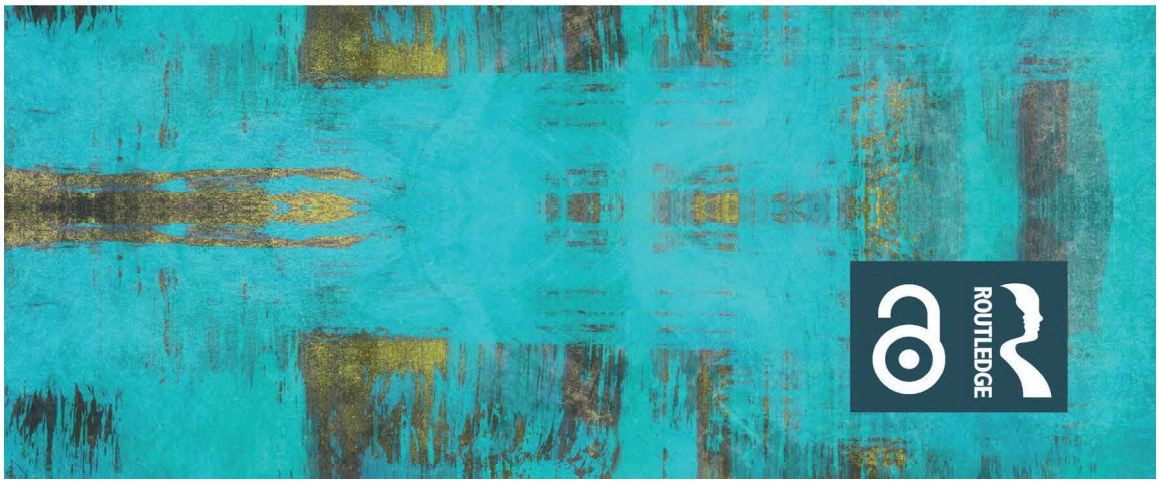
Earthscan Food and Agriculture

TRANSFORMING AGRICULTURE IN SOUTHERN AFRICA

CONSTRAINTS, TECHNOLOGIES, POLICIES AND PROCESSES

Edited by
Richard A. Sikora, Eugene R. Terry, Paul L.G. Vlek
and Joyce Chitja



Transforming Agriculture in Southern Africa

This book provides a synthesis of the key issues and challenges facing agriculture and food production in Southern Africa.

Southern Africa is facing numerous challenges from diverse issues such as agricultural transformations, growing populations, urbanization and climate change. These challenges place great pressure on food security, agriculture, water availability and other natural resources, as well as impacting biodiversity. Drawing on case studies from Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe, the chapters in this book consider these challenges from an interdisciplinary perspective, covering key areas in constraints to production, the most important building blocks of good farming practices, and established and emerging technologies. This book will be a valuable support for informing new policies and processes aimed at improving food production and security and developing sustainable agriculture in Southern Africa.

This informative volume will be key reading for those interested in agricultural science, African studies, rural studies, development studies and sustainability. It will also be a valuable resource for policymakers, governmental and nongovernmental organizations, and agricultural practitioners.

Richard A. Sikora is Emeritus Professor of the University of Bonn, Germany; former chairman of the Department of Plant Pathology and the Section, Soil Ecosystem Phytopathology and Nematology. He was Chair of the CGIAR System-wide programme on integrated pest management and is presently a Fellow of Stellenbosch Institute of Advanced Study (STIAS) and Convener of the Forum on Sustainable intensification. Richard has received numerous awards including the University of Illinois Alumni Association Award of Merit, the International Association for the Plant Protection Sciences Award of Distinction, the American Phytopathological Society International Service Award and the 2017 German Phytopathological Society Anton de Bari medal for excellence in phytopathology.

Eugene R. Terry was Director General of WARDA, now AfricaRice, and the Founding Director of the African Agricultural Technology Foundation (AATF). He currently serves as the Chair of the Advisory Panel for Biosciences for East and Central Africa (BecA) – ILRI Hub, and the Chair of the Advisory Board of the West Africa Centre for Crop Improvement (WACCI) hosted by the University of Ghana in Accra. Dr Terry was awarded the AfricaRice Distinguished Service Award in 2010, for exemplary leadership in rice research and development in Africa, and The Macdonald College, McGill University Distinguished Alumni Award in 2012, for outstanding contributions to society and humanity.

Paul L.G. Vlek is Emeritus Professor of the University of Bonn, Germany, and former Director of the Centre for Development Research ZEF as well as the West African Science Service Center on Climate Change and Adapted Land Use WASCAL. He devoted many years of service to a number of journal editorial boards and national and international scientific committees. In 2014, he was awarded the World Agriculture Prize for his lifetime contribution to agricultural development.

Joyce Chitja is Senior Lecturer in Food Security at the University of KwaZulu-Natal, South Africa. Her expertise and present research programme include food security and water use security, smallholder farmer development and market access. She has received a Women in Science (rural development of women) award and a Wonder Women in Science (WWS) award in 2018. She is a Cornell University and STIAS Visiting Scholar.

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Foreword

Much has been written and said about African food security and agricultural development. Results from economic and policy studies have provided input into a multitude of conferences and workshops. Problems have been diagnosed, challenges have been identified and recommendations for action have been made. The evidence created by these efforts is essential to guide action by policymakers.

So why is it that African policymakers are still confronted with huge challenges, and why are so many African children still malnourished and natural resources being degraded? Maybe lack of evidence is not the binding constraint to achieve food security and sustainability goals, or maybe the evidence is either not reaching the decision makers or is irrelevant to the situation within which decisions are made. Policymakers are busy people. They are under much pressure from various interest groups, trying to achieve a variety of goals, of which agricultural development and food security may or may not take priority. Policy recommendations based on an understanding of the policy process within which they will be received are more likely to translate into action than those that are not. First-best solutions from the sole perspective of food security and agricultural development may not be feasible with the policy space of the decision maker. Pragmatism, which may include second- or third-best solutions, is called for when trying to influence policy decisions.

Is this book going to make a difference? I believe so for at least three reasons. First, the editors and chapter authors are among the most knowledgeable experts on African agricultural development and food security. Equally important, they provide recommendations for action that take into account the pressures on policymakers from other interest groups. Second, each chapter is short enough to entice the policymaker or policy advisor to read it and sharply focused on how to turn the most relevant existing evidence into policy action, and third, the book provides an integrated, wholistic set of policy recommendations focused on some of the most critical challenges facing Southern Africa, including rapidly increasing population and urbanization, continued malnutrition and household food insecurity as well as land pressures and climate change.

Large productivity gaps in Southern African agriculture provide opportunities for expanded food production and improved productivity. As stressed by the

editors and several of the chapter authors, these opportunities are best exploited by accelerated use of existing technology and agricultural research to fill the gaps in the existing knowledge and technology. In particular, there is, in my opinion, an urgent need for more research to help African agriculture adjust to drought, floods, strong winds, new plant and animal diseases and other biotic and abiotic factors resulting from climate change and land pressures. Increasing food production and reduced risks do not, by themselves, solve the food security and nutrition problems in the region, but they are important components of a wholistic solution, particularly if they are oriented to a diversified portfolio of foods to meet both nutrient and calorie needs. As urbanization proceeds in Southern Africa and urban food demands increase, a closer look at land ownership and the future of smallholdings seems appropriate, along with an increasing emphasis on urban food security, nutrition and related health problems.

I congratulate the editors and chapter authors for an excellent book, which, I believe, will make a difference in both human and environmental health and well-being.

Per Pinstrup-Andersen
Professor Emeritus, Cornell University, USA, and
Adjunct Professor, Copenhagen University, Denmark

Preface

The Stellenbosch Institute of Advanced Study (STIAS) initiated a select number of long-term programmes in 2013, with the broad objective of making an impact on African development. One of the projects selected for long term support under the broader research theme of Sustainable Agro-Ecosystems was the "The impact of sustainable intensification of agriculture on food security, the environment and human well-being in the rural urban continuum of Southern Africa".

The STIAS Forum on Sustainable Intensification that materialized devoted particular attention to those challenges relevant to "Strategic directions for Agricultural Transformation in Southern Africa" towards the year 2050, which was the topic of a roundtable held at STIAS with regional representatives in 2015.

This book attempts to capture all the ideas, visions, strategies and lessons generated through the various discussion fora, seminars, individual research and analysis, as well as the visions of other stakeholders, in a consolidated publication on agricultural transformation.

The editors of the book are STIAS Fellows with a great deal of practical experience across Africa both in the field of education but also in applied research. They were the core fellows of the Forum and were responsible for developing the research programme and organizing the discussion fora.

Richard A. Sikora, is emeritus Professor of the University of Bonn, Germany; former chairman of the Department of Plant Pathology and Head of the Research Programme – Soil Ecosystem Phytopathology and Nematology. He is Convener of the STIAS Forum on Sustainable Intensification.

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Joyce Chitja is a Senior Lecturer at the University of KwaZulu-Natal in Food Security. Her expertise and present research programme include food security and water use security, smallholder farmer development and market access.

The authors of the chapters on technology and policy/processes were either from Southern Africa or had experience in other regions of Africa. Many of the authors were invited to the STIAS Forum on Sustainable Intensification to discuss their expertise as it relates to improving sustainable agricultural production.

The chapters are divided into distinct parts that include: an introduction to Southern African agriculture; discussion of the drivers and constraints influencing change; description of both current and proven as well as emerging technologies that can improve sustainable intensification; and finally a section on policies and processes that are needed to implement transformation.

The book directly targets decision makers, or those who have the greatest influence on agricultural transformation and make decisions that directly impact food production and food security. The authors of the chapters, therefore, were asked to include a section on policy recommendations for this target group.

The short and concise format of the chapters basically represents expanded science- and/or policy-briefs, which are used to ensure that the expert analyses and critical reviews of the factors important in driving future transformation are readable and useful for decision makers. The goal is to stimulate the development of government programmes that will lead to meaningful and substantive improvement of agriculture at the small- to medium-size family farm level. These farmers are underproducing at the present time, and they are an integral component of the responses to food security challenges and a key to solving future food security issues in the region. Many of the technologies and policy recommendations will also have importance for larger family and commercial farms.

We believe the findings presented in the chapters in this book are relevant to other agricultural regions of the world where transforming agricultural systems is needed and important for future food security.

Acknowledgements

The editors want to acknowledge STIAS for the excellent support given throughout the Forum's five year research program. We also want to thank them for their generous financial support for the open-access form of publication. The facilities they offered the Fellows and the financial support for workshops and expert visitation were outstanding.

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Professor Johann Groenewald, Coordinator: Strategic initiatives, who helped in the organization of the Roundtable Meeting.

Gratitude is also given to the STIAS Fellows Janos Bogardi, former acting Vice Rector of the United Nations University Campus, Bonn, Germany, and Lucas Gakale, Former Permanent Secretary, Ministry of Agriculture, Botswana, who supported the Forum in the first year and who were influential in making the roundtable meeting a great success.

We also greatly appreciate all those who actively participated in the Round-table on Strategic Directions for Agricultural Transformation in Southern Africa, and who expressed their vision for the future.

The support of the editors at Taylor & Francis were essential in ensuring the high quality of the book, and we thank them all.

11 Crop improvement for agricultural transformation in Southern Africa

Hussein Shimelis, E.T. Gwata and Mark D. Laing

Introduction

Crop genetic improvement is one of the strategies for transforming African agriculture to meet the demand for food, feed and bioenergy. Plant breeding can deliver genetically improved and high-performing nutritionally enhanced crop cultivars, with economic benefits and environmental sustainability for human well-being, which are in alignment with the United Nations goals that aim at ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture globally (Eriksson et al., 2018).

In Southern Africa, crop varieties are designed, developed or deployed by the public plant breeding programmes such as the National Agriculture Research Systems (NARS), International Research Centres, the private sector or non-government organizations (NGOs). The NARS in collaboration with international research centres breed cultivars of food security and cash crops including cereals, root tubers, legumes and oil seed crops (Table 11.1). The public sector breeding programmes are not well developed and are often under resourced due to limited investment in plant breeding education, research and infrastructure development. Conversely, some of the private sector programmes employ state-of-the-art breeding methods and biotechnological tools to develop new cultivars for the market.

Smallholder farmers in Southern Africa have had limited access to improved modern varieties that are specifically bred for cultivation under low input production systems. Most smallholder farmers continue to grow unimproved landrace crop varieties. Landraces are inheritably low yielding but stress resilient and possess various quality traits of intrinsic value for the indigenous farmers. If their new varieties are to be adopted by smallholder farmers, plant breeders have to develop and release crop varieties that meet all the key trait requirements of these farmers and the downstream value chains and that are adapted to perform well under increasingly adverse climatic conditions caused by global climate change. The objective of this chapter is to highlight the current breeding technologies, major constraints to plant breeding programmes and to present some of the reasons why there are low levels of adoption of freshly released, modern crop varieties by smallholder farmers in Southern Africa. The chapter

Table 11.1 National agricultural research institutes with crop improvement programmes and their major food security crops in the Southern African development community

Country	*Research institute*	*Major food security crop(s)*
Angola	Agricultural Research Institute of Angola	Maize, cassava
Botswana	Department of Agricultural Research	Maize, sorghum, millets, cowpea
Democratic Republic of the Congo	National Agricultural Research Institute	Maize
Lesotho	Department of Agriculture Research	Maize
Madagascar	Horticultural Technical Center of Antananarivo, Biotechnology and Plant Breeding Unit	Rice
Malawi	Department of Agricultural Research Services	Maize, cassava, pigeonpea, dry bean
Mozambique	Agricultural Research Institute of Mozambique	Maize, sorghum, cowpea, groundnut
Namibia	Ministry of Agriculture, Water and Forestry	Sorghum, pearl millet, cowpea, Bambara groundnut
Seychelles	Crop Research and Development Division	Cassava
South Africa	Agricultural Research Council	Maize, sorghum, pearl millet, wheat, barley, sweet potato, potato, fruits, dry bean, cowpea, ground nut
Swaziland	Agricultural Research Division	Maize, cowpea
Tanzania	Tanzania Agricultural Research Institute	Maize, rice, sorghum, pearl millet, soya bean, cowpea, potato, sweet potato, cassava
Zambia	Zambia Agriculture Research Institute	Maize, wheat, sorghum, pearl millet, cowpea
Zimbabwe	Department of Research and Specialists Services, Crop Breeding Institute	Maize, wheat, dry bean, ground nut, cowpea, sorghum, pearl millet, potato, sweet potato

Source: FAO, 2019

also discusses the support needs of plant breeders to guide policymakers to create enabling environments and to make investment decisions to support plant breeding as a core component of agricultural transformation.

Breeding methodologies and technologies

Various plant breeding methodologies and technologies are available, each with its advantages and limitations (Mwadzingeni et al., 2016). The public sector plant breeding programmes commonly use conventional plant breeding

methods, including selections from local and exotic genetic resources, population improvement, pedigree breeding, hybrid breeding and backcrossing. These procedures typically require ten to 15 breeding generations to release an improved cultivar, unless complemented by the doubled haploid (DH) technology and other scientific innovations. Mutation breeding is rarely used in the region despite its potential to enhance genetic variation for biotic and abiotic stress tolerance and quality traits (Horn et al., 2016; Gwata et al., 2016). Tissue culture methods are useful in DH breeding and rapid mass production and multiplication for large-scale production.

In the region, genomic and proteomic tools are rarely used. Genomic tools have great potential in enhancing plant breeding in the region by complementing the conventional breeding methods, enhancing selection response, improving the accuracy of selection schemes and ensuring the efficient use of plant genetic resources. Gene editing is a relatively recent addition to genomics that is yet to be explored in the public sector plant breeding programmes for accelerated breeding and genetic gain. Initially, the use of genetic engineering to transform crops was seen as a technology of great promise. However, genetically modified organisms have been rejected by most countries in southern Africa, and there is a lack of enabling legislation in these countries. South Africa is the only country in southern Africa that has enabling legislation for the release and production of genetically modified crops such as maize, soybean, canola and cotton.

Conventional breeding programmes in the region have achieved notable successes in the release of various field crops (Walker et al., 2014). However, public breeding programmes need to develop high yielding and stress resilient crop varieties to serve the diverse needs of millions of smallholder farmers, value chains and local and regional markets. For instance, production of cereal crops in the region and SSA faces a serious threat caused by the recent arrival of the fall armyworm (FAW), a polyphagous insect pest that has more than 180 host plant species. Plant breeders urgently need to enhance host plant-resistance to FAW, which will provide an affordable, sustainable and environmentally friendly approach to minimizing its ongoing impact.

Major constraints to regional breeding programmes and farmer access to varieties

Public plant breeding programmes in the region are inadequately resourced and lack a critical mass of active plant breeders and breeding technicians. Often a high turnover of the relatively few plant breeding personnel negatively affects the continuity and impact of crop breeding projects and programmes. There is no harmonization of plant breeding programmes in the region. This has led to disjointed breeding programmes, which often results in multiple parallel projects. The cultivar development and release systems could be regionally consolidated to serve market needs (AGRA, 2015). Further, funding should be made available for research including into neglected crops, such as cowpea, Bambara groundnut and sorghum.

The adoption rate of improved varieties in SSA (excluding South Africa) is below 35%, compared with above 60% in Asia and 80% in South America (Walker et al., 2014). The low uptake of modern crop varieties in Africa is partly due to a lack of suitability of many new plant varieties to adequately meet the needs and preferences of the farmers and other actors such as processors, retailers and consumers in the value chain. The new varieties may also fail to meet the current and changing market demands. Therefore, the next generation of plant breeders should be trained to undertake demand-led breeding, focusing on the needs and preferences of the value chains, the marketplace and the stakeholders in the region. For instance, during the variety design phase, plant breeders should incorporate product profiles relevant to farmers and consumers to ensure high levels of adoption of the new varieties (Shimelis, 2017). This requires understanding the needs and preferences of smallholder farmers, processors, traders, retailers, consumers and other actors along the value chain of each crop.

Plant breeder requirements from policymakers

Many studies have shown that concerted and sustained plant breeding brings substantial returns on investment (ROI) with varied economic, social and environmental benefits. In the United Kingdom, plant breeding has reportedly attained an ROI as high as 40:1 (Webb, 2010). However, the sector requires adequate attention from policymakers who generally perceive plant breeding as a cost rather than an investment that gives substantial returns. Therefore, there is a need to educate policymakers in the critical need for increased investment in plant breeding capacity development and long-term investments, as summarized in Table 11.2. It is unlikely that any other area of investment will give sustained returns to match plant breeding, especially given the multiplier effect of agriculture on downstream value chains such as farmers, retailers, processors and consumers.

Table 11.2 Core requirements of plant breeders from policymakers in Southern Africa

Requirement	*Reason/potential impact*
Plant breeding education: Increased investment in plant breeding education	• Training more plant breeders and breeding technicians to breed the diverse African food security crops and to serving distinct agro-ecologies and for continuity of existing breeding projects. • Enhancing plant breeding programmes, including curricula, to train the next generation of academics and demand-led plant breeders, in Africa, with expertise in African crops.

Requirement	*Reason/potential impact*
Plant breeding research:	
Increased investment in plant breeding research	• Allocating research funds for plant breeding projects to develop farmer- and market-preferred and high performing cultivars for food security, enhanced livelihoods and return on investment. • Establishing plant breeding infrastructure (e.g., breeding nurseries, greenhouses, tissue culture and seed testing laboratories, germplasm repositories, genomics and proteomics tools, phenotyping resources, automated trait measurement resources). • Adopting demand-led plant breeding research and cultivar development based on the needs and preferences of clients and value chain and using market research, market trends and derivers, public-private sector partnership and multidisciplinary approaches. • Promoting community-based seed systems, through seed production, processing, packaging and marketing.
Policy and regulations:	
Introduce or reinforce enablers for plant breeders	• Enforcing African Union and regional legislation that provide for the harmonization of regulations on variety release, registration and marketing. • Establishing and supporting a regional plant breeding society and networks to exchange ideas and experiences on scientific progress, technological applications and the business of plant breeding, to contribute to the training of future plant breeders, to create a forum for communication for all stakeholders in plant breeding and to promote cooperation and closer link and involvement with agriculture. • Recognizing and rewarding plant breeders through royalty fees and award systems. • Harmonizing regional plant breeding programmes and seed policies to minimize duplication of efforts and to save resources, to accelerate the release of new varieties or new traits at reduced cost. • Enhancing cross-border germplasm exchange, variety release and seed systems within the same agro-ecological zones, across political borders. • Promoting public-private partnerships to develop new traits, new inbred lines and to breed and distribute seed of new crop varieties. • Promoting and financing small seed companies and agro-dealers, to expand the delivery system of new seed varieties and crop inputs to smallholder farmers across the entire region. • Financing smallholder farmers to buy new and improved seeds, irrigation systems, fertilizers and crop protection resources and postharvest storage facilities. • Financing infrastructure development to ensure that smallholder farmers have access to regional markets.

Breeding for value chains and marketplace

Farmers are the starting point of every crop value chain. Hence, the market potential of a new crop variety is heavily dependent on the number of farmers who are interested in growing the variety. In turn, this is dependent on demand for the product in the market by consumers and processors.

Adoption rate and commercialization of modern crop cultivars in Africa can be enhanced by integrating the breeding objectives set by NARS breeders along with the needs and preferences of the clients and market in the entire value chain. This requires well-detailed and up-to-date analyses of the value chain, market and market trends of each crop. In the past, crop breeders in SSA prioritized traits based mainly on "a priority or historical assumption", that farmers need such traits without consulting them. Furthermore, plant breeders unilaterally use quantitative and qualitative selection indices and product profiles without involving clients or the needs of the market. This form of trait prioritization and product profiling rendered low adoption rates of modern crop varieties including high yielding ones. Therefore, trait prioritization and product profile should be guided by both the market demand (proportion of growers needing the variety, or the total area grown by this variety) and price differentiation (the price premium or market share of the varieties or their traits) rather than selection indices.

Demand-led variety design should follow best practices from public and private sectors in Africa and internationally for successful variety design, product profiling and market. Partnerships between the public and private plant breeding programmes is key to learn best practices and to provide customized services needed by small-scale farmers. Partnerships between the two sectors enable access to genetic resources and modern plant breeding training services and infrastructure support for the NARS breeders. It also ensures that the private partners have access to new varieties bred in the public sector, with new traits that meet the changing needs of farmers and downstream value chain. This combined with excellent breeding science and technology, vigourous awareness campaigns with farmers and customers can lead to significant gains in adoption rates and market share of new varieties developed by public sector and small seed company breeding programmes in Africa.

Conclusions and recommendations

Plant breeding can produce improved crop cultivars with economic benefits that help in achieving food and nutrition security and sustainable agriculture globally. However, in southern Africa, the public sector breeding programmes are not well developed, and they are often poorly resourced due to limited investment in plant breeding education, research and infrastructure development. The existing public breeding programmes have developed and released many crop varieties with significant yield and quality gains. However, smallholder farmers in the region have not adopted these varieties, primarily due to a

lack of access or rejection of the new varieties because they fail to carry critical quality traits. Also, the major constraints to regional breeding programmes can be attributed partly to a lack of harmonization of plant breeding programmes, restricted movement of plant germplasm resources across national borders and insufficient active plant breeding personnel in the region. The formal seed systems in the region have not engaged with smallholder farmers in seed production, distribution and marketing. In order to increase the uptake of modern crop varieties in the region, it is critical for plant breeders to incorporate quality traits that satisfy the needs and preferences of farmers and their value chains, markets and stakeholders. Success in agricultural development through crop improvement in the region is dependent on increased investment in plant breeding education, long-term research programmes and research infrastructure development. In addition, efforts should be exerted towards the development of infrastructure and markets for farmers in the region and enhancing partnerships between the public and private plant breeding programmes.

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