NELSON MANDELA
UNIVERSITY

Handout notes for a course on organic farming, quality management (PGS) and facilitation

The following course notes summarise that part of the short course content to be presented by Professor Raymond Auerbach from the Nelson Mandela University (George Campus).

Introduction (from CABI book to be published in 2019).

1 Organic research and government support improve organic policy and progress in Danish, Swiss, American and African case studies.

2 Sustainable Food Systems for Africa.

The above two papers will be published in December 2018 in the Italian Journal Number 3/2018 of "Economia agro-alimentare/Food Economy" and are from presentations given at the International Sustainable Development Research Society conference "Actions for a sustainable world: From theory to practice," held in Sicily in June 2018, and are based on a forthcoming book by Prof Auerbach: "Organic Food Systems: Meeting the needs of Southern Africa" (Commonwealth Agricultural Bureau International, 2019).

Acknowledgements

This course and the book "Organic Food Systems: Meeting the needs of Southern Africa" (to be published in 2019 by the CABI), would not have been possible without the generous financial support of the German government (GIZ in South Africa).

The two papers which follow are based on research funded by the SA National Research Foundation through the African Organic Farming Systems Research project, the Centre of Excellence in Food Security, and the Africa Earth Observatory Network-Prof Maarten de Wit; as well as the ISASAR project funded by the International Fund for Agricultural Development; and the German government ECOSOLA project (funded jointly by DAAD and BMBF), with co-funding from S Haddad Agricultural Services (Pty) Ltd.

INTRODUCTION (from CABI book)

Raymond Auerbach, Nelson Mandela University, South Africa

Climate change, food insecurity and on-going urbanisation combined with poor governance in many parts of Africa mean that small-scale farmers are not receiving the support they need. Food quality has also fallen resulting in increasing obesity, stunting and diabetes, and consumers often do not have access to nourishing food. Much of the support which farmers receive is provided by input suppliers who have a vested interest in selling seeds, fertilisers and agro-chemicals. The environmental impacts of industrial agriculture are enormous, with carbon, methane and nitrous oxide emissions, nitrates and phosphates in streams and groundwater, and toxins in food and the environment. The cheapest food on offer is often high in salt, hidden sugars and unhealthy fats. Support for public interest research is at an all-time low in agriculture, with most research funded by companies.

The organic agriculture (OA) movement world-wide helps farmers to produce healthy food with low levels of external inputs, and often shortens value chains, giving farmers a higher share of the consumer dollar. Agro-ecology is a broader approach, including certified and non-certified organic farming, conservation agriculture and a range of other “almost organic” approaches. The benefit of agro-ecology is that it is easy for small scale farmers to practise; the disadvantage is that the consumer is not certain whether poisons, chemical fertilisers and/or Genetically Engineered (GE) seeds have been used. Adopting an agro-ecological approach to sustainable development, without excluding too many farmers would appear to make sense, provided that a balance is maintained between ethical and healthy food production and inclusivity. The idea of Regenerative Agriculture as a broader framework is explored in Chapter 2 of this book.

On the other hand, there are controversial calls such as those made by the Swiss Organic Research Institute (FiBL), that organic farming should now selectively include some aspects of GE, and other biotechnologies. This may cause some current farmers and consumers to argue that organics has become too conventional and industrial; there are already calls for “beyond organic” and “Organic Plus”. Where should the line be drawn between organic and conventional? How can we do this in such a way that we encourage large-scale farmers to move towards greater biodiversity, less poison use and more responsible environmental stewardship? How can we put farmers in charge of their food production processes, and respond to demands from consumers for health-giving nourishment? How can African food systems promote food sovereignty?

Part of the challenge is understanding that food systems are more than just food production and distribution. Concern about resource use and primary food production, agro-chemicals and their residues in food and the environment, food processing, food additives, poor cooking and poor food choices, as well as the increasing impacts of poor nutrition on health has seen a shift in focus from “enough cheap food” to “the right kind of food produced sustainably and prepared intelligently”. Consumers, policy makers and natural resource managers are examining alternatives.

This book reports on long-term comparative organic farming systems research trials carried out over the last five years in the Southern Cape of South Africa (SA), on the George Campus of Nelson Mandela University (the “Mandela Trials”), as well as research into the successes and failures of the organic sector and the technical tools required for sustainable development in SA, Zambia, Uganda and Tanzania.

The trials compare organic and conventional farming systems, and show how, from an initial situation where organic yields were 20% lower than conventional, this yield gap was closed by the third year, once available soil phosphate levels were attended to in the organic treatments. Water use efficiency and water retention were also greater in the organic farming system, and pests and diseases were effectively controlled using biological products. The trials examine mono-cropped cabbage and rotated cabbage, sweet potato and cowpea in a complete randomised block design with four replications, split for organic and conventional farming systems. The trials were intended to run for ten years, but it seems unlikely that funding for this will be available, with my imminent retirement. At least the preliminary results have confirmed what other longer-term research found: organic yields can exceed conventional yields in dry years, but are likely to be a little lower in wet years. Under climate change, this is important to know, but this yield gap can only be closed if scientific and experiential understanding are combined to develop soil fertility and crop rotations which are ecologically appropriate and economically viable, and which are integrated into local culture and food systems.

The impacts of drought, climate change models, practical analysis of actual climate variability, farmer training approaches, soil carbon analysis, participatory guarantee systems, the Zambian organic farming sector (agronomy) and Ugandan organic farmer (training support) are analysed, and after the world context for organic and regenerative agriculture has been examined, and the conditions needed for supporting farmer innovation through experiential learning processes explored, a sector plan for Southern African organic farming is developed.

SUMMARY OF THE BOOK

The big issues are outlined in the first six chapters: a theme running through the book is the importance of the Critical Zone, Earth’s thin, fragile outer layer of soil, and the challenges of producing food on a small planet given climate change in the Anthropocene. Chapter 1 gives a context for participatory and sustainable development, and presents an overview of the how farmers can progress from sub-subsistence, through subsistence to semi-commercial and perhaps commercial farming systems. The development of organic farming and agro-ecology in Southern Africa is traced, and a conceptual framework for the book is developed. Progress across the world from a tiny “organic fringe” at the end of the 20th century to what Chapter 2 describes as “Organics 3.0” –organic farming as a major part of sustainable food systems – will require a range of adaptations, many of which will be controversial. On the one hand, it has to be possible for farmers, large and small, to produce nourishing food while caring for the environment and the people involved in the whole food system, and still making enough profit to sustain them; on the other hand, we have to accept that growing population pressure and climate change will make this more of a challenge, but that biotechnology will offer an array of emerging tools, and

Chapter 3 looks at the links between research and policy, while Chapter 4 looks at farmer training in this context.

Given these developments, we can no longer have agriculturalists looking at food production, food technologists looking at food processing, economists looking at food value chains, nutritionists looking at diets, each in isolation, otherwise we will continue the rapid expansion of the medical community looking at declining health, with pandemics of obesity, diabetes, hypertension, autism and cancer ever more prevalent! This book therefore adopts a “Food Systems” approach (described in more detail in Chapters 5 and 6) and examines how African food systems are changing, and how they could become more sustainable and healthy, in line with the work of the Centre of Excellence in Food Security, described in Chapter 7. Holistic systems, inclusive participatory approaches, institution building and experiential learning are examined.

It also reports on research into organic food production, farmer training, climate change, helping farmers to manage drought, building soil carbon and the role of organic farming in sequestering carbon in the soil where it is useful, rather than sending it up into the atmosphere and out into the sea to contribute to the ever-warming greenhouse! Chapter 17 shows how farmers can use simple but accurate soil carbon tests to track the changes in soil carbon; this is a major innovation, and could assist farmers in documenting how OA sequesters carbon in the soil where it is useful, removing greenhouse gases (GHG) in the process. We describe the long-term Mandela Trials on the George Campus of the Nelson Mandela University, comparing organic and conventional farming systems; we look at changing soil fertility, compare yields and soil microbiology, examine water use efficiency in the two systems and develop biological systems of pest and disease control. We present a number of specialised case studies in various countries. Finally, we present ideas on urban food gardens, we make recommendations for land reform and agricultural transformation in SA, and present a strategy for the organic sector in southern and eastern Africa.

STRUCTURE OF THIS BOOK

The book is structured as follows: In the first section, the historical development of organic farming systems is discussed, global issues which confront us are examined, and some concepts are developed showing a progression in small farmer development and how this can be supported with appropriate training and policy; the difference between national food self-sufficiency and household food security is examined, and the organic sector is introduced. An overview follows of organic and regenerative farming approaches by one of the world leaders of the organic movement and then a reflection on the importance for policy makers of long-term research in developing sustainable farming systems which can produce healthy food without damaging the environment, drawing on long-term research from Switzerland (the DOK Trials), Denmark (the work at Aarhus University) and Rodale Institute (Pennsylvania), and on policy development work from the United Nations Conference on Trade and Development (UNCTAD) and UNEP (United Nations Environmental Programme). This is followed by a review of international farmer training activities by the head of capacity building and training at International Federation of Organic Agriculture Movements (IFOAM). Chapters 5 and 6 present the food systems approach, first the concepts and then examples from around the world of how this approach has been applied, drawing on systems theory and integrated approaches to human development as a process of “eco-development” rather than “ego development”, for the good of the planet!

The first six chapters give a global picture, which is then followed by insights into capacity building in times of climate change, describing the likely future scenarios for SA: Chapter 7 deals with the impacts of the two most recent droughts on South African food prices and consumption patterns, and the concept of “weather shock” – of necessity, it will be incomplete, as we are at the time of writing still in the grip of the drought in certain parts of the country. The City of Cape Town is in a situation of critical water shortages! Since, given continuing recurrent droughts Cape Town must address food insecurity through peri-urban food production, Chapter 8 shows how to strengthen community participation in local planning using participatory rural appraisal (PRA) in the case of the Philippi Horticultural Area, situated on the Cape Flats Aquifer. Chapter 9 looks at value chains in the South African fresh produce sector, and ways of increasing participation by small scale farmers using a case study from the south coast of KwaZulu-Natal. Chapter 10 and 11 examine the potential for helping small scale farmers to access high-end markets through Participatory Guarantee Systems (PGS) and smart-phone “apps” which can help to shorten the value chain, and put research and marketing tools in the hands of small farmers.

Chapter 12 then combines three research papers produced for the International Fund for Agricultural Development (IFAD) on drought prediction models, on long-term rainfall patterns in the Eastern Cape, and on a strategy for supporting farmers in that province, where many areas have experienced a drop in rainfall over the summer rainfall production season. For the seven months from September to March, rainfed crops require at least 500 mm of rain – many areas of the Eastern Cape used to receive more than this on average, but have experienced a decline in rainfall over the past 20 years; - what are the implications for sustainable farming systems, and for farmer livelihoods?

Having looked at rainfall, urban gardens and methods of improving urban water and energy use efficiency are examined in Chapter 13, as well as some strategies for improving household food security in the area around George, where the author is based geographically, on the cusp between the Western Cape winter rainfall region and the Eastern Cape’s erratic summer rainfall. Chapter 14 examines approaches to farmer training, looking in detail at two case studies on experiential learning (farmers in KwaZulu-Natal at the Rainman Landcare Foundation, and Agriculture Diploma students at Nelson Mandela University). This is followed by a case study on Participatory Guarantee Systems (PGS) in SA, and the research carried out recently on PGS and organic farmers in SA, with assistance from the German government (GIZ) and the South African Organic Sector Organisation (SAOSO). This concludes the second section on approaches to sustainable rural development.

The third section examines practical support for organic farmers and organic food systems, starting with two case studies on the well-developed organic sector in Uganda, and the developing one in Zambia, including some of the reasons why some farmers who adopted organic farming and took the trouble to become certified organic producers, have “dis-adopted” organic certification – the reasons for this are explored, and some lessons for the organic sector are drawn from this experience. A simple and accurate method of determining soil carbon is then explained in Chapter 17, which could allow farmers to test their own soil carbon levels.

The focus then shifts to the results of the Nelson Mandela Long-term Comparative Organic Farming Systems Research Trials (the “Mandela Trials”) on the George Campus of Nelson Mandela University, with Chapter 18 describing the baseline study carried out in 2014 at the start of the Mandela Trials. Chapter 19 compares changes in water use efficiency between organic and conventional farming systems, while Chapter 20 compares soil fertility and crop yields. Chapter 21 looks at approaches to pest and disease control, and to soil fumigation (biological and chemical), while Chapter 22 compares soil microbiology in organic and conventional systems in the Mandela Trials.

Section four looks ahead with a study on the work of the ECOSOLA Project (a German government-funded consortium of the University of Dar es Salaam, the Carl von Ossietzky University in Oldenburg, Germany and the Nelson Mandela University), in Tanzania and SA. Urban food gardens and their current and potential future role are examined in Dar es Salaam (Tanzania), Giyani (SA's Limpopo Province) and George (Western Cape, SA); the likely impacts of climate change are examined and some preliminary broad strategic ideas for town planning and food security for the region are explored.

The final chapter becomes much more specific, proposing a strategy for developing the organic sector in SA over the next 20 years as an instrument for transformation of the agricultural sector. The dangers of confrontation between unwilling sellers who are currently producing much of the food grown in SA, and the politically empowered but economically disempowered majority of effectively landless South Africans, are examined, and some creative solutions are proposed. Ways of marrying the business, marketing and production skills of commercial farmers with the energy and entrepreneurship of emerging farmers are explored, and possibilities for internships and an apprenticeship system are presented.

Organic research and government support improve organic policy and progress in Danish, Swiss, American and African case studies

Raymond Auerbach[1] Nelson Mandela University, George, South Africa, raymond.auerbach@mandela.ac.za

ABSTRACT

Evidence-based policy development is promoted by organic research, according to studies in ten countries (in Africa, America and Europe). A seven country study by the *United Nations Conference on Trade and Development* (UNCTAD, 2008) on how governments can assist organic sectors, gave guidelines about regulation, special support for small scale farmers and under-pinning the emergence of a market for organic produce without distorting this market. Eight years later, UNCTAD published a further report on financing Organic Agriculture (OA) in Africa, which concluded that lack of finance hinders the development of OA in Africa. These reports emphasise the need for OA research; research into broccoli seed-breeding had a positive impact on the perceptions of commercial seed producers, and may help to improve regulatory frameworks. Three long-term research projects are then analysed. The Swiss research trials showed many benefits of organic farming, but also limitations; they cite many researchers around the world who show the benefits of OA, and argue for the establishment of a global platform for organic farming research, innovation and technology transfer. Long-term research has had a major impact on production, processing, marketing and consumption of organic produce world-wide, as shown by Danish research through four research programmes at Aarhus University (which contributed to Danish sales of organic produce increasing from €67 million in 1996 to €821 million in 2010), and this helped Danish farmers to expand production and understand the needs of the market. In the United States, the Rodale Institute carried out long-term research trials to show that OA can be economically competitive, while benefiting the environment and the health of consumers. All three studies had close links with agricultural policy, but the Danish and Swiss studies were more sympathetically received and resulted directly in positive changes to agricultural policies in those countries.

---

[1] This paper is based largely on the work on Danish research and its policy impacts from Lise Andreasen, Ilse Ankjaer Rasmussen and Niels Halberg (2015); it also summarises the Foreword and the Executive Summary from "Best practices for organic policy", published by UNCTAD, 2008, extracts from "Financing organic agriculture in Africa" (UNCTAD, 2016) and papers by Niggli *et al*. (2017), as well as Hepperly *et al*. (2006); it thus includes some reflections from the three long-running organic research trials which compare organic and conventional farming (Denmark – at Aarhus University, FiBL in Switzerland, and the Rodale Institute trials in Pennsylvania). This brings together the important work which motivated us to start the long-term comparative Mandela organic farming systems research trials (the Mandela Trials) to contribute to the development of evidence-based policy for OA in Southern Africa. Much of the content is taken from our forthcoming book "Organic Food Systems: Meeting the needs of Southern Africa" to be published in 2019 by the Commonwealth Agricultural Bureau International (Auerbach [Editor], Forthcoming).

INTRODUCTION

Do research projects and results enhance government support for the organic sector? The impacts of three comparative long-term organic research trials are reviewed (the Swiss DOK trials in Section 3.1; the Danish long-term trials at Aarhus University, as well as the whole Danish Organic Research programme in Section 3.2 and the Rodale trials in Pennsylvania in Section 3.3). Before this review of long-term research, the recommendations of two studies on best practices and financing of OA are discussed in Section 1, and then research on broccoli seed-breeding is discussed in Section 2.

1 Summary of UNCTAD (2008 & 2016) recommendations

The *United Nations Conference on Trade and Development* seven country study "Best practices for organic policy" (UNCTAD, 2008) studied organic policy development in seven countries; these were selected to reflect a variety of conditions and stages of development and various levels of government involvement in the sector, from almost none (South Africa [SA]) to deep engagement (Costa Rica and Denmark). I wrote the South African case study in 2007, in the middle of a tortuous process to develop national organic standards, which saw 11 years of fruitless engagement with the national department of agriculture, followed by four years of frustrating engagement with the South African Bureau of Standards. Eventually, the SA Organic Sector Organisation (SAOSO) worked with the International Federation of Organic Agriculture Movements (IFOAM) to develop a standard (www.saoso.org) which was accepted into the IFOAM Family of Organic Standards late in 2017.

Although a South African Organic Standard (SANS 1369) was developed with SABS, interference from outsiders made this an internationally unacceptable standard; the two standards should eventually be harmonised. Because the organic sector in SA has been actively opposed by elements of government and agribusiness, it is important to look at what governments should be doing to support the organic sector.

The Foreword to the UNCTAD 2008 study points out that the organic sector is part of the trend towards agro-ecology, and states "Organic agriculture is a production system based on an agro-ecosystem management approach that utilises both traditional and scientific knowledge… [and]… offers developing countries a wide range of economic, environmental, social and cultural benefits. …. While sales are concentrated in North America and Europe, production is global, with developing countries producing and exporting ever-increasing shares. Due to expanding markets and price premiums, recent studies in Africa, Asia and Latin America indicate that organic farmers generally earn higher incomes than their conventional counterparts. […] Modern organic techniques have the potential to maintain and even increase yields over the long term while improving soil fertility, biodiversity and other ecosystem services that underpin agriculture. Crop rotations in organic farming provide more habitats for biodiversity due to the resulting diversity of housing, breeding and nutritional supply. As synthetic agro-chemicals are prohibited in OA, its adoption can help prevent the recurrence of the estimated three million cases of acute severe pesticide poisoning and 300,000 deaths that result from agrochemical use in conventional agriculture every year. Organic systems have 57% lower nitrate leaching rates compared with other farming systems, and zero risk of surface water contamination. In terms of benefits for climate change, various studies have shown that organic farming uses 20 to 56% less [non-solar] energy per produced unit of crop dry matter than conventional agriculture […] it is estimated that converting the US' 160 million corn and soybean acres [66 million ha] to organic production would sequester enough carbon to meet 73% of that country's Kyoto targets for CO_2 reduction".

The UNCTAD report (2008) states that organic production helps resource-poor farmers depend less on external resources and enjoy higher and more stable yields and incomes, enhancing food security and supporting farmers' rich heritage of traditional knowledge and traditional agricultural varieties. OA provides employment for youth, and is a powerful tool for achieving the [then] Millennium Development Goals, particularly those related to poverty reduction and the environment. UNCTAD and the United Nations Environment Programme (UNEP) selected it as a priority issue to be addressed in the framework of the UNEP-UNCTAD Capacity Building Task Force on Trade, Environment and Development (CBTF). "Since 2004, CBTF efforts have focused on promoting production and trading opportunities for organic products in East Africa, including supporting, in cooperation with the IFOAM, the development and adoption in 2007 of the East African Organic Products Standard … the second regional organic standard after that of the European Union (EU) and the first ever to be developed through a region-wide public-private non-governmental organisations (NGOs) partnership process".

The key challenges for policy makers (both public servants and politicians) are to support processes for: building compliance with the organic standards of the markets in a cost-effective way, meeting quality and volume requirements of buyers, growing the domestic organic market and building farmers' capacities in organic production techniques and documentation requirements for demonstrating compliance.

The Executive Summary calls for protection of natural resources (e.g. water and energy) and biodiversity; improved quality of soils and thereby long-term high productivity; improved market access; improved profitability in farming and improved health or reduced health risks for farmers, farm-workers and consumers.

The report relates experiences from the cases of seven countries: Chile, Costa Rica, Denmark, Egypt, Malaysia, Thailand and SA, as well as from other parts of the world. It shows that OA is developing strongly in all the seven countries, despite quite different conditions and very different levels and kinds of government involvement. Most organic production is for export purposes but countries like Egypt, Malaysia and SA have developed substantial domestic markets. Malaysia is even a net importer of organic food. In almost all countries with an organic sector, the early drivers are NGOs and the private sector; governments have rarely played any role in the early stages. Countries with a unified organic movement develop the sector quicker […] A starting point for government engagement is to give recognition and encouragement [...] This also includes the recognition of the relevance of organic sector organisations and the close cooperation between them and governments. The study recommends that developing-country governments should facilitate and integrate rather than try to control OA. They should engage in dialogue with their organic sectors to identify their most pressing needs and consider conducting an integrated assessment of the sector, building OA supply capacities through education, research, extension services, local and regional market development and export facilitation. The study lists the following:

Integrate assessment of agriculture policies, programmes and plans, to understand how they affect the competitiveness and conditions of the organic sector.

Clarify government involvement for the development of the organic sector; involve stakeholders in the policy development and development of plans and programmes.

General and OA policies should support each other where possible to promote effective policy coherence, especially if OA is promoted as a mainstream solution.

Develop an action plan for the organic sector based on analysis of the state of the sector, participatory consultations, a needs assessment; the action plan should state measurable targets to help agencies and stakeholders focus their efforts.

Governments should actively contribute to awareness raising for OA on all levels, and should set up a formal body for interacting with the sector, establishing organic standards and collecting data.

Producers, especially smallholders, should be supported to comply with standards, certification procedures and regulations. Special consideration should be given to smallholder quality management. Training programmes for farmer groups to set up internal control systems should be supported. Public procurement of organic products should be encouraged, including featuring organic food in important public events.

Consumer education and awareness should be actively promoted, with a common (national, regional or international) mark for organic products, and support for the organisation of farmers through market information systems and export promotion activities, recognising the special nature of organic markets. Organic exporters should be encouraged to join forces to promote and market their products.

Organic extension services need to be established and the staff trained. Organic extension should be developed and implemented in a participatory manner and have the farm and the farmer as the centre of attention, and should build on traditional knowledge about pest control treatments, etc.

Seed breeding and seed testing should be oriented to organic production. Compulsory seed treatments should be waived for organic farmers and untreated seeds should be made available. Alternative seed treatments should be developed and promoted. Policies for genetically modified organisms (GMOs) need to ensure that GMO seeds do not cause contamination of agricultural seeds.

Special research programmes should be established for organic research, and the sector should be involved in priority setting. Research and development in OA should be participatory, build on and integrate traditional knowledge (where relevant) and be based on the needs of the producers.

In 2016, UNCTAD produced a report on “Financing Organic Agriculture in Africa”, which analyses the financial needs of OA, and barriers and opportunities for funding.

Extracts from the last two sections are summarised below:

Access to finance in the OA sector remains constrained and survey results do not suggest the situation is improving. The majority (64%) of surveyed stakeholders indicated that, over the last five years access to finance had remained the same, and close to a quarter of respondents (23%) even suggested that access to finance has become more restrictive. Limited credit guarantee mechanisms and insufficient capacity of commercial banks to integrate the specificities of OA are major hindrances to the ability of OA stakeholders to finance their activities in Africa. The commitment to support sustainable agriculture expressed in the 2015 Addis Ababa Action Agenda on Financing for Development, and the unanimous approval by the African Union Ministerial Council of the Ecological Organic Agriculture Strategic Plan (2015 - 2025), are opportunities to bridge the OA funding gap. In this regard, efforts to further embed OA in the Comprehensive Africa Agriculture Development Programme (CAADP) will play a key role in the allocation of funding and the systematic inclusion of OA considerations into national agricultural development plans and strategies.

These two UNCTAD studies show that country organic sectors benefit from certain kinds of government support in training and the setting of organic standards, but that government can also inhibit the development of the sector by a heavy-handed regulatory approach. The same is true of the organic seed sector.

2 Organic seed breeding and its impacts on regulatory frameworks

A doctoral research study by Erica Renaud (2014) examined the regulatory and technical challenges to the organic seed and breeding sectors in the US, Mexico and the EU. The abstract to this work states:

“The main findings of the regulatory component were: (1) New organisations, procedural arrangements and activities have emerged in the US, EU and Mexico, to support organic seed regulatory development, with both positive and negative results; (2) Official guidance on the interpretation of the regulation in the US has not been sufficiently decisive to prevent divergent interpretation and practice, and in consequence, the needs of a rapidly growing economic sector are not being met; and (3) Growth of the organic seed sector is hindered by regulatory imbalances and trade incompatibilities within and between global markets”.

Renaud explains that international organic standards compel organic producers who wish to be certified to use organically produced seeds, seedlings and breeding stock. She points out that regulators are waiting for non-government stakeholders to organise the sector to comply with the organic seed regulations. As there is therefore considerable regulatory ambiguity over what can and cannot be done, this contributes to potential violations of organic integrity, through the use of non-acceptable seed and seed-treatment inputs.

Although the organic seed sector is developing, it is not keeping up with increasing demand, as it is a relatively small sector. As cultivars bred for high input conventional growing conditions are often not optimal for organic farming systems, it is important to breed seeds under conditions where they are exposed to pests and diseases so that their performance (including pest and disease tolerance) can be assessed realistically. After the public defence of Renaud’s doctoral thesis on 2 July 2014 in The Netherlands, several seed breeders told me that they had found her work very interesting and now felt that much of their conventional seed breeding should also be done under conditions where the plant is challenged by pests and diseases, rather than the normal conventional approach, where, during breeding, all pests and diseases are rigorously controlled by chemicals. They felt that breeding seed under more challenging conditions could produce pest and disease tolerant plants which would require fewer chemical treatments.

3 Long-term organic comparative research: Three examples

Auerbach (Forthcoming) states that "In Europe and the US there has been considerable progress in long-term research into organic farming systems. Notably, the long term comparative trials in Switzerland showed that over a 34-year research period, comparative organic yield levels are about 80% of conventional yields, with lower levels of inputs and higher nutritional quality on 11 parameters (Mäder *et al*., 2006). Similarly, in Denmark, the ICROFS trials at Aarhus University obtained similar results over two decades, also with a yield gap between organic and conventional of about 20% (Rasmussen *et al*., 2006). In the US, the Rodale Institute in Pennsylvania has been able to close this yield gap with similar production levels for a number of crops (organic and conventional) in their long-term trials (Hepperly *et al*., 2006). The Rodale trials found that organic systems tend to out-yield conventional systems in dry seasons, where (as in many parts of Africa) irrigation is not available. All three of these long-running sets of trials (Switzerland, Denmark and the US) found that organic systems require three to four years to build up soil biology to productive levels".

In this paper, some reflections concerning effects on policy of these three major long-term comparative research trials (which inspired the Mandela Trials, see "Sustainable Food Systems for Africa" in this volume) are summarised, starting with the DOK trials (bioDynamic, Organic, Conventional = DOK) run by the Swiss Research Institute for Organic Farming (FiBL), followed by the impacts of Danish organic research, notably the long-term trials at Aarhus University in Denmark run by the International Centre for Research into Organic Farming Systems (ICROFS), and finally with some reflections from the Rodale Trials in Pennsylvania (Hepperly *et al.,* 2006).

3.1 The Swiss DOK Trials

The Swiss perspective is taken from the paper "Building a global platform for organic farming research, innovation and technology transfer" by Urs Niggli *et al*. (2017).

Under the heading "Benefits and challenges of organic food and farming systems", they say that empirical evidence shows the benefits and strengths of organic food and farming systems and highlights further challenges and opportunities. Soil quality and health can be improved by organic farming practices, as measured by soil fertility and structure and by biodiversity of soil organisms. Organic farming maintains and increases soil organic matter, sequesters carbon and reduces greenhouse gas emissions relative to other forms of agriculture. Soil erosion is less likely in organic soils in the long run, and increased biological activity in the soil helps to suppress pests and diseases and enhance plant immunity to various opportunistic infections. Organic farming has higher nutrient efficiencies by relying on the cycling of nutrients from renewable resources, mainly in the form of organic matter, rather than on synthetic fertilisers that are derived from non-renewable resources.

Swiss organic farming systems have yields about 20% lower than conventional farming systems in the country. Thus, more land may be needed to produce the same amount of food using organic practices, which may diminish the ecological and health benefits of organic relative to conventional farming when measured on a production unit basis. However, the greater biodiversity of organic food and farming systems through cultural practices such as inter- and relay-cropping and crop rotations, offsets yield gaps; yields in organic farming systems may also be more stable under environmental stress and adverse weather conditions than in conventional farming systems. Organic farming systems enhance the resilience of agro-ecosystems by increasing natural pest control and enhancing biodiversity in the soil, as well as at the plot, farm and landscape scale, and increase populations of pollinators and other beneficial organisms.

Organic farming is generally more profitable to farmers, particularly when they receive a price premium for their products; yield and gross returns can vary by crop, but the gross margin (after subtraction of the lower production costs) offsets yield reductions in the long run. At least in some cases, organic food and farming systems may also have higher returns to labour; however, organic farming systems can be less profitable, in part because of lower yields. The organic sector's small market share accounts for about one percent of global food sales which is probably the single most limiting factor for farmers in adopting organic practices, although demand has grown steadily over the past 40 years. Organic farming contributes to a "triple bottom line" accounting for social and environmental, as well as purely economic benefits.

Organic farming systems also provide environmental benefits across multiple physical, chemical, biological, economic and social parameters. Life cycle assessments (LCAs) have compared the relative environmental performance of certain aspects of organic and conventional farming, focusing on the inputs used by the different systems. However, LCAs have methodological shortcomings, as they have not been able to capture all of the environmental and social benefits reflected in ecosystem services and the market. The economic and environmental values of the biodiversity conserved by organic farming systems are difficult to estimate given the qualitative differences between extensive organic and intensive conventional production. Given that organic farming systems often require more land to produce the same amount of food, they would theoretically lead to less land being available for unfarmed wildlife habitats. In practice, however, the choices and outcomes are more complex. Biodiversity support and wildlife friendly agriculture can be complementary.

Because most pesticides are not permitted in organic food production, these contain significantly lower levels of pesticides than other food. As a result, organic foods pose lower dietary risks to human health from pesticides than conventional foods. Moreover, pesticide risks to the environment are also mitigated by organic production practices. Organic food also has lower levels of cadmium, nitrate and nitrite compared to conventionally produced food. Investment in research on organic food and farming systems and other sustainable technologies has increased in recent years but is still marginal compared to research expenditures on agrochemicals, genetic engineering, animal confinement systems and other technologies that are incompatible with organic principles and standards. Most of the research expenditures have been directed at temperate- and Mediterranean-zone agricultures in Europe and North America, while relatively little capacity exists for research on organic food and farming systems in tropical- and sub-tropical systems, particularly in low-income countries of Africa.

3.2 The Danish Organic Research Programme and its impact on Danish Policy

The above is a summary of global progress in establishing evidence-based OA development, based on the Swiss research, and other collaboration. Extracts from a report on specific impact measurement for organic research in Denmark follows (Andreasen *et al*., 2015), starting with extracts from their Abstract:

ICROFS analysed the effects of organic research in Denmark (1996 - 2010) on the Danish organic sector and on society in general. Over these 15 years, three national programmes and one programme with European collaboration were implemented in Denmark, financed through government grants totalling approximately $80 million). The analysis itself was carried out as a compilation of information from three perspectives, each of which has been independently documented: Interviews with end-users of results from Research and Development (R&D) investigating their assessment of the challenges and solutions in the sector; Assessment of the R&D endeavours in different thematic areas (dairy/milk, pigs, crops, etc.) as they related to end-users and the stated challenges at that time; and Documentation of the dissemination of R&D results in relation to themes and challenges in the sector.

The results showed very good correspondence between end-user perceptions of the challenges overcome in the sector, the R&D initiated in the research programmes, and the dissemination of research results and other forms of knowledge transfer. The analysis documented direct effects of the research initiatives targeting the challenges in the sector such as higher yields, weed and pest control, animal health and welfare, the potential for phasing out the use of antibiotics in Danish dairy herds and reducing the problems caused by seedborne diseases. It also describes where research did not contribute as much to overcoming challenges. Here the analysis showed that the effects of the research in the organic processing industry and among relevant governmental and non-governmental organisations were of a more indirect character. Research has helped stabilise the supply and quality of raw materials at a time of growing demand and sales. Organic research also generates new knowledge and leads to new opportunities which may inspire green conversion, product diversification and growth also in conventional agriculture. The analysis showed that research under the national research programmes overall has been very applied and directed at the barriers in the sector, in order to support the general market and growth conditions for the organic sector. Having laid a solid foundation, the private sector has taken advantage of commercial opportunities as demand grew, while adhering to the organic policy objectives of market-driven growth in the organic sector.

Since the mid-1980s, organic farming in Denmark has been promoted through political initiatives in order to respond to consumer demand for organic products. The policies of governments included financial support for the conversion of conventional farms, regulation and control, advisory services, information campaigns and education and research in organic farming. At the end of the 1980s and start of the 1990s, Danish research in organic farming was primarily carried out on private farms and in long-term crop rotations at research stations around the country. With the first action plan (Action Plan I) for the promotion of organic food production prepared by the Ministry of Agriculture and Fisheries in 1995 and followed by Action Plan II in 1999, research in organic farming was given a higher priority than earlier times, which resulted in the development of a national research programme and the establishment of the Danish Research Centre for Organic Farming (DARCOF) [now ICROFS] – a ‘centre without walls' to coordinate these programmes as research continued within existing research environments throughout the EU.

From 1996 to 2010 Denmark had four research programmes in organic farming and foods financed via special government grants (one of them with EU collaboration). While the first programme primarily addressed issues related to primary production, the following programmes also included issues related to industry (including processing), society (including environment and health) and the consumer level (including credibility of the sector). In these programmes, funds were allocated to coordination, communication and dissemination, as well as to knowledge synthesis, research methodology and to research education (PhDs at universities and research centres involved in the research). The centre maintained close contact with the players in the sector via user groups and extensive meeting and dissemination activities in order to ensure the continued relevance of research efforts and applicability of results.

In the same period the organic sector has undergone a strong development from niche market to an important part of the Danish food sector. The area under organic farming, including the area under conversion in 2010, was 6.4% of total farmed area. Of the total food sales in 2010, 7.2% was certified organic after a dramatic increase in sales from approximately $67 million in 1996 to approximately $821 million in 2010. By 2010, nearly all supermarket chains had a large assortment of organic products and for some product groups, such as eggs and milk, the organic market share was 20 to 30% of retail sales. Several important factors have contributed to the positive development of the organic sector in Denmark, including support for marketing and the regulatory framework from public and private sectors, establishment of strong institutions in organic farming, entrepreneurs and pioneers in the organic farming, processing and retailing sectors, as well as research carried out in universities, research stations and with advisors and farmers at private farms.

Under the heading Dissemination of R&D Results – Findings, Andreasen et al. (2015) state:

A total of 3,173 publications constituted the direct outputs from the projects (Organic Eprints.org, counted in 2012). About 20% (632) of these were peer-reviewed papers; another 1,311 were other publications in English, while 1,230 were publications or other forms of dissemination in Danish. Based on a search of the archives of the Knowledge Centre for Agriculture, it was found that there had been dissemination based on R&D in the projects within all the thematic areas. One example is the Danish Crop Rotation Experiment, from which there were 215 publications in Organic Eprints, and at least 50 dissemination articles based on the R&D in the archives of the Knowledge Centre for Agriculture. In the interviews, there were many statements about positive contributions from research. In each case, it was determined that research results were actually disseminated, so that the statements were justified.

The projects resulted in a high number of peer reviewed journal articles, in spite the fact that the research under the four programmes has mainly been 'applied research'. The paper focused on the effects of the research programmes and discussed how the close association between scientists and end-users in the DARCOF programmes influenced the effects achieved. Both crop production and animal husbandry research projects contributed with significant new knowledge and methods in response to the considerable challenges in primary production, from the handling of manure and weeds to animal health and feeding. The results have been widely applied partly because many of the projects were designed and selected as a response to challenges formulated by the sector. Organic production would have been much lower today if the research results had not been used, because the production itself is more profitable (higher yields per cow, pigs of higher quality resulting in a higher kilo price, etc.) and because some important problems have been solved, which has reduced the incidence of reconversion to conventional farming (for example, improved perennial weed control and recycling of nutrients using cover crops and good crop rotations).

The increasing production and the ability to ensure a good and consistent quality and stability has also been a precondition for the establishment of a professional and profitable processing sector. Companies interviewed found that these conditions have had an important effect on their development opportunities. Research had a strong focus on the barriers in the sector and on improving the general market and growth conditions in the sector, and formed the basis for a stronger commercial exploitation of the opportunities. The research focus dealt with the challenges in the commercial sector and also the political ambitions for market-driven growth in the organic sector.

In addition to the direct effects, there are other – more indirect – effects on processing and marketing, such as a better understanding of consumer motives for purchasing organic produce and a higher degree of integrity as a result of research. Integrity – here understood as consumer trust that the organic sector lives up to its declared ideals and added values – has been improved in two ways. First, the organic production itself has been improved in areas that are important to the consumer, and second, studies have evaluated organic farming in relation to its principles, consumer expectations and/or interests of society. In the first instance, research projects have – according to interviews with consultants and representatives of public authorities and organisations – enhanced animal health and welfare on organic farms through the development and description of better farm management, housing, feeding, etc. In the second instance, a series of projects have probed whether organic farming actually confers advantages compared with conventional systems or products.

Some projects have documented positive effects of organic farming on, for example, nutrient balances in livestock farming, conservation of biodiversity in hedgerows, as well as a higher nutritional content of organic produce. However, some results have also been critical regarding specific aspects of organic farming, e.g., when measured either on climate impact per kilo of produce, on flavour, or on general healthiness.

Such results have been used by organisations in the sector to launch campaigns to improve practical aspects of the systems. The sector has focused on improving animal health and welfare on organic farms based on the background of research projects and reviews. It can be assumed that the willingness to admit to weaknesses in the organic systems and the readiness to seek solutions to these has helped maintain integrity in the eyes of the public and ensured the continued political backing, although there is no documentation for this.

Some of the research projects have documented that large consumer segments favour organic produce for a variety of personal (health, quality, pesticide-free) and altruistic (animal welfare, environment) reasons. These preferences may also affect conventional food production. In addition to the described effects on the organic sector, the DARCOF projects have also produced results that are relevant for conventional farming and can aid a general green conversion. This applies to replacements for seed treatments, non-chemical weed control, reduction in the consumption of antibiotics and the need for supplementation of synthetic vitamins in animal husbandry. This could save farmers money in the conventional sector if the methods were widely implemented and would further improve the reputation of Danish agriculture as an eco-friendly system supplying high-quality products.

At the international level there is an awareness of the need to improve the relationship between research, extension and agricultural production. In the "International Assessment of Agricultural Knowledge, Science and Technology for Development" (IAASTD, 2009), the conclusions stress that a departure is needed from the traditional model of research and dissemination as separate actions. Instead, there is a need for the farmers' voice to be heard when prioritising and designing research projects and to integrate their local knowledge and experience into research and policy.

The applied nature and relevance of the projects under the DARCOF/ICROFS programmes has been strengthened via the close and continuous contact with consumer representatives. There has also been contact with the sector via the organic food council and a number of other actors involved in the preparation of the action plans and later in the knowledge synthesis in 2008, on the potential for a market-based development of the organic sector. This influence at programme level has been important for maintaining the relevance of the projects offered and funds granted in relation to the requirements of the sector.

Many of the projects have had contact with advisors and farmers where the acquired knowledge has been continually communicated and discussed. This has had two effects: a rapid application of results, because the users have discussed the results of the research with the scientists and thus achieved a better understanding of how results and knowledge can be adapted to specific practical situations; and secondly, research design and methodology were adapted as a result of practical experience. The scientists were persuaded by dialogue with the users to ensure that treatments are as relevant and practical as possible, without compromising scientific standards.

This shows the complex links between research, development and the application of knowledge in agriculture. The traditional route is one-way communication of scientific results via advisors to producers. Because the project structure and organisation of the organic research programmes supported this complexity in knowledge generation and exchange, the findings of the research projects have been used, and many barriers in the sector were overcome. There has also been continuity in many central research activities in terms of long-term experiments at the same localities over many years and in many research programmes.

3.3 The long term trials at Rodale Institute in Pennsylvania, USA

The field trials at Rodale Institute are reported (1981 to 2004), where conventional and organic five year rotations of cereal crops, legumes and forage crops were compared. Both manure and legume-based rotations saw soil carbon rise from 2% to over 2.5%, while conventional soil carbon remained unchanged. Soil carbon and nitrogen accumulation was also significantly greater for manure and legume rotations than for the conventional mineral fertiliser based rotation.

Once soil biology had been improved by the organic farming systems approach, the yield gap was closed. For the five drier years (where annual rainfall averaged less than 350 mm, as opposed to about 500 mm in average years), maize grain crops in the organic farming systems outyielded conventional by an average of 31%. In the extreme drought year of 1999, with only 224 mm in the growing season, average organic maize yields were 1511 kg/ha while conventional yields were 1100 kg/ha; for soy beans that year, the mean figures were 1600 and 900 kg/ha respectively.

These results have been communicated to a wide range of agricultural policy makers, and several publications (Board on Agriculture, 1989 and Reganold et al., 2011) have summarised the benefits from what they term "Alternative agriculture" and explained how US agricultural policy fails to support environmentally sound organic farming methods; they say "Transition toward transformative agricultural systems currently relies on a smaller, emerging knowledge base developed largely by farmers and nonprofit organizations independent of traditional scientific institutions."

Nevertheless, US agriculture continues to be dominated by intensive chemical-based conventional agricultural production, even though the consumption of organic produce has increased steadily over the past fifty years (Reganold and Wachter, 2016). In spite of the recommendations of the US National Research Council (2010), Reganold and Wachter report that "Considerably less public and private funding has been put towards research and development for organic systems than towards conventional systems", even though "organic farming is one of the fastest growing segments of American agriculture and helps farmers receive a higher price for their product as they strive to meet growing consumer demand" (2016). They conclude "The challenge facing policymakers is to create an enabling environment for scaling-up organic and other innovative farming systems to move towards truly sustainable production systems".

Conclusions on the importance of research for organic farming in Africa

This paper began with extracts from the UNCTAD (2008) seven country study, which summarised what governments in developing countries can do to support an emerging organic sector, and why this is important. This was followed by an analysis of the failure of governments and aid agencies to support effective organic development in Africa (UNCTAD, 2016). The evidence upon which these two UNCTAD reports was based, included work done in Switzerland by FiBL (the so-called DOK trials and subsequent establishment of a global organic research, training and innovation platform), the work of ICROFS in Denmark, and its impact on government policy and actual organic sector development there, and finally, the work in the US of the Rodale Institute together with the history leading to the long-term research trials, and their impact; these initiatives have been running for 25 to 40 years, and it is important for African organic farming research and development to draw on the results of this significant mass of research. Applied research on organic broccoli seed breeding also showed how the needs of the organic sector for robust, disease-resistant varieties can contribute to making conventional agriculture more sustainable.

We can make five major conclusions based on the results presented in this paper:

Without significant government and other support, organic sector development will be slow, and disinformation from suppliers of chemical inputs will continue to dominate the discourse on food sovereignty, food security and nutrition.

There exists an international body of peer-reviewed evidence to show that organic farming is cost-effective, culturally appropriate and leads to an increase in food security without increasing dependence on expensive external inputs, which are difficult to obtain (and to pay for) in many remote rural areas of Africa.

Organic farming methods use water and nutrients more efficiently, and build resilience, leading to better performance under drought conditions, and helping farmers to deal with climate change.
For the organic sector to be beneficial for small scale farmers, capacity building and institutional development are required; this needs support from National Agricultural Research Systems, and also requires specially trained organic extension agents to support those farmers wishing to take on organic farming or agro-ecological farming.
Finally, organic standards, organic value chains and the support for nutrition education around food quality and healthy food choices are all important to the development of thriving local and export markets for organic products.

REFERENCES

Andreasen, L., Rasmussen, I.A. and Halberg, N. (2015) Organic Research and Development in Denmark (1996-2010) - Effects on the Organic Sector and Society. *Sustainable Agriculture Research*, 4 (3),173-183. Available on-line at: www.orgprints.org/29259 (accessed 3 June 2018).

Auerbach, R. Editor (Forthcoming, 2019) Organic Food Systems: Meeting the needs of Southern Africa. Commonwealth Agricultural Bureau International, Wallingford, UK.

Board on Agriculture (1989) Alternative Agriculture: Study by the Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, National Research Council; Academies Press.

Hepperly, P., Douds, D. and Seidel, R. (2006) The Rodale Institute Farming Systems Trial 1981 to 2005: Long-term analysis of organic and conventional maize and soybean cropping systems. In: Raupp *et al*., 2006; pp. 15-31.

IAASTD (International Assessment of Agricultural knowledge systems, Science and Technology for Development). (2009) Agriculture at a Crossroads – Global Report. Available: http://www.fao.org/fileadmin/templates/est/Investment/Agriculture_at_a_Crossroads_Global_Report_IAASTD.pdf ; Island Press, New York.

Mäder, P., Flieβbach, A., Dubois, D., Gunst, L., Jossi, W., Widmer, F., Oberson, A., Frossard, E., Oehl, F., Wiemken, A., Gattinger, A. and Niggli, U. (2006) The DOK experiment (Switzerland). In: Raupp *et al*., 2006; pp. 41-58.

National Research Council. (2010) Towards sustainable agricultural systems in the 21st century. The National Academies, Washington.

Niggli, U., Andres, C., Willer, H. and Baker, B. (2017) Building a global platform for organic farming research, innovation and technology transfer. Organic Agriculture. Springer. Doi 10.1007/s13165-017-0191-9. Available at: **www.orgprints.org/29259**.

Rasmussen, I., Askegaard, M. and Olesen, J. (2006) The Danish organic crop rotation experiment for cereal production 1997-2004. In: Raupp *et al*., 2006; pp. 117-134.

Raupp, J., Pekrun, C., Oltmanns, M. and Kopke, U. Editors. (2006) *Long-term Field Experiments in Organic Farming*. ISOFAR (International Society of Organic Agriculture Research), Berlin.

Reganold, J.P. and Wachter, J.M. (2016) Organic agriculture in the twenty-first century. Review Article. Nature Plants Vol 2, no 15221. DOI:10.1038/NPLANTS.2015.221

Reganold, J.P., Jackson-Smith, D., Batie, S.S., Harwood, R.R., Kornegay, J.L., Bucks, D., Flora, C.B., Hanson, J.C., Jury, W.A., Meyer, D., Schumacher Jr. A., Sehmsdorf, H., Shennan, C., Thrupp, L.A. and Willis, P. (2011) Transforming US Agriculture. Policy Forum Agriculture. Science, 332, 670-671.

Renaud, E. (2014) Breeding and regulatory opportunities and constraints for developing broccoli cultivars adapted to organic agriculture. PhD thesis, Wageningen Agricultural University, Netherlands.

UNCTAD (United Nations Conference on Trade and Development) (2008) "Best practices for organic policy" United Nations, (accessed 3 June 2018). Available at: http://unctad.org/en/Docs/ditcted20073_en.pdf

UNCTAD (2016) Financing organic agriculture in Africa. UNCTAD/WEB/DITC/TED/2016/6), (accessed 3 June 2018). Available at: http://unctad.org/en/PublicationsLibrary/webditcted2016d6_en.pdf

Sustainable food systems for Africa

Raymond Auerbach
Nelson Mandela University, George, South Africa,
raymond.auerbach@mandela.ac.za

Abstract

Two conceptual models of the progression of small scale farmers in sustainable agriculture and of the characteristics of production, equity, natural resource management and sustainability are presented and their implications are discussed. The models inform an analysis of two development programmes, and they are linked to long term comparative organic farming systems research trials, which have been running for four years in South Africa's Southern Cape, comparing organic and conventional farming systems, crop rotation and mono-cropping, biological and chemical pest and disease control and water use efficiency in cabbage, sweet potato and cowpea crops. In Africa the high cost and limited availability of agricultural inputs make agro-ecological approaches attractive, as they are practically possible (with low levels of external inputs) and improve carbon sequestration, dietary diversity and food quality. The challenges for viable organic farming systems are thus seen to include: improving soil fertility (especially acidity and available soil P), controlling pests and diseases and convincing consumers of the quality of organic products. Benefits include: reduced dependency on externally-purchased agricultural inputs, lower soil acidity, higher soil water retention, sequestration of soil carbon, improved soil microbiology, better agro-biodiversity and elimination of poisons from the food chain. Support for small scale farmers will require technical and training support, market linkages and quality management.

Keywords: Organic food system; African organic farming system; sustainable development.

Introduction

If Africa is to feed herself, natural cycles and compost need to be used to improve soil fertility, but where needed, certain minerals, notably phosphate, need to be added to the soil. Building sustainable food systems requires experiential training of farmers, support for short value chains, understanding of various food system components and development and support for organic farming policies (Auerbach, Forthcoming b). Building of training and marketing capacity, and the development of robust institutions for farmers is essential, and requires support in Africa.

Given climate change, rainfall is likely to decline (or at least become more erratic) in many parts of Africa, and research shows that many areas which traditionally sustained rainfed crop will no longer be able to do so. Temperatures are also likely to rise by 2ºC, and the population of Africa is likely to be 2.5 billion by 2050 and 4.5 billion by the end of the century (De Wit, Forthcoming). De Wit shows that a 10% decrease in rainfall would already lead to a 17% decrease in run-off in wetter areas, but that in a region receiving 600 mm of rain per year, with a precipitation decrease to 550 mm/y (a change of less than 10%), perennial drainage will be cut by 25%, while a change from 500 mm/y to 450 mm/y would cut the drainage by half. The impacts on food security in these areas will be dramatic and tragic; vulnerability of farmers in the Eastern Cape, where many towns have seen a decrease from 550 mm to 450 mm/y over the past 20 years will increase dramatically (Auerbach, Forthcoming c).

This paper summarises some aspects of the 24 chapters of a forthcoming book which reports on ten years of research in southern Africa, and reports some of the main implications for sustainable food systems in Africa (Auerbach, Forthcoming a). Looking back on 45 years of experience in organic farming, farmer training and farming systems research and extension, I will attempt to distil some lessons and concepts from my experiences and those of other farmers, trainers, researchers and policy makers (UNCTAD, 2008, 2016).

Two conceptual models of South African Small Farmer Development

When developmental agencies attempt to assist food producers, sometimes there are suppositions, which may not be accurate. First, many agriculturalists assume that people with a small piece of land (or even a large one) wish to produce surplus food. Second, it is often assumed that they wish to sell this surplus food. Finally, it is sometimes presumed that they wish to become commercial farmers. While it is true that unemployed resource poor rural or urban dwellers do need food, and commonly produce some food on the land available to them, this is often a survival or even a desperation strategy, and may not be an aspiration at all.

Even for those who are fairly serious about food production, there may be a desire to use the land optimally, and perhaps a cultural desire to be able to share surplus crops or animals with family or neighbours. Many small scale gardeners feel reluctant to sell their own produce for money, and it is often seen as part of the natural bounty which is available for the community. This concept of stewardship and sharing is a deep and wonderful part of many African traditions. It is also a stark reality of small business development that many people who become able to run a business, growing food, having learned trading skills, may decide that there are many less risky ways to trade than primary agricultural production. They may then be lost to farming, but may contribute to the development of vibrant rural economies in other ways.

In discussion in the ‘nineties with Rob Small (co-founder of Cape Town-based urban vegetable producers group *Abalimi bezekhaya*), we agreed that the four research domains I had identified (Auerbach, 1995) in my farming systems research and extension MSc (sub-subsistence farming, subsistence farming, semi-commercial farming and commercial farming, lower part of Figure 1), represent a progression in skill and understanding which requires learning and experience. In our work with small scale farmers, we found that moving from each stage to the next usually requires at least three years. If a person decides that they want to improve their food production skills, they can be assisted with basic organic techniques such as crop rotation, mulching and the use of compost. They will need basic husbandry skills for soil preparation, weed control, and the management of pests and diseases. Provision and management of moisture will also be critically important. Learning these skill-sets is not technically or intellectually demanding, but it does require a shift towards an individualistic approach ("If I care for the soil and the plant, I am likely to harvest a good crop"). This development of a sense of agency is a fundamental pre-requisite for people to take charge of their lives.

After two or three years of steady application, the small scale farmer will often find that she has enough fresh vegetables for her children to derive significant nutritional benefits in terms of dietary diversity; she has moved from sub-subsistence to a subsistence farming system. After providing for her own family, she begins to find that there is some produce left over to share, and this may become the basis of social exchanges, assistance to those "less well off", or simply the capacity to provide welcome gifts to friends and family.

She has avoided desperate hunger, as she is already able to provide a lot of food for her family. She may then be ready to start moving into the semi-commercial farming system, where again, she may need two or three or four years to become highly proficient at food production, learning about preserving food, making jams, using her produce in a range of products for her family, some of which she may find she can sell. This movement from subsistence farming into the market is quite rare, and in each community, one usually finds only a handful of people who learn to be competent semi-commercial farmers (or had a grandmother who taught them these skills early).

The movement into semi-commercial farming requires an expansion of products and the beginning of business planning capacity: what can I produce at a time when there is a market demand, and can I get a good enough price to justify all of my effort? Again, very few subsistence farmers become efficient enough to derive major profitable commercial income from farming.

As indicated allegorically in the lower part of Figure 1, if 10,000 sub-subsistence gardeners take part in a farmer development programme, perhaps 1,000 will become productive subsistence farmers; of these, perhaps 100 may become semi-commercial farmers with a saleable surplus which brings in some cash.

However, many of these will find less risky outlets for their newly acquired business skills, which is wonderful for the local economy, but not always so good for agricultural development. Of a hundred semi-commercial farmers, perhaps one or two may be in a position to intensify production, or to access additional land and capital, and become commercial farmers.

The upper part of Figure 1 shows how the markets become increasingly complex as gardeners develop into semi-commercial and then commercial farmers. Whereas at the start of this development there is no cash economy involved, gradually business management and marketing become a more major part of the farming system. This increasing complexity requires increasing sophistication of production, as planting schedules must be developed according to what consumers want, and planning with other suppliers becomes important in order to prevent the market being flooded with too much of certain products and not enough of others. The farmer is soon running a business which may mean that the food produced is too valuable to give to neighbours!

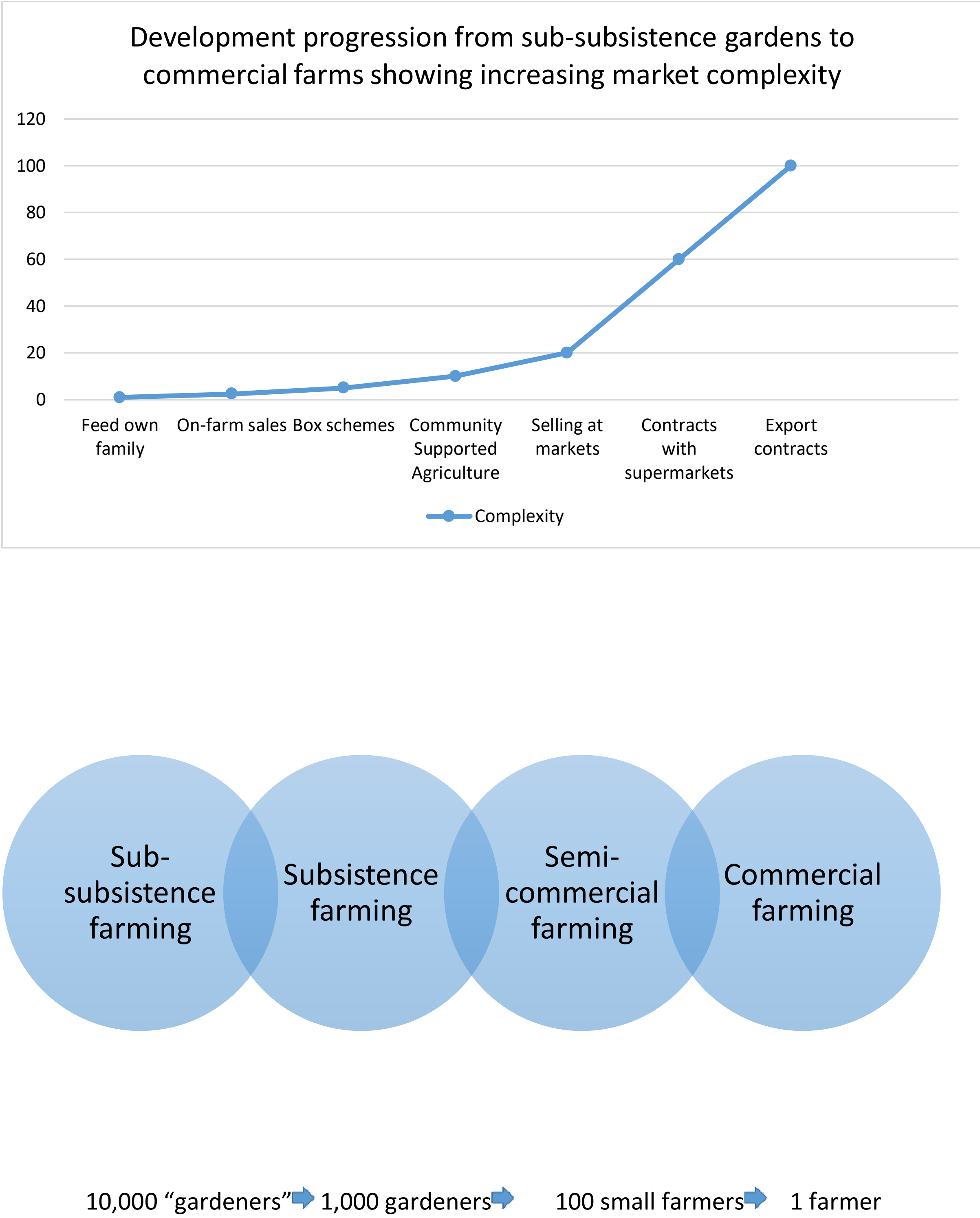

Figure 1: Food production systems: the journey from sub-subsistence to commercial.

My experience over the past 45 years (farming organically on eight ha, training farmers and carrying out farming systems research and extension – FSR-E) led me to believe that many small scale farmers, especially women, are reluctant to become commercial farmers partly because of the change in the nature of their relationships with neighbours in the community once they are seen as business people.

Transformation of our rural and peri-urban areas will require sensitive assistance to communities in dealing with feelings of exclusion, and with the commercialisation of basic foodstuffs. In 1994 I published an article in the journal “New Ground” entitled “Sustainable Development: Developing what to sustain whom?” which I then modified in my doctoral thesis (Auerbach, 1999). As it is relevant in this discussion of conceptual models for South African agriculture, I paraphrase the model below and in Figure 2:

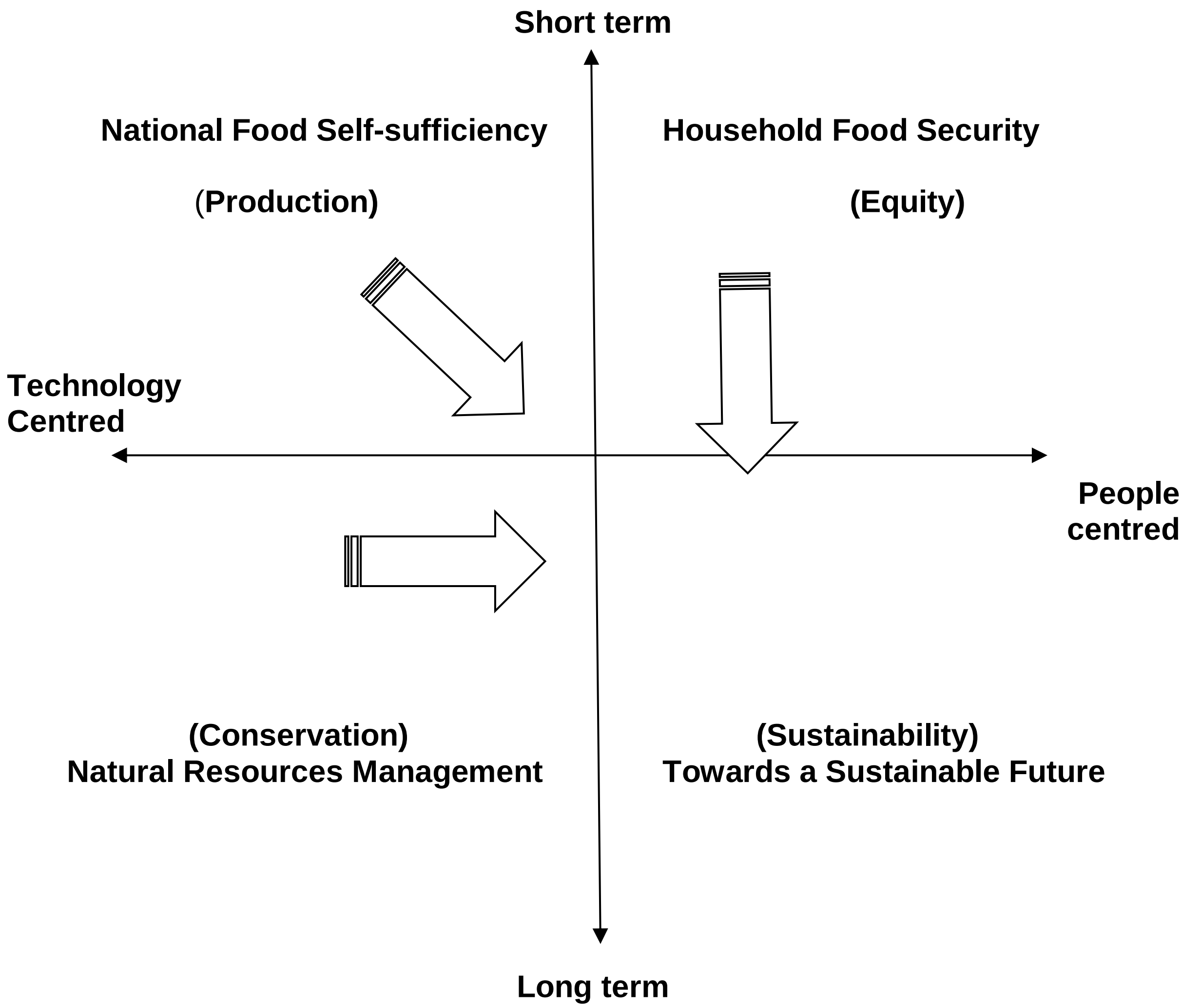

Figure 2: Production, Equity, Conservation and Sustainable Development
(Source: Auerbach 1994, cited in Auerbach 1999)

The figure summarises the four common perspectives on rural development which I identified: production, equity, conservation of natural resources and sustainable development.

Agricultural scientists are most comfortable with a production-oriented approach, which is often rather short-term and technology-centred. This is not to say that National Food Self-sufficiency is unimportant – it is essential, and requires high levels of skill and food production experience, as discussed above under commercial farming systems. In South Africa at present, 80% of our gross agricultural product is produced by 10,000 commercial farmers; this is a numerically tiny and strategically important fraction of the South African population. Half of this production comes from only 300 enormous farming enterprises, which must be regarded as national strategic key-points for food self-sufficiency).

However, politicians and social scientists are concerned that the poorer households may not be able to access food if they have to purchase it, and therefore Household Food Security is important if there is to be reasonable equity. Transformation of South African agriculture depends on the support and development of this group, and this realisation led to a report which supported the 1996 White Paper on Rural Development (Auerbach, 1996); this report for the Land & Agricultural Policy Centre (LAPC) drew on the privatisation of the Dutch Agricultural Extension System.

So, a tension exists between the technology-centred process of commercial food production, and the people-centred process of household food production; however, both of these perspectives are often short-term in nature. Commercial farmers think about "making a profit this season to repay my production loan", while politicians think about "helping the people to eat before the next election"!

Natural resource managers on the other hand, have long been critical of the damage being done to the resource base by industrial agriculture. While their philosophy has always been long-term, they were often rather technical in their approach. Over the past 30 years, however, the World Wide Fund for Nature (WWF) has increasingly emphasized the importance of working with communities, if conservation is to become socially sustainable.

> "While most conservationists have learned about people, and social scientists are learning about sustainability, those who research technical aspects of agricultural production have to learn about both: their research techniques need to take account of ways of working with people, and of long-term sustainability. This is what is required for "triple-bottom-line accounting": economics, environment and equity are all important – we cannot sacrifice any of them. We need to find ways to balance this triple equation. We also need to balance short-term individual interests (so important to wealth creation and the provision of efficient services) with long-term measures to increase both productivity and equity of access to resources, without damaging our resource base" (Auerbach, 1999, 6-7).

Movement towards a sustainable future requires a long-term, people-centred sustainable development perspective, out of which sustainable agro-ecological farming systems can develop.

Productivity in SA agriculture rose sharply towards the end of the 20th century with the removal of the agricultural control boards, and when SA embraced democracy, our products were once again welcome on international supermarket shelves (Ramaila *et* *al*., 2011, and Chapter 12 of my forthcoming book (Auerbach, Forthcoming). Figure 3 shows how the numbers of SA commercial farmers have dropped dramatically (there has been an accompanying increase in the size of SA commercial farms), and how productivity gradually decreased with inefficient *apartheid* policies in the first 60 years of the 20th century, and then increased dramatically when the agricultural control boards were abolished. The end of *apartheid* saw a brief but dramatic drop in production, with a number of farmers leaving the country, but as confidence returned, agricultural productivity has once again climbed, but reached a plateau in the year 2000, with only 300 mega-farms producing about 40% of the gross agricultural product, and another 10,000 producing about the same; thus SA depends for its national food self-sufficiency (top left quadrant in Figure 2) on just over 10,000 commercial farmers. Many of these farmers are willing and able to assist with the transformation of SA agriculture, and could act as mentors to emerging commercial farmers, but the SA government currently lacks the political will to engage these farmers in a practical apprenticeship arrangement, which could see universities such as Auerbach University offering agricultural management diplomas including an extensive practical period on a commercial farm and a follow-up mentorship link for emerging commercial farmers (Chapter 14 of Auerbach, Forthcoming).

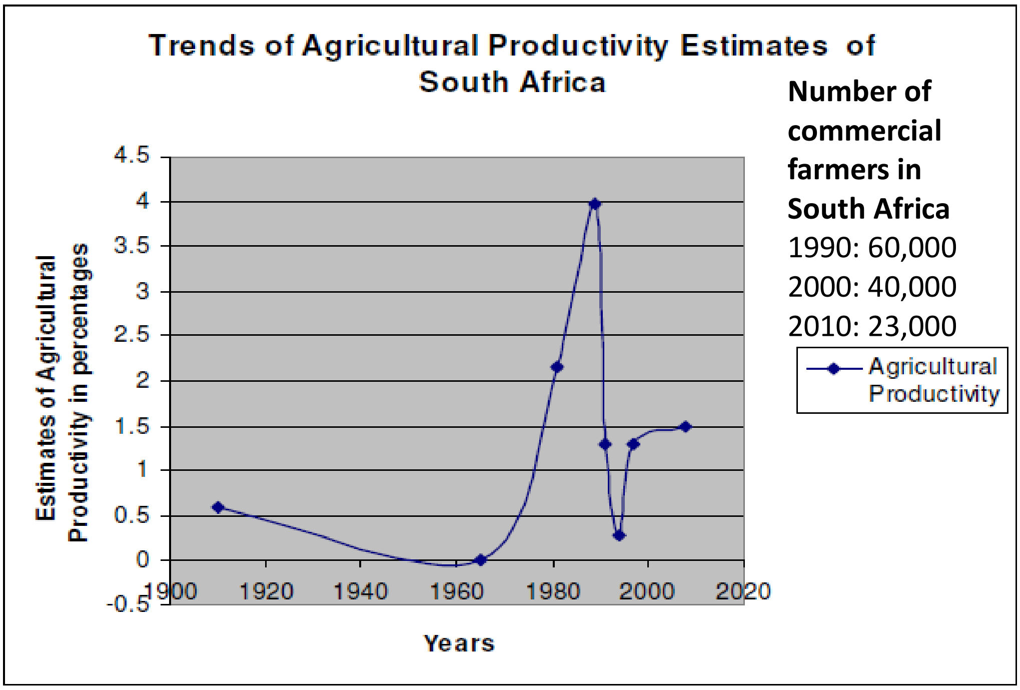

Figure 3: Declining number of commercial farmers and increasing productivity of South African commercial farmers (adapted from Ramaila *et al*., 2011).

In his much-publicised book “The end of poverty: How we can make it happen in our lifetime”, Professor Jeffrey Sachs (2005) postulates that if modern agricultural technology (fertiliser, hybrid seeds, pesticides and mechanisation) is combined with interventions on education and health, and made available to African villages, small scale African farmers will be able to produce a surplus, and by selling this will enter the market economy and improve their livelihoods. This pre-supposes that there are roads, trucks, agricultural inputs, finance, demand for the crops and a market able to pay for the crops produced. Several critiques of the approach adopted by Sachs claim that it has not worked (Munk, 2016), as the contextual conditions do not simply require technological solutions, but rather human and institutional capacity building. Thus, I concluded in my comparative analysis of the work of the Alliance for a Green Revolution on Africa's Millennium Villages Project (AGRA-MVP) and the Export Project for Organic Produce from Africa (EPOPA), that sustainable development requires a long-term approach to building community participation in agriculture and other aspects of rural development. Resilience, biodiversity, improved productivity and strategies which address soil fertility and water use efficiency need to be adapted to local conditions and to robust predictions of the major climate change constraints likely to affect small scale farming. Capacity building and farmer support are essential in this process.

How this can be done has been the subject of the last ten years of research of my agro-ecology group at Auerbach University (as reported in Auerbach, Forthcoming): organic farming techniques allow small scale farmers to use local resources to make compost; this needs to be supplemented by mineral correction of deficient soils, especially where the soil is acidic and low in available phosphate. At the same time, farmer training and capacity building through institutional development is essential for the social and economic dimensions of sustainability.

The dangers of insufficient attention to the building of local institutions and markets was shown by my comparison of the AGRA-MVP and EPOPA projects mentioned above; a histogram from page 30 of my chapter "Transforming African Agriculture" (Auerbach, 2013) is reproduced below as Figure 4.

Food security, food sovereignty, climate change and food quality: these are four linked topics which all revolve around soil fertility and water use efficiency. However, food systems are also linked to health issues such as diabetes, cancer, obesity and malnutrition, as well as to social justice factors such as household food insecurity, women's access to land, farmers' rights to exchange seed and fair trade access versus dumping of agricultural products; these issues are discussed by my research group and several international experts in 24 research papers covering research from 2010 to 2018 (Auerbach, Forthcoming). Food aid, which aims to help those who do not have access to adequate food, often distorts markets in a way which makes it difficult for local farmers to recover from droughts, given the unfair competition of free food (Auerbach 2013). Given this complex international context, helping small scale farmers in Africa to produce nutritious food while coping with increasingly erratic rainfall and rising temperatures, as well as erratic input supplies and rising prices (especially of energy) becomes challenging. Figure 2 shows the differences between national food self-sufficiency (enough food for the nation) and household food security (access to sufficient food by resource-poor people) and points out that both are short term phenomena; conservation takes a longer-term approach, but like national food self-sufficiency, it has mostly operated from a technology-centred approach. Recent changes in conservation strategy have seen a more people-centred approach involving local communities in the management of conservation areas, and many short-term household food security practitioners now try to incorporate longer-term resource conservation strategies.

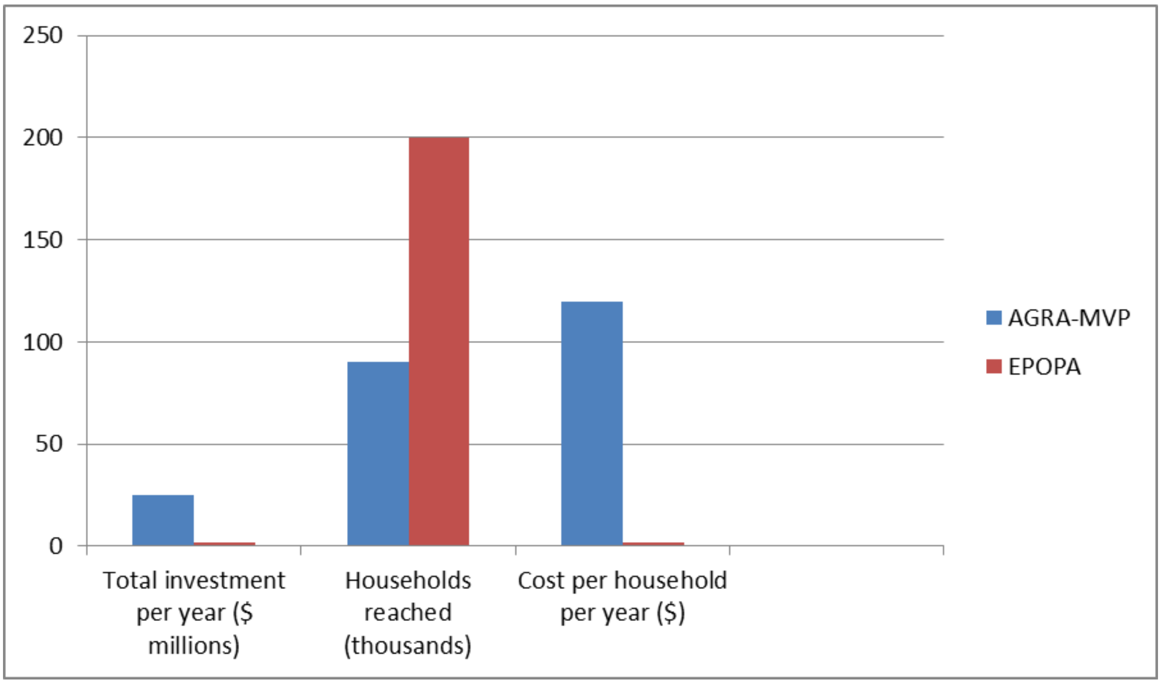

Figure 4: A comparison of the performance of the Alliance for a Green Revolution in Africa's Millennium Village Project (AGRA-MVP) and the Export Programme for Organic Products from Africa (EPOPA), with regard to scale of investment, number of households reached and cost per household per year (Source: Auerbach 2013, p.30)

Earlier, my MSc research had postulated that interventions to assist farmers will be most successful if they focus on relieving constraints (such as land preparation, access to seed and soil fertility), rather than providing technical advice, and had shown how this can be done practically with maize production in southern KwaZulu.

Organic farmers around the world have shown that it is possible to use locally available resources to develop sustainable farming systems which produce nutritious food while improving the soil and environment (Willer, Newcastle, Auerbach 1999). Using less poison, less non-solar energy, less externally-purchased inputs, they produce reasonable yields of high quality produce with less impact on the environment (Refs ++; EPOPA ref). The water- and nutrient-holding capacity of the soil is improved, agro-biodiversity is enhanced, and dependency can be avoided by developing systems which do not rely on bringing in synthetic fertilisers, agro-chemicals, genetically modified seeds and levels of industrial processing which negatively affect the quality of the food produced and of the environment.

Research in KwaZulu-Natal, Switzerland and the United Kingdom

Farming systems research on maize production in southern KwaZulu-Natal (SA) more than two decades ago (Auerbach, 1990) confirmed that in poorly farmed semi-arid areas, yields had already dropped to as low as 0.4 t/ha. Research examined three hypotheses from a farming systems' perspective which had been developed over two years of consultation with Zulu farmers (Auerbach, 1993):

Hypothesis 1: Increasing maize production of KwaZulu farmers will depend more upon easing constraints than upon providing technical information;

Hypothesis 2: Technical information will be effective if the extension message is matched with the socio-economic situation of the client smallholder farmer, and incorporates strategies to ease the accompanying constraints;

Hypothesis 3: The costs of additional purchased inputs will only be justified if matched by incremental inputs of effective management.

These hypotheses were tested through three formal on-station research trials over four seasons, and verified with seven on-farm trials carried out over three seasons. Economics of production (both on-station and on-farm) and farmers' attitudes to the research were also evaluated. The yield results were similar to those quoted by MVP (Sanchez, 2010; Nziguheba *et al.*, 2010). Maize yields were tripled relative to the system prevalent in the area (characterised by one weeding, no pest control, open pollinated seed and no fertilisation with mean yields of 1.1 t/ha). By controlling stalk borer and cutworm, weeding three times, using a well-adapted hybrid seed and fertilising with 1 t/ha of poor quality cow manure, the mean yield was increased to 3.2 tonnes per hectare (Auerbach, 1993).

The cow manure was found to be an exceptionally poor source of nitrogen, as the manure is commonly left out in the sun and rain for many months. Pot trials showed that lack of nitrogen rapidly limited plant growth of maize plants, nevertheless, with simple weed and pest control, yields were tripled. Weed control was at least as important as fertiliser in this process, strongly supporting hypothesis 3. Participatory rural appraisal techniques were applied to finding out what local farmers thought about the research results and the extension pamphlet guidelines produced (Auerbach & Lea, 1994). Results showed that early ploughing, hybrid seed, fertiliser and cow manure were the four top priorities cited by semi-commercial and commercial farmers. However, in practice, early ploughing and weed control were more closely linked to yield increases, supporting hypotheses 1 and 2. Farmers were interviewed to find-out how they felt about the research findings; with regards to the importance of technology in improving maize production, the conclusion was reached that "tempting as it might be to concentrate on a host of technical factors, the reality of the rural situation in KwaZulu-Natal requires a process of local capacity-building based upon the best local practice" (Auerbach, 1995).

However, in order to raise yields above the three t/ha level, compound fertilisers were by far the most effective in monoculture maize. Raising maize yields above 3.4 t/ha using organic methods could only be done with major inputs of manure (20 t/ha of manure), and/or composting and mixed cropping systems which would also improve agro-biodiversity. However, it is striking that, while the MVP research in western and eastern Africa used significant levels of fertiliser inputs, the South African research showed that yields can be raised to the three t/ha level without particularly high levels of external inputs (Auerbach, 1993), provided that there is some input of organic matter, a well-adapted hybrid cultivar and reasonable pest and weed control. Nevertheless, it supports the findings of the MVP team that increasing soil organic matter is vital for sustainable crop production in Africa. Globally, the world's soil organic matter contains two to three times as much carbon as is found in all the world's vegetation and poor ploughing coupled with deforestation deplete soil carbon by about two Pg (billion tonnes) per year and contribute significantly to global warming (Brady & Weil, 2008). Well-managed organic farming and conservation forestry could reverse this depletion, sequestering two Pg of carbon per year more than is removed, thus helping agriculture to mitigate climate change.

Long-term experiments in Switzerland (Maeder *et al.*, 2006) illustrate this possibility: comparative trials of organic, bio-dynamic and conventional production systems confirmed that soil carbon in the conventional systems decreased to about 85 percent of the original levels, while there was no decrease in the biodynamic production system and only a small decrease in the organic system. Conventional agriculture uses ploughing coupled with chemical fertilisers such as urea, which often acidifies soils as well as decreases soil carbon, and in these trials, soil pH increased from 6.3 to 6.6 in the biodynamic system, remained stable in the organic system and decreased to 5.8 in the conventional system. The same has been shown in the United Kingdom, where long-term trials at the Rothamsted Research Station showed that while yields (and soil carbon levels) for plots treated with farmyard manure rose steadily from 1850 to 1950 and then flattened out, soils with no farmyard manure added, declined slowly but steadily. Plots that received manure from 1852 to 1871 and did not receive any sort of fertiliser thereafter also declined slowly but steadily. Yet 100 years later, the beneficial effects of the 19 years of farmyard manure were still apparent, with soil carbon levels nearly twice those of the plots which had never had farmyard manure (Jenkinson & Johnson, 1977).

There seem to be major opportunities for exchange of research findings between MVP and the organic research and development projects underway in southern and eastern Africa. Transforming agriculture into a carbon positive sector would mean that it becomes part of the solution to climate change, rather than remains part of the problem. Apart from the impacts on soil organic matter quoted above, the farming systems work done by the organic movement in eastern Africa has had dramatic practical and economic results, largely through export market development (EPOPA, 2008). The South African government recently launched its Organic Farming Policy in recognition of these changes.

Organic market linkages: a vehicle for sustainable development

The strong point of the EPOPA development is that the linkages with the market were supported and that farmer institutions were strengthened, at a remarkably low cost, and with surprisingly efficient results.

The EPOPA project report summarises the project logic as follows: "Lack of market access is a major limiting factor for agricultural development. There is a market demand for organic products. African smallholders are close to organic because they can't afford expensive inputs. Access to international organic markets can provide income and be an incentive to increase production and productivity. There is a need to get the commercial sector involved to make this happen." EPOPA concludes that this commercial sector involvement has been a major factor in the success of the project.

Two more recent South African initiatives confirm the effectiveness of linking small-scale producers to the market: the Bryanston Organic Market links small farmer groups to its market in northern Johannesburg through a participatory guarantee system (PGS), where consumers, sellers and producers participate in assessing the quality of this produce. Similarly, at the Siyavuna Development Co-operative on the KwaZulu-Natal South coast, simply by providing a regular market for small-scale farmers at Nositha Village, Wim Troosters was able to help boost vegetable production from R24 825 in 2008 to R46 679 in 2009; sustaining growth has, however, proved more difficult (Troosters & Auerbach, 2011). The PGS approach has been widely adopted in recent years as a strategy to help small-scale farmers gain access to local markets. These two PGS initiatives and the EPOPA report agree that quality management is vitally important in helping small scale farmers to break into high-end markets.

In the USA, the Rodale Institute in Pennsylvania has been able to close the yield gap between organic and conventional farming systems, with a number of crops attaining very similar production levels in their long term trials. The Rodale trials found that organic systems tend to out-yield conventional systems in dry seasons, where (as in many parts of Africa) irrigation is not available. All three of these long-running sets of trials (Switzerland, Denmark and the USA) found that organic systems require three to four years to build up soil biology to productive levels. Many researchers have pointed to the need to change the way we produce food to reduce environmental impacts, use resources more effectively and develop sustainable food systems. On the other hand, many agricultural scientists dispute the capacity of organic farming systems to “feed the world”, claiming that organic farming has much lower yields and therefore requires much more land, they also argue that more water is needed and that more carbon is emitted by organic systems than conventional systems.

To evaluate organic farming systems in southern Africa, long-term trials were established in 2014. The study commenced with a baseline study (Auerbach, Mashele & Eckert in Auerbach, forthcoming) to evaluate soil fertility and plant growth on the site where these trials were located (George Campus of Nelson Mandela University, in South Africa’s Southern Cape), after which the first year of the comparative trials was planted in November 2014. The Auerbach Trials are now in their fourth year after the baseline trials, and already the third year data shows good improvement in soil fertility and a closing of the yield gap. This forthcoming book edited by Auerbach examines the changes in soil fertility parameters which have been seen in the first two years, the problems which were identified in the organic management system, and the soil remediation (rock phosphate) which was then applied.

The local climate in the Southern Cape is characterised by rain in most months, with a mean of 866 mm. The southern Cape lies between the winter rainfall area of the western Cape and the summer rainfall area of the eastern Cape; natural vegetation is Cape Fynbos, characterised by highly leached acidic soils with low available phosphate. Winters are cool, but frost is rarely experienced; summers are warm, but not as hot or dry as the arid Karoo biome situated north of George over the Outeniqua Mountains. The site is shown in Figure 5, with cabbages in the foreground, and sweet potatoes and cowpeas in the background.

The soil is acidic and low in available phosphate (Mashele & Auerbach, 2016), and the organic cabbages received less than a quarter of the N, P and K nutrients provided to the conventional crops, yet the yields were comparable. Organic sweet potatoes and cowpeas received no fertiliser at all (no compost, no synthetic fertiliser), while conventional sweet potatoes and cowpeas received half the fertiliser given to the cabbages (so, 100 kg/ha of 2.3.4 [30] + 0.5% Zn, and a top-dressing of 50 kg/ha LAN [27% N]); the organic sweet potatoes and cowpeas thus had to rely on nutrients left over from the cabbage crop, and this was sufficient to yield a reasonable crop.

Figure 5. The research trial site showing cabbages from the control treatment (left front, no fertiliser), conventional treatment (back left, fertiliser, no mulch) and organic treatment (right front, compost and mulch) with sweet potatoes behind and cowpeas back right (January 2016, Auerbach).

The organic management system raised soil organic matter levels and decreased acidity slightly, but modest compost applications alone failed to correct soil P deficiencies (see Table 1). All plots had received a total of three t/ha of dolomitic lime over the three years, which raised the pH slightly and decreased soil acidity from the original levels (shown in parentheses in the first column). Conventional treatments then received 400 kg/ha of 2.3.4 (30%) compound N.P.K fertiliser, and a top-dressing of 200 kg/ha Limestone Ammonium Nitrate (26% N). The organic plots received an initial compost dressing of 27 t/ha; thereafter, only the cabbage plots received five t/ha of compost per year (for details, see Auerbach, Mashele & Swanepoel, Forthcoming).

Table 1: Soil fertility changes over three years (2014 to 2016); main results only

Parameter (Jan 2016)	Control (Original)	Conventional	Organic
Soil P (Bray II) mg/kg	10 (4)	31	13
pH (KCl)	5.2 (5.0)	5.2	5.4
Acid saturation %	11.5 (16.6)	11.6	9.8
Exch Aluminium mg/kg	2.77 (3.3)	2.98	2.93
Organic C %	2.9 (4.4)	3.1	3.5
Soil K (av.) mg/kg	121 (160)	121	156
Cation Exchange Capacity	6.9 (7.5)	7.1	7.5

In the third year, 900 kg/ha rock phosphate (13.5% P) was added to the organic treatments to correct the P deficiency, which is permitted in organic agriculture. This raised plant available soil P from 13 to 26 mg/kg, and saw the organic cabbages (averaging 70.6 kg per plot) out-yielding the conventional cabbages (63.7 kg per plot average) in this dry year (605 mm against the long term average of 866 mm per year). The following year was much wetter, and indications are that the conventional cabbages out-yielded the organic this season. The last five years included two unusually heavy rainfall years, while 2016/17 (605 mm) was rather lower than the long-term average for George (866 mm). Both modest quantities of compost (at five t/ha, only on the cabbage crop, with nothing on the sweet potato or cowpea crops), as also moderate chemical fertiliser dressings (200 kg/ha of 2.3.4 [30] + 0.5% Zn, and a top-dressing of 100 kg/ha LAN [27% N]), yielded reasonable crops. In the dry year, the organic system out-yielded the conventional, and in the wetter years, conventional out-yielded organic. Detailed analysis will appear in Auerbach *et al*., Forthcoming.

Pests and diseases were a factor in both systems, but were controlled reasonably well (organic using biological control methods, conventional using poisons); an experiment measuring pests and disease in organic and conventional vegetable rotations is described in van Niekerk *et al*., (Forthcoming). Water use efficiency is being assessed with help of hydrologists from the University of KwaZulu-Natal (Eckert *et al*., forthcoming), and soil micro-biology with the University of Pretoria (Sibiya *et al*., forthcoming).

The research shows (Auerbach, Forthcoming) that organic farming brings about certain improvements (higher soil organic matter, lower soil acidity, better soil biology, aerobic soil conditions, greater water use efficiency). Initially organic farming systems had lower yields (20 to 31%), but this yield gap was eliminated in the third year; in this dry year, rainfed crops out-yielded equivalent conventional crops by 11% (Table 2). The trials are laid out as a complete randomised block experiment with mono-crop and rotation as factors and plots split for farming system (organic and conventional), with ten treatments and four replications.

Table 2: Mean results for cabbage yield harvests (kg/plot) – differences ns

Seasonal rainfall for three years of the research: (George Mean Annual Rainfall – 866 mm):		2015 754 mm	2016 975 mm	2017 605 mm
Management system	Planting practice	Mass (kg) Cabbages in nett plot		
	Monocrop / rotation	2015	2016	2017
	Mono-crop cabbage	48,9	65,5	61,0
	Rotated	50,5	74,6	66,3
Chemical mean		49,7	70,0	63,7
	Mono-crop cabbage	40,4	41,2	66,0
	Rotated	40,5	58,3	75,2
Organic mean		40,5	49,7	70,6
Control mean	Control monocrop cabbage	17,0	5,8	13,1

A detailed plan for the organic sector in southern Africa is presented in the final chapter of the forthcoming book (Auerbach, forthcoming, Chapter 24). It calls for the establishment of a national farm apprenticeship system, linked to mentorship and the development of emerging farmers through the stages described in Figure 1 above. These farmers who have the basic skills of plant production need three years of assistance on a commercial small-holding, and then six years of mentorship on a commercial farm if they are to become successful commercial organic farmers.

Conclusion

If the SA government finds the political will to establish such a system, the agricultural sector will transform, and will become an example to developing countries. There will no doubt be opposition from some agri-businesses, where claims will be made that organic farming cannot feed the world, is inefficient, requires more land and is unscientific. However, the evidence presented above and in Auerbach (Forthcoming) shows that with scientific support organic agriculture is more water efficient, as productive in drier years and producers more nutrient dense and nourishing food for the promotion of health in Africa. It allows small scale farmers who lack access to expensive agro-chemicals and synthetic fertilisers to care for their soil and nourish their clients, even under impending climate change and given population growth in Africa.

Technology alone (such as synthetic fertilisers, agrochemicals, genetically modified seeds and irrigation) will not solve the problems of African food insecurity; it will not (as Jeffrey Sachs claims) "End poverty in our time". What is required is systematic capacity building of farmer institutions with farmer training using agro-ecological (low external input sustainable agriculture or LEISA) approaches. Together with this, it is vital to build market linkages, and to create consumer awareness of the importance of dietary diversity. A LEISA approach will assist in increasing dietary diversity, and agro-ecology will support improved agro-biodiversity, improved water use efficiency and food sovereignty. Household food security will improve as small scale farmers move to efficient subsistence farming, and the rural economies will start to develop as they move into semi-commercial farming. Government policies for sustainable rural development will have to understand these inter-related, complex truths.

Acknowledgements

Support is gratefully acknowledged from the following:

- In-kind support from S Haddad Agricultural Services, BASF & Hygrotech.
- Support for the Mandela Trials from the South African National Research Foundation through African Organic Research Project, and through Centre of Excellence for Food Security.
- Support in establishing the trial site from the Africa Earth Observatory Network (AEON) the George Campus Principal's Fund, Nelson Mandela University, and the university's Science Faculty.

There is no conflict of interest financially.

I am on the Boards of the South African Organic Sector Organisation and the Participatory Guarantee Systems Association of South Africa.

References

Auerbach, R. 1990. An Experiment in Low-input Maize Production in KwaZulu. *Development Southern Africa,* 7(1)*,* 1990.

Auerbach, R. 1993. *Farming systems research evaluation of maize production practices in southern KwaZulu*. MSc thesis, University of Natal, Pietermaritzburg, South Africa.

Auerbach, R. 1994. *Sustainable Development: Developing what to sustain whom*? New Ground, Johannesburg, South Africa.

Auerbach, R. 1995. People, farming and research: How can South African science contribute to sustainable agricultural development? *South African Journal of Science*, 91, 3-6.

Auerbach, R. 1999. *Design for participation in ecologically sound management of South Africa's Mlazi River catchment*. PhD thesis, Wageningen Agricultural University, Netherlands

Auerbach, R. 2013. Transforming African agriculture. In: Auerbach, 2013. Organic farming: African experiences in resilience and sustainability. Food and Agricultural Organization, Rome.

Auerbach, R. (Editor). Forthcoming. *Organic Food Systems: Meeting the needs of Southern Africa*. Commonwealth Agricultural Bureau International (CABI), Wallingford, UK.

Auerbach, R. Forthcoming a. The developing organic sector in Southern and Eastern Africa; what have we learned about sustainable development? In: *Organic Food Systems: Meeting the needs of Southern Africa*. Commonwealth Agricultural Bureau International (CABI), Wallingford, UK.

Auerbach, R. Forthcoming b. Supporting vulnerable communities in the Eastern Cape: Assessing the rainfall evidence. In: Auerbach. (Ed) Forthcoming. *Organic Food Systems: Meeting the needs of Southern Africa*. CABI, Wallingford, UK.

Brady, N. and Weil, R. 2016. The nature and properties of soils. 15th edition, Pearson Education International, New York.

De Wit, M.J. and Stankiewicz, J. (2006) Changes in surface water supply across Africa with predicted climate change. *Science*, 311,1917-1921. Doi: 10.1126/science.1119929.

Eckert, C., Auerbach, R. & Lorentz, S. Comparative Water Use Efficiency and water retention in the Mandela Trials. Forthcoming. In: Auerbach. (Ed) Forthcoming. *Organic Food Systems: Meeting the needs of Southern Africa*. CABI, Wallingford, UK.

EPOPA (Export Programme for Organic Products from Africa). 2008. *Organic exports – A way to a better life? Export promotion of organic products from Africa*. Swedish International Development Agency, Stockholm, Sweden.

IPCC (2018) Global Warming of 1.5ºC, an IPCC special report on the impacts of global warming of 1.5ºC above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Working Group II, Inter-government Panel on Climate Change.

Jenkinson, D. and Johnson, A. 1977. *Soil organic matter in the Hoosfield barley experiment*. Rothamsted Experimental Station 1976, Wheathamsted, UK.

Maeder, P., Fliessbach, A., Dubois, D., Gunst, L., Jossi, W., Widmer, F., Oberson, A., Frossard, E., Oehl, F., Wiemken, A., Gattinger, A. and Niggli, U. 2006. The DOK experiment (Switzerland). *In:* Long-term field experiments in organic farming, Raupp, J., Pekrun, C., Oltmanns, M. and Koepke, U. (Eds). International Society of Organic Agriculture Research, Verlag Dr Koster, Berlin, Germany.

Mashele, N. and Auerbach, R. 2016. Evaluating crop yields, crop quality and soil fertility from organic and conventional farming systems in South Africa's Southern Cape. South African Journal of Geology, 119, 25-32. March 2016.

Munk, N. (2013) The Idealist: Jeffrey Sachs and the quest to end poverty. McClelland and Stewart, Toronto, Canada.

Ramaila, M., Mahlangu, S. and du Toit, D. 2011. *Agricultural productivity in Africa: A literature review*. Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa.

Raupp, J., Pekrun, C., Oltmanns, M. and Koepke, 2006. Long-term Field Experiments in Organic Farming. International Society of Organic Agriculture Research, Verlag Dr Koster, Berlin, Germany.

Sachs, J. 2005. The end of poverty: How we can make it happen in our lifetime. Penguin Books, London, UK.

Scialabba, N. 2007. *Organic agriculture and food security*. OFS/2007/5. Food and Agricultural Organization, Rome, Italy.

Sibiya M, Labuschagne N, Habig J. and Auerbach, R. Forthcoming. Initial assessment of microbiological soil health indicators in the Mandela Trials Forthcoming. In Auerbach. (Ed) Forthcoming. Organic Food Systems: Meeting the needs of Southern Africa. CABI, Wallingford, UK.

Troosters, W. and Auerbach, R. 2011. *Supporting farmer groups in South Africa. Paper delivered at the African Union/World Food Programme/IFOAM session on 'Putting vulnerable rural people at the centre of the agenda: ecosystem and community-based approaches to resilient rural livelihoods*. 17th Conference of the Parties, United Nations Conference on Climate Change, Durban, South Africa.

UNCTAD (United Nations Conference on Trade and Development). (2008) Best practices for organic policy. (Accessed 3 June 2018). Available at: http://unctad.org/en/Docs/ditcted20073_en.pdf .

UNCTAD. (2016) Financing organic agriculture in Africa. UNCTAD/WEB/DITC/TED/2016/6). (Accessed 3 June 2018). Available at: **http://unctad.org/en/PublicationsLibrary/webditcted2016d6_en.pdf .**

Wilson, F. and Cornell, V. 2014. Overcoming Poverty and Inequality: Guide to Carnegie 3 Conference. SALDRU, University of Cape Town, Cape Town, South Africa. Available at http://www.carnegie3.org.za/docs/Carnegie3_April13_WEB.pdf (accessed 3 July 2018).