculture a major contributor to global warming due to increasing greenhouse gas emissions. Soil and vegetation on the earth’s land surface store three times as much carbon as is present in the earth’s atmosphere. Land clearing and degradation turn this valuable carbon sink into a major source of greenhouse gas emissions.

Conservation agriculture is widely recognized as a viable approach to creating a sustainable agriculture. It is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with four interrelated principles viz. minimal soil disturbance, permanent residue cover, planned crop rotations and integrated weed management, along with other good production practices of plant nutrition and pest management.

Conservation agriculture is environment friendly and requires less fuel, resulting in lower emissions of carbon dioxide—one of the gases responsible for global warming. In addition, conservation agriculture is very effective in reducing soil erosion. A wide range of other environmental benefits accrue in conservation agriculture, including reduced run-off, improved nutrient cycling, reduced soil degradation, reduced soil and water pollution and enhanced activities of soil biota.

Although several papers and conference proceedings are available on the subject, a comprehensive textbook on conservation agriculture was lacking. This book is a timely effort to fill the gap. The book describes various elements of conservation agriculture, highlights the associated breeding and modeling efforts, analyses the experiences and challenges in conservation agriculture in different regions and proposes some pragmatic options and new areas of research in this very important area of agriculture.
I anticipate that this volume will be a ready reference on conservation agriculture and will reinforce the understanding for its utilization to develop environmentally sustainable and profitable food production systems.

Dr. Nick Austin
Chief Executive Officer
Australian Centre for International Agricultural Research
Canberra, Australia
Preface

The conventional mode of agriculture through intensive agricultural practices achieves production goals, but simultaneously degrades the natural resources. The growing concerns for sustainable agriculture are in response to the limitations of both low-input, traditional agriculture and intensive modern agriculture relying on high levels of inputs for crop production. Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes such as nitrogen fixation, nutrient cycling, soil regeneration, and the protection of natural enemies of pest and diseases as well as the targeted use of inputs. Agricultural systems relying on such approaches not only support high productivity, but also preserve biodiversity and safeguard the environment. Conservation agriculture is a new paradigm for achieving sustained agricultural production and is a major step in the transition to sustainable agriculture.

Over the past few decades, resource conservation technologies, such as zero and reduced-tillage systems, better crop residue management and planting systems, have evolved to enhance water and nutrient conservation. Conservation agriculture—an array of four components including permanent soil cover, minimum soil disturbance, diversified crop rotations and integrated weed management—is now considered the principal road to sustainable agriculture and the protection of natural resources and the environment. Currently, conservation agriculture is practiced on more than 125 million ha worldwide.

While the adoption of conservation agriculture is increasing globally, in some regions it is either slow or non-existent. As a result, we felt it timely to collect and synthesize the latest developments on conservation agriculture research. The contents of this book are divided into five sections and 23 chapters as detailed below:

(1) Introduction
   Chapter 1 is a brief history and overview of the components and adaptation of conservation agriculture.

(2) Elements of conservation agriculture
   • Chapter 2 collates and performs a meta-analysis on existing literature on the effect of crop rotations and crop residue management on maize grain yield under conservation agriculture.
• Chapter 3 describes weed problem in conservation agriculture systems and proposes the strategies for integrated weed management.
• Chapter 4 discusses the nutrient management perspectives in conservation agriculture, and suggests the strategies for improving the nutrient use efficiency in conservation agriculture systems.
• Chapter 5 is an overview of the essential machinery requirements for the different farm operations involved in conservation agriculture. Regional-specific issues with emphasis on developing countries are also discussed, and pragmatic solutions of vital interest to researchers, academia and policy makers globally are proposed.
• Chapter 6 describes the impact of conservation agriculture on the prevalence of insects, insect biodiversity, and proposes options for integrated insect pest management in conservation agriculture.

(3) Modeling and crop improvement for conservation agriculture
• Chapter 7 covers crop breeding for conservation agriculture. Crop improvement and breeding strategies are proposed to develop improved crop genotypes better adapted to conservation agriculture.
• Chapter 8 introduces the SALUS model and its tillage component to evaluate the effects of tillage on soil water infiltration, time to ponding and soil biophysical properties.

(4) The status of conservation agriculture including some case studies
• Chapter 9 discusses the evolution and adoption of conservation agriculture in the Middle East.
• Chapter 10 discusses Syrian experiences on conservation agriculture.
• Chapter 11 describes the experiences, challenges and options regarding conservation agriculture in South Asia.
• Chapter 12 covers conservation agriculture in South East Asia and introduces the Conservation Agriculture Network for South East Asia.
• Chapter 13 discusses conservation agriculture in China, particularly in rainfed areas, including early history and progress on research and adoption for better soil and water conservation.
• Chapter 14 discusses the future of conservation farming in Australia and New Zealand, and recent advances in weed control strategies.
• Chapter 15 outlines future prospects for up-scaling of conservation agriculture in Europe, and describes the likely impact of global changes and constraints for its adoption and spread.
• Chapter 16 describes the origins and impacts of conservation agriculture in different regions of Latin America, highlights the factors limiting its adoption and outlines the innovations and strategies developed in some countries to overcome these limitations.
• Chapter 17 illustrates the diversity of conservation agriculture adoption in North America, and provides an overview of several contrasting production regions.
• Chapter 18 describes the diversity and heterogeneity of farms in sub-Saharan Africa, and highlights the experiences and constraints in conservation agriculture in the region.

(5) Conservation agriculture in agricultural systems.

• Chapter 19 covers the sustainable use of soil and other natural resources in relation to agronomic productivity and environment quality. It also addresses soil C sequestration potential through conservation agriculture, and its management in diverse soils and agro-ecosystems.
• Chapter 20 discusses the potential applications of microbiology in conservation agriculture.
• Chapter 21 discusses the experiences, challenges and opportunities of conservation agriculture in organic farming in Europe.
• Chapter 22 outlines the potential role of conservation agriculture in mitigating the impact of climate change on crop production.
• Chapter 23 discusses the factors driving the adoption of conservation agriculture and proposes some possible future directions for conservation agriculture adoption research.

Professor Kadambot Siddique’s research on conservation agriculture is partly funded by the Australian Centre for International Agricultural Research (ACIAR) and is gratefully acknowledged. We thank all the authors for their contributions, and their help and cooperation during the manuscript writing and revision process. We also thank Dr. Maryse Elliott, Senior Publishing Editor and Melanie van Overbeek, Senior Publishing Assistant, Agronomy and Life Sciences Unit, Springer Dordrecht, The Netherlands.

Faisalabad, Pakistan
Perth, Australia

Muhammad Farooq
Kadambot H. M. Siddique
Contents

Part I Introduction

1 Conservation Agriculture: Concepts, Brief History, and Impacts on Agricultural Systems ................................................................. 3
Muhammad Farooq and Kadambot H. M. Siddique

Part II Elements of Conservation Agriculture

2 Crop Rotations and Residue Management in Conservation Agriculture ........................................................................................................ 21
Leonard Rusinamhodzi

3 Weed Management in Conservation Agriculture Systems ................. 39
V.P. Singh, K.K. Barman, Raghwendra Singh and A.R. Sharma

4 Nutrient Management Perspectives in Conservation Agriculture ............................................................................................................. 79
Christos Dordas

5 Farm Machinery for Conservation Agriculture .................................. 109
S. Mkomwa, P. Kaumbutho and P. Makungu

6 Insect Pest Management in Conservation Agriculture ...................... 133
Ahmad Nawaz and Jam Nazeer Ahmad

Part III Modeling and Crop Improvement for Conservation Agriculture

7 Crop Breeding for Conservation Agriculture .................................... 159
Tariq Mahmood and Richard Trethowan

8 Modeling Conservation Agriculture .................................................. 181
Bruno Basso, Ryan Nagelkirk and Luigi Sartori
Part IV  Status of Conservation Agriculture: Some Case Studies

9  Evolution and Adoption of Conservation Agriculture in the Middle East ................................................................. 197
Stephen Loss, Atef Haddad, Yaseen Khalil, Abdulsattar Alrijabo,
David Feindel and Colin Piggin

10 Explaining Adoption and Measuring Impacts of Conservation Agriculture on Productive Efficiency, Income,
Poverty, and Food Security in Syria .................................................... 225
Y. A. Yigezu, A. Mugera, T. El-Shater, C. Piggin, A. Haddad,
Y. Khalil and S. Loss

11 Conservation Agriculture in South Asia ................................................ 249
Hafeez-ur-Rehman, Ahmad Nawaz, Abdul Wakeel, Yashpal Singh
Saharawat and Muhammad Farooq

12 Conservation Agriculture in Southeast Asia ........................................ 285
Jean-Claude Legoupil, Pascal Lienhard and Anonh Khamhoung

13 Conservation Agriculture in Rainfed Areas of China ........................... 311
Lingling Li, Bill Bellotti, Renzhi Zhang and Hailin Zhang

14 Conservation Agriculture in Australia and New Zealand .................... 335
P. R. Ward and Kadambot H. M. Siddique

15 Conservation Agriculture in Europe ...................................................... 357
G. Basch, T. Friedrich, A. Kassam and E. Gonzalez-Sanchez

16 Conservation Agriculture in Latin America .......................................... 391
A. Speratti, M.-S. Turmel, A. Calegari, C.F. Araujo-Junior,
A. Violic, P. Wall and B. Govaerts

17 Conservation Agriculture in North America ........................................ 417
N. C. Hansen, S. Tubbs, F. Fernandez, S. Green, N. E. Hansen
and W. B. Stevens

18 Conservation Agriculture in Sub-Saharan Africa ............................... 443
Marc Corbeels, Christian Thierfelder and Leonard Rusinamhodzi

Part V  Conservation Agriculture in Agricultural Systems

19 Conservation Agriculture and Soil Carbon Sequestration .................... 479
Ch. Srinivasarao, Rattan Lal, Sumanta Kundu
and Pravin B Thakur
20 Application of Microbiology in Conservation Agriculture ............... 525
   J. Habig, A. I. Hassen and A. Swart

21 Conservation Agriculture in Organic Farming: Experiences,
   Challenges and Opportunities in Europe ....................................... 559
   J. Peigné, V. Lefevre, J.F. Vian and Ph. Fleury

22 Conservation Agriculture and Climate Change .............................. 579
   M. Pisante, F. Stagnari, M. Acutis, M. Bindi, L. Brilli, V. Di Stefano
   and M. Carozzi

23 Farmer Adoption of Conservation Agriculture: A Review
   and Update .......................................................................................... 621
   Duncan Knowler

Index ........................................................................................................ 643
Contributors

M. Acutis  Department of Agricultural and Environmental Sciences—Production, Landscape, Agroenergy—Via G. Celoria, University of Milano, Milano, Italy

Jam Nazeer Ahmad  Integrated Genomic, Cellular, Developmental and Biotechnology Laboratory, Department of Entomology, University of Agriculture, Faisalabad, Pakistan

Abdulsattar Alrijabo  University of Mosul, Ninevah, Iraq

C.F. Araujo-Junior  Agricultural Research Institute of Paraná (IAPAR), Londrina, Paraná, Brazil

K.K. Barman  Directorate of Weed Science Research, Jabalpur, India

G. Basch  Institute of Mediterranean Agricultural and Environmental Sciences, University of Évora, ÉVORA, Portugal

Bruno Basso  Department of Geological Sciences, Michigan State University, East Lansing, USA

Bill Bellotti  University of Western Sydney, Parramatta, Australia

M. Bindi  Department of Agri-food Production and Environmental Sciences, University of Florence -Piazzale delle Cascine, Firenze, Italy

Lorenzo Brilli  Department of Agri-food Production and Environmental Sciences, University of Florence -Piazzale delle Cascine, Firenze, Italy

A. Calegari  Agricultural Research Institute of Paraná (IAPAR), Londrina, Paraná, Brazil

M. Carozzi  INRA, AgroParisTech, UMR 1091 Environnement et Grandes Cultures, Thiverval-Grignon, France

Marc Corbeels  French Agricultural Research Centre for International Development (CIRAD), Montpellier cedex 5, France
**Christos Dordas**  Faculty of Agriculture, Forestry and Natural Environment, School of Agriculture, Laboratory of Agronomy, Aristotle University of Thessaloniki, Thessaloniki, Greece

**T. El-Shater**  International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria

**Muhammad Farooq**  Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

The UWA Institute of Agriculture, The University of Western Australia, Crawley, WA, Australia

College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia

**David Feindel**  International Center for Agricultural Research in Dry Areas, Amman, Jordan

**F. Fernandez**  University of Minnesota, Minneapolis, MN, USA

**Ph. Fleury**  Department of Agriculture, Laboratoire d’Etudes Rurales, Food Systems and Rural Areas, ISARA-Lyon, Lyon cedex 07, France

**T. Friedrich**  Plant Production and Protection Division, Food and Agriculture Organization, Rome, Italy

**E. Gonzalez-Sanchez**  Rural Engineering Department, University of Córdoba, Córdoba, Spain

**B. Govaerts**  International Maize and Wheat Improvement Centre (CIMMYT), Mexico, DF, Mexico

**S. Green**  Arkansas State University, Jonesboro, AR, USA

**J. Habig**  Soil Microbiology Unit, Plant Protection Research Institute, Agricultural Research Council, Pretoria, Gauteng, South Africa

**Atef Haddad**  International Center for Agricultural Research in Dry Areas, Amman, Jordan

**Atef Haddad**  International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan

**N. C. Hansen**  Brigham Young University, Provo, UT, USA

Brigham Young University, Rexburg, ID, USA

**A. I. Hassen**  Biological Nitrogen Fixation Unit, Plant Protection Research Institute, Agricultural Research Council, Pretoria, Gauteng, South Africa

**A. Kassam**  School of Agriculture, Policy and Development, University of Reading, Reading, UK
Contributors

P. Kaumbutho  Kenya Network for Dissemination of Agricultural Technologies, Nairobi, Kenya

Yaseen Khalil  International Center for Agricultural Research in Dry Areas, Amman, Jordan

International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan

Anonh Khamhoung  Department of Land Management and Development of the Ministry of Agriculture and Forestry, Vientiane, Laos

Duncan Knowler  School of Resource and Environmental Management, Simon Fraser University, Burnaby, British Columbia, Canada

Sumanta Kundu  Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh, India

Rattan Lal  Carbon Management and Sequestration Center, SNER/OAR DC, The Ohio State University, Columbus, OH, USA

V. Lefevre  Department of Agroecology and Environment, ISARA-Lyon, Lyon cedex 07, France

Jean-Claude Legoupil  Conservation Agriculture and Systems Engineering, CIRAD, Montpellier Cedex 5, France

Lingling Li  Gansu Provincial Key Laboratory of Aridland Crop Science/Faculty of Agronomy, Gansu Agricultural University, Lanzhou, People’s Republic of China

Pascal Lienhard  Conservation Agriculture and Systems Engineering, CIRAD, Montpellier Cedex 5, France

Stephen Loss  International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan

Tariq Mahmood  Plant Breeding Institute, The University of Sydney, Cobbitty, NSW, Australia

P. Makungu  Sokoine University of Agriculture, Morogoro, Tanzania

S. Mkomwa  African Conservation Tillage Network, Nairobi, Kenya

A. Mugera  The UWA Institute of Agriculture & School of Agricultural and Resource Economics, The University of Western Australia, Crawley, WA, Australia

Ahmad Nawaz  Integrated Pest Management Laboratory, Department of Entomology, University of Agriculture, Faisalabad, Pakistan

Ryan Nagelkirk  Department of Geological Sciences, Michigan State University, East Lansing, USA
J. Peigné  Department of Agroeocology and Environment, ISARA-Lyon, Lyon cedex 07, France

Colin Piggin  Australian Centre for International Agricultural Research, Canberra, Australia

International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan

M. Pisante  Agronomy and Crop Sciences Research and Education Center—Via C.R.Lerici, University of Teramo, Mosciano S.Angelo, Italy

Hafeez ur Rehman  Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Leonard Rusinamhodzi  CIRAD—Agro-ecology and Sustainable Intensification of Annual Crops, c/o CIMMYT Regional Office, Harare, Zimbabwe

French Agricultural Research Centre for International Development (CIRAD), Montpellier cedex 5, France

Yashpal Singh Saharawat  The Indian Agricultural Research Institute, New Delhi, India

Luigi Sartori  Department of Landscape and Agroforestry Systems, University of Padua, Padua, Italy

A.R. Sharma  Directorate of Weed Science Research, Jabalpur, India

Kadambot H. M. Siddique  The UWA Institute of Agriculture, The University of Western Australia, Crawley, WA, Australia

Raghwendra Singh  Directorate of Weed Science Research, Jabalpur, India

V.P. Singh  Directorate of Weed Science Research, Jabalpur, India

A. Speratti  Institute for Resources, Environment and Sustainability, University of British Columbia, Vancouver, BC, Canada

Ch. Srinivasarao  Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh, India

F. Stagnari  Agronomy and Crop Sciences Research and Education Center—Via C.R.Lerici, University of Teramo, Mosciano S.Angelo, Italy

Valentina Di Stefano  Department of Agri-food Production and Environmental Sciences, University of Florence -Piazzale delle Cascine, Firenze, Italy

W.B. Stevens  USDA-ARS, Sidney Montana, MT, USA

A. Swart  Nematology Unit, Plant Protection Research Institute, Agricultural Research Council, Pretoria, Gauteng, South Africa
Pravin B Thakur  Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh, India

Christian Thierfelder  International Maize and Wheat Improvement Centre (CIMMYT), Harare, Zimbabwe

Richard Trethowan  Plant Breeding Institute, The University of Sydney, Cobbitty, NSW, Australia

S. Tubbs  University of Georgia, Tifton, GA, USA

M.-S. Turmel  International Maize and Wheat Improvement Centre (CIMMYT), Mexico, DF, Mexico

J.F. Vian  Department of Agroeoclogy and Environment, ISARA-Lyon, Lyon cedex 07, France

A. Violic  Chilean Academy of Agricultural Sciences, Santiago, Chile

Abdul Wakeel  Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan

P. Wall  International Maize and Wheat Improvement Centre (CIMMYT), Mexico, DF, Mexico

P. R. Ward  CSIRO Agriculture Flagship, Wembley, WA, Australia

Y. A. Yigezu  International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan

Hailin Zhang  College of Agronomy and Biotechnology, China Agricultural University, Beijing, People’s Republic of China

Renzhi Zhang  Faculty of Resource and Environment, Gansu Agricultural University, Lanzhou, People’s Republic of China
Conservation Agriculture
Farooq, M.; Siddique, K. (Eds.)
2015, XIX, 665 p. 40 illus. in color., Hardcover
ISBN: 978-3-319-11619-8