No-tillage Seeding in Conservation Agriculture

Second Edition
This book is dedicated to the scientists and students whose work is reviewed, together with their long-suffering families. Such people were driven by a desire to make no-tillage as sustainable and risk-free as possible, and in the process to make food production itself sustainable for the first time in history. The odds were great but the results have been significant and will have far-reaching consequences.
No-tillage Seeding in Conservation Agriculture

Second Edition


Edited by

C.J. Baker and K.E. Saxton

Published by
Food and Agriculture Organization of the United Nations
CABI is a trading name of CAB International

CABI Head Office
Nosworthy Way
Wallingford
Oxfordshire OX10 8DE
UK
Tel: +44 (0)1491 832111
Fax: +44 (0)1491 833508
Website: www.cabi.org

CABI North American Office
875 Massachusetts Avenue
7th Floor
Cambridge, MA 02139
USA
Tel: +1 617 395 4056
Fax: +1 617 354 6875
E-mail: cabi-nao@cabi.org
Website: www.cabi.org

© FAO and CAB International 2007. All rights reserved. No part of this publication may be reproduced in any form or by any means, electronically, mechanically, by photocopying, recording or otherwise, without the prior permission of the copyright owners.

A catalogue record for this book is available from the British Library, London, UK.

Library of Congress Cataloging-in-Publication Data
p. cm.
Includes bibliographical references and index.
S604.B36 2006
631.5′31--dc22
2005035401

Published jointly by CAB International and FAO.
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla, 00100 Rome, Italy
Website: www.fao.org

ISBN: 92-5-105389-8 (FAO)

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The designations ‘developed’ and ‘developing’ economies are intended for statistical convenience and do not necessarily express a judgement about the stage reached by a particular country, territory or area in the development process.

The views expressed herein are those of the authors and do not necessarily represent those of the Food and Agriculture Organization of the United Nations.

All rights reserved. Reproduction and dissemination of material in this information product for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holders provided the source is fully acknowledged. Reproduction of material in this information product for resale or other commercial purposes is prohibited without written permission of the copyright holder. Applications for such permission should be addressed to the Chief, Publishing Management Service, Information Division, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy or by email to copyright@fao.org.

Typeset by AMA DataSet Ltd, Preston, UK.
Printed and bound in the UK by Cromwell Press, Trowbridge.
## Contents

**Contributors** x

**Foreword to the Second Edition** xii

*Shivaji Pandey and Theodor Friedrich*

**Preface** xiii

1. **The ‘What’ and ‘Why’ of No-tillage Farming** 1
   *C. John Baker and Keith E. Saxton*
   - What is No-tillage? 3
   - Why No-tillage? 5
   - Advantages 6
   - Disadvantages 7
   - Summary of the ‘What’ and ‘Why’ of No-tillage 10

2. **The Benefits of No-tillage** 11
   *Don C. Reicosky and Keith E. Saxton*
   - Introduction 11
   - Principles of Conservation Agriculture 12
   - Crop Production Benefits 13
     - Increased organic matter 14
     - Increased available soil water 15
     - Reduced soil erosion 15
     - Enhanced soil quality 16
     - Improved nutrient cycles 17
     - Reduced energy requirements 17
   - Carbon Emissions and Sequestration 19
   - Summary of the Benefits of No-tillage 20
3 The Nature of Risk in No-tillage
C. John Baker, W. (Bill) R. Ritchie and Keith E. Saxton

What is the Nature of Risk in No-tillage?
Biological risks
Physical risks
Chemical risks
Economic risk
Conclusions
Summary of the Nature of Risk in No-tillage

4 Seeding Openers and Slot Shape
C. John Baker

Vertical Slots
V-shaped slots
Slanted V-shaped slots
U-shaped slots
Vibrating openers
Horizontal Slots
Inverted T-shaped slots
Punch Planting
Surface Broadcasting
Summary of Seeding Openers and Slot Shape

5 The Role of Slot Cover
C. John Baker

The Role of Soil Humidity
Methods of Covering Seed Slots
Squeezing
Rolling
Pressing
Scuffing
Deflecting
Tilling
Folding
Summary of the Role of Slot Cover

6 Drilling into Dry Soils
C. John Baker

How Soils Lose Moisture
The Role of Vapour-phase Soil Water
Germination
Subsurface Survival
Seedling Emergence
The Effects of Pressing
Field Experience
Summary of Drilling into Dry Soils
## Contents

7 **Drilling into Wet Soils**  
*C. John Baker*  
Drilling Wet Soils  
- Vertical double (or triple) disc openers (V-shaped slots)  
- Slanted double (or triple) disc openers (slanted V-shaped slots)  
- Vertical angled flat (or dished) disc openers (U-shaped slots)  
- Hoe-type openers (U-shaped slots)  
- Power till openers (U-shaped slots)  
- Winged openers (inverted-T-shaped slots)  
Drilled Dry Soils that Become Wet  
- Opener performance  
Summary of Drilling into Wet Soils

8 **Seed Depth, Placement and Metering**  
*C. John Baker and Keith E. Saxton*  
Seeding Depth and Seedling Emergence  
Maintaining Consistent Opener Depth  
- Surface following  
- Depth-gauging devices  
- The value of semi-pneumatic tyres  
Walking beams  
Disc seed flick  
Soil disturbance  
Residue hairpinning or tucking  
Opener bounce  
Seed bounce  
Slot closure  
Drill and Planter Functions  
- Downforce mechanisms  
- Seed metering and delivery  
Summary of Seed Depth, Placement and Metering

9 **Fertilizer Placement**  
*C. John Baker*  
Toxicity  
- Banded fertilizer  
- Vertical banding versus horizontal banding  
- Retention of gaseous fertilizers  
Crop Yield  
- Banding options  
- How close should banded fertilizer be to the seed?  
Conclusion  
Summary of Fertilizer Placement

10 **Residue Handling**  
*C. John Baker, Fatima Ribeiro and Keith E. Saxton*  
The Forms that Residues can Take  
- Short root-anchored standing vegetation  
- Tall root-anchored standing vegetation  
- Lying straw or stover
Management of Residues on a Field Scale 138
Large field-scale no-tillage 138
Small-scale no-tillage 140
Management of Residues by Openers, Drills and Planters: Micro-management of
Crop Residues 145
Opener handling of residues 145
Row cleaners 147
Chopping of straw into short lengths 147
Random cutting of straw in place 149
Wet versus dry straw 155
The case for and against scrapers 156
Clearance between openers 156
Summary of Residue Handling 158

11 Comparing Surface Disturbance and Low-disturbance Disc Openers 159
C. John Baker
Minimum versus Maximum Slot Disturbance – How Much Disturbance is Too Much? 159
Disruptance effects 160
Disc opener feature comparisons 163
Summary of Comparing Surface Disturbance and
Low-disturbance Disc Openers 163

12 No-tillage for Forage Production 168
C. John Baker and W. (Bill) R. Ritchie
Forage Species 168
Integrated Systems 169
No-tillage of Pasture Species 171
Pasture renewal 171
Pasture renovation 175
Seed metering 183
Summary of No-tillage for Forage Production 183

13 No-tillage Drill and Planter Design – Large-scale Machines 185
C. John Baker
Operating Width 185
Surface Smoothing 186
Power Requirements 189
Weight and Opener Forces 190
Re-establishing Downforce 194
Wheel and Towing Configurations 195
End wheels 196
Fore-and-aft wheels 196
Matching Tractors to Drills and Planters 198
Product Storage and Metering 200
Summary of No-tillage Drill and Planter Design – Large-scale Machines 202
14 No-tillage Drill and Planter Design – Small-scale Machines 204
Fatima Ribeiro, Scott E. Justice, Peter R. Hobbs and C. John Baker

Characteristics 204
Range of Equipment 204
   Hand-jab planters (dibblers) 205
   Row-type planters (animal-drawn and tractor-mounted) 206
   Animal-drawn planters 212
   Planters adapted from power tillers 212
   Tractor-drawn planters 213
   No-tillage farming in Asia 213
Summary of No-tillage Drill and Planter Design – Small-scale Machines 225

15 Managing a No-tillage Seeding System 226
W. (Bill) R. Ritchie and C. John Baker

Site Selection and Preparation 226
Weed Competition 227
Pest and Disease Control 228
Managing Soil Fertility 228
Seeding Rates and Seed Quality 228
Operator Skills 229
Post-seeding Management 230
Planning – the Ultimate Management Tool 230
Cost Comparisons 234
Summary of Managing a No-tillage Seeding System 235

16 Controlled-traffic Farming as a Complementary Practice to No-tillage 236
W.C. Tim Chamen

What is Controlled-traffic Farming? 236
Why Adopt a CTF Regime within a No-tillage Farming System? 236
   The benefits of CTF 236
   The effects of CTF on soil conditions 237
Making CTF Happen 245
   Basic principles 245
   Forward planning and machinery matching 245
   The width-matching process 245
   Field layout and system management 248
   Orientation of permanent wheel ways 249
   Wheel-way management 249
   Guidance systems 251
Economics 251
   Transition costs and timescale for change to CTF 252
   Fixed and variable costs 253
   Change in output 253
   In-field management costs 254
   Summary of costs and returns 254
Summary of Controlled-traffic Farming as a Complementary Practice to No-tillage 254
# Contents

## 17 Reduced Environmental Emissions and Carbon Sequestration  
*Don C. Reicosky and Keith E. Saxton*

- Introduction 257
- Tillage-induced Carbon Dioxide Emissions 257
  - Emission measurements 258
  - Tillage and residue effects 258
  - Strip tillage and no-tillage effects on CO₂ loss 260
- Carbon Sequestration Using No-tillage 262
- Nitrogen Emissions 263
- Policy of Carbon Credits 265
- Summary of Reduced Environmental Emissions and Carbon Sequestration 267

## 18 Some Economic Comparisons  
*C. John Baker*

- New Zealand Comparisons 269
  - Assumptions 269
  - General conclusions 274
- European Comparisons 275
- Summary of Some Economic Comparisons 276

## 19 Procedures for Development and Technology Transfer  
*C. John Baker*

- Plant Responses to No-tillage Openers in Controlled Conditions 278
  - The micro-environment within and surrounding no-tillage seed slots 281
- Soil Compaction and Disturbance by No-tillage Openers 284
  - Soil strength 284
  - Instantaneous soil pressure (stress) 286
  - Instantaneous and permanent soil displacement 287
  - Soil bulk density 287
  - Smearing and compaction 287
- Locating Seeds in the Soil 287
  - Seed spacing 287
  - Seed depth 287
  - Lateral positioning of seeds relative to the centre line of the slot 288
- Seed Travel within No-tillage Openers 289
- Drag on a Disc Opener 291
- Accelerated Wear Tests of No-tillage Openers 292
- Effects of Fertilizer Banding in the Slot 292
- Prototype Drills and Management Strategies 294
  - Single-row test drills 294
  - Simultaneous field testing of several opener designs 295
  - Plot-sized field drills and planters 297
  - Field-scale prototype drills and a drilling service for farmers 297
- Summary of Drill Development and Technology Transfer 299

## References 301

## Index 317
Contributors

C.J. Baker, Centre for International No-tillage Research and Engineering (CINTRE), Feilding, New Zealand
W.C.T. Chamen, 4Ceasons Agriculture and Environment, Maulden, Bedfordshire, UK
P.R. Hobbs, Department of Crops and Soil Science, Cornell University, Ithaca, New York, USA
S.E. Justice, National Agriculture and Environment Forum (NAEF), Kathmandu, Nepal
D.C. Reicosky, United States Department of Agriculture, Agricultural Research Service, Morris, Minnesota, USA
M.F.S. Ribeiro, Instituto Agronômico do Paraná (IAPAR), Ponta Grossa, Parana, Brazil
W.R. Ritchie, Centre for International No-tillage Research and Engineering (CINTRE), Feilding, New Zealand
K.E. Saxton, Retired, formerly United States Department of Agriculture, Agricultural Research Service, Pullman, Washington, USA
Foreword to the Second Edition

The Food and Agriculture Organization (FAO) has a history of supporting the development and extension of conservation agriculture cropping systems. No-tillage seeding is one of the key operations of conservation agriculture; no-till seeding, together with the principles of cover crops and crop rotation, constitute conservation agriculture. The availability of suitable technology and equipment is a necessary precondition for making conservation agriculture work. Special equipment is required not only for direct seeding and planting, but also for the management of crop residues and cover crops.

The earlier book, entitled *No-tillage Seeding: Science and Practice*, by Baker, Saxton and Ritchie, was, at the time of its publication, one of the most comprehensive publications covering the engineering aspects of no-tillage seeding as well as the agronomic and environmental background for no-tillage farming. It has been valuable as a reference for scientists and students, and also as a guide for practitioners. A case was reported where a farmer after reading this book bought a no-till planter and converted his farm to no-till.

This new book, *No-tillage Seeding in Conservation Agriculture*, provides a broader picture of the equipment used in conservation agriculture cropping systems. It includes chapters on material not previously covered, for example, the management of crop residues and cover crops, preparation for the no-tillage seeding operation, and controlled-traffic farming as a complementary technology. There are also new chapters describing no-tillage seeding technologies for small-scale farmers. Technology developments from South America and South Asia are described, including manual equipment, draught-animal equipment and equipment for power tillers. The subject of greenhouse gases as driving forces for climate change is also discussed in a chapter on carbon sequestration under no-tillage farming systems.

We hope that this book contributes to a better understanding of the engineering components of conservation agriculture. It is also our wish that it helps with the introduction and expanded application of this technology. Conservation agriculture is a valuable approach to cropping that can lead to more productive, competitive and sustainable agricultural systems with parallel benefits to the environment and to farmers and their families.

*Shivaji Pandey*
Director
*Theodor Friedrich*
Senior Agricultural Engineer
Agricultural Support Systems Division
FAO
Rome, November 2005
Preface

And he gave for his opinion, that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country than the whole race of politicians put together.

Jonathan Swift, Gulliver’s Travels (1726) ‘A Voyage to Brobdingnag’

The authors of this book describe and analyse no-tillage technologies, particularly those related to no-tillage seed drilling, from a variety of accumulated experiences over the past 40 years. Most of us set out to discover why no-tillage did not always work and how to overcome these obstacles. The more we learned the more appealing no-tillage farming became. The understanding and system science have now been acquired and tested to the point where we are ever more confident it represents the future of farming.

Some of the reported research started from knowledge that none of the traditional drills, planters or opener technologies used for tillage farming then provided a fail-safe methodology for untilled, residue-covered soils. Inevitably that resulted in new machine designs and evaluations, and combined associated technologies. The guiding premise was that every functional part of any new design had to have a verifiable scientific reason and performance, which often resulted in a long evolution.

No functional assumptions were made. All commonly held ideas about what seeds required were challenged or discarded and new experiments set up to determine their requirements specifically in untilled soils. This new knowledge was combined with whatever existing knowledge proved still to be applicable. In other cases the rules for tilled soils simply did not apply, or were proved wrong, when applied to untilled soils. Undisturbed soils were found to provide different resources and challenges from those of tilled soils, thus requiring different approaches to seed sowing.

Other authors report what happened to soil when ploughing ceases. Everyone by now knows that no-tillage is good and ploughing is bad for the soil, but what are the causal mechanisms and can the improvements or damage be quantified? Can the gains be further improved by techniques such as controlled-traffic farming? Still other authors studied available equipment and management methods and relate these to no-tillage systems and
applications, large and small. Only when the capabilities of modern no-tillage equipment are understood and fully integrated into a crop production enterprise can it be fully quantified and realistic local recommendations made.

Collectively these authors have provided a comprehensive overview of what makes a successful no-tillage enterprise work. This includes machinery design and operating principles, the interactions of machines with the soil, the importance of parallel inputs, such as herbicides, pesticides and controlled traffic, and the management of the system as a whole, including quantifying the importance of soil carbon and tracking carbon dioxide emissions as a function of soil disturbance. They have also provided a guide to experimental procedures for evaluation of variables.

The book is not intended to be a blueprint on how to design any one style of no-tillage machine, component or system. It is a record of the comparative performances of several different machine design options and management practices, tested under controlled scientific conditions, and how these have been found to integrate into a whole no-tillage system. Much of the information is about the biological performance of machines and soils, since both primarily perform biological functions. But mechanical performance is not ignored either. The interface between the two is particularly important.

The reader is invited to place his or her own value on the relevance of the data presented. The relevance some of the authors placed on the data led to the design of the disc version of a winged opener, called Cross Slot®. Others will see different things in the data. However, independent research and field experience have increasingly shown that the data and the conclusions drawn from them have been remarkably accurate and prophetic.

The relevance of the book is that it illustrates that there are now ways and means to make no-tillage more fail-safe than tillage and to obtain crop yields not only equal to those from tillage but, in many cases, superior. Untilled soils contain greater potential to germinate, establish and grow plants than tilled soils ever did. And, of course, they are much more environmentally friendly. The problem for humankind has been to learn and understand how to harness that potential. We hope this book goes some way towards achieving that objective.