

Mark Otieno

Sustainable Agroecological Practices in Sub-Saharan Africa in the Face of Climate Change

 Springer

Mark Otieno
Department of Water and Agricultural Resource Management
University of Embu
Embu, Kenya

ISSN 2198-3542 ISSN 2198-3550 (electronic)
Advances in Geographical and Environmental Sciences
ISBN 978-3-031-70471-0 ISBN 978-3-031-70472-7 (eBook)
<https://doi.org/10.1007/978-3-031-70472-7>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2024

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

If disposing of this product, please recycle the paper.

To the students pursuing courses in Agroecology at various levels, the researchers delving into the depths of sustainable agriculture, the lecturers and professors imparting knowledge and shaping minds, the educators spreading awareness and nurturing future leaders, the extension practitioners bridging the gap between theory and practice, and to all the agroecology enthusiasts who understand the profound connection between farming and ecology—this book is dedicated to you.

May your commitment to understanding and implementing sustainable agroecological practices inspire positive change, foster innovation, and cultivate a harmonious relationship between agriculture and our precious ecosystems. Your efforts and dedication are essential in shaping a resilient and sustainable future for all.

Preface

In recent times, the world has faced profound effects of climate change. The consequences, such as temperature fluctuations, heavy rainfall, and intensifying extreme weather conditions, have diverse impacts that significantly affect our global food systems. These impacts are more pronounced in sub-Saharan Africa, a region that relies on agriculture for sustenance and food security. These changes in our atmosphere are influencing drastically the environment, leaving hazardous aftereffects to be mitigated. Climate change is a reality, with drastic consequences that must be addressed in order for us to have a sustainable future. To confront this challenge, strategies and resourcefulness are critical in dealing with unpredictable atmospheric events and impacts. The acknowledgement of the severity of the situation is the first step toward tackling this problem effectively.

The critical significance of agroecological practices in response to the climate crisis plaguing sub-Saharan Africa is highlighted in this book. The intricate link between agriculture, ecosystems, and climate is further highlighted, calling for an overwhelming need to transform farming systems for long-term sustainability. Research, case studies, and practical examples bring to light the potential of agroecology in combating the effects of climate change. Sustainable practices aimed at promoting biodiversity, preserving resources, boosting soil fertility, and curtailing greenhouse gas emissions all provide the reader with a comprehensive glimpse of the topic. To drive home the success stories from different countries in sub-Saharan Africa, the book manages to spark much-needed inspiration among farmers, policy-makers, and practitioners to make and sustain change. The vulnerabilities of small-holder farmers in the region must also be acknowledged, thus traditional knowledge in conjunction with scientific advancements must be integrated in order to give farmers the resources, information, and capacity-building opportunities required to deal with changing climatic conditions. Governments, research institutions, civil society organization, and local communities must align to foster better collaboration and innovation to ensure sustainable agricultural development.

It is our firm conviction that agroecological practices that are sustainable can be the answer to achieving food security, and uplifting the resilience of the ecosystem, nurturing the rural development in sub-Saharan Africa. By incorporating

climate-friendly agriculture and sustaining ecological balance, a future can be formed where communities grow, ecosystems flourish, and the effects of climate change can be mitigated.

I offer our utmost gratitude to the numerous researchers, authorities, farmers, and organizations who have provided their vital contributions to the knowledge and practices elaborated in this book. Their dedication and promise to continue sustainable agriculture during these hard times of climate change is truly inspiring. We hope this book can serve as a source of wisdom for all those who share this reality of a self-sufficient and prosperous sub-Saharan Africa.

Together, we should start this venture toward sustainable agroecological practices, realizing that the joint efforts will be highly beneficial to the future generations.

Embu, Kenya

Mark Otieno

Acknowledgements

I would like to express my sincere gratitude to the Alexander von Humboldt Foundation for providing the financial support through an alumni grant and a research stay in Germany during the summer of 2023, which enabled me to complete this book titled “Sustainable Agroecological Practices in Sub-Saharan Africa in the Face of Climate Change.”

Special thanks to Prof. Dr. Ingolf Steffan-Dewenter for hosting me at the Department of Animal Ecology and Tropical Biology, University of Wuerzburg, during the writing process of this book, offering valuable guidance and insights that greatly enriched its content. I am appreciative of Dr. Marcell Peters at the same department for sharing invaluable knowledge and providing exceptional insights on the topics explored in this book. Your expertise and contributions have been instrumental in shaping the narrative.

I extend my heartfelt thanks to Dr. Rosie Trevelyan, the Director of the Tropical Biology Association, for her continuous mentorship and inspiring encouragement, fostering an environment where I could strive for excellence and innovation in my work.

Lastly, I am grateful to the University of Embu and its top management for granting me the necessary research leave to embark on this journey and travel to Germany for the completion of this book. Your support and understanding have been vital to the realization of this project.

Thank you to all those mentioned for your unwavering support and contributions that have made this publication possible.

Contents

1	Introduction	1
1.1	Definition of Agroecology	1
1.2	Agroecological Context in Sub-Saharan Africa	1
	References	10
2	Water-Use Efficiency, Water Quality, and Irrigation	15
2.1	Water-Use Efficiency in Agroecological Systems	15
2.2	Water Quality Management in Agroecology	17
2.3	Sustainable Irrigation Practices in Agroecology	18
	References	18
3	Current Climate, Soil, and Natural Vegetation	21
3.1	Current Climate	21
3.2	Climate-Smart Agriculture	21
3.3	Agroforestry	22
3.4	Water Management	24
3.5	Climate-Resilient Crop Varieties	27
3.6	Drought-Resistant Varieties	28
3.7	Heat-Tolerant Varieties	29
3.8	Pest-Resistant Varieties	30
3.9	Integrated Pest Management	31
3.10	Soil	33
3.11	Soil Health	33
3.12	Soil Fertility	34
3.13	Soil Conservation	34
3.14	Soil Biodiversity	36
3.15	Carbon Sequestration	36
3.16	Soil Water Management	38
3.17	Natural Vegetation	40
3.18	Biodiversity Conservation	40
3.19	Ecosystem Services	41
3.20	Soil Health and Fertility	42

3.21	Water Management	43
3.22	Resilience to Climate Change	44
3.23	Landscape Connectivity	45
	References	47
4	The Geography of Agriculture in Sub-Saharan Africa	53
4.1	Agroecological Diversity	53
4.2	Addressing the Challenges of Rainfed Agriculture in Sub-Saharan Africa	55
4.3	The Role of Traditional Techniques in Subsistence Farming	56
4.4	Pastoral and Arable Farming in Sub-Saharan Africa	59
4.5	Arable Farming in Sub-Saharan Africa	60
4.6	The Influence of Climate, Soil, and Natural Vegetation on Livestock and Crops in Sub-Saharan Africa	62
	References	64
5	Energy-Use Efficiency in Sub-Saharan Africa	67
5.1	The Fate of Fossil Fuels in Sub-Saharan Africa	67
5.2	The Renewable Energy Transition in Sub-Saharan Africa	68
5.3	The Role of Renewable Energy in Enhancing Agricultural Productivity in Sub-Saharan Africa	70
5.4	The Role of Natural Gas in Powering Agricultural Transformation	71
5.5	The Implications of Climate Change Mitigation on Energy Choices in Sub-Saharan Africa	72
5.6	The Viability of Renewable Energy in Sub-Saharan Africa's Agricultural Sector	73
5.7	Alternative Energy Sources	74
5.8	The Promising Role of Solar Energy in Sub-Saharan African Agriculture	74
5.9	The Potential of Wind Energy in Agricultural Production Across Sub-Saharan Africa	76
5.10	Harnessing the Power of Hydroelectricity to Agricultural Transformation in Sub-Saharan Africa	76
5.11	The Potential of Biomass and Bioenergy in Sub-Saharan Africa's Agricultural Landscapes	77
5.12	Harnessing Geothermal Potential: Powering Sustainable Agriculture in Sub-Saharan Africa	78
5.13	Enhancing Energy Efficiency in Agriculture: Strategies for Reducing Inputs Without Compromising Outputs	79
5.14	Smart Energy Management Systems in Agriculture	80
5.15	The Role of Behavior Changes and Awareness in Reducing Energy Inputs in Agriculture	81
	References	81

6	Traditional and Industrial Farming Practices	85
6.1	Traditional Farming Practices	85
6.1.1	Agrobiodiversity Conservation: The Resilience of Traditional Farming Systems.	85
6.1.2	Sustainable Soil Management in Traditional Farming Systems	86
6.1.3	Sustainable Water Management in Traditional Farming Systems	87
6.1.4	The Importance of Community Participation and Knowledge Sharing in Sustainable Agriculture	88
6.1.5	Resilience of Traditional Farming Practices to Climate Variability.	89
6.1.6	The Synergistic Integration of Traditional Farming Practices and Agroecology.	90
6.2	Industrial Farming Practices	91
6.2.1	Contrasting Industrial Farming and Agroecological Practices: Toward Sustainable and Regenerative Agriculture.	91
6.2.2	Monoculture Versus Polyculture: Evaluating the Ecological and Sustainability Implications	92
6.2.3	Agroecology: Promoting Soil Health and Sustainability.	94
6.2.4	Sustainable Water Management in Agroecological Farming	95
6.2.5	The Role of Agroecology in Preserving Biodiversity and Habitat Conservation.	96
6.2.6	The Social and Economic Benefits of Agroecology	96
	References.	97
7	Biodiversity and Ecosystem Services	101
7.1	Biodiversity Conservation: The Cornerstone of Agroecological Resilience.	101
7.1.1	The Role of Agroecological Practices in Supporting Pollination and Pest Control	102
7.1.2	Soil Health and Nutrient Cycling: The Importance of Agroecological Practices	104
7.1.3	Water Management and Regulation: The Role of Biodiversity in Agroecological Systems	104
7.1.4	The Role of Biodiverse Agroecosystems in Climate Regulation and Resilience	105
7.2	On-farm Biodiversity	106
7.2.1	Harnessing Crop Diversity: The Agroecological Approach	106
7.2.2	Preserving Livestock Diversity for Sustainable Agriculture.	107
7.2.3	The Multifaceted Benefits of Agroforestry Systems	108

7.2.4	Enhancing Agroecosystem Biodiversity: The Role of Habitat Creation and Conservation	108
7.2.5	Conserving Genetic Resources for Sustainable Agriculture: The Role of Agroecology	110
7.3	Nutrient Cycling in Agroecological Systems.	112
7.3.1	Organic Matter Management.	112
7.3.2	Nutrient Cycling and Biodiversity.	112
7.3.3	Crop Rotation and Diversification: Enhancing Agroecological Resilience.	113
7.3.4	The Role of Green Manure and Cover Crops in Agroecological Practices	113
7.3.5	Nutrient Cycling in Livestock-Integrated Agroecological Systems.	114
7.3.6	The Synergistic Benefits of Composting and Vermiculture in Agroecology	115
7.3.7	Sustainable Nutrient Management in Agroecological Systems	116
7.3.8	Pest Regulation in Agroecological Systems: Harnessing Biodiversity and Ecological Principles.	116
7.3.9	Participatory Approaches in Agroecological Pest Management.	117
7.3.10	The Role of Biological Control in Agroecological Systems	118
7.3.11	Minimizing Pesticide Use in Agroecological Systems	119
7.3.12	Landscape-Level Approaches in Agroecology: Enhancing Biological Control Strategies.	119
7.3.13	The Role of Agroecology in Greenhouse Gas Regulation and Mitigation	120
7.3.14	Reducing Synthetic Fertilizer Use and Greenhouse Gas Emissions	121
7.3.15	Agroecological Approaches to Efficient Livestock Management: Mitigating Greenhouse Gas Emissions.	122
7.3.16	The Role of Agroforestry and Tree Planting in Sustainable Agriculture and Climate Change Mitigation	123
	References.	124
8	Ecology-Based Concepts of Sustainable Agriculture.	129
8.1	Biodiversity Conservation in Sustainable Agriculture.	129
8.2	Conservation Agriculture: Principles, Practices, and Relationship with Agroecology.	130
8.3	Integrating Ecological Principles into Agricultural Systems.	131
8.3.1	The Importance of Crop Diversity in Agroecological Farming	132
8.3.2	The Multifaceted Benefits of Agroforestry	133

8.3.3	The Benefits of Organic Farming: Promoting Soil Health, Biological Pest Control, and Sustainable Nutrient Management.	134
8.3.4	The Importance of Conservation Tillage Practices in Sustainable Agriculture	134
8.3.5	Integrated Pest Management: A Comprehensive Approach to Sustainable Agriculture	135
8.4	Water Management in Agroecological Systems	136
8.5	Agroecological Practices for Sustainable Soil Conservation.	137
8.6	Livestock Integration in Agroecological Systems	137
8.7	The Role of Cover Crops in Sustainable Agriculture	139
8.7.1	The Role of Cover Crops in Soil Erosion Prevention	139
8.7.2	Use of Legume Cover Crops for Sustainable Soil Fertility Improvement.	140
8.7.3	Weed Suppression and Pest Management in Agroecological Systems.	141
8.7.4	The Role of Cover Crops in Enhancing Biodiversity and Promoting Natural Pest Control Within Agricultural Systems	142
8.7.5	The Role of Cover Crops in Nutrient Cycling and Carbon Sequestration	143
8.7.6	The Role of Cover Crops in Improving Water Management in Agricultural Systems	143
8.8	The Benefits of No-Tillage Farming: An Agroecological Approach	144
8.8.1	The Role of No-Tillage in Soil Conservation	145
8.8.2	The Role of No-Tillage in Enhancing Soil Health and Fertility	146
8.8.3	Water Conservation and Efficiency: The Role of No-Tillage Practices	146
8.8.4	Carbon Sequestration and Climate Change Mitigation Through No-Tillage Practices	147
8.8.5	Biodiversity and Wildlife Habitat: The Benefits of No-Tillage Systems	148
8.8.6	The Environmental and Economic Benefits of No-Tillage Systems	149
8.9	Integrating Fertilizer Application and Fertigation into Agroecological Practices in Sub-Saharan Africa.	149
8.10	Balanced Nutrient Management in Agroecology.	151
8.11	The Role of Organic Fertilizers in Agroecology	151
8.11.1	Nutrient Cycling and Sustainable Soil Management in Agroecology.	152
8.11.2	Optimizing Nutrient Management: The Benefits of Fertigation and Precision Agriculture	153

8.11.3	The Environmental Advantages of Fertigation in Agroecological Systems.	153
8.12	Climate Resilience Through Agroecological Practices: The Role of Efficient Fertilizer Application Techniques	154
8.13	The Role of Permaculture in Sustainable Development in Sub-Saharan Africa	155
8.13.1	Agroecological Design: Integrating Permaculture Principles for Sustainable Agriculture in Sub-Saharan Africa	157
8.13.2	Food Security and Sustainable Agriculture: The Role of Permaculture	157
8.13.3	Sustainable Water Management Strategies in Sub-Saharan Africa: The Role of Permaculture	159
8.13.4	Soil Conservation and Regeneration in Permaculture Systems: Strategies for Sustainable Agriculture in Sub-Saharan Africa	160
8.13.5	Energy Efficiency and Renewable Energy in Permaculture Systems	160
8.13.6	Community Engagement and Knowledge Sharing: The Transformative Potential of Permaculture in Sub-Saharan Africa	162
8.14	Agroforestry and Agroecology: Sustainable and Resilient Agricultural Approaches in Sub-Saharan Africa.	163
8.14.1	Agroforestry Systems in Sub-Saharan Africa: Enhancing Sustainability and Productivity	163
8.14.2	Enhancing Biodiversity Conservation and Ecosystem Services	164
8.14.3	The Role of Agroforestry in Enhancing Soil Health and Nutrient Cycling	165
8.15	The Role of Agroforestry in Climate Change Adaptation and Mitigation in Sub-Saharan Africa	166
8.16	Agroforestry Systems: Enhancing Livelihoods and Food Security in Sub-Saharan Africa	167
8.17	The Role of Perennial Crops in Agroecological Systems	167
8.17.1	The Long-Term Sustainability Advantages of Perennial Crops	168
8.17.2	The Importance of Perennial Crops in Soil Health and Nutrient Cycling	169
8.17.3	The Importance of Perennial Crops in Supporting Biodiversity and Habitat Creation	170
8.17.4	Water Management in Agroecological Systems: The Role of Perennial Crops	170
8.17.5	The Role of Perennial Crops in Climate Change Mitigation and Resilience	171

8.17.6	The Economic and Food Security Benefits of Perennial Crops	172
8.18	Grassland Management Strategies in Sub-Saharan Africa	173
8.18.1	Rotational Grazing: Sustaining Grassland Ecosystems	173
8.18.2	The Importance of Preserving Biodiversity in Sub-Saharan African Grasslands	174
8.18.3	Soil Conservation and Restoration: Agroecological Approaches in Grassland Management.	175
8.18.4	The Role of Agroecological Grassland Management Practices in Carbon Sequestration	176
8.18.5	Sustainable Pastoralism in Agroecological Grassland Management.	177
8.18.6	Participatory Approaches and Local Knowledge in Grassland Management: An Agroecological Perspective	178
8.19	The Role of Seeds and Planting Materials in Agroecological Practices in Sub-Saharan Africa.	179
8.20	Agrobiodiversity Conservation: Preserving Genetic Diversity for Sustainable Agriculture	179
8.21	The Vital Role of Farmer-Managed Seed Systems in Agroecology.	180
8.22	Expanding Access to Organic and Non-GMO Seeds in Sub-Saharan Africa	181
8.23	The Role of Tree Seedling Providers in Promoting Agroforestry Practices	182
8.23.1	Agroecological Seed Multiplication and Distribution Networks	183
	References.	184
9	Biodiversity Conservation	193
9.1	The Role of Habitat Preservation and Restoration in Agroecological Systems.	194
9.2	The Importance of Crop Diversity in Agroecological Systems	194
9.3	The Role of Agroforestry in Promoting Biodiversity and Ecosystem Services.	195
9.4	The Importance of Conserving Indigenous and Traditional Crop Varieties in Agroecology	196
9.5	Promoting Pollinators and Beneficial Insects in Agroecological Systems.	197
9.6	Integrating Participatory Approaches and Indigenous Knowledge in Agroecology	199
	References.	200

10	Farm Health: Crop Health, Animal Health, and Food Quality	203
10.1	Enhancing Farm Health Through Agroecological Practices in Sub-Saharan Africa	204
10.2	Agroecological Approaches to Improving Crop Health in Sub-Saharan Africa	205
10.3	Promoting Animal Health and Agroecology in Sub-Saharan Africa	205
10.4	The Impact of Agroecological Practices on Food Quality in Sub-Saharan Africa	207
	References.	208
11	Post-Harvest Handling Technologies.	211
11.1	Integrating Post-Harvest Technologies and Agroecological Principles for Sustainable Food Systems in Sub-Saharan Africa	212
11.2	Maintaining Food Quality Through Agroecological Practices in Sub-Saharan Africa.	213
11.3	Agroecological Approaches to Post-Harvest Food Safety in Sub-Saharan Africa	214
11.4	Reducing Post-Harvest Losses Through Agroecological Practices in Sub-Saharan Africa.	215
	References.	216
12	Climate Change Mitigation Strategies and Carbon Storage in Agricultural Systems	217
12.1	Climate Change Mitigation Strategies: The Role of Agroecology.	217
12.2	Agroecological Practices and Carbon Sequestration: Mitigating Climate Change Through Sustainable Agriculture	218
12.3	The Role of Agroforestry Systems in Climate Change Mitigation and Adaptation	219
12.4	The Role of Organic Farming in Climate Change Mitigation	220
12.5	Water Management Practices for Climate Change Mitigation in Agriculture	221
12.6	The Environmental Benefits of Integrated Pest Management Practices	221
12.7	Crop Diversity: A Cornerstone of Agroecological Resilience.	222
12.8	Agroecology's Embrace of Energy Efficiency and Renewable Energy	224
12.9	Carbon Storage in Agroecological Systems: Strategies for Climate Change Mitigation	224
12.10	Agroecological Practices for Soil Organic Carbon Sequestration.	225

12.11	The Role of Agroforestry Systems in Enhancing Carbon Storage.	226
12.12	Biodiversity and Carbon Storage: The Role of Agroecological Approaches	227
12.13	Agroecology and Carbon Sequestration: The Role of Reduced Input Intensity	228
12.14	Agroecosystem Resilience: Enhancing the Carbon Storage Capacity of Agricultural Systems	229
12.15	Livestock Integration in Agroecological Systems: Enhancing Carbon Storage and Mitigating Methane Emissions	229
	References.	230
13	Climate Change and Its Consequences on Future Agriculture in Sub-Saharan Africa	235
13.1	The Impact of Rising Temperatures on Crop and Livestock Production	236
13.2	Adapting to Altered Rainfall Patterns: Strategies for Sustainable Agriculture	237
13.3	The Impact of Increased Frequency of Extreme Weather Events on Agricultural Systems.	237
13.4	The Implications of Climate Change on Pest and Disease Dynamics in Sub-Saharan Africa	238
13.5	The Impact of Climate Change on Water Availability and Irrigation in Sub-Saharan Africa	239
13.6	The Impact of Climate Change on Biodiversity and Ecosystem Services in Agriculture	240
13.7	Adapting to Climate Change: Strategies for Resilient Agriculture.	241
	References.	242