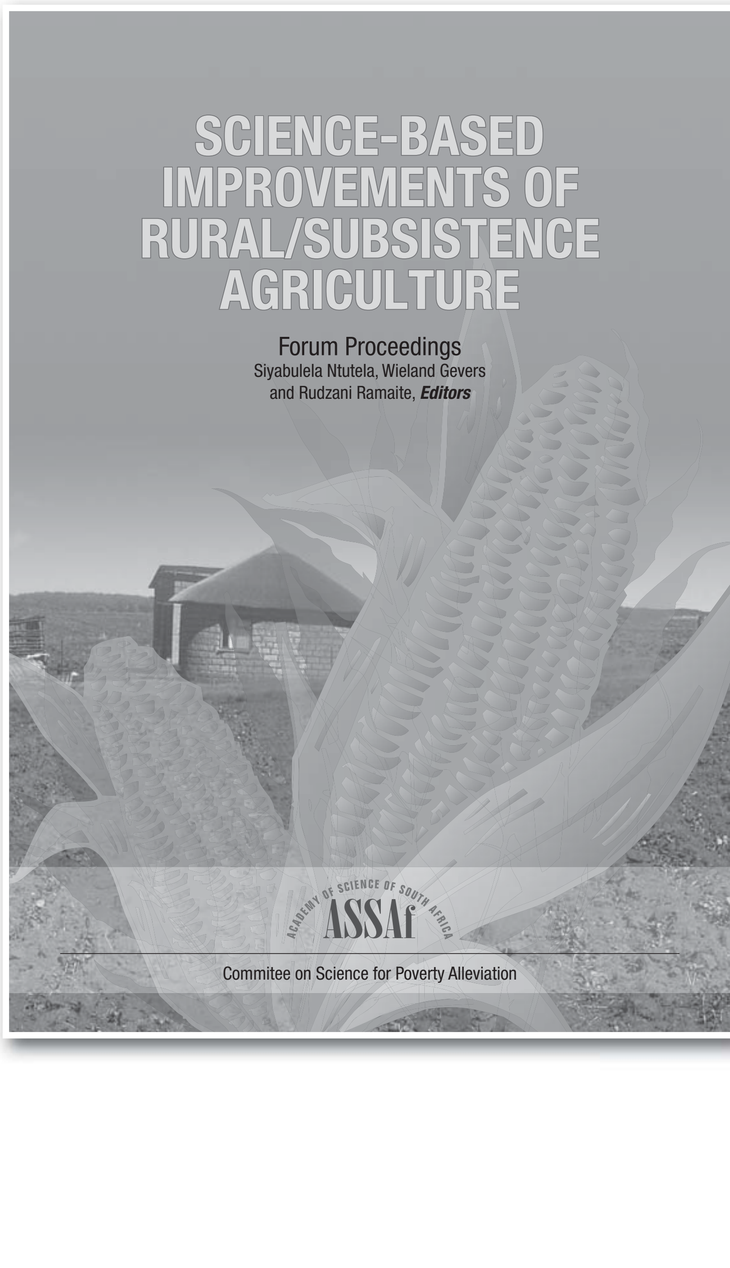


ACADEMY OF SCIENCE OF SOUTH AFRICA
ASSAf

18 October 2006
Auditorium, Department of Science and Technology, Pretoria, South Africa

Published by the Academy of Science of South Africa
ISBN: 978-0-620-39210-5
July 2007

P O Box 72135
Lynnwood Ridge 0040
(Pretoria, South Africa)

Building 53
1st Floor Block C
CSIR Site, South Gate
Meiring Naude Road
Brummeria 0184

Web: www.assaf.org.za

Phone: +27 12 843 6482
Fax: +27 0866 810 143
e-mail: fundi@assaf.org.za

Layout, typesetting, cover design, reproduction and printing
Marketing Support Services (012) 346-2168

The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996 in the presence of then President Nelson Mandela, the Patron of the launch of the Academy. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science for the benefit of society, with a mandate encompassing all fields of scientific enquiry in a seamless way, and including in its ranks the full diversity of South Africa's distinguished scientists.

The Parliament of South Africa passed the Academy of Science of South Africa Act, Act 67 in 2001, and the Act came into operation on 15 May 2002.

This has made ASSAf the official Academy of Science of South Africa, recognised by Government and representing South Africa in the international community of science academies.

Table of Contents

About ASSAf

The Academy of Science of South Africa Act (2001): A statutory body placed strategically in the national System of Innovation.

The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996 in the presence of **then President Nelson Mandela, the patron of the launch of the Academy.** It was formed in response to the need for an academy of science consonant with the dawn of democracy in South Africa: activist in its mission of using science for the benefit of society, with a mandate encompassing all fields of scientific enquiry in a seamless way, and including in its ranks the full diversity of South Africa's distinguished scientists.

The Parliament of South Africa subsequently passed the **Academy of Science of South Africa Act, Act 67 of 2001,** which came into operation on 15 may 2002.

ASSAf is thus the official national Academy of Science of South Africa, recognized by Government and representing South Africa in the international community of science academies.

Internationally recognized science academies are similar in that they are:

- **self-perpetuating,** with a merit-based membership that creates an upward aspiration for quality and excellence in scientific endeavours;
- **multi-disciplinary,** striving to represent science as a consilient continuum of knowledge, insight and practical solutions;
- **independent** of government, but can be funded by government for performing certain tasks;
- a **credible voice of science** to be heard on topics of national concern, independent of institutional or commercial linkages, obligations and agendas; and
- linked together in an **independent global community** that can mobilize scientific thinking, skills and knowledge across the world.

ASSAf places a particular emphasis on **excellence in the application of scientific thinking to the problems and challenges facing South African society.** It draws its membership from all population groups and from all scientific disciplines.

OBJECTIVES

Scientific thinking for the good of society

According to the Act the **objectives of the Academy** are:

- to promote common ground in scientific thinking across all disciplines, for example the physical, mathematical, life, human, social and economic sciences;
- to encourage and promote innovative and independent scientific thinking;
- to promote the optimum development of the intellectual capacity of all people;
- to provide effective advice and facilitate appropriate action in relation to the collective needs, opportunities and challenges of all South Africans; and
- to link South Africa with scientific communities at the highest levels, in particular within Africa, and further afield.

VISION

An engine of excellence in scholarship and intellectual cooperation

ASSAf aspires to be the apex organisation for science and scholarship in South Africa, internationally respected and connected, its membership simultaneously the aspiration of the country's most active scholars in all fields of scientific enquiry, and the collective resource making possible the professionally managed generation of evidence-based solutions to national problems.

MISSION STATEMENT

Clarifying the niche of the Academy

Like democratic South Africa in general, ASSAf aspires to play both a national and an international role, particularly with respect to the African continent. We see the Academy as usefully at arm's length from government and other organised sections of the state, comprising an assembly of excellent scholars from many disciplines who are well-networked both nationally and internationally, and have shown their interest in and capacity for promoting the development of a prosperous and a fully enabled society. Membership of the Academy (by election) is both an honour and an obligation to work individually and collectively (as the Academy) to ensure that decision making requiring scholarly scrutiny and analysis is based on the best and most integrated understandings and insights available to the country. The Academicians thus represent an organised, independent but responsive scholarly voice to help guide the development of the country and its people.

The mission of ASSAf is thus to

- become increasingly associated in the mind of the nation with the highest levels of scholarly achievement and excellence in the application of scientific thinking for the benefit of society;
- consolidate its infrastructure and capacity, and to expand and mobilise the membership to ensure that scholars from a full disciplinary spectrum are available for its work, and that these are indeed both thinkers and doers, willing to put significant effort into the Academy's activities;
- embark on a programme of systematic studies of evidence-based issues of national importance, some proposed by government or other sectors, and some identified by the Academy itself;
- develop a sound and robust methodology for constituting consensus study panels, organising their work, including conferences and workshops, and producing authoritative reports that are well-disseminated and have significant impact;
- alternatively, constitute committees to oversee the Academy's work in broad areas of focus, usually expressed by the holding of national forums on particular key issues, leading to forum reports that have a significant impact on policy and practise;
- publish science-focused periodicals, especially a multidisciplinary journal of high quality (the *South African Journal of Science*) and a science magazine that will showcase the best of South African research to a wide national (and international) audience (*Quest – Science for South Africa*); and to promote the development in South Africa of an indigenous system of research journals of internationally recognised quality and usefulness;
- develop productive partnerships with other organisations, especially (but not only) the National Departments of Science and Technology, Education, Health and Agriculture; the National Advisory Council on Innovation; science councils; higher education institutions, etc., with a view to the building of capacity in science and its applications within the National System of Innovation (NSI);
- create new and diversified sources of funding for the sustainable functioning of an independent Academy;

- communicate effectively with the general and specific publics, as well as with partners and sponsors;
- develop a plan for the expansion of the activities of ASSAf in partnership with the national science academies of other countries, including contracted partnership with the US National Academies; and
- play a significant role in the international science system, particularly in Africa, through organisations such as the InterAcademy Panel (IAP) and the InterAcademy Council (IAC), the Academy of Sciences of the Developing World (TWAS), the International Council on Science (ICSU), as well as the Network of African Science Academies (NASAC), all in the context of the New Partnership for Africa's Development (NEPAD).

MEMBERS

Core asset of the Academy (each styled "MASSAf")

After nomination by four existing Members (at least two of whom do so from personal knowledge of the candidate), new Members of the Academy are elected in a secret ballot. The normal criterion for election is significant achievement in the advancement or application of science, and, in addition, Members should be persons who can be expected significantly to assist the Academy in achieving its objectives. By October 2006, ASSAf had over 250 Members drawn by self-categorization from the earth, economic, life, mathematical, physical, social, technological, education, and agricultural sciences as well as the humanities.

COUNCIL

Steering Academy activities and taking responsibility

The affairs of the Academy are governed by a Council comprising 12 members, each of whom holds office for four years. This Council is elected by the Members every two years. For the sake of continuity, six members continue to serve a further term, while six new members are elected once they have been nominated according to the constitutional mechanism. To provide a better balance of race, gender or disciplinary area, the Council can co-opt additional members from persons who were nominated for election to the Council.

The office-bearers are, respectively, the President, two Vice-Presidents, a General Secretary and a Treasurer. Committees can be formed in order to carry out specific functions but each must be chaired by a Member of the Academy or, preferably, of its Council. Reports drawn up by its committees or *ad hoc* task group are approved by the Council before entering the public domain.

INTERNATIONAL CONNECTIONS

Crucial catalyst for Academy-type activities

ASSAf is an active member of the IAP, a growing organisation that embraces the national science academies of over 90 countries. The Academy of Sciences for the Developing World now has an office in Africa based in Nairobi, and the Network of African Science Academies, of which the President of ASSAf is a Vice-President, is also located in that city.

ASSAf became an "intense partner" of the US National Academies (together with the Nigerian and Ugandan Academies of Science) as part of the African Science Academy Development Initiative (ASADI), receiving a substantial 5-year grant to build its capacity for generating evidence-based advice for the government and the nation in general.

STRATEGIC PLAN AND POLICY DEVELOPMENT

The way to go

ASSAf has developed a comprehensive strategic plan following a thorough process for identification of its strengths, weaknesses, opportunities and threats. Through its governing Council, the Academy has developed policies and guidelines for its activities. The initiation of the ASADI partnership with the US National Academies prompted the generation, proposal and adoption of the following items:

- Guidelines for proposals of science-based topics in terms of the ASSAf ct
- Guidelines for proposals of science-based topics (project proposals)
- Guidelines for the appointment of consensus study panels and forum steering committees
- Policy on conferences
- Formation of a forum steering Committee on Science for Poverty Alleviation (first example of an ASSAf "Board")
- Panel for the Consensus Study on Nutritional Influences on Human Immunity, with special reference to clinical tuberculosis and HIV infection (first ASSAf Consensus Study).

ASSAf's strategic plan and the Academy's policies and guidelines are publicly featured on the ASSAf website at http://www.assaf.org.za

RESEARCH PUBLISHING

The core of the quality assurance system for the dissemination of research findings

The Academy of Science of South Africa signed a contract in 2001 with the Department of Science and Technology (DST) for various activities in connection with the "strategic management" of research journals published in South Africa. The first component was a comprehensive study of the present and best-possible future role of research journals published in South Africa, now completed through the release of a full report in March 2006, with evidence-based recommendations, and a range of follow-up project integration and implementation strategies.

SAJS

Publishing the *South African Journal of Science*: a Nature for South Africa

The *South African Journal of Science* is the leading multidisciplinary research journal in Africa, and features a great diversity of original work by researchers throughout the country and abroad, concentrating on articles that have an appeal that is wider than that of single disciplines. Among the highlights of the volume published in 2005 were articles featuring the research at historically black universities supported by the Royal Society-NRF bilateral programme. The journal appears six times a year, and is accessible online as one of the e-publications managed by SABINET.

QUEST

Publishing *Quest*: A quarterly magazine of high quality, presenting science for South Africa

The Academy publishes the national science magazine *Quest: Science for South Africa* that was launched in 2004. Quest serves as a platform for communication about scientific research done in South Africa. It strives to showcase South African science in action, and is aimed at the broad scientific community, decision-makers, the public, students, and especially the senior grades at secondary schools.

Forum Steering Committee on Science for Poverty Alleviation

- **Sagadevan Mundree (Chair),** Chief Executive Officer, PlantBiotech Trust, Pietermaritsburg.
- **Ann Bernstein,** Executive Director, Centre for Development and Enterprise.
- **Daniel Ncayiyana**, editor of the *South African Medical Journal* and Advisor to the President of the Human Sciences Research Council.
- **David Dewar**, Professor of Architecture, Planning and Geomatics and Deputy Dean of the Faculty of Engineering and the Built Environment, University of Cape Town.
- **Mamphela Ramphele,** Chairperson, Circle Capital Ventures.
- **Priscilla Reddy,** Director, The Health Promotion Research and Development Group, Medical research Council (MRC), Cape Town.
- **Renfrew Christie,** Dean of Research, University of the Western Cape.
- **Solomon Benatar,** Professor of Medicine, University of Cape Town.

STAFF

- **Rudzani Ramaite,** Projects Officer and Study Director
- **Wieland Gevers,** Executive Officer
- **Xola Mati,** Supervisory Projects Officer
- **Boitumelo Mabina,** Assistant Projects Officer

CONSULTANT

- **Robyn Arnold**, Write Connection CC

Foreword

This forum on Science-based Improvements of Rural/Subsistence Agriculture is the first in a series that are being convened by the ASSAf Forum steering Committee on Science for Poverty Alleviation. During 2005, the Academy engaged in discussions with the Director-General of the Department of Science and Technology (DST) and a number of officials of the Department regarding matters of national interest in the national system of innovation. The Director-General indicated that studies by the Academy would be welcomed with a view to providing evidence-based advice that could guide policy development, since this was seen as one of the major roles that the Academy should fulfil in the future. The participants in that discussion identified Science for Poverty Alleviation as a broad general framework in which the Academy might initiate a number of studies. Early in 2006, the Council of the Academy agreed to the establishment of a Committee on Science-based Approaches to the Alleviation of Poverty and identified a number of members of the Academy who would be invited to be members of that committee that would take the matter forward on behalf of the Academy. Prof. Sagadevan Mundree was appointed chair of the committee and was instrumental in organising the forum.

Workshops such as this one, operate in the 'forum mode', which is a system whereby the Academy brings together leading national and, where appropriate, international scholars in the field to assess the empirical evidence that can be used to illuminate solutions to the identified problem, especially those that will lead to the alleviation of poverty. The purpose of this workshop was to bring together a group of experts in the field of agricultural research and to help identify promising scientific and technological strategies for improving agricultural productivity and food security, specifically for small-scale farmers. The people who were invited to attend the forum were individually considered to be able to make a significant contribution to the topic under discussion. The outcome of the forum and the discussions that flowed from it shows that translation of that knowledge into practical recommendations is in many cases feasible and desirable for the improvement of agricultural productivity and food security. I would like to thank Prof. Sagadevan Mundree for organising the forum and for chairing the sessions. Furthermore, I would like to thank the participants for contributing to the development of a significant report.

R M Crewe
June 2007

Acknowledgements

The Committee on Science for Poverty Alleviation of the Academy of Science of South Africa (ASSAf) wishes to express its warmest appreciation to the presenters, session chairpersons, as well as all the individuals and organisations who gave their valuable time to provide information and advice to the forum through their participation in the forum. The workshop programme indicating names of all presenters is included as an Appendix.

The valuable leadership and guidance provided by Professor Sagadevan Mundree, Chair of the Committee, is gratefully acknowledged.

Ms Robyn Arnold (consultant), Dr Siyabulela Ntutela (editor), Prof Wieland Gevers (editor) and Marketing Support Services (production house) are warmly acknowledged for producing this publication.

Ms Rudzani Ramaite, ASSAf Projects (Professional) Officer and Study Director for this forum, is thanked for her much valued contributions during the course of the forum process and the production of this proceedings.

The support offered by all ASSAf staff and others who contributed to the success of this forum is also greatly appreciated.

Finally, the Committee acknowledges the financial support provided by the United States National Academies through the African Academies Development Initiative (ASADI) Programme, as well as that provided by the South African national Department of Science and Technology (DST).

Introduction

Sagadevan Mundree
Committee Chair: ASSAf and CEO: PlantBiotech Trust

PURPOSE OF THIS FORUM

This event is intended to be a participative, interactive one, in which your inputs will result in a report that will ultimately be of value to the Department of Science and Technology but especially to the many stakeholders in the key development area of small-scale agriculture. The objective of the forum is to bring together national and international experts to identify promising science and technology strategies for improving agricultural productivity and food security, specifically of small-scale subsistence and rural farmers.

ASSAf following international best practice uses two contrasting methodologies to generate evidence-based consensus policy advice. Consensus panels are constituted to conduct a detailed review, from many disciplinary perspectives, of the available evidence-based in order to generate systematic findings and implementable recommendations. Forum steering Committees are set up to address a series of problems in a broad field through serial forums of the kind represented by the present occasion. We are not dealing with talk shops here but with a purposeful approach designed to produce real benefits for people. We have done our best to select speakers whose authoritative contributions can be debated individually and in a concluding plenary session, in order to create a new synthesis of pooled expertise that is translatable into action.

I should mention that this forum is the first significant forum-type activity of the ASSAf Committee on Science for Poverty Alleviation.

IMPORTANCE OF THE AGRICULTURAL SECTOR IN AFRICA

In 2001, South Africa developed a National Biotechnology Strategy, which came up with the following key tenets:

- Poverty alleviation through biotechnology products that enable subsistence and small-scale livelihoods

- Improved quality of life through the development of biotechnology products that focus on human health in the African context
- Development of projects that positively impact food security and poverty alleviation for small-scale farmers
- Wealth creation by building start-up companies and commercialising products
- Job creation through the development of new start-ups and entrepreneurial skills
- Development of world-class science and technology capacities and skills
- Black economic empowerment (BEE).

It is clear that poverty alleviation and food security are high on the agenda of the strategy.

The following points should be noted with respect to the role of agriculture in Africa:

- 50–75% of the labour force is associated with agriculture
- 70% of the population depends on agriculture as the sole source of income
- Africa's crop production is the lowest in the world (1.7 tons/ha Africa, compared with the global average of 4.0 tons/ha global)
- 40% of the harvest may be lost due to post-harvest damage
- Most African countries depend on agriculture for foreign currency earnings.

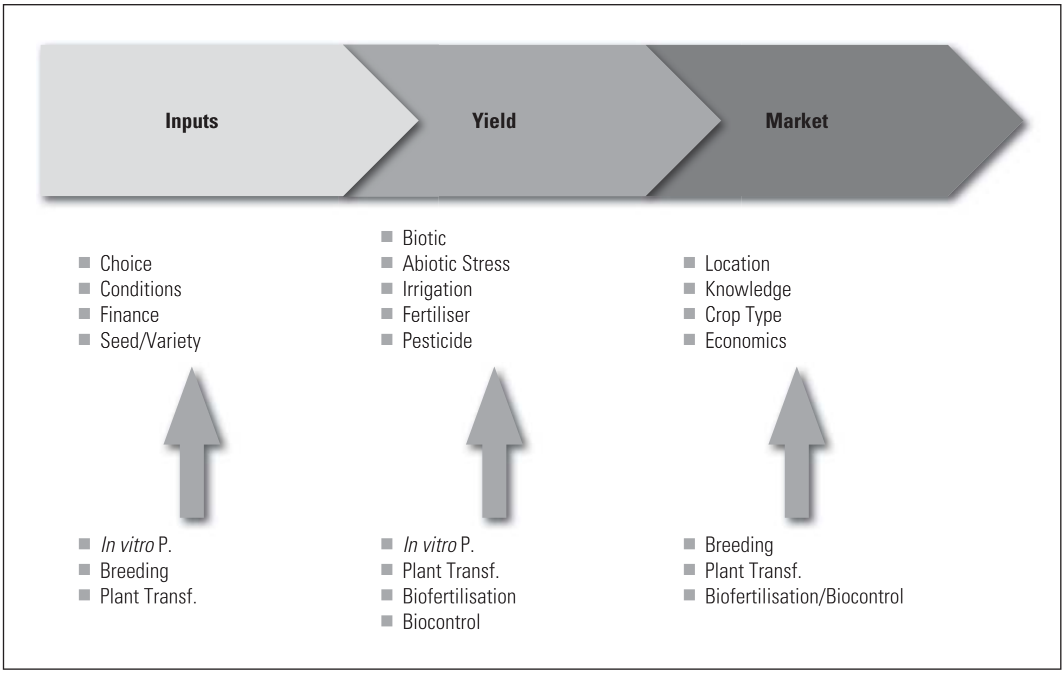
Table 1 below shows some of the statistics gathered by the National Innovation Centre for Plant Biotechnology, PlantBio, with respect to the landscape of agricultural activity in South Africa. Between a third and half of South Africa's population is dependent on subsistence, small-scale farming (see Table 1).

Table 1: Small-scale farmers in South Africa

Subsistence farmers	**Minimum**	**Maximum**
Number	1 500 000	3 000 000
Heads per household	3	7
Number dependent	4 500 000	21 000 000
%	9%	44%
Farm size	< 1 ha	< 5 ha
Emerging farmers	**Minimum**	**Maximum**
Number	250 000	500 000
Heads per household	3	7
Number dependent	750 000	3 500 000
%	2%	7%
Note: Emerging farmers have small-scale commercial operations		

Source: Discussions with National Department of Agriculture

Figure 1: Issues affecting small-scale farmers in South Africa



There are programmes in place to develop them into emerging farmers, but the problems and challenges that these farmers face will be felt by the entire nation.

We consider the entire value chain in which subsistence farmers function, starting with the choice of crops to grow, the prevailing conditions, the financing of the operation, the availability of or access to specific seed varieties or germplasm, the challenges around yield, the biotic and abiotic stresses that farmers are exposed to, the access to (or inability to access) fertilisers and pesticides, which impacts on yield and productivity, and increasingly the issue of access to markets, which affects sustainability (see Figure 1).

The specific issues include the following:

- The maize streak virus is endemic to Africa and causes huge economic losses, crop losses and losses in productivity. Not many multinationals are investing resources in addressing the problem. Small-scale farmers across the continent face this issue regularly.
- Uganda was thrown into food insecurity about ten years ago, largely because of the mosaic virus that affects cassava, and there are already attempts to deal with it using a variety of approaches, including breeding and genetic modification.
- At a recent conference, Gordon Conway highlighted the susceptibility of maize crops to drought, particularly at the most crucial stage, when the grain filling occurs. This is particularly a problem in southern Africa.

TWO RECENT EXAMPLES OF THE POTENTIAL FOR SCIENCE TO IMPROVE PEOPLE'S LIVES

I will cite the examples of two communities of small-scale farmers that I have personally had experience with:

- Umvumbulu, south of Durban,
- Makhatini flats, which have been publicised internationally, close to the Mozambican border.

The Umvumbulu community comprises approximately 140 families, who grow traditional vegetables organically (without chemicals, pesticides or fertilisers). An academic at the University of KwaZulu-Natal, Prof. Albert Modi, has been working closely with this community for the past six years, listening to the challenges that the community is exposed to, ranging from the selection and breeding programmes to access to specific markets. I am happy to report that this community has been linked to a number of chain stores, for example, the *madumbe* varieties that are produced on their farms are now on the shelves of all Woolworths stores around the country. They continue to face many of the problems and challenges, however, that have been highlighted. We believe that by having an effective R&D programme, linked to this community, one could provide them with appropriate guidance on how they could improve yield and deal with the challenges.

The Uvongo Farmers Association located on the Makhatini Flats has a membership of 5 000 small-scale farmers, each cultivating between 1 and 30 ha of land and growing Bt cotton. Largely due to the challenges these farmers have been faced with, they have opted to use GM crops, much to their advantage.

The familiar three-legged African pot symbolises sustainability, with the three legs standing for:

- Improved crop varieties
- Enhanced soil fertility
- Better markets for better income generation and improved livelihoods.

Taking these factors together, one could potentially bring about improved livelihoods and quality of life of these small-scale farmers and hopefully create a range of opportunities for them.

ROAD MAP FOR THE REST OF THIS REPORT

Each contribution has been finalized after the forum by the relevant author(s), including the discussion sections concerned. They are broadly grouped as per figure 1 in terms of their main focus on Inputs, Yield or Market. They cover many aspects of the topic, with contrasting approaches to putting science to work in improving agricultural productivity, new and potentially important trends of the future such as biofuels, and some exciting examples of sustainable innovations where scientists work in partnership with farming communities. Some of the research programmes are large scale, involving significant international funding and partnerships, while others are smaller in scale and closer to implementation.

The final plenary discussion is reproduced in full, in edited form. An attempt to reflect such consensus as was achieved on certain issues, but other matters will have to be followed up in a variety of appropriate ways. We recognize that we have much to learn about forum-type, science-based interventions of this type, but we are excited about the liveliness generated in the course of the forum and the possibility that this report will be useful to many stakeholders, particularly the people who depend for subsistence and livelihood on small-scale agriculture in both rural and peri-urban contexts

SECTION 1

Focus on inputs affecting small-scale farmers in Africa

Biotechnological approaches to crop plant development for adaptation to local African conditions

Edward P Rybicki
Department of Molecular and Cell Biology and Institute of Infectious Disease and Molecular Medicine, University of Cape Town

INTRODUCTION

Agricultural production in most of Africa lags far behind most of the developed and even much of the developing world, for a variety of reasons. High on this list are biotic and abiotic stresses, which exacerbate the problems facing resource-poor farmers. While many of the biotic stresses are preventable, or can be ameliorated, by good husbandry or farming practices, which are skills that can be taught, others may only in the final analysis be controllable by large-scale application of pesticides, varying of planting dates, or use of pest-resistant crop varieties – which options may not be open to the subsistence level or even small-scale commercial farmer in Africa. Thus, while the use of GM-derived resistance in developed countries is contentious, the application of such sophisticated biotechnology to improving African crop yields seems imperative – especially given the fact that sub-Saharan Africa is now by far the worst-off region in the world in the current Food and Agriculture Organisation (FAO) 'Hunger Map' (FAO 2006) compared to the situation in the 1970s, when south-east Asia was as badly off. The case for its use is bolstered by the fact that Africans themselves are calling for it, and it is not being imposed from the outside (Wambugu 1999). However, GM crops are not the only application of biotechnology that could be useful: accordingly, this paper will discuss the case of viruses affecting food crops in Africa, and the possibilities of applying especially molecular biotechnological methods to facilitate breeding as well as to confer resistance. The associated problem of how best to use biotechnology for the accurate identification of plant diseases will also be discussed. Another useful resource in this regard is the FAO 'Statement on Biotechnology' (FAO 2000).

SUB-SAHARAN AFRICAN FOOD CROPS

While the top African commercial crops are rice, wheat, maize, cassava, fresh vegetables and sweet potatoes, the most important *food* crops are maize, cassava, rice, bananas, sweet potatoes, vegetables (beans, pumpkins) and fruit (mangoes, coconuts) (Rybicki & Pietersen 1999). While the large and rapidly growing urban populations in Africa will buy most of their food in local markets – from both commercially-grown and locally-grown sources – the still significant rural and peri-urban populations grow much of their own food, especially in tropical and sub-tropical Africa where the climate allows year-round cultivation. It is these people – who support a very significant fraction of Africa's population – that face the severe disease problems, without the means to deal with them.

MAJOR VIRUS DISEASE PROBLEMS

The major food crops in sub-Saharan Africa and their most important identified viral diseases are listed below (see Rybicki & Pietersen [1999] for details):

- **Maize:** major African staple food crop
  - Maize streak virus (MSV); Maize dwarf/sugarcane mosaic viruses (MDMV/SCMV); Maize mosaic virus (MMV)
- **Cassava:** major staple, increasing use
  - Cassava mosaic viruses (begomoviruses)
- **Rice:** increasingly widely grown food crop
  - Rice yellow mottle virus (RYMV)
- **Bananas:** major tropical staple
  - Banana streak (BSV); Banana bunchy top virus (BBTV); Cucumber mosaic virus (CMV)
- **Sweet potato**: major and increasing staple
  - Feathery mottle/chlorotic stunt viruses (SPFMV + SPCSV/SPSVV)
- **Vegetables**: secondary staple
  - bean potyviruses, tomato geminiviruses, tospoviruses.

I will discuss a few important examples taken from the list above, outline conventional commercial farming practice for the amelioration of disease, and illustrate what can be done with the appropriate application of biotechnological methods.

Cassava mosaic disease

Cassava is perhaps the most important African root crop, and certainly the most important in many tropical areas, according to the UN's Centro Internacional de Agricultura Tropical (CIAT) (www.ciat.cgiar.org/africa/cassava.htm). African cassava mosaic disease (ACMD) is present wherever cassava is grown in Africa, and is the most important production constraint in Africa. ACMD provides very important object lessons; first, in showing how badly an infectious disease can impact African crop production and human health; second, in showing how sophisticated molecular biological techniques may be necessary for a complete identification of the problem and for accurate disease diagnosis; third, for lessons in what to do and not to do in combating a problem.

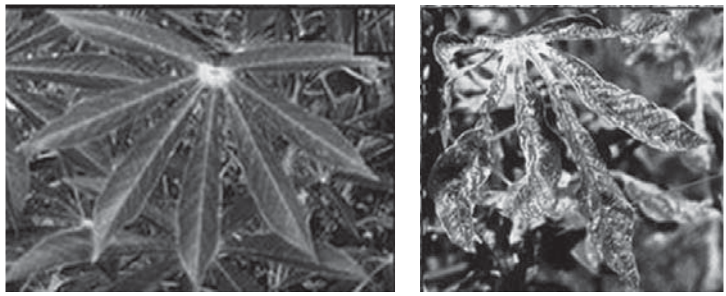
The best-characterised viruses associated with ACMD are the begomoviruses (family: *Geminiviridae*; genus *Begomovirus*): these are single-stranded circular DNA-genome viruses spread by the single whitefly species *Bemisia tabaci*. While the disease presentation is similar across Africa, ACMD is caused by a variety of distinct species of geographically localised begomoviruses, including African cassava mosaic virus (ACMV; Nigeria and Kenya), East African cassava mosaic virus (EACMV), East African cassava mosaic Malawi virus (EACMMV), EACM Zanzibar virus (EACMZV), and the south and east African SACMV (Legg & Fauquet 2004). However, a recent survey in Kenya (Were, Winter & Maiss 2004) threw up the fact that a significant number of mosaic-diseased plants were in fact infected with unidentified filamentous viruses, which highlights a problem of disease identification that will be discussed below.

While ACMD has been known for many years, it was thrust into the public eye in the early 1990s, when it became evident that a catastrophic wave of severe cassava disease was spreading out of a corner of rural Uganda: "By 1989, a severe epidemic was reported in the West Nile Region of north-western Uganda. A comprehensive survey of cassava in the area revealed that the disease was spreading rapidly and causing crop failure. By April 1992, most fields were 80–90% infected and cassava production had virtually ceased due to the poor yields of the diseased crops" (Anderson 2004). The wave of disease was spreading into western Kenya by mid-1997 (Rybicki & Pietersen 1999), and has since gone on into Rwanda/Burundi and both Congos (Legg & Fauquet 2004).

The disease agent is now known – thanks to a number of molecular virological investigations – to be a natural recombinant of ACMV and EACMV (termed EACMV-Ug), usually in a pathologically synergistic association with ACMV (Legg & Fauquet 2004; Were, Winter & Maiss 2004; Anderson 2004; Bull *et al.* 2006). The epiphytotic has caused severe food insecurity, especially in Uganda, and has been linked with an increase in mortality in the area. Combating the spread of the disease received much attention in Uganda from the early 1990s, and some early relief was found in the distribution of naturally tolerant varieties of cassava from highland areas. Conventional means of combating severe ACMD are intensive spraying for vector control, roguing and selection, crop isolation, clean-up of planting stock by meristem culture, the planting of naturally tolerant varieties, and possibly cross-protection by infection with mild ACMV/EACMV. However, it is the application of modern biotechnological methods such as marker-assisted breeding that may result in the best control (Legg & Fauquet 2004), despite the initial promise of pathogen-derived GM resistance (see below).

Conventional breeding for ACMD resistance was made difficult by the fact that the viruses do not occur in the centre of genetic diversity of cassava – namely,

Figure 1: Healthy cassava (left) and cassava with very severe mosaic disease (right). Pictures taken in west Kenya near Kisumu in 1997



Source: EP Rybicki, personal collection

South America. Thus, there has been a significant constraint on the introduction of otherwise agronomically desirable varieties of cassava from this region, as only land races from Africa have developed any resistance at all to the viruses. However, conventional breeding has received a significant boost recently by the demonstration by CIAT researchers of molecular markers that are closely associated with genes that confer high levels of resistance to ACMD (CIAT 2006). CIAT and its sister organisation, the International Institute of Tropical Agriculture (IITA), have embarked on a comprehensive programme of cassava breeding for resistance to a number of pests including ACMD, but also for nutritional improvement.

Transgenic resistance to ACMD has been trumpeted as 'the' solution to the problem, in the previous apparent absence of resistant germplasm by a number of research groups (see Zhang, Vanderschuren, Futterer & Gruissem 2005; Legg & Fauquet 2004). Results in experimental trials have in fact been very promising, but there are important caveats (see Failures to Learn from, below).

Maize streak virus

Maize streak virus (MSV) is a leafhopper-transmitted geminivirus (family: *Geminiviridae*; genus: *Mastrevirus*; single-stranded circular DNA genome), and is the causal agent of maize streak disease (MSD). This is the most important viral disease of maize in Africa (Bosque-Perez 2000), and was first described from South Africa over 100 years ago (Rybicki 1999). The disease does not occur outside of Africa and neighbouring islands. The development of resistant varieties has therefore had high priority throughout Africa for over 40 years Rybicki & Pietersen 1999; Bosque-Perez 2000; Rybicki 1988). The virus can cause yield losses of up to 100%: this depends upon the following factors:

- **Time of planting/infection**: infected seedlings produce no yield or are killed, while plants infected later yield proportionately more

Figure 2: MSV particles (left; courtesy K Kasdorf); severely-diseased maize (middle, EP Rybicki, 1997), and the leafhopper vector Cicadulina mbila Naudé (right; courtesy of B Odhiambo)

- **Spread between crops**: this is facilitated by successive cropping in tropical/sub-tropical areas
- **Spread from weedy reservoirs**: this is facilitated by the presence of wild grasses as reservoirs of both virus and vectors
- **Maize variety**: a complex of five pairs of different alleles, both dominant and recessive, is required to confer effective MSV resistance in maize (GJMA Gorter, personal communication to EP Rybicki); much open-pollinated maize grown by small farmers in Africa is MSD-susceptible (see Rybicki 2006).

Commercial farmers control virus by spraying for vector control; varying planting date (for irrigated crops); and using tolerant/resistant commercial varieties or hybrids. Small farmers generally cannot spray, and have to plant with the rains – and while many farmers do in fact use commercial hybrid seed (in Zimbabwe and Zambia; E.P. Rybicki, personal knowledge), poorer or genuinely subsistence farmers generally use their own stored seed (open pollinated varieties, OPVs). Thus, while MSD is in fact controlled quite well by larger commercial growers, small farmers are at the mercy of a severe pathogen, which has caused, and continues to cause, significant loss of valuable food.

The way in which MSD has been combated in recent years also provides valuable object lessons in how to apply biotechnology appropriately to African problems – and in Africa rather than for Africa. Two recent research programmes in particular provide contrasting approaches: in the first, a modern conventional approach was applied to a regional problem; in the second, pathogen-derived GM resistance was developed for universal application.

A survey in Kenya in 1990 sponsored by the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) determined that MSD was one of the two most important biotic constraints affecting maize production in Kenya in particular. The core of the problem was the lack of resistance in locally bred maize supplied by the national seed company. This led to the ISAAA MSV project, initiated in 1996, which involved international collaboration of public institutions and the private sector: the bodies involved included the Kenya Agricultural

Research Institute (KARI), the John Innes Centre (JIC) in Norwich, UK, the then Microbiology Department of the University of Cape Town in South Africa, and the UN-affiliated International Centre of Insect Physiology and Ecology in Kenya (ISAAA 2006). Funding came from the US Rockefeller Foundation, and Novartis in Europe donated some technology to KARI; the South African Grain Crops Research Institute (GCRI) and PANNAR Pty Ltd. donated streak-resistant maize breeding lines, as did the UN-affiliated CIMMYT. Advanced biotechnology skills, including the use of advanced agroinoculation techniques and molecular markers, were at the core of this effort. Marker-assisted breeding and agroinoculation-based challenge allowed the rapid development of two MSV 'tolerant' varieties of maize for local use in Kenya, released in 2006 (F. Wambugu, personal communication).

In the second approach, researchers at the University of Cape Town developed a strategy for GM resistance based on expression of a 'dominant negative' mutant version of the rolling circle replication initiator protein encoded by the virus *rep* gene. This ten-year effort built on a pre-existing knowledge base from more than ten years' study of virus diversity, investigations of host-pathogen interactions, development of tissue culture, regeneration and transformation protocols for maize and for a model grass system, and an earlier unsuccessful effort at engineering resistance – all of it totally home-grown. Success with several different MSV-derived gene constructs in isolated maize cells was followed by success with a single gene in the grass system (Shepherd 2007), and then in maize. The single gene apparently provides near-immunity to MSV infection to plants containing it, even in hybrid crosses of the experimental maize with susceptible breeding line material (Shepherd, Mangwende, Rybicki & Thomson, submitted for publication). This hugely simplifies the problem of conventional breeding, where the whole complex of resistance genes has to be transferred for maximal resistance – and this can take many years for just one local-use variety. Moreover, from results of approximately 20 years of virus diversity work from the same laboratory, it can be predicted that resistance should be broad-spectrum and durable as *all* of the many maize-derived MSVs isolated in Africa *and* Indian Ocean territories vary by only about 4% in the whole genome and <2% in the *rep* gene (Martin, 2001; Martin & Rybicki, 2002). This development should therefore allow simple and rapid breeding of hybrid parent varieties for commercial use in all climatic regions in Africa/Madagascar/Indian Ocean areas, as well as breeding of OPVs for subsistence farmers.

Rice yellow mottle virus

This disease agent is a beetle-transmitted sobemovirus: these are single-stranded RNA viruses with small isometric particles. The virus is limited in its distribution to Africa and neighbouring islands; thus, germplasm from elsewhere is not of much use in breeding for resistance. Epidemiological studies showed that the virus is not seedborne in rice and that it has very few natural hosts: the primary source of the virus inoculum is probably cultivated rice regrowths and wild rice (Konate 2004). There are five RYMV serotypes – three in west and central Africa and two in east Africa and Madagascar – which are adapted to different geographic zones. It has been speculated that RYMV originated in east Africa and then dispersed and differentiated gradually from the east to the west of the continent (Fargett 2004).

The virus can cause yield losses varying from 25 to 100%, depending on time of infection, type of rice cultivation and cultivars used. West Africa has had devastating epidemics of RYM disease since the early 1990s. The reasons appear to be linked to intensive rice cultivation due to the increasing adoption of new production modes such as water-fed rice farming, annual double cropping and high yielding but highly susceptible Asian rice varieties. In agronomically desirable rice varieties, there is virtually no source of sound resistance to RYMV (Konate & Fargette 2004); however, recent sophisticated work – done in association with Africans – holds more promise for crop improvement. For example, it has been shown that certain mutations of a host rice gene – the eukaryotic translation initiation factor 4G (eIF (iso)4G) – confer high resistance to the virus (Albar *et al.* 2006). This development allows both conventional breeding and the possibility of engineering susceptible varieties with the mutant rice gene, which may be more politically palatable than pathogen-derived resistance. In this regard, it has also been shown that coat protein gene-derived GM resistance is possible – however, this trait was shown in plants transformed with antisense or untranslatable genes, and not with the functional CP gene (Kouassi *et al.* 2006).

Other biotechnology-related work of recent interest on this virus is the study of its diversity, related to resistance in the host: there have been recent systematic molecular studies of diversity, in which important phylogeographic variation have been described, as well as a number of resistance-breaking isolates (Hebrard, Pinel-Galzi, Bersoult, Sire & Fargette 2006; Sorho *et al.* 2005; Traore 2005). This work is important, because it – like the MSV and ACMD diversity studies mentioned above – point the way to what should be done across Africa, for all pests limiting crop production. Aspects of this will be dealt with in the section below.

MAJOR PROBLEMS IN DISEASE IDENTIFICATION

The problems of biotic stresses of crop plants in Africa are compounded by widespread problems with disease identification or diagnosis. These are caused by:

- **Lack of qualified personnel**: few African countries have government staff qualified for extension work with infectious pathogens

- **Lack of facilities**: outside Nigeria, South Africa and Kenya, most sub-Saharan African countries lack significant infrastructure for the work
- **Lack of money**: even when they have staff and premises, government money for even simple testing is often scarce.

As an example of the problems facing even commercial farmers in Africa, a recent Zambian government vegetable virus survey – reported in an MSc thesis (Ndunguru 1997) – relied on donated detection kits from Europe and donated electron microscope time from an Agricultural Research Centre institute in South Africa for identification of viruses in commercial vegetable growers' plots. As another example, during the 1st International Maize Streak Disease Symposium held in Hazyview, Mpumalanga, South Africa in 1997 (www.mcb.uct.ac.za//msv/MSVsymposium.htm), a field visit to demonstrate MSD symptoms ended up with the demonstration of at least another three unsuspected virus infections in the same field – by electron microscopic examination of clarified sap from symptomatic plants (G. Pietersen, personal communication).

Thus, although in many cases of crop disease in Africa viruses are suspected, these are mostly not identified – and as a result, it is very hard to be fully aware of factors limiting crop yields. There is therefore a burning need for extensive, thorough, integrated surveys of virus disease in all major crops and vegetables, as well as an obvious need to develop local infrastructure and expertise. The value of this has been shown by the results of surveys done for cassava mosaic viruses (Legg & Fauquet 2004; Were, Winter & Maiss 2004; Anderson 2004; Bull *et al.* 2006) and for maize streak (Martin 2001): Once the biodiversity of the viruses is known, one has a much clearer idea of the scope of the problem in achieving resistance to them, whether by marker-assisted breeding or engineering of transgenic resistance. The two major requirements for this to happen are first, MONEY for the surveys, and second, cheap, simple test kits for common pathogens to allow comprehensive disease and pathogen variation surveys. There are many kits available from a number of commercial companies for identification of a huge variety of viruses and indeed other pathogens: however, these are often expensive, and while many are enzyme-lined immunosorbent assay (ELISA)-based and therefore use a common technology, a significant number of the rest rely on technologies that are incompatible with a basic microtitre plate reader. This means that any one laboratory would have to be able to support several assay systems, entailing considerable expenditure on infrastructure as well as widely varied expertise among the technical staff. Needless to say, this would be very difficult to implement in most African countries, especially in the government service.

Biotechnology could play a very useful role in alleviating the problems associated with disease identification. For example, the Central Science Laboratory in the UK – an Executive Agency of the UK Government Department for Environment Food and Rural Affairs – is in the business of developing inexpensive, rapid, single-technology detection kits for a wide variety of plant pathogens (the Pocket Diagnostics™ range), as well as providing a centralised inexpensive service for pathogen identification (www.csl.gov.uk/prodserv/diag/pest.cfm). A programme to develop similar reagents and kits for Africa would undoubtedly reap huge dividends: for the first time, Africa-wide surveys could be done to broaden the pathogen knowledge base, which would very significantly inform efforts aimed at controlling the incidence and spread of specific disease agents.

Failures to learn from

There have recently been two high-profile 'failures' of genetically-engineered antivirus resistance in African crop plants, which have been seized upon by anti-GM organisations such as GM Watch (www.gmwatch.org/) as being evidence that the technology has no future in Africa. The two instances were:

- Transgenic resistance to sweet potato feathery mottle virus disease in Kenya failed because the coat protein gene of the wrong strain was used (Anonymous 2004)
- GM cassava with multiple copies of virus-derived transgenes lost resistance after seven years due to gene silencing by methylation (Danforth Center 2006).

GM Watch had this to say after the news of the cassava: "…on the 26 May 2006, the Danforth Center quietly announced that it had discovered that GM virus-resistant varieties of cassava, first developed seven years ago, had lost resistance to the African cassava mosaic virus (CMVD) …. This is not the first time that these kind of false promises have been held out to KARI [Kenya Agricultural Research Institutes], which previously ran field trials on a much hyped transgenic sweet potato – part of another USAID supported project. The sweet potato had been touted as high-yielding and virus-resistant, but during three years of field trials KARI discovered the virus resistance was no better than for ordinary varieties and the yields were sometimes less. By contrast, a conventional breeding programme in Uganda successfully produced a high-yielding virus-resistant sweet potato more quickly and more cheaply, without any recourse to genetic engineering" (Mayet 2006).

Inevitably, the truth lies somewhere between the extremes of positive and negative hype: for example, maintenance of ACMD resistance for even a few years could mean an enormous amount to a cassava grower; equally, choice of the appropriate coat protein gene in a genuine field trial of a high-yielding transgenic sweet potato, rather than a first-generation test sample (Africa Harvest Biotech Foundation International 2006), could have significantly increased sweet potato yield.

It is also true that the real contribution of sophisticated biotechnology in Africa has been ignored in the hype surrounding the GM issue: the contributions that marker-assisted breeding has made in recent years are immense, and have been applied across the board from cassava to rice to vegetables (see CIAT 2006). This will happen increasingly often in the near future as well, as the results of ongoing investigations into African crops filter down to people best suited to applying them.

CONCLUSIONS

In summary, there are a number of ways in which biotechnology could be put to work to improve African agriculture. While this paper has dealt specifically with virus diseases, the lessons are obviously applicable to other infectious agents, and even in certain cases to abiotic stresses. It is also important to stress that biotechnological interventions span from the development of diagnostic kits, through the facilitation of conventional breeding, to the development of GM crops – and that the last is NOT the only way in which sophisticated biotechnology can be used. Thus, the take-home messages of this paper are as follows:

- There is an urgent need for a concerted programme to identify LOCAL resistance genes in local crops, for the application of conventional breeding techniques, possibly facilitated by molecular techniques.
- There is a need for concerted programmes to engineer transgenic resistance in crops ONLY where no resistance genes exist or where resistance is complex – although GM resistance as an adjunct to conventional sources should not be ignored.
- There is a very urgent need for cheap, simple test kits for common pathogens to allow comprehensive disease and pathogen variation surveys.

ACKNOWLEDGEMENTS

I gratefully acknowledge the students and colleagues – present and past – that have allowed me to practice in this area for the last 21 years, as well as the almost entirely South African funding bodies that have facilitated our work.

References

Africa Harvest Biotech Foundation International. 2006. Kenyan genetic scientist defends GM sweet potato. AfricaBiotech.com. www.africabiotech.com/news2/article.php?uid=64.

Albar, L. *et al.* 2006. 'Mutations in the eIF(iso)4G translation initiation factor confer high resistance of rice to rice yellow mottle virus', *Plant Journal*, 47: 417–426.

Anderson, P. 2004. 'Whiteflies as vectors of viruses in cassava and sweetpotato in Sub-Saharan Africa', Tropical Whitefly IPM Project. www.tropicalwhiteflyipmproject.cgiar.org/project-profile05.jsp.

Anonymous. 2004. 'Monanto failure', *New Scientist*, 181(2433): 7.

Bosque-Perez, N.A. 2000. 'Eight decades of maize streak virus research', *Virus Research,* 71: 107–121.

Bull, S.E. *et al.* 2006. 'Genetic diversity and phylogeography of cassava mosaic viruses in Kenya', *J. Gen. Virol.,* 87: 3053–3065.

CIAT. 2006. Agrobiodiversity and Biotechnology. www.ciat.cgiar.org/africa/biotechnology.htm.

CIAT. 2006. Cassava improvement. Centro Internacional de Agricultura Tropical. www.ciat.cgiar.org/africa/cassava.htm.

Danforth Center. 2006. Danforth Center Cassava Viral Resistance Review Update. Donald Danforth Plant Science Center. www.danforthcenter.org/newsmedia/NewsDetail.asp?nid=121.

FAO. 2000. FAO Statement on Biotechnology. Food and Agriculture Organization. www.fao.org/biotech/stat.asp.

FAO. 2006. FAO Hunger Map. Food and Agriculture Organization. ww.fao.org/es/ess/faostat/foodsecurity/FSMap/map14.htm.

Fargette, D. *et al.* 2004. 'Inferring the evolutionary history of Rice yellow mottle virus from genomic, phylogenetic, and phylogeographic studies', *Journal of Virology,* 78: 3252–3261.

Hebrard, E., Pinel-Galzi, A., Bersoult, A., Sire, C., & Fargette, D. 2006. 'Emergence of a resistance-breaking isolate of Rice yellow mottle virus during serial inoculations is due to a single substitution in the genome-linked viral protein VPg', *J. Gen. Virol.,* 87: 1369–1373.

ISAAA. 2006. Maize. International Service for the Acquisition of Agri-Biotech Applications. www.isaaa.org/africenter/html/maize.htm.

Konate, G. & Fargette, D. 2004. 'Overview of rice yellow mottle'. In Hughes, J. & Odu, B. (eds), *Plant Virology in Sub-Saharan Africa,* 1–17, International Institute for Tropical Agriculture, Ibadan, 2004.

Kouassi, N.K. *et al.* 2006. 'Expression of rice yellow mottle virus coat protein enhances virus infection in transgenic plants', *Archives of Virology,* 151: 2111–2122.

Legg, J.P. & Fauquet, C.M. 2004. 'Cassava mosaic geminiviruses in Africa', *Plant Molecular Biology,* 56: 585–599.

Martin, D.P. & Rybicki, E.P. 2002. 'Investigation of Maize streak virus pathogenicity determinants using chimaeric genomes', *Virology,* 300: 180–188.

Martin, D.P. *et al.* 2001. 'Sequence diversity and virulence in Zea mays of Maize streak virus isolates', *Virology,* 288: 247–255.

Mayet, M. 2006. 'GM cassava fails in Africa', *GM Watch*. www.gmwatch.org/archive2.asp?arcid=6979.

Ndunguru, J. 1997. Identification of viruses infecting pepper (*Capsicum annuum* L.) in Lusaka Province, Zambia, MSc dissertation, University of Zambia.

Rybicki, E.P. & Pietersen, G. 1999. 'Plant virus disease problems in the developing world', *Advances in Virus Research,* 53: 127–+.

Rybicki, E.P. 1988. 'Maize streak virus – an African pathogen come home', *South African Journal of Science,* 84: 30–32.

Rybicki, E.P. 1999. The maize streak virus centenary pages. University of Cape Town. www.mcb.uct.ac.za//msv/fuller.htm.

Rybicki, E.P. 2006. Maize Streak Virus Home Page. University of Cape Town. www.mcb.uct.ac.za//msv/mastrevirus.htm.

Shepherd, D.N. *et al.* 2007. 'Inhibition of maize streak virus (MSV) replication by transient and transgenic expression of MSV replication-associated protein mutant', *J. Gen. Virol.,* 88: 325–336.

Sorho, F. *et al.* 2005. 'Durability of natural and transgenic resistances in rice to rice yellow mottle virus', *European Journal of Plant Pathology,* 112: 349–359.

Traore, O. *et al.* 2005. 'Processes of diversification and dispersion of Rice yellow mottle virus inferred from large-scale and high-resolution phylogeographical studies', *Molecular Ecology,* 14: 2097–2110.

Wambugu, F. 1999. 'Why Africa needs agricultural biotech', *Nature* 400: 15–16.

Were, H.K., Winter, S., & Maiss, E. 2004. 'Viruses infecting cassava in Kenya', *Plant Disease* 88: 17–22.

Zhang, P., Vanderschuren, H., Futterer, J., & Gruissem, W. 2005. 'Resistance to cassava mosaic disease in transgenic cassava expressing antisense RNAs targeting virus replication genes', *Plant Biotechnology Journal,* 3: 385–397.

Developing Sustainable Food Security through Agricultural Biotechnology: The ABS Project Model

Florence Wambugu
CEO, Africa Harvest Biotech Foundation International

INTRODUCTION

Africa Harvest Biotechnology Foundation International (AHBFI) was founded in 2002 and incorporated in the USA. Its African-focus made Nairobi, Kenya a natural headquarters. The Foundation has regional offices in Washington DC, USA and Johannesburg, South Africa. Africa Harvest is an international non-profit foundation with a global vision with an African focus to fight poverty, hunger and malnutrition. Our mission is to use science and technology, including, biotech tools for sustainable agricultural development.

STRATEGIC APPROACH

Projects implementation with other partners using the Whole Value Chain for rural communities development

Science and technology is changing the way business is conducted, for example, through simple technologies such as tissue culture-based banana propagation. To achieve the greatest possible impact in the shortest possible time, Africa Harvest's strategy is to give priority to the delivery of practical, need-driven, cutting-edge agricultural technologies to local farmers. We know that no single technology is a panacea for all the problems that face the communities we work with. We therefore identify technologies and harnessed them to address specific challenges our target communities face. The pillar of our implementation strategy is the Whole Value Chain (WVC). All Africa Harvest technology-transfer programs are designed to be holistic, addressing diverse challenges such as soil fertility, good agronomic practice, link to local and export markets, and the frequent need for micro-finance.

It is estimated that the Tissue Culture (TC) Banana Project in Kenya has benefited over half a million small-scale farmers since its introduction 10 years ago. Africa Harvest's strategy is also driven by the urgent need to "scaling up and out" successful models, and in particular the TC Banana Project. Africa Harvest has developed and perfected the WVC model, which has emerged as a critical development strategy. The WVC model is a vertical alliance of enterprises collaborating to achieve a more rewarding position in the market. Our experience in Kenya has shown that the WVC model can help farmers, processors and retailers to cope with the new realities of market competition. Africa Harvest WVC model begins by establishing demand, adapting the supply side's response to it and ending with the market.

The Afforestation Program provides fast-growing trees seedlings to poor farmers; we believe this is the only way to ensure the poor do not destroy the environment. We view the Africa Biofortified Sorghum (ABS) Project as long-term intervention to the health and nutrition challenge that Africa faces.

Capacity Building & Knowledge Transfer for strengthening science & technology in Africa

The main focus of the Capacity Building Programme is human resource development, in terms of technical skills in general and the capacity of public officials to grasp policy issues that surround effective transfer and application of new technologies. Africa Harvest's outreach work is combined with an international development programme. It links African institutions to relevant international development initiatives with which they can share information and expertise.

Achieving sustainable development in Africa will require capacity building initiatives as an integral part of any programme that sets out to tackle constrains on food and nutrition. A major barrier to introducing GM crops and products in Africa is a lack of biotechnology expertise and capacity to introduce and apply biosafety policies, laws and codes of practice. Africa lacks relevant capacity, especially in biotechnology. Africa Harvest emphasizes on capacity Building because there is need for homegrown solutions to current problems

Facilitating development of new crops and products using GM techniques in partnership with others

Biotechnology is currently open to criticism for a lack of products suitable for African needs, such as biofortified food products or drought-tolerant crops for semi-arid regions and rainfed areas where rainfall is unreliable. Africa Harvest counters this deficiency by bringing together consortia of institutions that have complementary expertise and comparative advantages, to focus on product development and the transfer of appropriate inputs to receptive rural communities.

Africa continues to experience declining aid and research and development (R&D) funding, resulting with low investment in crop improvement. While a general increase in R&D funding is urgently required, the enormity of the African Agricultural Challenge underlines the need for renewed focus on the development of biotech crops and products suitable for the continent. Apart from South Africa, most African countries have not commercialized GM products. It is however encouraging that there are some field trials in Kenya, Uganda, Egypt and Nigeria.

Africa Harvest supports the adoption of this GM technology, and in particular, when applied to African 'orphan crops', based on Africa-identified needs. Our position is based on scientifically proven findings that biotechnology is an important arsenal in Africa's war against poverty, hunger and malnutrition. By introducing high-yielding plant varieties and new irrigation techniques into agriculture systems around the world, the Green Revolution of the 1960s and 1970s boosted crop yields and helped lift millions of people out of hunger and poverty. We support the African Green Revolution initiative of the Rockefeller and Bill & Melinda Gates Foundation.

Genetic engineering can thus be considered essential to addressing food security and malnutrition in developing countries.

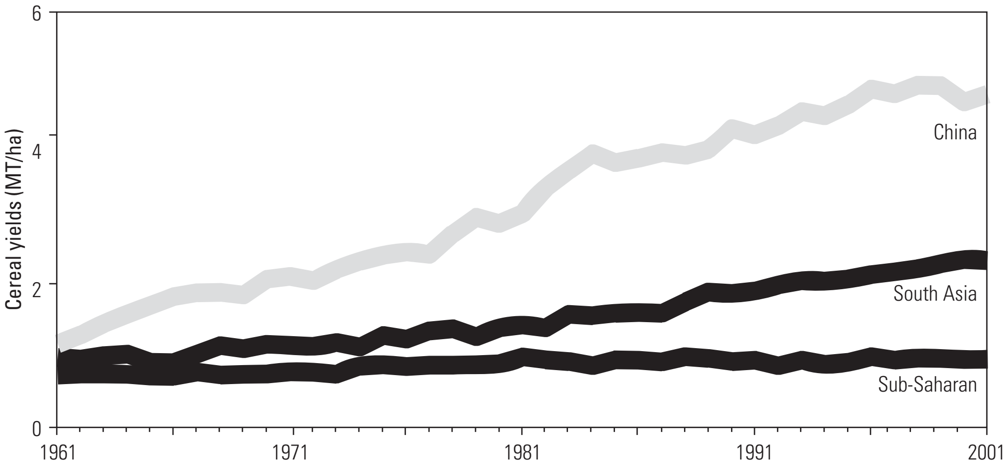
THE NEED FOR SCIENTIFIC INNOVATION TO IMPROVE AFRICAN AGRICULTURE

African Agriculture is Under-Performing

Agriculture has been the foundation for nations that have moved out of poverty, for instance, Europe and Japan. It is clear that African agriculture is currently under-performing. The agriculture sector will remain the primary engine of economic growth for most African countries. However, relative to other developing regions, Africa's agriculture is undercapitalized, uncompetitive and under performing and this declining performance is symptomatic of inadequate expenditures in the sector by African Governments. In the last few decades, agriculture received less than 10 percent of the national budget in most countries, yet its contribution to the GDP of most African countries was between 20 and 50 percent (Report of the Experts' Workshop on Agriculture Expenditure Tracking System 2006).

Africa is the only region in the world in which average per capita food production has been constantly falling for the past 40 years. If current trends persist, the number of undernourished persons on the continent will increase between now and 2015, in contrast to the other developing regions. In 1999-2001, 26 percent of the African population was chronically undernourished a total of 207 million people. The current levels of undernourishment and the alarming trends provide ample justification for giving high priority to

Figure 1: International comparison of cereal yields (1961–2001)



Source: FAOSTAT (2001)

agricultural development in Africa (FAO, 2004). What is more, agriculture accounts for 17 percent of GDP, 57 percent of employment and 11 percent of export earnings. The continent's countries suffer the consequences of variability of output, relatively low yields and heavy dependence on the export of primary commodities, in a context of low elasticity of supply and high volatility of price. Africa's agriculture is undercapitalized, underperforming and uncompetitive.

There are many root causes for this. There is, for example, the insignificant use of modern inputs, with only 22 kg of fertilizer applied to each hectare of arable land compared to 144 kg in Asia. The level is even lower in sub-Saharan Africa, which uses 10 kg per hectare. The selected seeds that spurred the success of the Green Revolution in Asia and in Latin America are barely used in Africa. There is also a profound shortage of rural roads and storage and processing facilities. Another factor strongly influencing the continent's poor agricultural performance is water: Africa fails to make good use of its water resources, whether these be surface waters, groundwaters or runoff waters from rainfall. It only uses 1.6 percent of its available water reserves for irrigation as compared to 14 percent in Asia. Only 7 percent of Africa's cropland is irrigated against 40 percent in Asia, and if we exclude the five most developed countries in this regard – Morocco, Egypt, Sudan, Madagascar and South Africa – the proportion for the remaining 48 countries drops to 3 percent.

Yields from irrigated crops are three times higher than yields from rainfed crops, but agricultural activity on 93 percent of Africa's arable land is dependent on extremely erratic rainfall and therefore seriously exposed to the risk of

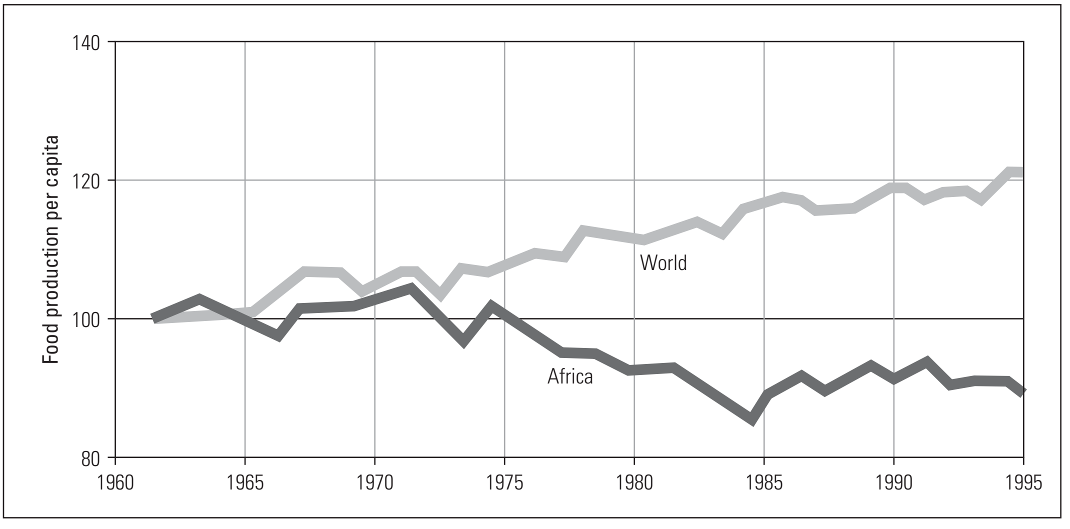
Table 1: Global biotechnology status of selected crops

Crop	Average yield per hectare		Biotechnology status
	Africa	World	
Maize	1.7	4.11	GM technology available
Cassava	8.4	9.98	R&D
Sugarcane	62.3	64.4	GM technology available
Sweet potato	4.8	14.7	GM technology available
Sorghum	0.86	1.31	GM technology available
Wheat	2.01	2.54	GM technology available
Bananas	6.0	48.11	GM technology available
Soybeans	0.7	2.08	GM technology available
Rice	2.2	3.7	GM technology available

drought. Eighty percent of food emergencies are linked to water, especially water stress. This inadequacy of water control and lack of infrastructure constitute the structural limitations that largely explain why Africa's agriculture is unproductive and uncompetitive.

- Yields either remain constant or are declining (Figure 1 and Table 1).
- Production keeps up with population by expanding land under agriculture. Africa is the only continent where agricultural productivity is declining.
- Productivity per capita is declining (Figure 2).

Figure 2: Food production per capita: Africa vs. rest of the world



GLOBAL BIOTECH STATUS OF SELECTED CROPS

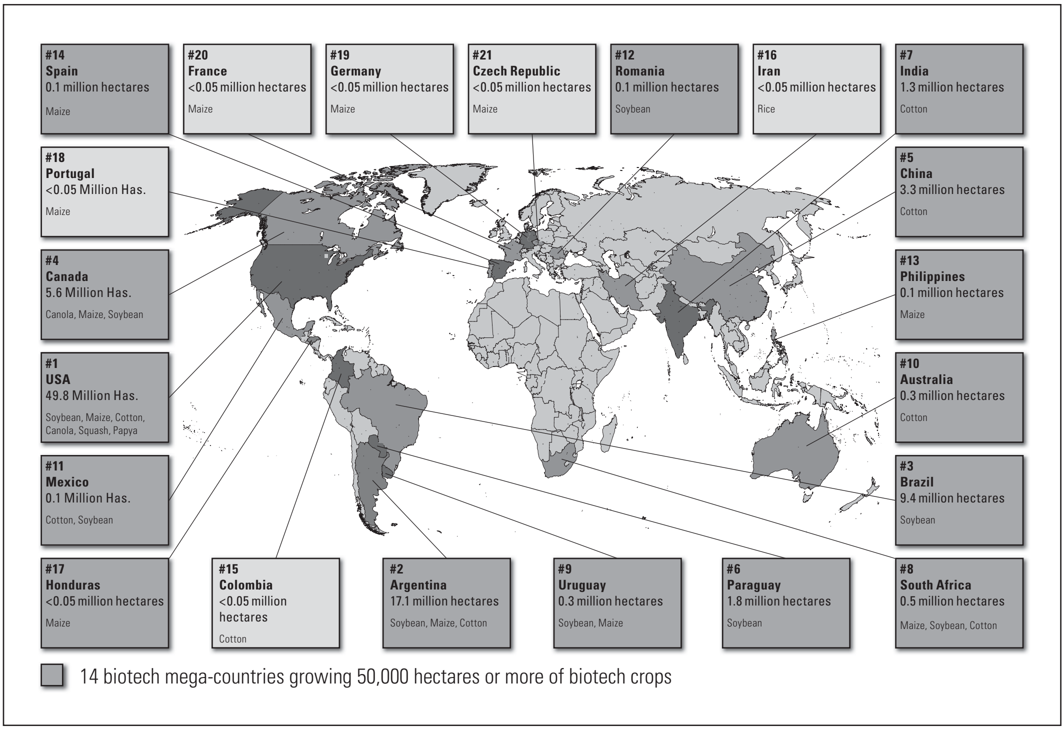
In 2005, the billionth acre, equivalent to the 400 millionth hectare of a biotech crop, was planted by one of 8.5 million farmers, in one of 21 countries. This unprecedented high adoption rate reflects the trust and confidence of millions of farmers in crop biotechnology. Over the last decade, farmers have consistently increased their plantings of biotech crop by double-digit growth rates every single year since biotech crops were first commercialized in 1996, with the number of biotech countries increasing from 6 to 21 in the same period. Remarkably, the global biotech crop area increased more than fifty-fold in the first decade of commercialization. The global area of approved biotech crops in 2005 was 90 million hectares, equivalent to 222 million acres, up from 81 million hectares or 200 million acres in 2004. The increase was 9.0 million hectares or 22 million acres, equivalent to an annual growth rate of 11% in 2005 (James 2005).

A historic milestone was reached in 2005 when 21 countries grew biotech crops up significantly from 17 countries in 2004. Notably, of the four new countries that grew biotech crops in 2005, compared with 2004, three were EU countries, Portugal, France, and the Czech Republic whilst the fourth was Iran. Portugal and France resumed the planting of Bt maize in 2005 after a gap of 5 and 4 years respectively, whilst the Czech Republic planted Bt maize for the first time in 2005, bringing the total number of EU countries now commercializing modest areas of Bt maize to five, they are: Spain, Germany, Portugal, France and the Czech Republic (James 2005).

Bt rice, officially released in Iran in 2004, was grown on approximately four thousand hectares in 2005 by several hundred farmers who initiated commercialization of biotech rice in Iran and produced supplies of seed for full commercialization in 2006. Iran and China are the most advanced countries in the commercialization of biotech rice, which is the most important food crop in the world, grown by 250 million farmers, and the principal food of the world's 1.3 billion poorest people, mostly subsistence farmers. Thus, the commercialization of biotech rice has enormous implications for the alleviation of poverty, hunger, and malnutrition, not only for the rice growing and consuming countries in Asia, but for all biotech crops and their acceptance on a global basis. China has already field tested biotech rice in pre-production trials and is expected to approve biotech rice in the near-term.

In 2005, the US, followed by Argentina, Brazil, Canada and China continued to be the principal adopters of biotech crops globally, with 49.8 million hectares planted in the US (55% of global biotech area) of which approximately 20% were stacked products containing two or three genes, with the first triple gene product making its debut in maize in the US in 2005. The stacked products, currently deployed in the US, Canada, Australia, Mexico, and South Africa and approved in the Philippines, are an important and growing future trend

Figure 3: 21 biotechnology crop countries and mega-countries (2005)



Source: Clive James, 2005

which is more appropriate to quantify as "trait hectares" rather than hectares of adopted biotech crops. Number of "trait hectares" in US in 2005 was 59.4 million hectares compared with 49.8 million hectares of biotech crops, a 19% variance, and globally 100.1 million "trait hectares" versus 90 million hectares, a 10% variance. The largest increase in any country in 2005 was in Brazil, provisionally estimated at 4.4 million hectares (9.4 million hectares in 2005 compared with 5 million in 2004), followed by the US (2.2 million hectares), Argentina (0.9 million hectares) and India (0.8 million hectares). India had by far the largest year-on-year proportional increase, with almost a three-fold increase from 500,000 hectares in 2004 to 1.3 million hectares in 2005.

Biotech soybean continued to be the principal biotech crop in 2005, occupying 54.4 million hectares (60% of global biotech area), followed by maize (21.2 million hectares at 24%), cotton (9.8 million hectares at 11%) and canola (4.6 million hectares at 5% of global biotech crop area). During the first decade, 1996 to 2005, herbicide tolerance has consistently been the dominant trait followed by insect resistance and stacked genes for the two traits. In 2005, herbicide tolerance, deployed in soybean, maize, canola and cotton occupied 71% or 63.7 million hectares of the global biotech 90.0 million hectares, with 16.2 million hectares (18%) planted to Bt crops and 10.1 million hectares (11%)

to the stacked genes. The latter was the fastest growing trait group between 2004 and 2005 at 49% growth, compared with 9% for herbicide tolerance and 4% for insect resistance (James, 2005).

Biotech crops were grown by approximately 8.5 million farmers in 21 countries in 2005, up from 8.25 million farmers in 17 countries in 2004. Notably, 90% of the beneficiary farmers were resource-poor farmers from developing countries, whose increased incomes from biotech crops contributed to the alleviation of their poverty. In 2005, approximately 7.7 million poor subsistence farmers (up from 7.5 million in 2004) benefited from biotech crops – the majority in China with 6.4 million, 1 million in India, thousands in South Africa including mainly women Bt cotton farmers, more than 50,000 in the Philippines, with the balance in the seven developing countries which grew biotech crops in 2005 (James, 2005).

CHALLENGES FACING MAIZE

About 638 million tons of maize are produced annually on approximately 143 million hectares. Developing countries account for sixty-four percent of the world's maize area and 43 percent of global maize production (FAO, 2003). Where it is grown for human food, maize is an important source of calories for the poor. Subsistence farmers grow the crop widely in mixed cropping systems. Average annual per capita human consumption of maize is 20kg in developing countries, but in Latin America and the Caribbean it approaches 80kg and, in Sub-Saharan Africa, 60kg. Maize provides about one-third of the mean calorie intake in these two regions and less than 5 percent in other regions. In addition to its use as food for humans, it is also used as a feed grain, a fodder crop, and for various industrial purposes.

The challenges that face maize production are grouped into two categories. Abiotic factors include climatic conditions, such as temperature, rainfall regimes, and season length, and soil-related factors such as fertility, acidity, and susceptibility to erosion. Biotic factors include primarily related to tropical insects, diseases, and weeds. Most tropical maize is produced under rain fed conditions, in areas where drought is widely considered to be the most important abiotic constraint to production (CIMMYT 1999). Drought stress is evenly distributed across the world's major regions and is a particularly severe problem for slightly more than one-fifth of the tropical and subtropical maize planted in developing countries (Heisey and Edmeades 1999). Drought at any stage of crop development affects production, but maximum damage is inflicted when it occurs around flowering.

LOW SOIL FERTILITY

Tropical soils are renowned for their low soil fertility, particularly low nitrogen, and consequently this ranks as the second most important abiotic constraint to maize production in tropical ecologies. Intensified land use and the rapid decline in fallow periods, coupled with the extension of agriculture into marginal lands, have contributed to a rapid decline in soil fertility, particularly in sub- Saharan Africa. Nitrogen (N) and phosphorus (P) deficits are a severe and widespread biophysical constraint to smallholder maize productivity, and in turn to the long-term food security of the resource poor in southern and eastern Africa (Sanchez *et al.* 1997).

Turcicum blight. This disease, caused by *Exserohilum turcicum*, is most serious in relatively cool and humid regions, specifically in the tropical mid-altitude areas where maize is grown as a winter crop. It causes large lesions on the leaves that affect photosynthesis and therefore yields. Yield losses up to 70% have been recorded, but normally yield losses are around 15-20%. The only known economical solution to the problem has been resistant cultivars (Pingali & Pandey 2000).

Maize streak virus. Maize streak virus (MSV) is a major disease of maize in Africa and is most prevalent in tropical lowlands and parts of tropical mid-altitude maize growing areas. The pathogen is transmitted by leafhoppers and causes serious yield losses, but its occurrence is sporadic. Asevere outbreak in Kenya in 1988, for example, destroyed more than half the crop over large areas (Pingali and Pandey 2000). Practices such as timely planting and treatment of seed with systemic insecticides can help control yield losses, but a more effective and practical solution for subsistence farmers is high yielding maize that carries genetic resistance to the disease.

Insects in the developing world cut annual maize production by attacking roots (rootworms, wireworms, white grubs, and seed-corn maggots), leaves (aphids, armyworm, stem borers, thrips, spider mites, and grasshoppers), stalks (stem borers, termites), ears and tassels (stem borers, earworms, adult rootworms, and armyworm), and grain during storage (grain weevils, grain borers, Indian meal moth, and the Angoumois grain moth). Insect damage can occur at any stage of maize production and storage. Its severity depends on germplasm used, cultivation practices, levels of pest infestation, control strategies used, and climate.

Striga hermonthica and *S. asiatica* are parasitic weeds that negatively affect the livelihood of more than 100 million Africans and inflict crop damage totaling approximately US$ 7 billion annually to the African economy (Berner *et al.* 1995). *Striga* attaches to growing maize roots beneath the ground and siphons off nutrients that would normally feed the plant. *Striga* also exerts a potent phytotoxic effect on its host that results in severe stunting and a characteristic "bewitched" and chlorotic whorl (Ransom *et al.* 1996). Several pre- and post-emergence herbicides are available for *Striga* control, but they are often too expensive or inaccessible to resource poor farmers. Due to years of neglect, *Striga*

Table 2: Comparative maize productivity: US and Africa

Country	Cultivation (million ha)	Production (1000 T)	Yield (T/ha)
Africa	27.9	47 400	1.70
USA	30.4	282 300	9.27

infested areas have extremely high levels of long-lived *Striga* seeds in the soil, with only some of the seed breaking dormancy each season when stimulated by crop exudates (Pingali and Pandey 2000).

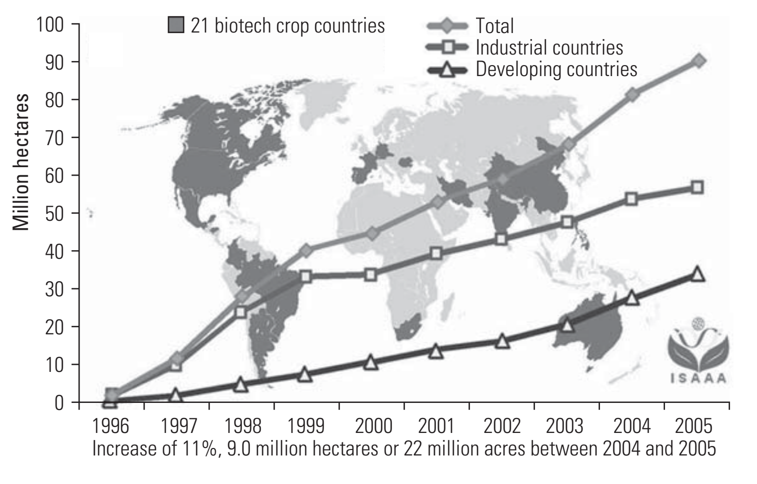
In comparing maize productivity in the US and Africa (which have a similar number of hectares under cultivation for maize), African farmers achieve only 18% of the productivity of US farmers because of technology and inputs (Table 2).

We need a comprehensive approach to addressing the issues.

GLOBAL CONTRIBUTION OF BIOTECH, INCLUDING GM TECHNOLOGIES

During the period 1996 to 2005, the proportion of the global area of biotech crops grown by developing countries has increased every year. More than one-third (38%, up from 34% in 2004) of the global biotech crop area in 2005, equivalent to 33.9 million hectares, was grown in developing countries where growth between 2004 and 2005 was substantially higher (6.3 million hectares or

Figure 4: Global area of biotechnology crops (million hectares, 1996–2005)



Source: Clive James, 2005

23% growth) than industrial countries (2.7 million hectares or 5% growth). The increasing collective impact of the five principal developing countries (China, India, Argentina, Brazil and South Africa) representing all three continents of the South, Asia, Latin America and Africa, is an important continuing trend with implications for the future adoption and acceptance of biotech crops worldwide (James, 2005).

In the first decade, the accumulated global biotech crop area was 475 million hectares or 1.17 billion acres, equivalent to almost half of the total land area of the USA or China, or 20 times the total land area of the UK. The continuing rapid adoption of biotech crops reflects the substantial and consistent improvements in productivity, the environment, economics, and social benefits realized by both large and small farmers, consumers and society in both industrial and developing countries.

The most recent survey of the global impact of biotech crops for the nine-year period 1996 to 2004, estimates that the global net economic benefits to crop biotech farmers in 2004 was $6.5 billion, and $27 billion ($15 billion for developing countries and $12 billion for industrial countries) for the accumulated benefits during the period 1996 to 2004; these estimates include the benefits associated with the double cropping of biotech soybean in Argentina (James, 2005). The accumulative reduction in pesticides for the period 1996 to 2004 was estimated at 172,500 MT of active ingredient, which is equivalent to a 14% reduction in the associated environmental impact of pesticide use on these crops, as measured by the Environmental Impact Quotient (EIQ) – a composite measure based on the various factors contributing to the net environmental impact of an individual active ingredient.

There is cause for cautious optimism that the stellar growth in biotech crops, witnessed in the first decade of commercialization, 1996 to 2005, will continue and probably be surpassed in the second decade 2006-2015. The number of countries adopting the four current major biotech crops is expected to grow, and their global hectarage and number of farmers planting biotech crops are expected to increase as the first generation of biotech crops is more widely adopted and the second generation of new applications for both input and output traits becomes available.

BENEFITS OF BIOTECHNOLOGY

Science

The benefits of biotechnology, today and in the future, are nearly limitless. Plant biotechnology offers the potential to produce crops that not only taste better but are also healthier. Agronomic or "input" traits create value by giving plants the ability to do things that increase production or reduce the need for other inputs such as chemical pesticides or fertilizers. Already, farmers in Romania are growing potatoes that use 40% less chemical insecticides than would be possible using traditional techniques. Quality traits -- or “output” traits -- help create value for consumers by enhancing the quality of the food and fibre produced by the plant. Someday, seeds will become the ultimate energy-efficient, environmentally friendly production facilities that can manufacture products which are today made from nonrenewable resources. An oilseed rape plant, for example, could serve as a factory to add beta carotene to canola oil to alleviate the nutritional deficiency that causes night blindness. GM plants could nevertheless provide a means of significantly improving human health, first of all by supplying better quality food. Plants could be deprived of their most harmful ingredients (such as lipids which are bad for cholesterol) or enriched with molecules of nutritional benefit, the latter of particular benefit to southern countries. European laboratories recently developed ‘golden rice’ enriched with carotene. This molecule is a precursor of vitamin A and could therefore help correct the nutritional deficiencies affecting millions of people. Another example is research aimed at increasing the lycopene content of tomatoes. This molecule has beneficial anti-oxidizing effects which reduce the risk of prostate tumors (http://europa.eu.int).

Environmental

Although the misuse of agricultural chemicals can have negative environmental impacts, fears that those chemicals would produce ecological catastrophe have proven unfounded. More importantly, any attempt to go without those chemicals would have meant sacrificing tremendous productivity gains and having to bring new, undeveloped land into agriculture. What if similar benefits could be gained without such a heavy dependence on chemicals? Today, a new crop protection revolution is underway, and it is helping farmers combat pests and pathogens while reducing humanity’s dependence upon agricultural chemicals. Biotechnology has made tremendous progress in transferring useful traits from one organism to another, allowing plants to better protect themselves from insects, weeds, and diseases (Conko 2003).

The introduction of bioengineered crop varieties onto the market has not been without controversy, however. Some critics have suggested that recombinant DNA modification could make foods unsafe to eat, though most concerns have revolved around the potential impact of bioengineered crops on the environment. Environmentalists have claimed, for example, that gene-spliced varieties could harm wild biodiversity by killing beneficial insects and other living organisms, or by becoming invasive weeds. Those and related concerns have been used as the justification for increasing regulation on biotechnology in developing and developed countries. While it cannot be claimed that modified crops pose no risks to the environment, it is important that those risks be put into perspective. The threat posed by any plant --bioengineered, conventionally bred, or wild -- has solely to do with the traits it expresses. Risk has nothing to do with how, or even if, a plant was modified. Thus, bioengineered varieties are less likely, not more likely, to pose environmental or human health risks than are conventionally bred plants with similar traits.

Economics

Farmers growing biotech crops increased their income by US$27 billion (Brookes & Barfoot 2005). Farmers have increased income through higher yields and lower production costs — including fewer pesticide applications and the more efficient use of farm labor. Research indicates an increase in income is consistent worldwide with significant economic benefits realized by small- and large-scale farmers alike. Farmers are marketing more than US$44 billion of GM crops to processors and consumers around the world each year. Food, feed and fiber markets are open and available for biotech crops (Runge & Ryan 2004). In 2004, farmers planting biotech crops earned an additional US$4 billion due to increased crop yields and/or decreased production costs.

Chinese farmers planting *Bt* cotton realized a three-year average yield increase of 24 percent and net economic returns of US$332 per hectare (US$132 per acre) compared to conventional cotton farmers (Huang *et al.* 2003). *Bt* cotton farmers in South Africa consistently experienced higher yields and increased revenues of US$86 to $93 per hectare (US$34 to $37 per acre) compared to conventional cotton (Morse *et al.* 2004). Hawaiian farmers planting ring spot-tolerant papaya increased their incomes by more than US$3,000 per hectare (US$1,200 per acre) due to average yield increases of 44 percent over conventionally bred varieties, and saved their industry.

TRADE POLICY AND GM TECHNOLOGY

African farmers cannot compete because of subsidies in both Europe and United States. African farmers cannot compete because they don't have access to technology and inputs. Africa does not even feed its own market today with 25% of its needs imported. Africa exports coffee, tea, flowers, cotton, fruits &vegetables to the European market.

THE BIOFORTIFIED SORGHUM (ABS) PROJECT

Billions of people in Africa and developing countries suffer from a form of "hidden hunger" caused by micronutrient malnutrition. Vitamin A – known to be a crucial ingredient for effective functioning of the immune system – is a leading contributor to child mortality in Africa and the developing world. Its deficiency affects the ability of 250 million children to fight off diseases such as HIV/AIDS, malaria and diarrhea. The ABS Project is committed to improving the nutritional quality of sorghum by developing a more nutritious and easily digestible sorghum that contains increased levels of essential amino acids, especially lysine, increased levels of Vitamins A and E, and more available iron and zinc. The ABS project is committed to ensuring that public health solutions are optimized for the purpose of facilitating (i) the broad availability of data and information to the scientific community and, (ii) the access to affordable health solutions for the benefit of people most in need in Africa and the developing world. The ABS Project is committed to ensuring that knowledge created by the Project is available for humanitarian purposes and potential products are accessible at an affordable cost to the people most in need in Africa and the developing world. Innovations and related Intellectual Property Rights (IPR) have been donated to the project and are managed in such a way that they do not hinder access to eventual products.

The ABS consortium is a strategic alliance of nine member organizations that leverage the best of private, public and academic sectors to deliver technology to fight malnutrition in Africa and the developing world. Africa Harvest is partnering with scientific teams from agricultural company DuPont, through its subsidiary Pioneer Hi-Bred International and the Council for Scientific and Industrial Research (CSIR) in South Africa to make this project a reality. Other consortium members include the African Agricultural Technology Foundation (AATF), the Forum for Agricultural Research in Africa (FARA) the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the University of Pretoria (UP), the University of California Berkeley (UC Berkeley) and the Agricultural Research of South Africa (ARC).

CHALLENGE

Poor nutrition is a leading cause to non-communicable diseases. Statistics show that about 46% of Africans suffer from anaemia due to iron deficiencies and 36% of African pre-school children suffer from Vitamin A deficiency and are at risk of blindness, mental retardation and reproductive disorders. Deficiencies in Vitamin B1, B3 and B12 are linked to diseases such as pellagra, anaemia, beriberi and rickets. In the past, research funding was generally targeted at developing solutions to treat disease. There is now a global shift to finding novel solutions that tackle the causes of both communicable and non-communicable diseases.

More than one-quarter (27%) of all under fives in the developing world are underweight. This accounts for about 146 million underweight children in developing countries. Of these 146 million underweight children, nearly three-quarters (73%) live in just 10 countries. Significant variation in underweight prevalence exists among children under five of the developing world. The highest levels of underweight prevalence are found in South Asia, where almost half (46%) of all children under five are underweight. In Sub-Saharan Africa more than one-quarter (28%) of all children under five are underweight. The lowest levels are found in Latin America and the Caribbean (7%) and CEE/CIS (5%) (http://childinfo.org/areas/malnutrition/).

South Asia has staggeringly high levels of underweight prevalence with nearly half (46%) of all children under five in the region underweight. Three countries in this region drive these high levels – India, Bangladesh and Pakistan – which alone account for half the world's total underweight children. Note that these three countries are home to just 29% of the developing world's under-five population. In Sub-Saharan Africa more than one-quarter (28%) of children under five are underweight. Nigeria and Ethiopia alone account for more than one-third (37%) of all underweight children in Sub-Saharan Africa. In Ethiopia, nearly half (47%) of all children are underweight (UNICEF statistics, 2006).

BMGF GRAND CHALLENGES IN GLOBAL HEALTH

BMGF Grand Challenges in Global Health initiative focuses on harnessing the power of science and technology to dramatically improve health in the world's poorest countries. The initiative supports ground-breaking research to develop scientific breakthroughs for preventing, treating and curing diseases that kill millions of people in developing countries each year. The GC#9 goal is to create a full range of optimal, bioavailable nutrients in a single staple plant species. 43 projects involving 33 countries were selected for funding. GC is supported by US$450 million from the BMGF, the Welcome Trust, and the Canadian Institutes of Health Research.

The GCGH initiative recognized that today, only 10% of medical research is devoted to the diseases that cause 90% of the health burden in the world. During the last century, an incredible scientific research and development engine has been built, concentrated mainly on issues and problems within developed countries. GCGH acknowledges that what's needed now is new funding to support scientists around the world in working together to articulate and prioritize great scientific challenges. The funding of the ABS Project is designed to accelerate research to overcome one of Africa's pressing scientific obstacles, which is meeting the nutrition needs for millions of poor people throughout the world.

AFRICAN CHALLENGES

The challenges facing Africa are many, including:

- Scientific leadership

- Intellectual property
- Ethical and social issues
- Access to information
- Enabling policy frameworks
- Technology transfer
- Public acceptance
- Funding – strategic research
- Capacity building (human and infrastructure)
- Limited food choices for nutritional sufficiency
- Biosafety issues such as gene flow.

CONSORTIUM SUCCESS FACTORS

Our success factors include attractive vision/mission & purpose, effective management & coordination, knowledge of where different capacities exist & willingness to network, 'virtual organization' overcomes the challenge of limited capacity, identification of external partners was based on Africa's needs, and sufficient funding commensurate to task – $18.5m

ADDRESSING THE NUTRITIONAL CHALLENGE

Our goal is to develop more nutritious and easily digestible sorghum that contains increased levels of pro-vitamins A, vitamin E, iron, zinc, amino acids and protein for the Arid and Semi-Arid Tropical Areas of Africa. This will benefit over 300 million people in arid regions of Africa who rely on this grain as their primary source of food. Sorghum originated in the north-east quadrant of Africa and spread from there throughout Africa and into India. In 1994, sorghum ranked fifth among the most important cereal crops of the world after wheat, rice, maize, and barley in both total area planted and production. Eighty percent of the area devoted to sorghum is located within Africa and Asia, with average yields of 810 and 1150 kilograms per hectare, respectively. In 1992, sorghum was planted on approximately 5.4 million hectares in the United States with an average yield of 4,566 kg/ha and a farm value of over $1.7 billion.

Grain sorghum is well-known for its capacity to tolerate conditions of limited moisture and to produce during periods of extended drought, in circumstances that would impede production in most other grains. Sorghum leaves roll along the midrib when moisture- stressed, making the plant more drought resistant than other grain plants. Like corn, sorghum can be grown under a wide range of soil and climatic conditions. Unlike corn, however, sorghum's yield under different conditions is not so varied. Consequently, it is grown primarily in arid areas where corn wouldn't make it without substantial irrigation. Sorghum is an important part of the diets of many people in the world. It's made into unleavened breads, boiled porridge or gruel, malted beverages including beer, and specialty foods such as popped grain and syrup from sweet sorghum.

The sorghum bran is low in protein and ash and rich in fibre components. The germ fraction in sorghum is rich in ash, protein and oil but very poor in starch. Over 68 percent of the total mineral matter and 75 percent of the oil of the whole kernel is located in the germ fraction. Its contribution to the kernel protein is only 15 percent. Sorghum germ is also rich in B-complex vitamins. Endosperm, the largest part of the kernel, is relatively poor in mineral matter, ash and oil content. It is, however, a major contributor to the kernel's protein (80 percent), starch (94 percent) and B-complex vitamins (50 to 75 percent) (FAO, 1995).

SPECIFIC PROJECT OBJECTIVES

Our project objectives are to develop more nutritious and easily digestible sorghum, get the technology transfer from USA to Africa, develop human & infrastructure capacity building, attract Public/Private networking in GM technology by several institutions in Africa & USA, champion for biosafety Policy Development and increase Public Acceptance on GM technology in Africa.

ADDRESSING THE CHALLENGE

Sorghum nutritional targets are beyond reach of plant breeding approaches. In this case we intend to use transgenic approaches to leverage and evaluate genes and gene leads from other species. We also intend to develop product prototype.

BIOSAFETY

ICRISAT is conducting gene flow studies for the ABS Project. Research shows gene flow enhances quality in landraces of Maize in Mexico (CIMMYT). Gene flow happens every day: Sorghum growers in Africa have used gene flow to create new landraces (ICRISAT). Gene flow—also called migration—is any movement of genes from one population to another. Gene flow includes lots of different kinds of events, such as pollen being blown to a new destination or people moving to new cities or countries. If genes are carried to a population where those genes previously did not exist, gene flow can be a very important source of genetic variation.

REFERENCES

Berner, D.K., Ikie, F.O. and Aigbokhan E.I. 1995. Some control measures for Striga hermonthica Utilizing critical infection period on maize and sorghum. In D.C. Jewell, S.R. Waddington, J.K. Ransom, and K.V. Pixley eds.

Brookes, G. and Barfoot, P. 2005. GM Crops: The Global Economic and Environmental Impact — The First Nine Years 1996 -2004.

CIMMYT 1997/98. World Maize Facts and Trends. Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation. Mexico.

CIMMYT. 1999. Maize Research for Stress Environments. Proceedings of the Eastern and Southern Africa Regional Maize Conference, Harare, Zimbabwe pp. 267–74.

Conko, G. 2003. Regulation, Spring 21. www.cato.org

FAO. 2003. Production Yearbook.

FAO. 2004. Twenty-Third Regional Conference for Africa, Johannesburg, South Africa, 1-5 March

Heisey, P.W. and Edmeades, G.O. 1999. Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation.

http://childinfo.org/areas/malnutrition/

http://europa.eu.int

Huang, J. *et al.* 2003. Five Years of *Bt* Cotton in China: The Benefits Continue. The Plant Journal, 31 (4), 423-430.

James, C. 2005. Global Status of Commercialized Biotech/GM Crops. ISAAA Briefs No. 34.

Morse, S. Bennett, R. & Ismael, Y. 2004. Why *Bt* Cotton Pays for Small-Scale Producers in South Africa.

Pingali, P.L. (ed.). 2001. CIMMYT 1999–2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. Mexico, D.F.: CIMMYT

Pingali, P. L. and Pandey, S. 2000. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector

Ransom, J.K., Odhiambo G.D. , Eplee R.E., Ubero J.I., Berner D., and Musselmann L.J. (eds.). 1996. Proceedings of the 6th International Symposium on Parasitic Weeds, Cordoba. Spain. pp. 327–34.

Report of the Experts' Workshop on Agriculture Expenditure Tracking System, at the AU Ministerial Conference of Ministers of Agriculture, January 31- February 1, 2006 Bamako, MALI.

Runge, C.F. and Ryan, B. 2004. The Global Diffusion of Plant Biotechnology: International Adoption and Research in 2004. University of Minnesota Center for International Food and Agricultural Policy.

Sanchez, P.A., Shepherd K.D., Soule M.J., Place F.M., Buresh R.J., Izac M.N., Mokwunye A.U., Kwesiga F.R., Ndiritu C.G., and Woomer P.L. 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In R.J. Buresh, P.A. Sanchez, and F. Calhoun (eds.), Replenishing Soil Fertility in Africa. SSSA Spec. Publ. 51. Madison, Wisconsin: SSSA. pp.1–46.

SECTION 2

Focus on yield issues for small-scale farmers in Africa

Developing Bio- and Agri-technologies for Poverty Alleviation in Rural South Africa

Felix Dakora
Cape Peninsula University of Technology

ABSTRACT

Plant species richness and diversity is extremely high in Africa. The Leguminosae are a dominant family with diverse biological traits that make them candidate species for improving livelihoods in rural households. By being able to fix N_2 with symbiotic members of the Rhizobiaceae, legumes and their associated bacteria can serve as biofertilizers for increased crop yields, enhanced food security and improved quality of life. The commercial production of Rooibos tea from a nodulated legume called *Aspalathus linearis* subsp. *linearis* currently contributes R350 million to the South African economy. Similarly, the production and sale of the *Cyclopia* tea legume also contributes significantly to the national economy. Increased research on cowpea and Bambara groundnut has also raised yields of the two legumes and thus increased household incomes. Taken together, the increased production of legumes and their commercial products has the potential to increase the income of households, and thus alleviate poverty in rural communities. The added value of biofertilization from the host plant, the microsymbiont, and their interaction ensures sustainable production, while promoting yields of cereals and other crops. Funding research on indigenous food crops species (especially legumes), medicinal plants as well as species with newly discovered value should promote their commercialization by agri-enterpreneurs and reduce poverty in rural households.

EXPLORING INDIGENOUS PLANT SPECIES FOR POVERTY ALLEVIATION IN RURAL SOUTH AFRICA

South Africa is very rich in plant species diversity and endemicity. With the ever-increasing urban development and human settlement, populations of legumes and non-legumes now exist mainly in the rural, semi-rural and peri-urban environments, thus creating an opportunity for exploitation as source of economic development for those communities. In South Africa, many plant species are currently tapped for economic growth, while others have the potential to be developed as commercial crops.

Aspalathus linearis subsp. *linearis* (Rooibos tea)

Although seedlings of *A. linearis* subsp. *linearis* are sensitive to frost and snow, the mature plants are adapted to both cold winters and hot summers (Morton 1983). Their distribution confined to the Cedarberg mountains. The use of wild *A. linearis* plants as tea by the Khoi San was reported in 1772. The plant has since been domesticated and is presently cultivated as a commercial crop for export and local consumption (Morton 1983). Compared with oriental tea, Rooibos tea is caffeine-free and has significant medicinal value. It is often prescribed to alleviate nervous tension, allergies and various stomach and indigestion problems (Petereit et al. 1991). The tea is low in tannins and has been suggested to have anti-ageing effects due to its high concentration of anti-oxidants (Yoshikawa et al. 1990). Rooibos tea also contains various flavonoid molecules, including quercitrin and luteolin, which have antispasmodic properties (Snykers and Salemi 1974), aspalatin (a dihydroxycha1cone), and the flavones orientin and iso-orientin, which together account for its flavor and antioxidant effects (Robak and Gryglawski 1988). Rooibos tea is therefore a natural medicinal beverage that is rich in nutriceuticals, with great potential for establishing regional business incubators, and in so doing, creating wealth and jobs, and alleviating poverty.

Cyclopia species (Honeybush tea)

The Honeybush tea (*Cyclopia* spp.) plant is another nodulating legume that is endemic to the Western Cape and is used for making tea. The genus *Cyclopia* consists of 14 species that grow in a variety of environments with differing soil ecologies throughout the Western Cape. The soils are characteristically sandy, nutrient-poor and highly acidic (pH 2-5), with total N often lower than 0.01%. As with *A. linearis,* the leaves and twigs of *Cyclopia* spp. have historically been used as a source of herbal tea by the local Khoi San people. Honeybush tea is also very rich in flavonoid compounds and is therefore used as a health supplement. Additionally, like Rooibos, and Honeybush tea is used in various culinary preparations and in the manufacture of baby foods. Consequently, the local and export markets of Honeybush tea have increased dramatically, and this has necessitated a move from the harvesting of wild *Cyclopia* for tea to its cultivation as a commercial crop. Emerging Black farmers on the East coast of the Western Cape have started to produce and sell Honeybush tea as an income earner.

Vigna unguiculata (Cowpea) and *Vigna subterranean* (Bambara groundnut)

Food grain legumes such as cowpea and Bambara groundnut are indigenous to the African continent and therefore highly adapted to the soil ecologies of the local environment. Since independence in 1994, increased cultivation of the two grain legumes has occurred in South Africa as a result of land being made available to rural Black communities for agricultural production. From North-west Province through Mpumalanga and KwaZulu-Natal to Limpopo, emerging farmers (largely rural African women, see Figure 1) have started to undertake the production of cowpea and Bambara groundnut as "new" commercial crops for the local markets. This is evidenced by the large number of farmers who attend Farmer's Schools organized by scientists at the ARC Small Grain Research Institute focusing on developing technologies for cowpea and Bambara groundnut production (see Figure 1).

Work undertaken by a McKnight Foundation-funded project has identified a number of high-yielding cowpea genotypes suitable for the local conditions in South Africa (see Figure 2). Other genotypes were identified that produce ample leafy foliage when provided with adequate water supply. Because cowpea leaves are eaten as vegetables in South Africa, the luxuriant-growing leafy foliage of these genotypes is also sold as a vegetable in local markets of Black African communities. The adoption of the high grain-yielding genotypes, and their

Figure 1: Emerging cowpea farmers at a Farmers School at an ARC Station in Taung (in 2005)

Figure 2: A high-yielding inbred cowpea line developed from the McKnight Foundation project (2005 field trials at Taung)

counterparts with heavy vegetative growth, or both, can lead to increased cash income and household food security.

Unlike the situation in West Africa, where insect pests can cause up to 100% loss of a cowpea crop, in South Africa it is disease-causing pathogens which are the major source of low cowpea yields.

Buchu: a Major Medicinal Plant

Like Rooibos and Honeybush tea, Buchu is emerging as a major contributor to the South African economy. The export of crude Buchu plant extracts has increased considerably since independence in 1994. Unlike Rooibos and Honeybush plants, which are currently under cultivation in plantations, Buchu still continues to be harvested from wild populations. As a result, Buchu has attracted less research as a commercial crop compared to the two tea legumes. Not only has little been done on its domestication, but also on its role as a medicinal plant. Furthermore, unlike the Rooibos tea and Honeybush tea industries, which attract significant numbers of tea farmers from rural Black communities, the Buchu industry is monopolized unsustainably by few groups of White individuals who export large volumes of Buchu extract without value added.

Marama bean: an important Commercial Species Native to the Kalahari Desert

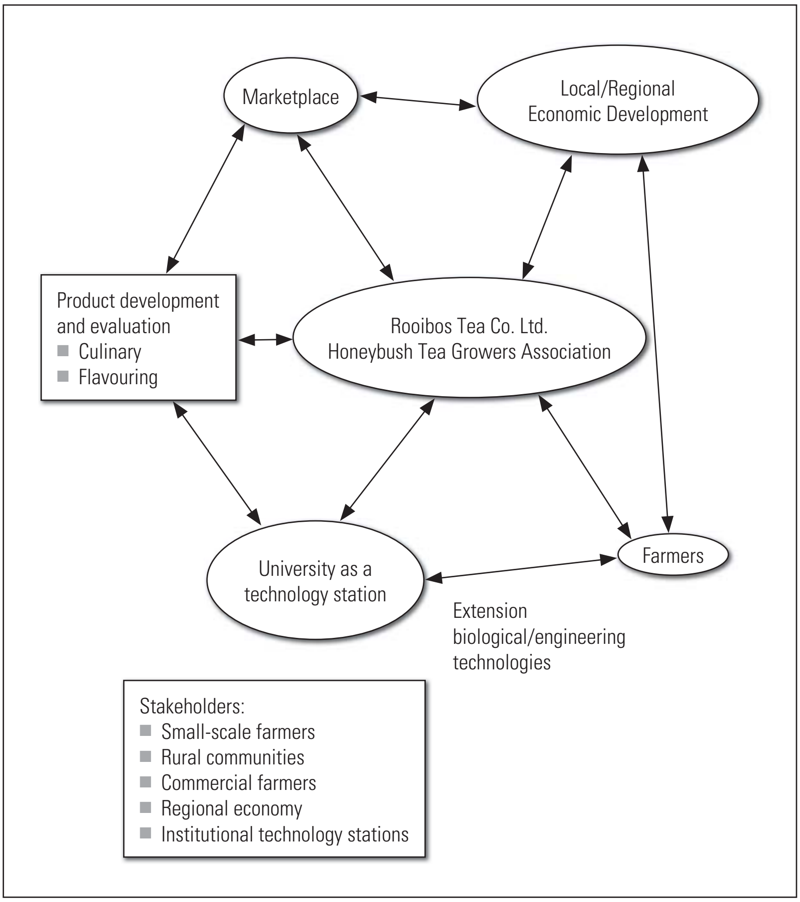
Marama bean (*Tylosema esculentum),* a tuber-forming grain legume indigenous to the Kalahari, is known historically as the major food crop of the Khoi and San people of South Africa, Botswana and Namibia. The edible grain of this non-nodulating legume contains about 30-39% protein compared to 38-40% in soybean, and 43% oil relative to 48% in groundnut (Dakora *et al*., 1999) The young tubers (1-3 yr old) of marama bean are edible and contain about 9% protein relative to conventional root crops such as yam (7% protein) (Dakora *et al*., 1999), potato and sweet potato (5% protein), and cassava (3% protein). Marama bean therefore has the potential to be developed into a new market crop for poverty alleviation in rural South Africa.

Developing Agri-Technologies for Rooibos and Honeybush tea in Rural South Africa: *An example of a job creation and poverty alleviation project.*

The current Rooibos and Honeybush tea industries consist of emerging small farmers and large-scale commercial farmers. The former are resource-poor and produce their tea organically, while the latter use chemical inputs. The two tea industries provide jobs for rural people at different stages of the enterprise, starting with land preparation, planting of seedlings, harvesting of leaves and twigs for tea, and during processing and packaging. On average, one large-scale Rooibos tea farmer can employ up to 30 workers during the planting of seedlings, and another 30 during harvest. Small farmers, on the other hand, run household units. Thus, the more economically-empowered a tea farmer becomes in the expanding tea industry, the more jobs he potentially creates for rural communities.

The development of agri-technologies such as inoculant production, manufacturing of tea harvesters, and designing of equipment for tea processing, when combined with their sale and distribution to farmers, offers great opportunities for the emergence of small, micro, and medium enterprises (SMMEs). As described by Dakora and Mvalo (2004), the chain of economic activities associated with the Rooibos tea (or the Honeybush tea) industry are vast, and can, at various stages, provide job opportunities for the rural unemployed, while creating wealth for enterpreneurs. So, from our knowledge of the growth and symbiotic performance of these tea legume species to sustainable harvesting of leaves for tea processing, a number of SMMEs can emerge within rural communities where these tea species are cultivated. That, in turn, can lead to economic empowerment, improved quality of life, and ultimately poverty alleviation among the rural communities. In this way, our knowledge of the biological traits in these tea species would transcend mere academic exploration into the realm of household economics, wealth creation, poverty alleviation and improvement in livelihoods.

Figure 3: Interactive effects of developed agri-technologies for community empowerment via SMMEs



CHALLENGES AND OPPORTUNITIES TO ALLEVIATING POVERTY IN RURAL SOUTH AFRICA USING BIOLOGICAL AND AGRICULTURAL APPROACHES

Poverty can be alleviated using science-based agricultural approaches. With symbiotic legumes, however, effective nodulation and higher levels of N_2 fixation are key to robust plant growth and increased yields. Unlike Honeybush tea, which is inoculated in nurseries, there is still no commercial inoculant for Rooibos tea. Thus, greater tea yields could be stimulated with a super inoculant strain of *Rhizobium*. Research funding towards identifying a high N_2-fixing *Rhizobium* could potentially double Rooibos tea yields and create wealth for both commercial and emerging tea farmers.

Another constraint is the serious lack of funding for indigenous food crops, especially legumes. Strategic funding of research into ecologically-adapted indigenous food grain legumes (e.g. cowpea and Bambara groundnut), medicinal plants (e.g. Buchu) and other plant species with newly discovered commercial value (e.g. *Hoodia gordonii*) should be undertaken by Government in order to promote their commercialization by emerging farmers in rural communities.

There is also a strong absence of a central body (such as a National Bio-Intelligence Centre) for co-ordinating and monitoring the commercial utilization of indigenous flora and fauna as food, nutriceuticals, and medicines both nationally and internationally. The existence of such a body could reduce bio-piracy and bio-prospecting, while promoting benefit-sharing of profits from bio-products from rural communities, the true owners of all indigenous knowledge and the fauna/flora.

Another challenge to the empowerment of emerging Black farmers and the elimination of poverty in rural communities is the lack of tangible material support provided by government and commercial farmers to small farmers, in terms of assisting them with management skills, finances, experience, and technical knowledge in the particular area of agri-business. There is therefore the need to identify, through a tender process, genuinely committed NGOs who would form NGO/Government Partnerships (with a 1:1 financial commitment) in order to undertake and promote commercial production of “new” crops, and indigenous medicinal plant products (e.g. Buchu extracts) for sale in the market place using emerging farmers in the rural communities.

Government should also actively support initiatives such as Pick’n Pay’s Organic Freedom Project (OFP) which aims to boost the local production of organic foods, as well as increase the cultivation of organic crops for bio-fuels, and in so doing, massively create jobs in rural South Africa (Anon, 2007). To further create more jobs and alleviate poverty, Government should make funds available for the production of organic crops and medicinal plants in rural areas under the supervision of the Pick’n Pay OFP technical staff in order to ensure quality for guaranteed purchase of the produce by Pick’n Pay and Woolworths. In so doing, skills will be transferred as a bonus to the rural farmers involved in these projects. Clearly, Government support of OFPs and Government funding of OFP-style production of organic foods by rural communities in South Africa, with a guaranteed market by the likes of Pick’n Pay and Woolworths, is a productive proactive and progressive route to poverty alleviation.

Furthermore, there is a lack of credible and functional agricultural credit facility for emerging farmers in rural South Africa. The granting of agricultural finance to emerging farmers through the Land Bank, for example, could lead to a doubling of agri-businesses, the creation of more jobs, and a reduction of poverty in rural South Africa.

REFERENCES

Anon (2007). Retailers enter battle for high ground in GM foods. Business Report 23/04/2007. In:Parker Review, Issue 146: 1-12.

Dakora FD, Lawlor DW and Sibuga KP (1999) Assessment of symbiotic nitrogen nutrition in Morama bean, (*Tylosema esculentum* L.) a tuber-producing, underutilized African legume. Symbiosis 27:269-277.

Dakora FD and Mvalo MG (2004) Exploring the biological potential of indigenous African legumes for developing agri-technology amd SMMEs to alleviate poverty in rural communities. *In*: Symbiotic Nitrogen Fixation: Prospects for enhanced application in tropical agriculture (Ed; Serraj R.). New Delhi: Oxford and IBM Publishing, pp 261-265.

Hoodia-Wikipedia, the free encyclopedia (http://en.wikipedia.org/wiki/Hoodia) 2007/06/11.

Morton JF. (1983). Rooibos tea, *Aspalathus linearis,* a caffeine-less, low-tannin beverage. Economic Botany 37:164-173.

Petereit F, Kolodziej Hand Nahrstedt A. (1991). Flavan-3-ols and proanthocya.nidins from *Citrus incunus*. Phytochemistry 30:981-985.

Robak J and Gryglawski RJ. (1988). Flavonoids are scavengers of superoxide anions. Biochemical Pharmacology 37:837.

Snykers Fa and Salemi G. (1974). Studies of South Africa medicinal plants. Part I. Quercetin as the major *in vitro* active component of Rooibos tea. Journal of South African Chemical Institute 27:5-7.

Yoshikawa T, Naito Y, Oyamada H, Ueda 5, Tanigawa T, Takemura T, Sugino Sand Kondo M. (1990). Scavenging effects of *Aspalathus linearis* (Rooibos tea) on active oxygen species. *In:* Antioxidants in therapy and preventive medicine (ed; Emmerit I). New York: Plenum Press,pp171-174

Achieving some of the Potential of 'clean' sweet potato in small-holder farmers' fields in Zimbabwe

Ian Robertson
Agri-Biotech and University of Zimbabwe

SUMMARY

Sweet potato is by tradition a women's crop and as such neglected. However, with modern biotechnological methods, it can be revitalised into both a positive food security factor and a small farmer's cash crop. In Zimbabwe, much of the rural population and a high proportion of the jobless urban population is reduced to hunger and perhaps one meal a day. Three things are needed for improvement: quality germplasm, quality know-how and quality finance. Tissue culture and virus-elimination provided the first for the cultivar Brondal, which is widely successful in Zimbabwe and also in South Africa. University graduates of Zimbabwe with three years' field experience provide for the second through a commercial Company, Agri-Biotech, and numerous non-governmental organisations (NGOs) have provided the third for Zimbabwe, aiming to help 'the poorest of the poor'. Three case studies illustrate that rural farmers can achieve 20–40 tons per hectare on poor soil, given access to water early in the season or with rains later in the season. Nursery farmers starting early (in September) can supply 10–100 others late (December to February) with second generation planting material. In this way, 20% of the country – over two million people, the family members of 400 000 small farmers – are growing the elite 'clean' material and have thus regained their dignity and economic independence. The case studies are of a rural woman, a retired school-teacher in a pastoralist region and a hard-working entrepreneur who has made a fortune. We will ask a series of questions and try to answer them positively.

INTRODUCTION

Why do we choose sweet potatoes to alleviate hunger and poverty? Why choose this crop in particular? It is traditionally a women's crop, and therefore a neglected crop. It has also been neglected by research workers, farmers' organisations and by government. It is an orphan crop – and yet potentially it is an ideal subsistence crop for providing food security. It is good food, proven to be high-yielding, and somewhat drought-tolerant. Any tubers surplus to family requirements can readily be sold to neighbours or in local markets where there is a dearth of food, and especially food of decent quality.

JUSTIFICATION

Are we addressing a real problem, or just spending money?

Casual observation and serious investigation (FAO Donors Coordinating Committee, monthly reports, Harare) both show that there is serious hunger, and when combined with energy-sapping disease, there is a real need.

And what about HIV/AIDS? Can it help in this domain?

Many rural families have lost family heads, men and women, and often the survivors are eating only one meal a day. This meal therefore needs to be nutritious. To be so, elite planting material needs to be increased in availability. 'Born-again', virus-eliminated, sweet potato can be used to mitigate the effects of poor nutrition and low resistance in rural districts of Zimbabwe.

(Why born-again? We call it this because the predominantly Christian rural population understand that being born again does not mean you remain perfect forever – this helps us get across that the new material will pick up more virus via vectors from the neighbours and so degenerate, back-slide, over several seasons. We do not wish to disappoint through unfair expectations of total immunity to viral infection).

Can our crop improve the diet? Can it sustain and can it support the struggling immune system? Can it help fight and delay the virus?

Because of its good features, we believe it can, and does. It has a high fibre content,, little fat, good digestible carbohydrates, an ideal amino acid balance

Table 1: Average values per 100 gm dry matter

Energy	1700 kilojoules
Protein	5.6 gm
Carbohydrate	82.1 gm (fresh tuber is 70–80% water)
Total Fat	0.5 gm
Fibre	11.1 gm
Sodium	62 mg
Vitamin C	113 mg

(adequate S-amino acids),a low sodium,content, and one third of the daily Vitamin C requirement (see Table 1 and Figure 1).

Some Olympic athletes demand sweet potato because of its taste, its balance of protein and carbohydrate and its quality protein. They have the expertise to demand the best.

Figure 1: Yellow-fleshed tuber, high in Vitamin A precursors

What does it take to succeed in delivering the benefits of virus-elimination to actual farmers?

Agri-Biotech believes that q*uality* germplasm, *quality* know-how, and *quality* finance are the basic requirements (Figures 2 and 3). The finance is supplied by ten NGOs whose mandate includes assisting 'the poorest of the poor' in rural and urban settings. These are currently at least two thirds of the Zimbabwean population. Stomach-fill for family members, energy for the bread-winners and field workers and good nutrition for old and young are needed. Surveys have shown that Zimbabwe communal farmers are generally getting 3–4 tons per hectare from their handed-down vines. Our data shows that rural farmers on poor soils can average 20 t/ha and achieve as much as 40+ t/ha under good farming practice.

'Virus-elimination' is not new. It is a laboratory technique first used by Kassianis to 'clean' King Edward potatoes for the UK seed potato industry in 1977. It has been used in the North regularly ever since. IITA in Nigeria has used it in the past for cassava to dramatically lift yields. However, due to trained personnel moving on to other jobs, the skills have seldom been retained in Africa. This technique has been under-utilised, and still is, in 50 African countries.

RESULTS: A SITUATION REPORT FROM ZIMBABWE

We note that the topic of this workshop is 'Science-based improvements of rural/ subsistence agriculture'. The aim is "to identify promising science and technology strategies for improving agricultural productivity and food security specifically of small-scale farmers".

Can we in Zimbabwe address this issue from our experiences? And forgive us for asking, but is it just plans and funding – or should we be focusing on successful delivery? We believe we can help, as we have four years of partial failures and limited successes to draw upon.

Our first project was with the Swedish Centre for Cooperation (2002-2004), a farmers' organisation from Sweden. We were paid for our planting material and for our professional services in training, monitoring and trouble-shooting:

Figures 2 and 3: Composites of quality Germplasm and quality know-how

nursery farmers were chosen if they had access to some water in our dry season and if they were recognised by the community as good farmers with a good track record. We do the necessary scientific work at the university as well as in a small Agri-Biotech laboratory. The 'virus-elimination' is the heart of the technology, the *sine qua non*. All African countries could use it to increase potential yields of tuber crops by three times, or even five or ten times the current yields. Rooted cuttings are produced via the laboratory and greenhouse, packed in cardboard boxes and delivered to nursery farmers by NGOs after two days of sensitisation in groups at local schools and churches. These farmers are challenged to sell to at least ten others when the vines are mature and the rains arrive. The majority have done so, averaging well above ten (anecdotal evidence during feedback workshops and farm visits: e.g. Amai Chipara sold to 172 in one week, during and after her field day, Figures 4 and 5). We have earned the trust of many rural communities through our company policy of integrity, transparency and sincerity. Field days always surprise the community with the large, tasty tubers being dug up and our cook specialist usually demonstrates how to make bread,

Figures 4 and 5: ***Amai Chipara in Sunday best at her field day and some of her young neighbours, all of whom bought second generation vines from her***

scones, muffins and sadza from the flour, as well as fried chips, relish, jam and orange juice (Figure 6). Silas Hungwe, President of the ZFU, is reported to have said, "Government talks of research, research, research to support our small farmers but we see nothing. But you Agri-Tech boys from the University have delivered the fruits of your research to our ZFU farmers. Thank you. Makorokoto." A number of our beneficiaries are 'urban refugees' who returned from the job search in Harare to grow our sweet potato to provide for their families and earn cash above that (Figure 7)

Thereafter, in 2004-2006, we supplied another ten NGOs (FAO, Care International, Save the Children, Help Germany, LEAD, GOAL, Assemblies of God, World Vision, CAFOD, Farmed and others) with quality vines and rooted cuttings and the professional services that ensure effective uptake. Between them, they have delivered vines to over 400 000 families, thereby serving at least two million people. A 20 x 20 meter plot, properly cultivated and timed, can provide stomach-fill for a family of five every day of the year.

Evidence in this area is hard to quantify, but we will offer anecdotal evidence by introducing you to three case studies, or, as our manager Tapiwa Ruhode calls them, 'witnesses'.

Mrs Mombeshora is part of a large marketing cooperative near Rusape. She harvested 30 tons per hectare, part of which was sold by truck through the cooperative to markets in faraway Botswana, earning hard currency for the members. Mrs Chipara (Figure 4) is one of her neighbours to whom she introduced the new material and methods. She kept her plants growing by carrying water from a well over 100 meters twice a week, but reaped the benefit with her huge yields in the off-season, which gained her high prices. Over three hundred attended their field day. The whole district has increased yields by at least three-fold.

Then there is Mr Gumede, recently retired from teaching. He lives in a rocky landscape – not easy land to cultivate, except on his (dry) stream bank, but with irrigation from a small dam, much-needed food is now

Figure 6: Delicious bambaira preparations

Figure 7: Mrs Mombeshora

Figure 8: 'Urban refugee'

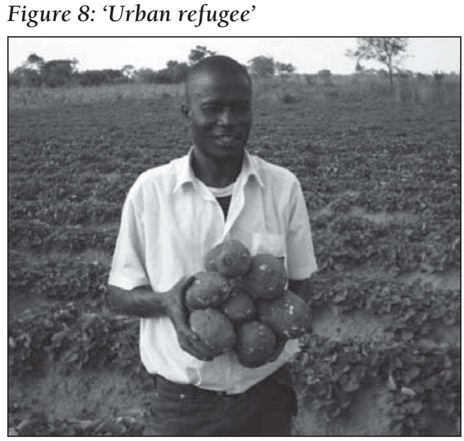


Figure 9: The school teacher, Mr Gumede

Figure 10: The entrepreneur, Boy Ncube

growing in a semi-arid area. The majority of his neighbours are cattle herders. He did a trial on his own initiative, saving his vines, not selling, but replanting himself. He got 24 t/ha on pure river sand without any fertiliser, 32 t/ha with Compound D, and 36 t/ha with liberal kraal manure. (Some Compound fertiliser was lost due to over-irrigation in well-drained soil.)

Thirdly we are giving full details on Boy Ncube because he illustrates a great deal about self-help, empowerment and the potential for success from modest beginnings.

Ncube attended Gumede's field day and demanded to be included the next time. We supplied 3 000 plants, and he bought another 3 000 from Gumede. He had a well and got started properly, taking vines off his September crop in January and re-planting. He finished with three hectares, his five-member family harvesting three tons every two days for 12 weeks. He has earned the equivalent of US$17 000. He has bought a milk-cow, bricks for a decent home for his family, and plans to buy a bakkie. His earnings exceed those of this university lecturer by four-fold.

These three examples are typical rather than exceptional, although we have had our share of farmers who refused to take the opportunity seriously, which was the result of poor selection. Those who took us seriously reaped excellent results from their fields.

CONCLUSION

Why do we emphasise food security? What is its effect?

- Vital to 'stomach fill' – food for survival
- Vital to free the spirit – freedom from self-concern

- Vital to political progress – avenue for finding dignity.

It is not just a matter of applying technology, but of adopting a new life-style. For successful acceptance, we need to create trust. What creates trust?

With this question in mind, our company style is:

- Integrity – no cheating on expenses, no ghost journeys paid for by the sponsors, no lies to farmers
- Transparency – share our ideas with farmers, listen to their problems, history and experience, never bluff when we do not know, avoid political judgements, tell the truth about our difficulties and worries
- Sincerity – always deliver quality plants, be there when promised, share ideas on our hopes and plans for the future, above all get the job done, whatever excuses are available.

We believe this has helped to create the trust we enjoy.

QUESTIONS AND DISCUSSION

- **Kobus Eloff:** Congratulations on the project. This is what we need – more people actually getting down to the coal face.
- **Unidentified speaker:** How much white sweet potato is used compared with yellow sweet potato?
- **Ian Robertson:** It is nearly all white sweet potato, because the cultivar that we use is widely adaptable. The yellow-fleshed cultivar is only occasionally used in Zimbabwe. Taste is the most important factor for farmers.
- **Unidentified speaker:** People prefer yellow maize now in South Africa.
- **Ian Robertson:** When I came to Zimbabwe 29 years ago, people preferred white maize. However, after a serious drought, the only maize that was available was yellow, and people became used to it very quickly.
- **Florence Wambugu:** There is a need for the private sector to deliver products. We need to understand the mechanism of being a private company with donor funding. There is a need to help private-sector initiatives to deliver products. Delivery is a specialised institutionalised skill and needs to be identified as a challenge. Is there anything we can learn from you in this regard?
- **Ian Robertson:** You may be interested to learn our financial structure. We get money from two sources: (1) professional fees for teaching and training and (2) money from planting material. We pay ourselves from the professional fees. My manager is better paid that the directors of the main company producing cooking oil in Zimbabwe, so he is well paid. The money from planting material is split into four quarters: (1) tissue culture on which the company depends, (2) administration and vehicles, (3) employee bonuses, and (4) molecular R&D to develop new products.

- **Wieland Gevers:** What are the consequences of sustained 40 ton/ha use on the need for fertilisers? Do you make provision for replacing the nutrients in the soil?
- **Ian Robertson:** We have not done so yet. We have been going for three years. We recommend rotation. Most of the crops grow on poor soils.
- **Wieland Gevers:** We need studies on soil depletion.

Soil science-based improvements in subsistence agriculture

Martin Fey
Department of Soil Science, University of Stellenbosch

INTRODUCTION

This paper is one of several presented on the theme of Science-based Approaches to the Alleviation of Poverty, with specific reference to subsistence agriculture. My assigned title implies that an improvement in subsistence agriculture is one of the routes to be taken in alleviating poverty. Interestingly, however, specialist institutes concerned with this field seem increasingly to emphasise (http://www.unmillenniumproject.org/) that the way forward is for subsistence agriculture to transform itself into commercial agriculture, with growers having as their main incentive the production of a surplus above their own requirements. In this scenario, although agriculture might conceivably remain relatively small in scale, the market would become the major determinant of regional self-sufficiency in food production.

In this paper I aim to show (1) that soil science knowledge is already more than adequate for producing good crops on even the poorest of soil types, (2) that a focus on subsistence agriculture *per se*, as if it were an end in itself, could be counterproductive, perpetuating poverty rather than alleviating it, and (3) that the 'alternative agronomy', often recommended as the best route to follow in improving subsistence agriculture, and purportedly having such plausible goals as sustainability and environmental quality and being based on so-called 'organic' farming methods, potentially represents an abuse of terminology and a misrepresentation of conventional farming methods that border on fraud and should be exposed. The best way to achieve this is by promoting an understanding of chemistry. At the end, I shall make a few brief comments, quite unrelated to soil science, about agriculture and emancipation.

THE PRINCIPLES OF SOIL SCIENCE APPLIED TO AGRICULTURAL PRODUCTION

Let us first consider, for the benefit of non-specialists, the scope of knowledge required to make the best use of soils in producing crops. Crops need nutrients, air, water from the soil and an absence of chemical or physical barriers to root penetration.

Soil fertility and plant nutrition

At least 13 chemical elements are essential for plant growth, and mixtures of fertilisers seldom contain more than four or five of these. To find out whether and how much of an element is needed for satisfactory crop growth, soil samples need to be taken and analysed chemically using methods that are calibrated against crop responses to nutrient addition. Experimental work over many decades has enabled sufficiency norms to be identified for different nutrients and has also shown how some nutrients, such as phosphate, when added to the soil, are chemically bound by soil minerals, a phenomenon which needs to be compensated for in calculating fertiliser requirements. Some elements, especially trace elements, are not routinely analysed for because they commonly occur in sufficient quantity in the soil. A deficiency of some elements is difficult to ascertain from soil analysis alone, and so samples of plant tissue (especially leaves) are sometimes taken for analysis to find out whether the crop is getting enough of them. Added to this, some soils may be excessively acidic or alkaline, and amendments such as lime or acidifying materials (sulphur or ammonium salts) may have to be added to neutralise the effects of toxic or otherwise harmful elements such as aluminium and sodium. This can mean that, for an intensively cropped field, a great deal of chemical analysis has to be performed both to achieve and to maintain a satisfactory level of fertility.

Soil physical properties

Most emphasis on crop production constraints in subsistence agriculture is placed on nutrient management, but in many cases, the factors limiting crop yields are physical. Soils often have too much clay, too little clay and organic matter, are too hard when dry and too sticky and impermeable when wet, have too little depth for effective root development or have insufficient structural stability to withstand crusting and erosion following cultivation to be well suited for crop production. Modern agriculture makes use of a variety of techniques for improving and maintaining soil physical properties, but typically these involve tractors, implements and fuel. Soils are mechanically beaten into shape, moulded, ridged, planed, terraced or drained where needed to ensure that surplus water is removed, and sometimes ripped to soften inhospitable subsurface layers and irrigated when water can be obtained. To do such jobs manually is back-breaking, fat-burning work and is often impractical or even physically impossible.

In agriculture, soil physics is ultimately about managing soil pores, ensuring that there are balanced proportions of fine, water-retaining pores and larger, water-transmitting and aerating pores. A stable soil structure results from appropriate colloidal interactions (mutually flocculated clay, humus and metal oxides). These bind the soil matrix and delay pores from becoming blocked. Porosity reduces the amount of contact between particle surfaces and ensures that Van der Waal's forces do not produce an impossibly hard consistence when the soil dries out. Colloid chemistry and mineralogy are an important part of the arsenal of knowledge used in wrestling with soil.

Soil biology

Imagine being able to substitute diesel-powered mechanical implements or maize/fat/ATP-powered human effort with earthworms (and sometimes other burrowing fauna such as golden moles which eat earthworms) fuelled by crop residues? This is exactly what modern methods of conservation tillage achieve. The minimum tillage farmers' association in southern Brazil, with 7 000 members, has the name Cluba de Minhoca[1] (earthworm club). They know the bio-tillage principle, and no doubt their bank managers do too. Worms feed on a surface mulch of crop residues, drawing them down and creating continuous channels that conduct air and water to plant roots below the surface.

We do not yet know the extent to which the termite-ridden maize plots of central Africa benefit physically and chemically from the presence of these little creatures. The ubiquitous termitaria are broken down and used for soil amelioration by farmers in the region. Termites may devour crops, but their benefits need to be identified and weighed against any harm they may do. One can imagine an equivalent of the Brazilian farmers' organisation, the termite club, emerging and flourishing on the African savannas.

Applying principles to subsistence agriculture

I have tried to convey some idea of the scope of agriculturally applicable knowledge of soils while standing on one leg, and of the exciting revolution that has taken place in returning soil biology to a place in our thoughts about soils that it has probably not enjoyed since the writings of Charles Darwin.[2] How do we apply all of this to the problem of growing food for subsistence? The short answer is that the scientific principles remain unaltered, but the technical means

1 Spelling is approximate, from memory of a visiting Brazilian student's T-shirt. He supplied the anecdote.

2 I am indebted to one of my grandfathers, W.J. Dawson, an agricultural pioneer in East Africa, for having read Darwin and passed his books on replete with enthusiastic annotations; to my father, Venn Fey, for having been my first teacher of the principles of bio-tillage working in pastures (long before conservation tillage methods had been 'discovered'); and to Don Johnson of the University of Illinois for having recently reminded me of this legacy – almost erased by my study of soil science in the mainstream – with his pedogenic paradigm of the biomantle.

of applying them must be adapted to the context. A nice account of some the approaches that have been developed is given by Gruhn *et al.* 2000.

In remote rural areas, just as firewood substitutes for electricity in cooking and keeping warm, manual labour and local materials such as wood ash, manures or compost substitute for tractors and fertiliser in preparing lands for crop production. The scythe replaces the combine harvester. Empirical local knowledge and inventiveness, developed through centuries of trial and error, invariably confirm, and even inform, the soil scientist's theoretical understanding of physical and chemical processes. Sometimes a practice which intuitively seems to be naïve and ill-conceived turns out to be the only one that works satisfactorily in unique local circumstances of climate, soil and infrastructure. Local strains of maize developed by generations of Zulu subsistence farmers, for example, have been found to out-perform modern cultivars developed especially for the acid soil context in which they are grown. Sometimes tools and the way they are used are quite different, which begs the question as to whether they each represent a form and function matching local soil properties or are simply accidental local variants of the same tool. The *kedja*, *kaweya* and *jembe*, for example, are interestingly different species of southern, central and east African hoe in terms of length of handle and size, width and shape of blade. Why?

There is as much for soil scientists to learn from traditional subsistence practice as there is for us to contribute to its improvement. But is subsistence an end in itself? Are the aims of producing enough to feed the family not served better by going commercial?

BEYOND SUBSISTENCE: THE CASE FOR COMMERCIAL AGRICULTURE

That question was rhetorical. Africans – like all people – have traded with each other for as far back as records exist[3]. In the poorest, remotest regions of Africa you will find humming marketplaces in which an assortment of produce is on offer. It is inherent in the nature of climatic variation that there will be good and bad seasons and a spontaneous distribution of surplus through storage and trading. All agriculture involves commerce. The term subsistence agriculture seems inappropriate. Even small-scale agriculture, as a substitute term, has connotations of size limitation which convey a sense of resignation that things can never get bigger and better, that bigger is not necessarily better, or that things are not going to get bigger (or better) even if they could. The largest,

3 John Reader's *Africa: A Biography of the Continent* (Penguin) provides compelling reading on this subject.

sweetest, juiciest pineapple I have ever eaten was grown by a Zambian farmer who has expanded his operation into the bush over several hectares in response to local demand. He seemed to have the energy and enthusiasm that would see him readily selling his produce at a premium in European supermarkets, off substantially larger acreage, if refrigeration and a local airport were available. There was no indication that he needed an extension service.

I have a theory that "subsistence agriculture" and related terms are perpetuated, sometimes perhaps unwittingly, by people who have a vested interest in their use. Subsistence, like poverty, arouses sympathy and for good reason. International aid agencies, as Paul Theroux has pointed out[4], have a vested interest in human misery, as do despotic governments who cream off their share of the donations. I would go so far as to suggest that international research funding is often tainted with the same kind of hidden agenda, in which scientists derive much benefit from the myth of subsistence being inevitable and therefore demand "research" in order to improve the lot of those who are consigned to survive off tilling the soil for the rest of their lives. By perpetuating this myth of inevitability, through devising techniques that apply and adapt scientific knowledge to local drudgery, scientists themselves could be helping to prolong the drudgery. This view may seem cynical but it deserves consideration. In trying to keep our research programmes running we all may have fallen into the same trap. It is like putting bandaging a festering sore and trying to alleviate the discomfort, whereas with some extra effort, thought and commitment, a ready cure might be at hand.

ORGANIC FARMING AND SUSTAINABILITY

The environmentalist agenda mutates every few years in response to boredom and awareness among the public. The awareness aspect consists of people becoming immune to the slogans and scare stories, especially when it becomes apparent that they carry much less substance than was first implied. The sky does not fall. And so our attention is diverted from soil erosion to water pollution to air pollution in the cities to acid rain on a continental or even hemispheric scale to global warming and then to extreme weather events.[5] Research programmes feed off these bandwagons, and the researchers, whether they want to admit it or not, have a vested interest in fuelling public apprehension.

Somewhere in there, never quite extinguished, have been the issues of overpopulation and resource degradation or depletion, especially in developing

4 *Dark Star Safari.*

5 Or so roughly suggests Michael Crichton in his neo-novel, *State of Fear.*

countries. Naturally, these issues were also dressed up in new clothes as time went by, and the crisis-predicting spotlight fell in turn on dwindling resources, degraded land or growing human misery. The millennium project I referred to earlier seems to have achieved a hybrid agenda that includes environmental quality, sustainability and the alleviation of poverty. Under sustainability comes the inevitable emphasis on environmentally 'friendly' methods of farming. These typically imply preference for organic amendments over inorganic fertilisers, sometimes to the exclusion of the latter. Cost and local availability play a role in this selectivity, but there seems to be an element of cashing in on the organic option that is currently so much in vogue in the affluent North.

From a chemist's point of view, the pure organic option is actually a misnomer, because it involves a mixture of organic and inorganic soil additives. The latter include natural products such as rock phosphate (sometimes worthwhile but never more profitable than inorganic P fertilisers), crushed rock of other kinds (mostly of dubious value) and minerals such as sylvite (potassium chloride), which also happens to be the mainstay of inorganic chemical fertilisers containing K. The genuinely organic materials such as farmyard manure (fym, an old standby of European agriculture), fishmeal, chicken litter and composted plant residues are dilute sources of nitrogen and other nutrients, which means that large applications have to be made to meet crop needs for good yields. A big advantage is that the N is released slowly through microbial decomposition, which reduces waste and polluting effects. A big disadvantage is the enormous volumes that are needed per unit area of land. In poorer communities it is increasingly found that many organic wastes have greater value as structural materials or as animal feed and there is seldom enough left to make an impact on soil fertility (Gruhn *et al.* 2000). Importing organic amendments is an option, but this implies mining the nutrient status of other soils in the vicinity and ultimately degrading them.

However, hand maintaining and improving the humus content of soils is invariably desirable and is a standard goal of intelligent conventional farming. The organic movement does not have a monopoly on the idea of humus conservation. Humus confers important physical and chemical advantages, especially to sands and to oxide-rich soils of the humid tropics. It enhances storage of water and nutrient cations and reduces phosphate fixation, for example. One of the best ways to boost or maintain soil humus levels is to fertilise generously with nitrogen and other inorganic fertilisers. The high-yielding crop provides an abundance of surface residues and a well-developed root system. Besides contributing to humus reserves, the denser crop canopy reduces raindrop impact, enhancing both soil conservation and water quality. It is only when inorganic fertilisers have been applied in excess (e.g. by heavily subsidised European farmers) that serious environmental problems arise. They can stem from overdoses of organic fertilisers too. It has been argued that farming for maximum profit (and without artificial price support) is likely to coincide quite closely with the point at which environmental damage – by soil erosion on the one hand and nutrient leaching on the other – is minimised. This goal is most unlikely to be attained in a strictly 'organic' farming system without imports of nutrients in organic matter robbed from land elsewhere.

In order to minimise environmental degradation in farming, we require chemical fertilisers. That is my hypothesis, and I have yet to find evidence that refutes it. Nevertheless, especially when access to such fertilisers is limited and costly, alternative materials should always be valued, since some of them are probably the most cost -effective of all in the long run. An example is ash and charcoal from cooking fires, which is conveniently available and of great value, especially in areas with leached, acidic soils. Stockpiling, homogenisation, measured application based on chemical analysis and thorough incorporation and mixing are likely to sufficiently enhance the benefit from such materials to justify the trouble taken in applying them properly. The maxim should be that chemistry still pays, even when using additives that carry little or no expense.

EMANCIPATED FARMING

I have been taking some swipes at some cherished notions of modern agriculture. While I am at it, let me offer some other thoughts that I have been saving for an occasion such as this – ones that will probably also ruffle a few feathers.

Subsistence agriculture priorities need to be subjected to economic evaluation no less rigorously than in commercial agriculture. The cost of manual labour needs to be quantified in terms that *labourers* themselves appreciate, not simply in monetary terms. The price of fertiliser needs to be quantified in terms of the hours of labour required to gather and apply substitutes that will produce the same yield. Only then will it be possible for economic options to be weighed rationally. But making choices based on such options will only be realistic when labourers (mainly women and younger children) are emancipated and when land tenure by individuals is more secure. There is often an excessively authoritarian community structure at both local and national level. Individual initiative and enterprise are inhibited.

It may take a while for the realisation to widely sink in that inorganic chemical fertilisers are, when all factors are considered, more environmentally friendly than organic ones.[6] In the end, these fertilisers, alongside more secure

6 I have already mentioned vested interests in another context. It can be quite entertaining to consider who has them whenever an issue becomes controversial.

land tenure and in the hands of people making freer choices for themselves and celebrating chemistry, will be the saving grace that rescues future generations from both poverty and the destruction of their land.

REFERENCES

Gruhn, P. Goletti, F. and Yudelman, M. 2000. Integrated nutrient management, soil fertility, and sustainable agriculture: current issues and future challenges, Food, Agriculture and the Environment Discussion Paper 32, International Food and Policy Research Institute, Washington DC. pp 31.

The Earth Institute at Columbia University: Innovative Approaches to Meet the Hunger Millennium Development Goal in Africa http://www.unmillenniumproject.org/

QUESTIONS AND DISCUSSION

- **Ed Rybicki:** An observation – the person that invented the Ames test once showed that apples that are completely saturated in pesticides are far less carcinogenic than organically grown apples because there are far more mycotoxins on organically grown fruit and vegetables than on ones soaked in pesticides. It is a lack of knowledge of exactly what we eat that we are trying to save people from.
- **Martin Fey:** I have developed a checklist of all the benefits of organic matter in humus in the soil as well as a checklist of the negative factors. The list of benefits is longer. I try to arm my students with a memory of that list so that they are equipped with the intellectual ammunition to argue rationally about the controversies related to organic farming.
- **Kobus Eloff:** Are the humic compounds mainly involved in the soil structure or do they also have direct physiological effects on plants?
- **Maritn Fey:** I am not sure about direct physiological effects on plants, although they may well do, but humic substances can complex trace elements such as copper, for example, which are then taken up more readily, and even translocated in the plant more readily, in that complexed form than they would have been simply as an inorganic salt. There are benefits like that.
- Humic substances are involved in soil structure, but not always beneficially. They do not always aggregate the soil. Sometimes you get clay dispersion more readily when you have clay organic complexes. Sometime they cause structural deterioration.
- **Florence Wambugu:** A comment on organic farming – there is a strong lobby group against Africa using fertilisers, urging Africa not to make the mistakes of Europe. The argument is reaching policy level. One of the

major problems of low productivity is related to fertilisers. To what extent could the Academy influence policy? What message would you convey?

- **Martin Fey:** My message is that if you are growing food in order to feed people, because that is the priority, rather than a novelty in a European supermarket, use fertilisers, which is the most economical and efficient way. Anyone who says we should not use fertiliser is making it more difficult for farmers to feed their families. Organic farming is a luxury for Europeans.
- **Felix Dakora:** I would argue differently, in favour of the complementarity of the two systems as the ideal. We have to acknowledge that excessive use of fertilisers abuses the environment.
- **Martin Fey:** There are not two systems. The full system is conventional scientific farming. Organic farming is half a system. It is a question of whether you go for the full system or half a system.

SECTION 3

Focus on market issues for small-scale farmers in Africa

The Socioeconomics of Subsistence Farmers and the Contribution of the Social Sciences to Agricultural Development

Tim Hart
Senior Research Manager in the Urban, Rural and Economic Development Research Programme of the Human Sciences Research Council

INTRODUCTION

The original request was that this paper contributes to the ASSAf workshop by providing some facts and figures about the socioeconomic conditions and circumstances of subsistence farmers in South Africa. For a number of reasons, it was decided that the paper should take a slightly different line of argument and present other pertinent facts. The first reason is that there are no nationally representative statistics for subsistence and smallholder farmers in South Africa. Often, the figures that are cited represent only those farmers who are members of the National Agricultural Farmers' Union (NAFU), who are in many cases better organised and have access to greater resources than the majority of farmers who are termed subsistence – in itself an inappropriate term to which we shall later return. Secondly, the contribution of the social sciences to agricultural development is often overlooked, with most emphasis placed on the contributions of the natural sciences and occasionally on those of agricultural economists. In light of this, the decision was taken to present some examples of how the social sciences contribute to agricultural development in South Africa. This is especially pertinent, as most of the audience at this workshop are natural scientists.

THE SOCIOECONOMICS OF SUBSISTENCE FARMERS

As already pointed out, there are no countrywide representative statistics on agricultural actors in South Africa; especially those termed African, Coloured and Asian. This is worrisome, as it suggests that we know very little about those people engaged in agriculture that current agricultural policy aims to assist. However, a number of smaller and often purpose-specific studies have been done across the country by various Provincial Departments of Agriculture, science councils, universities and a handful of non-governmental organisations (NGOs). Put very simply and based on the numerous case studies that exist, we get a general picture of farmers[11] in South Africa, irrespective of race or gender, generally falling somewhere along three axes:[22] size of land and farming operation; access to resources and inputs; and primary purpose of production. Firstly, they fall somewhere on a continuum between large-scale and small-scale. Secondly, they fall along a continuum of resource-rich and resource-poor. And thirdly, they fall along a continuum of commercial production and subsistence[33] production. This means that a small-scale farmer might be resource-rich, resource-poor or somewhere in between (resource-medium). Such a farmer could also be involved either in commercial production, subsistence production or somewhere in between the two (producing primarily for household consumption but selling any surplus where possible). We should furthermore bear in mind that these characteristics are all relative. Movement within or across these categories is not a fact of evolution, progress or a result of modernisation. Location within any category and mobility to another category are rather the result of an individual farmer's physical environment, socioeconomic and physical circumstances, occasionally personal choices and a host of external factors, including political policies and instability. Most farmers in developing countries are identified as being resource-poor (Chambers, Pacey & Thrupp 1989), but in South Africa farmers will fall somewhere within a grid composed of all three of the axes we have described. In recent collaborative research by the Human Sciences Research Council (HSRC) and the Agricultural Research Council (ARC), it is evident that in most instances, agriculture commonly supplements the household food supply, allowing cash to be spent on other food and non-food goods and services (Hart & Vorster 2006b & 2006c). The bi-annual Stats South Africa Labour Force Survey provides some interesting data about the reasons why rural and urban households pursue agricultural activities.

---

1 'Farmers' include peasant/family smallholders, pastoralists, forest dwellers and artisanal fisherfolk, among others. The term 'farming' is used in a wide sense to refer to the activities of all people who produce and/or harvest from plants, animals and aquatic resources.

2 Other important criteria would include age, gender, education level, equity aspects, infrastructure, input and output markets, political economy, etc. For the sake of simplicity, we confine ourselves to three criteria.

3 Subsistence is used incorrectly in the South African context, as very few farmers to whom this term is applied rely exclusively on agriculture to subsist. Table 1 in this section, derived from the Labour Force Survey, provides a picture of recent trends of those black South Africans who are engaged in some form of agricultural activity. Migrant and wage labour, state pensions and grants, remittances and other livelihood strategies enable such households to survive. To this end, agriculture supplements household income/food supply. In its pre-1994 form, agriculture in the homelands and Coloured rural reserves was shaped by European colonialism, and more recently, a manifestation of the apartheid separate development and migrant labour policies – in essence a consequence of industrialisation and the political economy emerging in the late 19^{th} and 20^{th} centuries.

THE LABOUR FORCE SURVEY

The lack of national statistics regarding the agricultural production of Black smallholder farmers or agrarian households in South Africa is slightly overcome by the introduction of the Department of Labour's bi-annual and national Labour Force Survey (LFS) in September 2000. This study provides some interesting information regarding households' reasons for engaging in agricultural activities. This information is provided in Table 1. From 2000 to 2004, the survey focused exclusively on rural households. From 2005 onwards, urban households engaged in agriculture were also included in the sample. During the period of the survey, the sample of respondents who were engaged in any form of agriculture ranged from around 3.4 million households to 4.8 million households. Over the five-year period from September 2000 until September 2005, the survey illustrates the following trends:

- The number of households engaged in agriculture as the main source of household food supply has decreased by slightly more than half, from 33% to 15% of households farming for this purpose. Therefore few households rely on agriculture as a main source of household food.
- The number of households engaged in agriculture as the main source of household income has slightly decreased from 3% to 2%. Thus very few households rely on agriculture as a main source of household income. The figures suggest that at least since 2000 agriculture was only the main source of income for a very small number of households in South Africa.
- The number of households engaged in agriculture as an extra source of household food has increased from 55% to 77%, reaching 88% in March 2004. This peaking and then decline is more clearly represented in Figure 1 below and suggests that people make decisions on when to engage in or disengage from agricultural production. Some possible reasons for these decisions might be a new source of income, death of the person responsible for production, loss of labour and time for production, loss of alternative or previous sources of income, along with a host of other reasons. The LFS does not look into the reasons and merely provides the trends.
- The number of households engaged in agriculture as an extra source of household income has also declined slightly, moving from 5% to 3%.
- The number of households engaged in agriculture as a leisure activity or hobby has also declined slightly, moving from 4% to 3%.

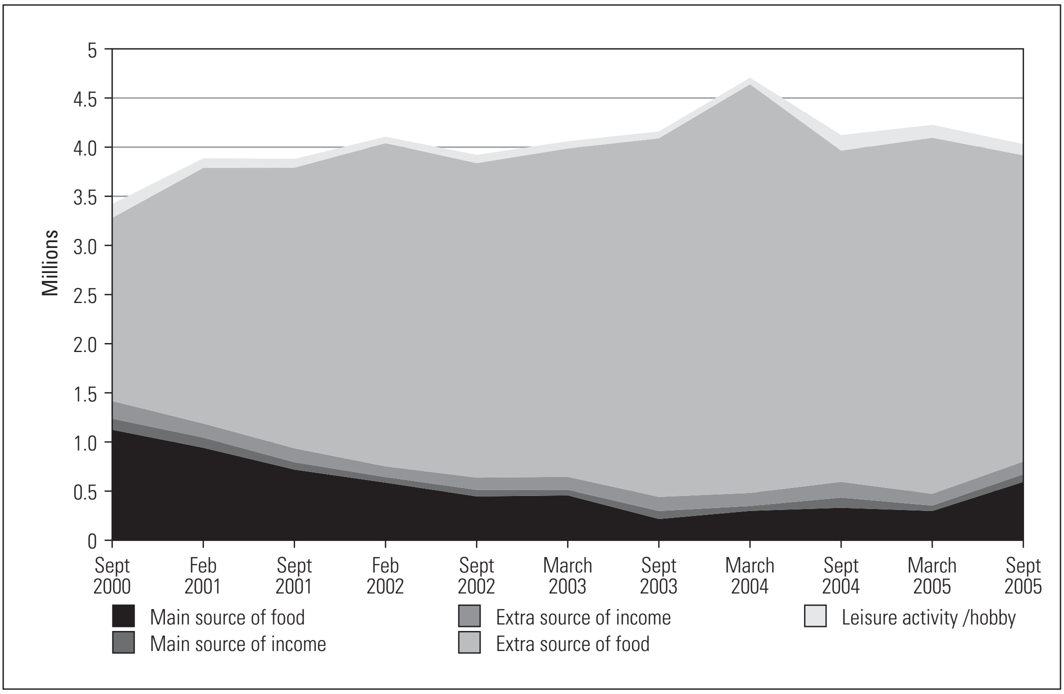
It is clear from the LFS that between September 2000 and September 2005, more than half the households primarily engaged in agriculture as an extra source of household food and that this reached almost 90% in March 2004 and just over 75% in September 2005. The survey also indicates that relatively small percentages of households engage in agriculture either as a main or extra source of income. While these percentages were small at the outset, they have decreased.

Table 1: Reasons that Black households engage in agricultural activities

Survey Dates	As a main source of food for the household	As the main source of income/earning a living	As an extra source of food for the household	As an extra source of income	As a leisure activity or hobby
2000,Sept	33%	3%	55%	5%	4%
2001,Feb	24%	3%	67%	4%	3%
2001,Sept	19%	2%	73%	4%	2%
2002,Feb	14%	2%	80%	3%	2%
2002,Sept	11%	2%	81%	3%	2%
2003,March	11%	1%	82%	3%	2%
2003,Sept	5%	2%	87%	4%	2%
2004,March	6%	1%	88%	3%	2%
2004,Sept	8%	3%	82%	4%	4%
2005, March	7%	1%	85%	3%	3%
2005,Sept	15%	2%	77%	3%	3%

Source: Labour Force Survey Statistics

Figure 1: Area chart of reasons that Black households to engage in agricultural activities



Source: Labour Force Survey Statistics

Unfortunately, reasons were not sought for these trends, and figures for the two surveys in 2006 are not yet available. Many of the trends illustrated in the LFS coincide with the findings of the current study on smallholder agricultural practices and purposes.

The implications of the Labour Force Survey are that very few of South Africa's Black farmers can actually be labelled as subsistence farmers (i.e. households that satisfy household needs through agricultural activities). In fact, the suggestion is that they have to depend on alternative sources of livelihoods to satisfy household needs

THE USE OF NATURAL RESOURCES

Recent research in South Africa (Twine *et al.* 2003; Hunter & Twine 2005; Kaschula *et al.* 2005; Hart & Vorster 2006a and 2006b) indicates that rural households interact closely with their local natural resource base when securing livelihoods, irrespective of whether or not these are agricultural or other sources of livelihood. Rural households harvest wild plants and animals for food and medicinal purposes. They also harvest wood and grasses for housing and fuel, and for making implements, tools and for fencing. Wood, grasses and their products are often sold to local people in order to generate an income. Soils are often used in the construction of dwellings and other structures and particularly clayey soils are used for brick-making and are often sold to generate an extra source of income. Agricultural activities of varying scales also make use of the natural resources and often encroach on these. This can occur in both sustainable and unsustainable ways, and the end result is heavily dependent on the users of the natural resources. Overgrazing and soil erosion are often the consequences of unsustainable natural resource use, while soil reclamation and fertility are the tangible results of sustainable natural resource management (see Reij & Waters-Bayer 2001). Given the generally low socioeconomic circumstances and low household incomes of most farmers considered to be resource poor, they tend to rely more on locally available natural resources as opposed to the externally available and costly conventional agricultural inputs (Hart & Vorster 2006c).

OTHER SOCIOECONOMIC FACTORS

In recent years, much has been said about the dual economy in South Africa, with many individuals and institutions relegating most Black South African farmers to the 'second economy' (see Slater 1980 for a historical perspective and argument against the simple dual economy model). Despite these popular assumptions and the state's persistence with a modernist dichotomy syndrome, agrarian households and resource-poor farmers are in fact deeply embedded in the national economy. In fact, it could be argued that their present situation is a result of the nature in which they are embedded in the national economy, both historically and currently. Consequently, many rely on other forms of livelihoods for income and ultimate survival over and above local agricultural practices and natural resource use. These alternative and supplementary livelihood sources include the following (Hart & Vorster 2006c):

- Migrant labour in the urban areas
- Remittances from family members situated either permanently or temporarily in other areas
- State social grants and old age pensions
- Local wage employment – often influenced by national and international markets
- The purchase and resale of goods from other areas and even the resale of imported goods, suggesting the influence of globalisation on current livelihood strategies.

If the figures obtained from the Labour Force Survey exhibited in Table 1 and Figure 1 are anything to go by, then the so-called subsistence farmers in South Africa are not really subsistence farmers. While the figures strongly suggest that they rely heavily on other sources of livelihoods for their survival, this was not always the case in southern Africa.

AN INTEGRATED PERSPECTIVE

In order to understand the current socioeconomic circumstances of smallholders in South Africa, it is necessary to consider historical and political-economic approaches. However, as posited by Chambers (1983) we also need to integrate these analytical approaches with more technical issues, such as declining national resource bases and climate change.

In South African during the 19th century, there existed a number of profitable and sustainable agricultural areas that were farmed by the some of the indigenous population groups (as opposed to the first and second generation European settlers). The former Transkei and Ciskei homelands in the Eastern Cape were evidence of this during the 19th century (Wilson & Thompson 1982). These areas and some of the other former homeland areas were renowned for their agricultural products and surpluses. These agricultural surpluses sustained both the local European markets and the international markets. Local farmers also had their own local markets and economic trading networks with indigenous people situated in the south and east trading with those in the north and the west (*ibid.*). Beinart (1980) points out that maize and local corn, along with tobacco and dagga (marijuana) were popular trading items on the Eastern Cape Frontier, with the area becoming known as the granary of South Africa during the mid-1800s.

Cattle and cattle products were also exchanged, as were wild animal skins and teeth (*ibid.*). Wilson & Thompson (1982) note that these networks often involved the exchange of copper and iron for agricultural produce, indicating diversity of skills in the different areas, largely based on the availability of natural resources and interaction with other people.

During the 19th century, Lesotho also provided resources and agricultural produce to the Cape Colony and the Boer Republics – the South African Republic and the Orange Free State Republic. In fact, it was a main exporter of wheat and maize during the latter part of the century (Wilson & Thompson 1982; Ferguson 1990). However, since the 1970s, Lesotho has been classified by the World Bank and the Organisation for Economic Cooperation and Development (OECD) as a Least Developed Country (LCD), attributed with having a traditional or peasant economy (Ferguson 1990). Given the agricultural success of Lesotho, a century before there is nothing traditional about the current status of the economy. Lesotho's agricultural deterioration first started in the latter part of the 19th century when its prime agricultural land south of the Caledon River in the current area of Lady Grey and Sterkspruit (Herschel District) as far as Aliwal North was expropriated by the colonial powers and the Boer Republics, following the latter's independence and the subsequent wars with Moshoeshoe (Wilson & Thompson 1982).

If prosperity was the case in the mid-19th century we need to ask ourselves what has happened to bring about the change and current situation? Evidence from researchers (historians, social anthropologists and economists) indicates that interaction with, rather than exclusion from, the global economy produced the existing situation (Marks & Atmore 1980). In this regard, the nature of interaction is important, as various scholars such as Wolf (1982), Bundy (1980) and Slater (1980) have shown. Factors that have contributed to the current status quo of smallholder Black farmers in South Africa include the following:

- The direct dominance and indirect subjugation of the local people encountered as a result of policies of colonialism and more recently neo-colonialist or imperialist exploitation
- Previous state policies relating to apartheid and separate development
- Current government policies that ignore the historical situation and seem to be based on the illusion of a group of subsistence agriculturalists existing up until 1994
- Overpopulation in rural areas and diminished natural and other resources
- Erosion and the expropriation of land
- Climate change
- Declining interest in agriculture among the youth
- The HIV/AIDS pandemic, which directly affects a household's ability to produce agricultural produce and often removes the primary source of income

- The persistence of educating research and extension personnel in outdated principles and quick-fix solutions.

Historically change is clearly a result of political-economic and technical attributes of interactions and changes in the natural resources available for production. The latter are often influenced and exacerbated by political considerations.

AGRICULTURAL DEVELOPMENT

The modernist, input–output model of development largely influences the current approach to agricultural development. This model assumes that a country's economic and social development can be externally induced (Donnelly-Roark 1998). Such an assumption ignores the roles of actors and the effects that they have on the development process. Furthermore, it assumes that actors are mere passive recipients of development. This model also ignores the effects of broader internal and external influences, including natural, historical and political influences. In this rather simple model of development, identified *beneficiaries* receive various externally derived and often locally unavailable and typically expensive inputs, the use of which is expected to bring about development. However, such development approaches seem not to have brought about sustainable development. Once the flow of these inputs is stopped – due to any number of reasons (including withdrawal of funding, subsidisation, increased costs of inputs, etc.) – the associated *development* falters. *Silver bullet technologies*, including the recent introduction of genetically modified crops, are seldom accepted outright in their original forms by resource-poor farmers. In most instances, where this is possible, farmers adapt this technology to suit their requirements and circumstances. Often these technologies are rejected outright due to their incompatibility with farmers' socioeconomic and agro-ecological circumstances. The success of the recent introduction of genetically modified cotton to smallholders in the KwaZulu-Natal Makhatini Flats is highly qualified (Ismael, Bennett & Morse 2002; Thirtle, Beyers, Ismael & Piesse 2003) and only applies to a few of the farmers in the area, most notably those endowed with better resources (Witt, Patel & Schnurr 2006). The main reason for this is that these and similar technologies proposing universal application and suitability are in fact context insensitive. They fail to take cognisance of the following:

- Farmers' socioeconomic status, circumstances and access to and type of resources
- The diversity of the agro-ecological zones in which the technology needs to be applied
- Local and national politics
- Farmers' individual motivations for engaging in and disengaging from agricultural activities.

Context is seldom considered, and the farmers are often seen to be making ill-informed decisions, when rejecting or using this technology in alternative ways from those prescribed, by those who do not understand their circumstances. For example, the fact that most black smallholder farmers and their households are engaged in numerous livelihood activities, of which agriculture is only one and often plays a small role as a livelihood source, is something that few agricultural specialists acknowledge. Despite the limited contribution to livelihoods made by agricultural production activities, especially as a means of income, specialists continue, in such instances, to emphasise the profitability of new technologies. In many cases, it may well be more suitable to focus greater attention on the other sources of livelihood and to work with these (Aliber, De Swardt, Du Toit, Mbhele & Mtethwa 2005)

Because there are a number of factors, beyond merely technical considerations, that influence agricultural development, the social science methodologies offer a number of contributions for understanding the context in which agricultural development occurs. In this way, the applied social sciences can integrate with the natural sciences in achieving agricultural and rural development.

SOCIAL SCIENCE CONTRIBUTIONS

Small- and large-scale surveys can be used to provide development service providers and actors with an overview of micro, meso and macro trends. When these surveys are combined with panel studies, they can illustrate longitudinal trends over time. Quantitative questionnaire surveys are useful in that they provide researchers with a picture of WHAT is happening at a particular point in time. However, the shortcoming is that surveys do not necessarily provide reasons for WHY something is happening.

The more qualitatively oriented research methods can provide a more detailed picture and understanding at the micro-level. Such studies are more in-depth, providing a richer picture of the local or micro situation. From these, a better understanding is obtained as to why certain trends are emerging, persisting or changing. They place the diversity of farmers and their circumstances in context; thereby providing scientists with clearer pictures of WHAT is happening, WHY it is happening and HOW it has happened.

During recent decades, social scientists and natural scientists have collaborated in agricultural research and development programmes (Chambers et al 1989; Scoones & Thompson 1994; Van Veldhuizen *et al.* 1997). Social scientists use their methods and tools to complement those of the natural scientists. Activities in which they participate during agricultural research or development projects include diagnostic studies, monitoring and evaluation, and implementation research. Given the typical micro nature of this work, the research is usually qualitative in nature. With the advent of participatory research methods and approaches in development, qualitative and quantitative methods from a number of disciplines are combined.

PARTICIPATORY METHODS

Go to the people
Live among them
Plan with them
Work with them
Start with what they know
Build on what they have
Teach by showing
Learn by doing

(James Yen, Founder of the International Institute for Rural Reconstruction)

Eighty years later, these words are important, although still not applied by most of those involved in rural development. In recent years, especially since the late 1970s, there has been an increase in participatory approaches in rural development (Scoones & Thompson, 1994; Reij & Waters-Bayer, 2001; Perret & Mercoiret, 2003; Pound *et al.* 2003; CTA 2004). This follows a realisation that sustainable development requires a bottom-up approach and local involvement beyond passive consultation. The reasoning behind this argument is that farmers have many of the solutions to their own problems (Reij & Waters-Bayer 2001), or can at least make meaningful contributions to solving their problems by virtue of knowledge regarding their circumstances and local environment (Chambers *et al.* 1989; Scoones & Thompson 1994). The combination of farmers' knowledge and that of appropriately focused research and extension can be a formidable force in agricultural development as the two can complement each another (Scoones & Thompson 1994; Reij & Waters-Bayer 2001; Perret & Mercoiret 2003; CTA 2004). In agricultural development, a number of approaches have unfolded. These started with Rapid or Relaxed Rural Appraisal, Participatory Rural Appraisal, Participatory Learning in Action and have evolved into a number of other approaches, each latter one further emphasising the principle of participation as empowerment of and ownership by the farmers and rural participants. In recent years, Participatory Technology Development and Participatory Innovation Development have become important for optimising agricultural research (Waters-Bayer & Van Veldhuizen 2004; Reij & Waters-Bayer 2001; Wettashina *et al.* 2002). Farmers are recognised as technology developers and innovators in their own right, and such approaches encourage scientists to assist farmers in strengthening their innovations. Local or indigenous knowledge is often considered as a starting block.

LOCAL KNOWLEDGE

Participation with rural inhabitants and the exchange of experiences and ideas made social and natural scientists aware that local or indigenous knowledge is a valuable resource for rural and other sector development initiatives. Other sectors wherein local knowledge is recognised include the human and animal health sector, marketing and manufacturing of goods, agricultural activities, etc. Awareness and understanding of local knowledge provides:

- Context sensitivity
- An awareness of local resource-based low external input technology, which is usually of low cost to the user
- Knowledge for the production of cost-effective and locally appropriate technology
- Practical alternatives to *silver bullet* technologies
- New ways of looking at problems and developing solutions
- An awareness of farmers as innovators rather than as passive recipients of technology.

CONCLUSION

Agricultural development requires the input of the social sciences in order to understand the current situation and manifestation of black smallholder farmers in South Africa. An analysis of the their history and the political economy illustrates why they are in fact not subsistence farmers but are more a manifestation of South Africa's social and economic development during the 19^{th} and 20^{th} centuries.

The correct application of applied social science methodologies in collaboration with the natural sciences along with appropriate analyses can:

- Increase our understanding of agrarian households' livelihood sources and choices
- Bring about appropriate technology development within the agricultural sector – both locally and also in conjunction with South Africa's National Agricultural Research System
- Identify the trends of households' on- and off-farm livelihood strategies
- Illustrate the micro and macro contexts that smallholder farmers inhabit and in which they operate
- Identify longitudinal changes, patterns and their causes
- Encourage participation, knowledge-sharing and the development of all participants.

Given the wealth of experience and understanding that the social sciences bring to development and an understanding of the root causes of poverty, subsequent collaboration and integration with the natural science initiatives is vital to sustainable development in agriculture and other sectors of developing countries. This is especially so when identifying solutions and understanding the causes of current circumstances and problems.

REFERENCES

Aliber, M., De Swardt, C., Du Toit, A., Mbhele, T. & Mtethwa, T. 2005. *Trends and Policy Challenges in the Rural Economy*. Cape Town: HSRC Press.

Beinart, W. 1980. 'Production and the material basis of chieftainship: Pondoland c. 1830–80', In S. Marks & A. Atmore (eds) 1980. *Economy and Society in Pre-industrial South Africa*. Hong Kong: Longman.

Bundy, C. 1980. 'Peasants in Herschel: a case study of a South African frontier district', In S. Marks & A. Atmore (eds) 1980. *Economy and Society in Pre-industrial South Africa*. Hong Kong: Longman.

Chambers, R. 1983. *Rural Development: Putting the Last First*. Hong Kong: Longman.

Chambers, R., Pacey, A. & Thrupp, L.A. (eds) 1989. *Farmer First: Farmer Innovation and Agricultural Research*. London: Intermediate Technology Publications.

CTA. 2004. 'Agricultural training: Farmers in the front line', *SPORE*. 113. Wageningen: Technical Centre for Agricultural and Rural Cooperation (CTA).

Donnelly-Roark, P. 1998. 'Indigenous knowledge systems in sub-Saharan Africa: an overview', *IK Notes* No. 1, October 1998. Washington: World Bank.

Ferguson, J. 1990. *The Anti-Politics Machine: "Development", Depoliticization and Bureaucratic Power in Lesotho*. Cambridge: Cambridge University Press.

Hart, T.G.B. & Vorster H.J. 2006a. The importance of Indigenous Knowledge in Reducing Poverty of Rural Agrarian Households. Report for the Department of Science and Technology. Pretoria: HSRC.

Hart, T. & Vorster, I. 2006b. 'Indigenous knowledge on the South African landscape: potentials for agricultural development?', *URED Occasional Paper* No. 1. Cape Town: HSRC Publishers.

Hart, T.G.B. & Vorster H.J. 2006c. Smallholder potato production activities in South Africa: a socioeconomic and technical assessment of five cases in three provinces. Report for the Agricultural Research Council. Pretoria: ARC.

Hunter, L. & Twine, W. 2005. Adult mortality and household dietary use of the local environment: qualitative evidence from the Agincourt field site in rural South Africa. *Institute of Behavioural Science Working Paper EB2005-0001*. Boulder: University of Colorado at Boulder.

Ismael, Y., Bennet, R. & Morse, S. 2002. 'Benefits from Bt cotton use by smallholder farmers in South Africa', *AgBioForum*, 5(1): 1–5.

Kaschula, S.A., Twine, W.E. & Scholes, M.C. 2005. Copice harvesting of fuelwood on a South African common: utilizing scientific and indigenous knowledge in community based natural resource management', *Human Ecology,* 33(3), June 2005.

Marks, S. & Atmore, A. (eds) 1980. *Economy and Society in Pre-industrial South Africa*. Hong Kong: Longman.

Reij, C. & Waters-Bayer, A. 2001. *Farmer Innovation in Africa: A Source of Inspiration for Agricultural Development*. London: Earthscan Publications.

Perret, S.R. & Mercoiret, M-R. (Eds) 2003. *Supporting Small-scale Farmers and Rural Organisations: Learning from Experiences in West Africa*. Pretoria: Protea Book House, IFAS & CIRAD.

Pound, B., Snapp, S., McDougall, C. & Braun, A. 2003. *Managing Natural Resources for Sustainable Livelihoods: Uniting Science and Participation*. London: Earthscan Publications.

Scoones, I. & Thompson, J. (eds) 1994. *Beyond Farmer First: Rural Peoples' Knowledge, Agricultural Research and Extension Practice.* London: Intermediate Technology Publications.

Slater, H. 1980. 'The changing pattern of economic relationships in rural Natal, 1838–1914', In S. Marks and A. Atmore (eds) 1980. *Economy and Society in Pre-industrial South Africa*. Hong Kong: Longman.

Thirtle, C., Beyers, L., Ismael, Y. & Piesse, J. 2003. 'Can GM-technologies help the poor? The impact of Bt cotton in the Makhatini Flats, KwaZulu-Natal', *World Development,* 31(4): 717–732.

Twine, W., Moshe, D., Netshiluvhi, T. & Siphugu, V. 2003. 'Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa', *South African Journal of Science,* 99, September/October 2003.

Van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson, D.A. & Thompson, J. (eds) 1997. *Farmers' Research in Practice: Lessons from the Field*. London: Intermediate Technology Publications.

Waters-Bayer, A. & Van Veldhuizen, L. 2004. 'Promoting local innovation: Enhancing IK dynamics and links with scientific knowledge', *IK Notes,* 76, January 2004, www.worldbank.org/afr/ik/default.htm

Wettasinha, C., Van Veldhuizen, L. & Waters-Bayer, A. 2003. *Advancing Participatory Technology Development: Case Studies on Integration into Agricultural Research, Extension and Education*. Silang, Cavite, Philippines: IIRR / ETC Ecoculture / CTA.

Wilson, M. & Thompson, L. (eds) 1982. *A History of South Africa to 1870*. Cape Town: David Phillip.

Witt, H., Patel, R. & Schnurr, M. 2006. 'Can the poor help GM Crops? Technology, representation and cotton in the Makhathini Flats, South Africa', *Review of African Political Economy,* 109: 497–513.

Wolf, E. 1982. *Europe and the People without History*. Berkley: University of California Press.

QUESTIONS AND DISCUSSION

- **Kobus Eloff:** When we wish to give feedback to communities with respect to their plants that we have used for experiments, is it sufficient to use MSc and PhD students from those communities that have been involved in the research, or should we involve social scientists?
- **Tim Hart:** Social scientists have certain skills, for instance, in psychology and communication. However, from experience, in some cases, natural scientists communicate better with rural communities.
- **Wieland Gevers:** Your paper has contributed a very useful quantitative perspective of agrarian individuals. Can you give an idea of their quantitative contribution to the total of food consumed in South Africa, including commercial farming and imports, as opposed to the 77% of your sample of the labour force that deliberately undertakes small-scale agriculture for extra food for the family and community?.
- **Tim Hart:** I do have any figures in that regard.
- **Wieland Gevers:** How big is the problem we are addressing today?
- **Tim Hart:** We import a lot, as is cheaper than producing it. From experience of working in some rural communities, there is definitely a trend away from agriculture. If people can get other work, they take it. Household plots are becoming smaller. In some cases, for instance near Phalaborwa where I was working last year, a number of households were not using their household plot for growing any crops or vegetables at all. In the urban areas, there is a growing trend of young infants being given Niknaks and chips as opposed to fresh fruit and vegetables.
- **Neil Gardinier:** A comment – agrarian agriculture is hard work and high risk. However, if yields were to increase with the same input (e.g. from 4 tons to 40 tons of produce per hectare), it would be interesting to see whether there would there still be a shift away from agriculture.
- **Tim Hart:** If we consider food security, a number of strategies are required, not only production. If people could produce larger volumes and store it, they might engage more in agriculture.
- **Unidentified speaker (CSIR):** Some people do not like agriculture, even if it is profitable. They do not like to get themselves dirty.
- **Tim Hart:** Not everyone with a garden plot is a farmer. Many are not innovative. Sometimes the land is taken up and farmed by others that are more active and innovative.

Biofuels for Africa: Horses for Courses

David Glasser and Diane Hildebrandt
Centre of Material and Process Engineering, School of Chemical and Metallurgical Engineering, University of the Witwatersrand

INTRODUCTION

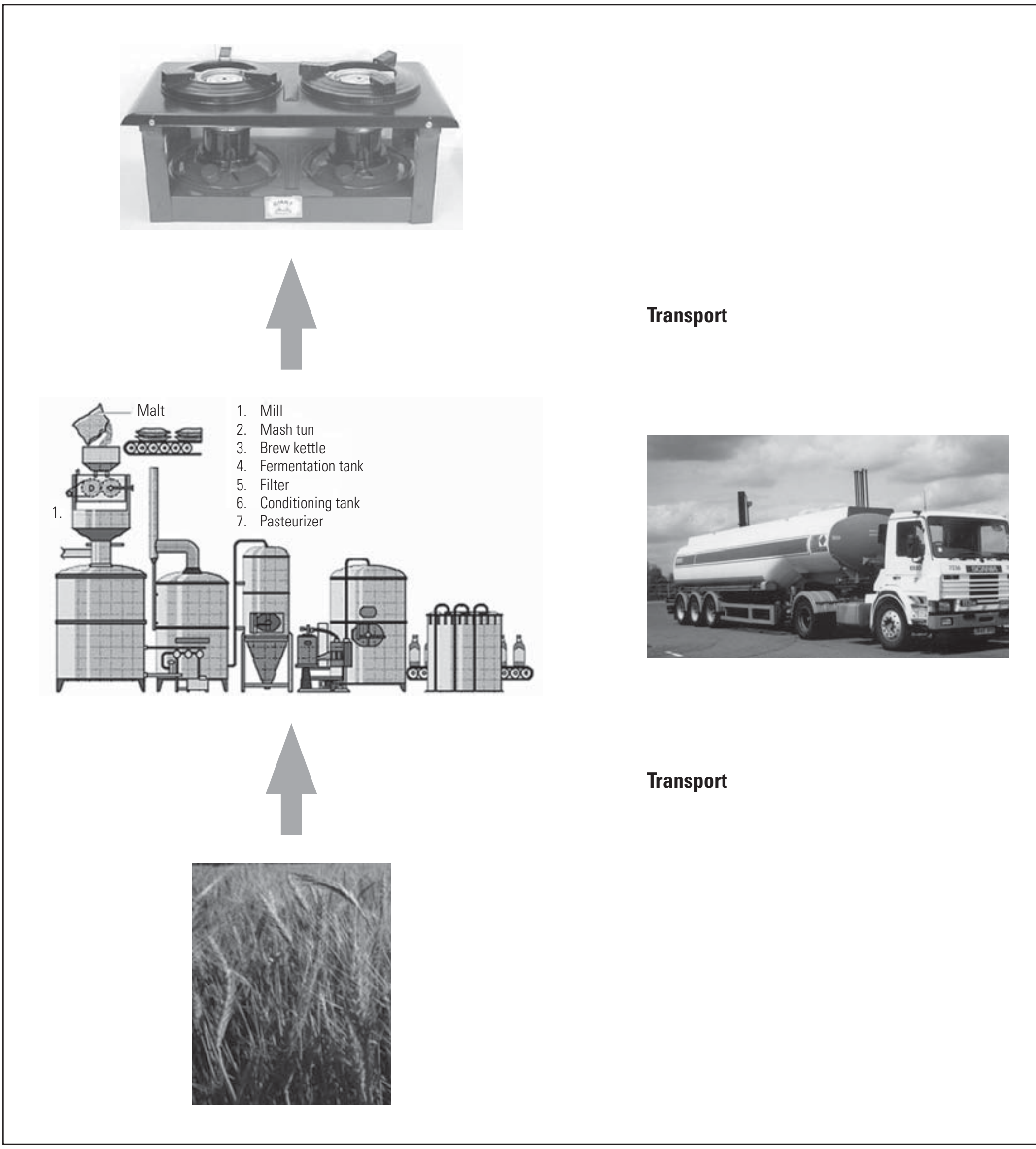
We have a unique opportunity to set up a sustainable new biofuels industry for Africa and the developing world. We are in a unique position to look at the *complete system* with new eyes. In the biofuels industry, this means considering all aspects, from the raw materials to consumption, as well as social and economic realities. If we do not do this, we risk using inappropriate models. Let us examine what we mean by inappropriate models.

The current model for a biofuels industry is essentially a Western-based centralised model. This model has certain paradigms associated with it, and we will explore these. We can do this best in terms of a picture of the *bio fuels system* that is shown in Figure 1. This model has, as its core, a centralised mega-plant. If we examine the system as a whole, we see that it involves the following major aspects. We grow the raw material in a decentralised area, namely a farm. We then transport the raw material to the centralised plant where it is processed. Any waste material then has to be dealt with centrally as well. The product from the plant has to then be taken to its use point that is again decentralised. Thus one extra factor that is important in looking at the system as a whole is the transport and reticulation system. This sub-system is actually a huge user of the fuel that is being made, and if we are in the position of setting up a new system, we should take the opportunity to do something about it.

Where does such a system with a centralised plant make sense, and why did it arise? This is the case where the raw material is itself centralised. Thus if we are mining coal and then building an oil from coal plant, it makes no sense to transport the coal to a number of smaller plants; we are better off building the centralised mega-plant. Here we are distributing the final product that is much more economic to transport than the raw material.

We may ask why the West uses this model, even for its biofuels industry? The West already has a very well developed economic system and transport network, and

Figure 1: From raw material to end-use: the Western model



it is relatively easy just to use this as it stands. Furthermore, because of the capitalist system, each of the economic entities in this system has its own agenda. By this, we mean that the individual parts of the system are run by large companies (growing, transport and manufacture) that have a vested interest in maintaining the status quo. Another important factor is that in the West, there is a food surplus, which is already collected and stored centrally, and again, mega-plants make more sense. In Africa and the developing world, there are major differences that potentially invalidate this model. There are not generally, and certainly not reliably, huge food surpluses and thus there is not such a large drive to turn these food surpluses into valuable products. Thus one might ask: should Africa be using food crops as a feedstock for biofuels? The answer is probably no. One might ask what could then be used as a feedstock for these processes. We propose that it would be sensible to rather use waste materials to make these biofuels. Another difference is that the climate is different in Africa. In parts of South Africa, the crop densities are not that high as rainfall might be limiting. Furthermore, the types of crops that can be grown are also variable from one side of a *koppie* (hill) to the other. Thus a large centralised mega-plant that is designed to handle one feedstock only is not particularly suitable under these situations.

What we have tried to show is that the drivers for making an efficient and successful biofuels industry in Africa and the developing world are completely different from those in the developed world, and we should take note of these before blindly using the developed worlds models. We should take the good parts from these models, but should ensure that we do not use inappropriate parts.

We are not, however, advocating a Luddite approach. In fact, we are suggesting that we develop good new science and engineering that can make a more decentralised, highly flexible approach work. This will be based on the best science and engineering, but will need to be such that people without specialised training will be able to operate and repair the equipment. This involves a completely new look at the total system in the context in which it will operate. We might call it 'Science for the Citizen, Engineering for the Environment'.

AN AFRICAN MODEL

In order to better illustrate what we are advocating, let us do it by way of an example. We will use the example of the production of bio-ethanol. This bio-ethanol might be used to make a bio-ethanol gel for cooking or heating or as a fuel or fuel extender. We will follow through each of the stages of the system and show potential improvements and why we believe they will provide advantages. The way we approach the example will not necessarily be exhaustive, and individual ideas may not work and will have to be re-worked as the system is researched. However, we do believe the systems approach, where we look at the implications of each step and its interaction with all the other steps, is at the core of what we are trying to do, and the final outcome will benefit from this systems approach.

BIO-ETHANOL EXAMPLE

Growing

Growing the crop is the work of the farmer, and we do not necessarily have any direct new ideas in this respect. However, the processing or initial processing of the raw materials on the farm using biological methods will give rise to wastes. These wastes will be very suitable as animal feeds and fertilisers, however, and will thus cut down on the commercial fertilisers that are required. The manufacture of these fertilisers requires energy and uses up fuels both in manufacture and transportation; this is thus already our first potential benefit. We note as an aside that the large, well-resourced chemical companies in a Western-type system, would not necessarily be keen to drive this type of initiative.

Fuel production

Up until now, the materials that are turned into bio-ethanol have been foods (this is true for other biofuels as well), particularly those that are high in starches and sugars. This is a threat to security of supply of the food, particularly for the developing world. It further distorts the land use by making farmers try to grow crops on perhaps inappropriate land. The technology that we develop needs to look to the waste materials, not the food.

As an alternative fuel source, it is possible to produce ethanol from cellulose, and the technology is fundamentally different from that for production from food crops. Plant matter makes up the largest portion of biomass on Earth. The major constituents of the plant matter are cellulose and lignin, which leads to the common name of lignocellulose. We need to find ways to use this as a raw material. To see these possibilities, we only need to look at the veld around us and see nature at work.

For instance, termites are known to dissimilate a considerable portion of cellulose (74–99%) and hemicellulose (65–87%) of the lignocellulose. The protozoa in the termite gut ferment the glucosyl units of cellulose into acetate. It has further been shown that various protists in the termite gut degrade cellulose into acetate. The gut of the termites also contains methanogens and acetogens, which convert the excess hydrogen and carbon dioxide into methane and acetate respectively. Why could we not try to copy from nature? We could, for instance, use these organisms in bioreactors, and we are currently conducting research to investigate this.

Here we have a system that nature has spent millions of years perfecting. We need to be smart enough to use it for our own purposes. The apparent problem with the organisms is the speed with which they perform the operation. This means that if we try to carry out the operation in a mega-plant, it will be too big, because the reaction is apparently very slow and will appear uneconomical. However, if we carry out the same operation on a farm, the land use area will not be a problem and all we have to do is match the production rate with the growing rate of the plants. Thus, what was a major problem with the centralised plant disappears when we decentralise the operation.

Notice that we have not suggested going the Western route of trying to produce enzymes and then using these as catalysts. The problem with this approach is that we are likely to end up with a very complex system that could be operated only in a centralised mega-plant.

In considering the system as a whole, one must also consider the system even at the technology level as a whole. For instance, much work is often done in find the 'best' organism for a particular reaction, but does this lead to the best process? In many cases, the separation of the product from the feed is more expensive and complex than the reactor, and thus the optimal system must balance the efficiency of reaction and separation in some way. Let us give an example of how this could be applied in the production of bio-ethanol.

We have also started a research programme on using a thermophile (an organism that operates at high temperature) to do the fermentation of the lignocellulose. This could have the advantage of removing the alcohol by evaporation, thus not inhibiting the organisms. This is a very important concept, as most organisms are inhibited or poisoned in the presence of high concentrations of ethanol, and hence its efficient removal from the growing medium could increase the efficiency of the fermentation systems (reaction and separation) enormously.

In fact, ethanol separation is a major obstacle in making the overall process more efficient and addressing it at the same time, as the fermentation could lead to major advances. There are many other ideas that we are currently exploring. All of these are associated with looking at the complete system rather than looking at each of the parts individually.

Notice that we are not advocating second-class science and technology. We are going to use the best of what is available internationally to come up with systems that are the best in the world for the circumstances in which we wish to implement it.

The bio-ethanol that is produced may not be pure enough to be used directly in an engine, and the impure material may need to be transported to a small, decentralised plant for purification, but the amount transported would not be very large, and it would not need to be taken very far. As previously mentioned, the wastes from the fermentation process now become the fertiliser and animal feeds for the growing process and do not have to be transported long distances.

If one were making a bio-ethanol gel, for instance, one might not need to purify the raw material to the same extent. Furthermore, research work should be done on producing the gelling agent from the materials on hand. Perhaps some of the by-products from the processes would be suitable. Again, work needs to be done in this area.

Transportation

We notice that apart from trying to make more efficient processes for the manufacture of the fuel, we have saved enormous amounts by doing away with many of the transportation costs. This will be true even for the fuels that are eventually taken into urban areas. If these transportation cost savings are taken into account, the economics of these processes will become far more attractive. This is not currently how it is done, as everything is costed relative to some world price for a commodity that can be sold on an open market. This does not take into account the true cost for the individual of doing it the way described above. Current costing and financial models are thus not appropriate for costing such a system.

OTHER BIOFUELS

These ideas are not applicable only to bio-ethanol. We have research projects associated with the production of bio-hydrogen and bio-diesel as well. Again, we have to look at the system as a whole. For instance, if we make diesel via the trans-esterification of vegetable oils, we produce large quantities of glycerol. These are much larger than the current market will bear. We have thus started with a project to look at the fermentation of this to use in making other useful products.

FLEXIBILITY

If this technology is to help the poor in rural areas in South Africa, we believe that apart from robustness, the technology will need to be flexible. It would need to be able to handle a wide range of feedstocks (somewhat like the termite and goat!). Doing this will allow the small-scale farmer to turn waste products into potentially useful ones. These wastes could vary from season to season and year to year. The farmer would be in a position to adapt and modify what he plants in response to outside factors and not to be tied down to a single crop. Furthermore, consider the gain in quality of life and economics if the small subsistence farmer could turn the waste into a more valuable commodity that could either be turned into cash or possibly even, if are smart enough, be turned directly into a biofuel for heating, cooking and lighting.

CONCLUSIONS

We have proposed an approach to developing a biofuels industry for a developing country. The outcomes of this approach are very different from what would be, and indeed is being, used in more developed countries at present. We believe that we, in South Africa, have a unique opportunity to become world leaders in this area. In order to achieve this goal, we need to be pro-active in setting up the systems and research projects. We believe that this would be best done by setting up some organisation such as an Institute of Bio-Energy to drive this work.

For the reasons given above, it is very unlikely that Western governments or big business would drive or support such initiatives. If we believe that these ideas are worth pursuing, then African governments and funding institutions have to take the initiative to drive the processes. The examples that we have quoted in this paper are not necessarily the best way of doing things, but what we are advocating is that government policy be based on looking at the system as a whole and that we do not blindly follow probably inappropriate Western models.

ACKNOWLEDGEMENTS

We would like to thank all our co-workers in this area, including Drs Vince Grey, Michaela Vrey, Denise Lindsey, Brendon Hausberger and Prof. Chrissie Rey.

QUESTIONS AND DISCUSSION

- **Rachel Chikwamba:** In China, with a conglomeration of small-scale farmers, what you propose might be feasible but in sub-Saharan Africa, is there scope for the development of biofuels, unless we grow special crops?
- **Diane Hildebrand:** We need to understand what waste materials are available. Even sewage, for example, even though it is not cellulose, could be used as a chemical feedstock. The waste of fruit skins and even natural cut grass could be used as a feedstock. We would have to investigate what is available and we might need to adapt. There might be different levels of farming, with different feedstock and equipment. The kind of equipment that I would envisage if we get our job right is a small bin that you throw waste into and, from time to time, collect chemicals from. When you have enough, someone would come and take them away. Otherwise you use the chemicals you produce as your own energy source for cooking and heating.
- **Martin Fey:** Could we start the termite counts? Apparently the reason why Australian termites are more sluggish than South African termites is that they do not have fungus gardens, as South African termites mostly do. Presumably it is the fungi in the fungus garden that do the digestion, rather than the termite itself.
- **Diane Hildebrand:** The bacteria in the gut of the termite perform the function. The termite even seems to have different stomachs, containing different bacteria.
- **Martin Fey:** What function does the fungus then perform?
- **Diane Hildebrand:** I think it also helps with the breaking down. We need to investigate this, first looking at the operation of all the chemicals

together and then isolating them. Termites use acetate rather than glucose as their energy source.

- **Kobus Eloff:** What about ruminants, including sheep and goats?
- **Diane Hildebrand:** If you have ideas, we would be willing to discuss these and perhaps to work with you.
- **Florence Wambugu:** In the USA, excess grain sugar beet and corn stems are used for biodiesel. What happens if there is a famine? South Africa produced excess grain last year, but there could be a famine next year, in which case the stored excess would be used. Africa cannot feed itself and imports 25% of its grain. If we use grain for biofuel, who will feed the rest of Africa? Another concern is the Middle East crisis.
- **Diane Hildebrand:** For these reasons, we need multidisciplinary groups, including economists, to look at the issues and consider the implications. If one starts initially on a small scale, it is not a philosophical issue of a megaplant that is consuming a considerable proportion of the country's maize production. In Africa, we should avoid using food crops for producing biofuels and use waste as the focus.
- **Felicity Blakeway:** Thank you for a very stimulating presentation. Have our local timber producers aligned themselves with you in terms of what they do with their waste?
- **Diane Hildebrand:** No, but we are aware of the existence of mounds of wood chips. One of the ideas is to sell the process once we have developed it.
- **Unidentified speaker (CSIR):** So much land is dry where oil crops could grow, and there would be no competition with food crops. In developing biofuels, it might be possible to make use of drought-resistant plants in areas like that.
- **Diane Hildebrand:** We need to be multifaceted and use different technologies and feed materials in different situations.

SECTION 4

General discussion and summing up

Introduction

Wieland Gevers

The Academy thanks Prof. Mundree for convening the forum and chairing the Committee on Science for Poverty Alleviation. The Academy is very young and, with some humility, is trying to ensure, as it develops its activities, that it is actually adding value to the national system of innovation. Delegates are therefore encouraged to complete the feedback forms which will enable us to improve the effectiveness of our activities.

In that context, it is important to know that the Academy is broadly speaking following the lead of the US National Academies, which in 1863 were commissioned constitutionally by Abraham Lincoln to advise the American nation at the level of the executive, the judiciary and the legislature on matters that are science-based, requiring scientific knowledge and insight. Over 150 years of operation, they have developed a very sophisticated set of methodologies in order to try to make that contribution. In a nutshell, there are two contrasting, but not mutually exclusive, methodologies that they now use to produce over 200 reports a year, which is by far the highest volume produced by any Academy. However, many of the other world academies (such as the Royal Society, the French Academy and the national academies of Mexico, Brazil, China and India) are showing a marked tendency to concentrate on this activity.

The two methodologies are:

- A consensus panel – a number of people, experts in different aspects of the problem under investigation –, who investigate the evidence, test it in various ways and ultimately write an authoritative report on the matter, with findings based on the evidence and carefully considered recommendations for the government and for the country at large.
- A forum steering Committee (known as a board in the USA) considers a broad topic over a period of time (possibly many years) and identifies particular topics to be discussed, usually at a public forum such as this, which is multidisciplinary and multi-perspective, while having a focused

topic. Forum proceedings are then published, which are not simply the collection of papers, but are carefully usually edited for continuity, with an introduction in which the Committee chair and/or forum organizer explains why a certain group of papers has been included.

We are using the latter methodology in the present case. The session we are about to embark upon is designed to establish whether there is agreement among the delegates about key issues that been raised by the presentations.. Anyone is free to make a proposal and to test it against the opinions of other delegates, with a view to having it taken up as a recommendation if consensus can be achieved.. It may still be a very raw recommendation, requiring considerable further elaboration, or may be crystal-clear already. This methodology has already been found extraordinarily useful in the USA and is being used in many countries. It is part of what the Academy is doing to show that it can add value to the national effort.

Many of the concepts we have heard today (e.g. which are clearly multifaceted and multidisciplinary) have a bearing on something that is important in modern thinking about research and its application in practice. Michael Gibbons (a Canadian working in the UK) has contributed the concepts of Mode 1 and 2 research : Mode 1 is traditional disciplinary research, which until recently accounted for nearly all the research activities of university departments. Mode 2 by contrast recognises the multi-faceted nature of all real problems faced by society and is team research done by teams of people with different expertises, who seek to make a synthesis in their joint project, building on the strengths of the different disciplines involved. North-West University has recently formally adopted a policy of doing mostly Mode 2 research/

Another term is 'consilience', which as some of you may know from the book by Edward O. Wilson, is the notion that all the disciplines that humans have created are artificial constructs designed to deal with the same reality in different ways. They are simply useful tools to sharpen our wits in certain ways. However, ultimately they need to cross boundaries to deal with one reality, in order to provide solutions that really work in practice.

These things tell us that in the modern world, while disciplinary strengths are still essential as the foundation for sound training – people must be well trained and have a good detailed knowledge of what they are working with and researching – they need to cooperate in order to create a useful synthesis. The real world is not a mono-disciplinary construct.

PLENARY DISCUSSION

- **Unidentified speaker:** Would Ian Robertson please elaborate on how you take results to small-scale farmers? There do not seem to be extension agents involved. What inputs are there?

- **Ian Robertson:** The first project we were involved in was together with the Swedish Centre for Cooperation, who mandated to us that we must work with the Zimbabwe Farmers Union (which is dominated by politicians). The Zimbabwe Farmers Union selected the farmers for us to work with. This was difficult for us. Because our graduates were mostly from the rural agricultural society (two-thirds grew up in a village), they knew the context and worked with the Farmers Union, establishing who were serious farmers and who were politicians. That is why I emphasised the importance of transparency.

The extension workers are very short of money. We always invite them to our functions. They are excellently trained people, but they are not able to attend unless we pay them, which we are not in a position to do. We have therefore had to take our results to communities on our own. Our graduates are from villages and thus provide continuity. Researchers disseminate the results. NGOs sponsor us to meet with groups of farmers. We are thus in direct contact.

- **Unidentified speaker:** Where does the input finance come from? Who interprets the results? Do you use fertilisers?
- **Ian Robertson:** Mostly personal financing was used initially. We ran up a debt of £30 000. We are now breaking even and even financing some students. We make very little use of fertilisers. The planting material is so good and there is often residual in the soil.
- **Unidentified speaker (CSIR):** Most of the farmers that Ian Robertson is working with have on average a grade 10 education. They can read and write and conduct planning. They have certificates and are trained. They understand. This is where the role of participatory rural appraisal comes in, in order to understand how they think.
- **Kobus Eloff:** One of the things we have missed at today's workshop has been the most important resource of the rural people, namely the local resource plants available to them. It is difficult to derive the value from such plants, but it is something that should be considered. We talk mostly of medicinal plants, but there are many other valuable uses of plants that require more work.

We have spoken very little about agricultural animals, which are another important aspect of poverty alleviation. We need better procedures for treating sick animals and for animal production.

The papers were very good, but not all were relevant to the issue of poverty alleviation. The most valuable aspect of the workshop was to listen to the views from the different disciplines, so that we can see the possibilities of collaboration.

- **Wieland Gevers:** Delegates are directed to the supplementary reading contained in the workshop folders on agriculture for high value, for instance the perfume and medicinal industries, which augment today's theme.

- **Ian Robertson:** With respect to the earlier question on costs, our staple food in Zimbabwe is maize. We need 2.5 million tons per annum. Stem borer takes 5% of that, and we thus lose US$30 million per annum. The Bt gene is available, along with the technology for inserting the gene. I cannot understand why we do not use it. The technology has to be adapted for the differing germplasm in different place. South Africa and Zimbabwe have both begun working on the issue. President Mugabe has recently acknowledged the value of biotechnology, so there is likely to be some progress. It would help the farmers to have disease-resistant crops.
- **Florence Wambugu:** I have learnt a lot from the workshop. The policy aspects of science were missing, however. The government positions are very important. Policy and politicians control funding, policies and directions. We have to find way of reaching out to get the results we are looking for. In the future, we should include the NEPAD position, which is integral to policy throughout Africa and is also in a position to be a disseminator.
- **Rachel Chikwamba:** The Academy is looking into issues of policy as an enabling background. In this workshop that has focused on technology for poverty alleviation, is there scope for investigating facets of science that foster the development of home-grown technologies? We would have to look at how the funding tools could be used in this regard. Many would want to see products and see impacts. We need to step back and consider the fundamental resource on which we can grow technologies at home.

Two speakers were from other countries in the region (Florence Wambugu and Ian Robertson). I hope there is an opportunity for the Academy to engage with other academies or other research institutes with respect to the outcomes of the workshop. Is there a way to have a forum to consolidate science at this level, in other words, a NEPAD or regional approach and outlook to scientific research issues?

- **Wieland Gevers:** With respect to the way in which the Academy is seen in the national system of innovation, I couild mention that the DST works with other line departments, who are beginning to accept that the national Academy can develop policy recommendations to them and help resolve national debates. For example, we have heard from Prof. Crewe and Prof. Mundree that the Academy was commissioned to set up the Committee on Science-based Approaches to the Alleviation of Poverty and to bring back the "products" to the relevant departments (whether Agriculture, Health, or Science and Technology). The government departments concerned could achieve this in other ways, setting up their own panels or holding their own workshops. But the value of the Academy synthesis that it is an independent body without vested interests. professionally run to do this kind of job.

The proceedings of this forum will be brought to the attention of relevant authorities, and the Academy can engage with government departments such as the DST or DoA directly. Comments, for instance, on the poor support for plant pathology, will appear and can lead to a process whereby the National Research Foundation (NRF) and other funding agencies change their polices. We will highlight that the MSV project is to a large extent a local, very high-level intervention, with large potential for South Africa and other countries in Africa. We will point out that this is the type of initiative in which South African science and technology should be engaging, rather than adopting overseas technologies.

The Academy thus has the brief to act as a free agent and then come back to brief government.

- **Laurie Steenkamp:** I am part of SEDA Technologies, which is a small enterprise development agency with two parts to our programme: (1) incubation – we have a number of agriculturally based incubators, including biodiesel, essential oils and floriculture and (2) technology transfer, in the course of which we become involved in agricultural processes. I believe that the multidisciplinary approach is the right way to go, because one needs the input of many disciplines to address all the relevant aspects. We have found we need to work with a number of institutes, universities and government to make things work. We get involved in big projects, for example, hundreds of hectares of sisal in Limpopo are now being processed to fibres. The approach should be to look not only at the basics but also the implementation of projects.
- **Stroebel Hofmeyer:** We should bear in mind that the commodity market in South Africa is not accessible to small farmers due to the global market situation and the efficiency of high-tech commercial farming. Small farmers have to rely on markets of proximity for their surplus commodity products. The challenge is to involve small farmers to the value-adding chain leading to high value speciality products.
- **Wieland Gevers:** One of the most thought-provoking things to come out to the workshop was Tim Hart's reality check on the high proportion of people in South Africa (77% in 2005) who undertake agriculture at a small scale to add additional food to their table or supplement their income (but not in a commercial sense).

We have to take this in the context of Florence Wambugu's comment about Africa as a whole having a very low yield per hectare of selected major crops. Whereas sugar in Africa has approximately the same yield as elsewhere, the yield for bananas is only one tenth of the global average. There are thus gross disparities. This is an Africa-wide view, which is obviously based on the issue of whether

Africa can feed itself as well as export specialty crops such as tea and coffee, which find a good export market. We have to interface this with Tim Hart's analysis of the actual situation in South Africa's population, as well as with Diane Hildebrandt's contribution of a systems approach, which is a particular mindset of thinking in terms of whole systems whenever making any intervention.

- **Felicity Blakeway:** I would like to comment on the influence that the Academy can have on government policy. This is a very broad statement, but we have a very specific opportunity at the moment, namely to feed into the institutional response to ASGISA (Accelerated Shared Growth Initiative of South Africa), some of the objectives that relate directly to the topic of today's discussions, particularly the growth of the second economy. My challenge to the organisers is how quickly the synthesis of today's workshop can be made available so as to feed into the institutional responses to ASGISA.
- **Sagadevan Mundree:** We appreciate the urgency and undertake to work expediously. Your feedback, and the turnaround time, is also important.
- **Wieland Gevers:** One is accustomed to conference proceedings appearing two years later. The Academy had a successful workshop on Evidence-based Advice on 3 March 2006. The volume was published just before the end of September. We can shorten that time. We accept that we should move as fast as we can.
- **Felicity Blakeway:** I wish to clarify why I raised the issue. I know that there is opportunity for institutional response on ASGISA to the Deputy President, starting in about February 2007. Much of what was raised at the workshop is relevant to both ASGISA and JIPSA (Joint Initiative on Priority Skills Acquisition).
- **Unidentified speaker (DST):** I am a strong believer that ASSAf has a responsibility to convert some of the research to tangible outcomes that can be taken to communities of small-scale farmers (for instance, the work of Prof. Dakora), at which level it could make a difference. We need to consider how to communicate the research to small-scale farmers.
- **Wieland Gevers:** With that prompt, how does Prof. Dakora see some of the innovative biofertilisation approaches becoming general practice if they are really so much better?
- **Felix Dakora:** If one narrows it down to South Africa, what are the major crops that are cultivated by small-scale farmers? If we could identify these, it would allow us to narrow down the short-term priorities in making recommendations to government.

Another issue is the scarcity of land. We have not touched on the issue of land limitations for small-scale farmers. In Mpumalanga, women farmers have a partnership with Sappi and Mondi to access land for cultivation. The forestry companies allow women to crop between the forestry lands, free of charge, which provides nitrogen to the trees and works well for both parties. Mondi and Sappi do not have to use pesticides, as the women remove the weeds

Emerging farmers need to become involved in farming two new crops, namely rooibos and honeybush tea. In Wupperthal and elsewhere in the Western Cape, emerging farmers are engaging in tea production. Europe is prepared to pay more for organically produced tea. The small-scale farmers do not have the resources for additional inputs. The rooibos tea plants usually die off after five to seven years, but with zero inputs, the plants survive up to 12–14 years. Government could encourage and invest in research in this field to enable small-scale farmers to engage in tea production.

It is a matter of working together with the farmers. In the urban townships of Cape Town, there is a programme based on vegetable gardens. In a small plot of land, a legume-based system works best. We need more research effort on the input versus the output with respect to legumes, in cooperation with DST. However, it would be difficult to be prescriptive about the way forward.

- **Prof. Kunert:** In legume work, we need to differentiate between commercial crops and smaller ones. The problem is that there is not much financial support to put effort into, for instance bambara nut, marama bean (found in Botswana and Namibia) and peanuts, although the latter is one of the most important crops in Africa.
- **Jonathan Dowey:** The programme I operate is essentially a commercialisation programme linked to a municipality. The focus is on natural resources, including agricultural crops and beneficiation. We had an invitation to attend the workshop, which we regard as a networking exercise. We face the challenge of funding. I will circulate to all delegates by e-mail information on our programme and would welcome feedback.
- **Wieland Gevers:** We will circulate the list of contact details of delegates as feedback to enrich the process.
- **Florence Wambugu:** I have two comments:
  - The traditional medicine programme that is mentioned in the transformation review of Biochemtek, CSIR could have an impact on the whole of Africa. I realise that most African countries still use herbs. The facilities in the CSIR could become involved in packaging and marketing. At present, Chinese herbal medicine is taking over in the USA. African herbal medicines have the potential to become generic, and I would like to recommend make them commercially available.
  - With respect to the leadership position of South Africa in biotechnology in Africa, it is important to realise the need for the South African government to help other African countries in biosafety policy development so that they can expand their trade. Kenya, Burkina

Faso and Nigeria, for example, are trying to establish biotechnology industries. The products could go to the rest of Africa.

- **Wieland Gevers:** Prof. Mundree is to attend a conference in Cameroon where the major science academies of Africa will be represented. Perhaps he could use that opportunity to talk about this workshop and link with other similar academy efforts.
- **Kobus Eloff:** We are involved in an initiative with European Union (EU) funding. During a meeting with people from all over Africa, involving scientists working on medicinal plants, as well as producers, exporters and importers of medicinal plants into Europe, they identified that southern Africa has just under 30% of the world's plant species, but a low level of medicinal plants imported into Europe. The main reason is that there is insufficient information on them available to enable a comparison with plants from China and Asia, which have written documentation on their medicinal plants. At a subsequent meeting, the 50 most important African medicinal plants were identified, and trading profiles have already been written for 21 of these. An initiative such as this could create jobs, partially through growing these crops in small areas as well as in quality control. A positive aspect of the project is the large-scale cooperation and collaboration, as well as enthusiasm.
- **Unidentified speaker:** The DST is funding the CSIR to do that with medicinal plants.
- **Felix Dakora:** I have a question to Prof. Wambugu. I am impressed with the success of the consortium and the large grant they have received, which will make a big difference to research in Africa. I have read of a huge sum that the Gates Foundation is making available for agricultural research in Africa, in conjunction with the Rockefeller Foundation. How can African researchers access some of the money? One of the fundamental problems confronting African researchers is that initiatives often end up in the hands of outside colleagues. African researchers are only involved as an add-on. Could the Academy do something to address this issue by identifying opportunities and assisting individuals who would be interested in accessing the funding? This would lend greater legitimacy to what we came to do. The main aim of the project is to train agricultural scientists across the board, including scientists engaged in the kinds of issues we have discussed. Could Prof. Wambugu provide more information on the funding available?
- **Florence Wambugu:** The Gates Foundation has started an agricultural programme, for which US$100 million has been made available. Previously they only funded medical research. They are committed to investing in R&D and delivery. They want products as the outcome of the research.

They want to fund projects with several consortium members and clear paths of technology delivery. The challenge is to identify good projects, as well as institutions that could be involved. I would advise the Academy to take a proactive approach and write to the Gates Foundation. Three months ago, they floated the announcement of projects. The Academy could look these up on the Gates Foundation website and spread the word.

Of the half a billion dollars available for the programme in which we are involved, only one project out of 43 is operated in Africa. The rest of the money all went to the West. It is up to us as African researchers to network and to market good projects and researchable ideas.

- **Felicity Blakeway:** We will circulate to delegates a summary document of the Gates Foundation programme, which they are calling A New Green Revolution in Science and Technology.
- **Wieland Gevers:** Thank you very much.
- **Danie Brink:** Since much of the output of this workshop will have major inputs on policy and policy processes, I am concerned at the poor reflection of animal science in the programme. Strategically, one should not overlook the contribution of animal science.

Another matter of concern, from a national perspective, is the job losses in the first agricultural economy. Most of the technologies we have been discussing today are generated in the first economy.

If we link science institutions to rural communities, we can solve the technological requirements of those communities. The Minister, at the recent International Science, Innovation and Technology Exhibition, expressed this as something he would like to see. We can gain more, more quickly, if we can also link the first, second and subsistence economies. We might be surprised at the technology flow between them, but they are highly segregated in South Africa at present. Policies and strategies should focus on creating more efficient links between these various economies, fostering the flow and exchange of technologies, and not only on linking conventional research institutions with communities, which is also important.

- **Wieland Gevers:** It has become clear that the meeting supports a proposal to have a complementary forum dealing with animal production as a second major theme in small-scale agriculture.

CONCLUDING REMARKS

- **Wieland Gevers:** Finally, many thanks again to the organiser, Prof. Sagadeven Mundree, as well as all the speakers especially those from other countries, and all the participants for attending and engaging in the deliberations associated with this important evolving methodology for the Academy for investigating how the contributions of science to national development can be maximised, especially to the alleviation of the manifest poverty that still plagues the land.

APPENDIX 1

Committee Member, Speaker and Staff Biographies

COMMITTEE MEMBERS

- **Sagadevan Mundree**, MASSAf, (Chair) is the Chief Executive Officer of PlantBio Trust. He is currently an Associate Professor in the Department of Molecular and Cell Biology at the University of Cape Town (UCT). Sagadevan returned to South Africa in 1997 and took up a Post-Doctoral position in the Botany Department at UCT, and in 1998; he was offered a lectureship in the same department. In 1999, he moved to the Microbiology Department where he developed his research further. His research focuses on the molecular dissection of abiotic stress tolerance in plants using the monocotyledonous resurrection plant *Xerophyta viscosa* as a model system. He received the Distinguished Teacher Award at UCT recently. Sagadevan has been inspired by the role of entrepreneurship and innovation in the biological sciences and has an unwavering commitment to develop the Plant Biotechnology sector in South Africa. During his PhD studies, he received a number of accolades.
- **Ann Bernstein,** MASSAf, is the founding director of the Centre for Development and Enterprise. She was educated at the University of the Witwatersrand and the University of California, Los Angeles. The first part of Ann's professional career was spent working for the Urban Foundation. In 1991 she was a Visiting Fellow at Peter Berger's Institute for the study of economic culture, Boston University. In 1994 she was appointed to the Development Bank Transformation Team and subsequently to the Transitional Board of the Development Bank of Southern Africa. From 1997 – 2001 she was a member of the Board of the Development Bank. In 2007 she was appointed to the board of the Brenthurst Foundation, which focuses on African development. Acknowledged as one of the country's leading development experts, she is a strong proponent of the importance of economic growth in promoting democracy and sustainable development.

She has published extensively on business, democracy, development and policy-making in South Africa. In 2005 she was selected as a Reagan-Fascell Fellow at the National Endowment for Democracy in Washington DC.

- **Daniel Ncayiyana,** MASSAf has been editor of the *South African Medical Journal* since 1993, and currently serves as Advisor to the President of the Human Sciences Research Council. He received his medical degree from the University of Groningen Medical School in the Netherlands in 1970. Subsequently and following post-graduate training at Albert Einstein and New York University medical schools, he was Board-certified by the American Board of Obstetrics and Gynaecology, was elected Fellow of the American College of Obstetrics and Gynaecology, and was in practice in the US 1970-1983. Back in South Africa, he served as chief medical superintendent of Umtata General Hospital, Dean of Health Sciences, and acting vice chancellor, University of Transkei. Subsequently, he was deputy vice-chancellor, UCT 1996-2001; and vice chancellor, Durban Institute of Technology 2001-2005. He was awarded an Honorary Fellowship of the Colleges of Medicine of South Africa, and was appointed honorary professor of obstetrics and gynaecology at the Universities of Cape Town and KwaZulu-Natal. He is a longstanding consultant to the World Bank and the WHO.
- **David Dewar,** MASSAf is Professor of Architecture, Planning and Geomatics and Deputy Dean of the Faculty of Engineering and the Built Environment, University of Cape Town, and founder member of the Urban Problems Research Unit and Director of it from 1980-1991. From 1993-5 he was Dean of the Faculty of Fine Art and Architecture. In 1998-1999 he was a member of the National Development and Planning Commission, appointed to prepare a Green Paper on the future role of Planning in South Africa, and was Chair of one of the three working groups. From 1992-98 he was a member of the Statutory South African Council of Town and Regional Planners. He was awarded the Ernest Oppenheimer Travel Fellowship twice (in 1979 and 1985), the J.B Harbour Visiting Scholar, Israel and won the Four Outstanding Young South Africans Award in 1983. He has received numerous awards from the South African Institute of Architects, the South African Institute of Town and Regional Planners, and the Journal of South African Architecture, both for his research outputs and professional work. He was elected an Honorary Life Member of the newly formed Urban Design Institute of South Africa in 2005. In 2005 he (with P Louw) were placed in two international competitions of the Union des Architects (UIA), including first prize for a plan for the Centre of Port Louis. Dewar is a Life Fellow of the University of Cape Town

- **Mamphela Ramphele,** MASSAf, is currently Chair of Circle Capital Ventures, a Black Economic Empowerment company that focuses on unleashing the fortune at the margins of the socio-economic circle. She is a former World Bank Managing Director, responsible for human development activities in the areas of education; health, nutrition, and population; and social protection. Mamphela qualified as a doctor in 1972, and in 1975 she founded a Health Centre in a village outside King William's Town and was also the manager of the Eastern Cape branch of the Black Community Health Programme. In 1996 she became the vice-chancellor of the University of Cape Town. She played a key role in the Black Consciousness movement in South African and has published a wide range of books and articles on the themes of education, health and social development. She serves on the boards of major corporations and non-governmental organizations, including the Nelson Mandela Children's Trust, and has received numerous national and international awards, including three honorary doctorates.
- **Priscilla Reddy,** MASSAf, is presently Director of the health promotion research and development group at the Medical Research Council in Cape Town, South Africa. She is currently advising the Chief Directorate of Health Systems, Directorate Health Promotion and Department of National Health. Since 1992 she worked as a scientist at the Medical Research Council, first as a researcher in the National AIDS Programme, and then as a senior scientist in the Health Promotion Research & Development Office. She studied Nursing at the University of Cape Town and Public Health at the University of Massachusetts. She was a member of the Communication Working Group of the National AIDS Committee of South Africa. Some of her many contributions has been to create a science out of the study of behaviour and health promotion and garnering methods from a range of disciplines which has led to a zealous approach to changing lifestyle trough public intervention.
- **Renfrew Christie**, MASSAf is Dean of Research at the University of the Western Cape, where he has also been Community Law Centre since 1995 to date. Previously, in 1971 and 1972, he was Deputy President of the NUSAS, prior to that he was tutor and then junior lecturer at the University of Cape Town. Between 1986 and 1987, he was an Economics Research Fellow at SAIRR and then became an Academic Planning Officer at the University of Cape Town during the period of 1987 till 1990. Some of Renfrew`s achievements and awards includes, Hon Life Member of the National Union of South African students (NUSAS) 1972; Field marshal Smuts Scholar, St Antony`s College, Oxford, 1975-1979; Fellow and General Secretary of the Royal Society of South Africa, 2004 and Chief of

the South African navy`s Certificate of Commendation, 2005. During the period of 1989-1993, he was Chairperson of South newspaper. He has been a visiting fellow at Michigan State University in 2006; Woodrow Wilson Internat Centre Scholars, Wash DC in 1994; Stiftung fur Wissenschaff und Politik Ebenhausenin 1994 and the Indian Ocean Peace Centre Perth WA in 1992.

- **Solomon Benatar**, MASSAf is Professor of Medicine and Founding Director of the University of Cape Town's (UCT) Bioethics Centre, and was Chairman of UCT`s Department of Medicine and Chief Physician at Groote Schuur Hospital. He is Visiting Professor in Public Health Sciences and Medicine at the University of Toronto, and Director of a NIH (Fogarty International Center) funded program for capacity building in International Research Ethics in southern Africa. His academic interests have included respiratory medicine, academic freedom, medical ethics and the humanities in medicine, human rights, health care systems, health economics and global health. Honours include election as: Foreign Associate Member of the U.S. National Academy of Sciences' Institute of Medicine; Honorary Foreign Member of the American Academy of Arts and Sciences; Fellow of the Royal Society of South Africa; Life Fellow of the University of Cape Town, Honorary Fellow of the South African Thoracic Society; Honorary Fellow College of Physicians of South Africa; and Honorary Member of the Alpha Omega Alpha Honor Medical Society, California.

SPEAKERS

- **Diane Hildebrandt**, MASSAf, a member of the Academy of Engineers in South Africa and Fellow of the Royal Society of South Africa. She is the co-Director for the Centre for Optimization, Modeling and Process Synthesis at the University of the Witwatersrand. In 1998 Diane became the first woman in South Africa to be made a full professor of Chemical Engineering when she was appointed as the Unilever Professor of Reaction Engineering at the University of the Witwatersrand. She has worked at Chamber of Mines, Sasol and the University of Potchefstroom and has spent a sabbatical at Princeton. Her main research is in systems analysis of processes. She was awarded the Presidents' Award by the Foundation for Research and Development as well as the Distinguished Researcher Award by the University of the Witwatersrand in 1996. In 2005 she was recognized as a world leader in her area of research when she was awarded A rating by the National Research Foundation.
- **Ed Rybicki**, MASSAf is a Professor in Microbiology at the University of Cape Town and a Founder Member of the Institute of Infectious Disease

and Molecular Medicine (IIDMM) based in the University's Health Sciences Faculty. His teaching specialty is Molecular and General Virology, then Molecular Biology Techniques specializing in PCR, with some dabbling on the side in Molecular Immunology. Rybicki`s main research interests are presently in making human and animal vaccine candidates in plants and insect cells: these include vaccines for mucosal Human papillomaviruses (HPV) and Human immunodeficiency virus type 1 (HIV-1) subtype C. His other interest is in the diversity of Southern African *Mastreviruses* (family *Geminiviridae*), the molecular determinants of pathogenicity and host range in these viruses, and especially in *Maize streak virus*, the use of geminiviruses as vectors of foreign genes in plants, and in the engineering of viral resistance in crop plants.

- **Florence Wambugu** is the Chief Executive Officer of Africa Harvest Biotech Foundation Int'l. (AHBFI or Africa Harvest). Previously she was Director, International Service for the Acquisition of Agri-biotech Applications, African Region Office (ISAAA – *Afri*Center), Nairobi -Kenya. Florence holds several awards and honors from local and international institutions in recognition of her outstanding work in Africa. Some of her memberships to professional boards includes, Executive Committee member of Forum for Agricultural Research in Africa (FARA), Board of Trustees International Plant Genetics Resource Institute (IPGRI) and member of United Nations Millennium Development goals Hunger Task Force. Over the last ten years, Dr. Wambugu has successfully provided leadership in public/private partnership and scientific consortium for implementation of various major projects for crops and tree improvement, with significant impact on the livelihoods of smallholder farmers in rural communities.
- **Ian Robertson** is the Chief Executive Officer of Agri-Biotech (Pvt) Ltd, which aims to supply small and large-scale farmers with quality germplasm. He used a tissue culture system to show that plant cells need twice the DNA before they can divide in his PhD from Edinburgh University, Scotland. Since 1977 he has tried to teach over 3,000 Zimbabwean agriculture students how to think scientifically and innovatively. Currently he is supervising six post graduates doing translational research that aims to put useful, already characterized, genes into Zimbabwean crop cultivars from which farmers will really benefit.
- **Martin Fey** is Professor of Soil Science & Chair, Dept Soil Science, University of Stellenbosch. Prior to that, he was Senior Lecturer/ Associate Professor at the Department of Geological Sciences, University of Cape Town. In 2000 he convened the 5th International Symposium on Environmental Geochemistry in Cape Town. He was editor of the South African Journal of Plant and Soil and on the editorial board of Applied

Geochemistry. He has worked in close conjunction as a researcher and environmental consultant with several South African industrial and mining companies, has consulted on soil problems in the Congo, has visited Kenya regularly to advice on soil problems in the tea industry and has conducted bauxite investigations in Guyana. His awards include the BP scholarship in Agriculture, Soil Science Society of South Africa medals for best conference papers and the Fertilizer Society of South Africa's Silver Medal for Research. He serves on the South African Soil Classification Working Group and the National Research Foundation evaluation panel for Earth Sciences.

- **Robin Crewe**, MASSAf is Vice Principal of the University of Pretoria, and President of the Academy of Science of South Africa (ASSAf). He obtained his Ph.D. in Entomology from the University of Georgia where he developed his interest in chemical communication and social organization in social insects. He was Director of Communication Biology Research Group of the University of the Witwatersrand for 10 years and Dean of Science Faculties at both the Universities of the Witwatersrand and Pretoria. Robin has been active in the development of professional registration of natural scientists and the promotion of a number of learned scientific societies, including the presidency of the Entomological Society of southern Africa. Some of the Honours he received include, Gold medal of the Zoological Society of South Africa, honorary member of APIMONDIA and Fellow of the Royal Entomological Society. He is a Member of two academies of Science.
- **Siyabulela Ntutela** is currently Deputy Director: Biotechnology at the South African Department of Science and Technology. Prior to that in 2002 Nov – 2005 December he was a USAID/ Fogarty Postdoctoral Fellow at the Desmond Tutu HIV Centre in the University of Cape Town. Between January 2002 and October 2002, he worked at the Medical Research Council / University of Cape Town, Department of Pharmacology as a Postdoctoral Researcher. He worked at the University of Cape Town's Department of Pharmacology as a Research Assistant between January and March 1998. He has been a Postdoctoral Fellow at the Public Health Research Institute, NJ, USA between September 2003 and December 2004 participating in a study of the molecular epidemiology of TB in HIV endemic communities. He has presented numerous research papers in the fields of TB, HIV and traditional medicines as well as intellectual property rights.
- **Tim Hart** is a Senior Research Manager in the Urban, Rural and Economic Development Research Programme at the Human Sciences Research Council (HSRC). Before joining the HSRC in July 2004, he was a senior researcher at the Agricultural Research Council (ARC) Infruitec-Nietvoorbij

in Stellenbosch. Tim is a member of a number of South African professional organizations, including the international network PROLINNOVA (Promoting Local Innovation in Ecologically-oriented Agriculture and Natural Resource Management); and also serves as a reviewer of various scholarly journals. His areas of research interest include indigenous knowledge and its contribution to sustainable development, with special emphasis on its use in agriculture amongst smallholder farmers and as a means to improve food security amongst rural communities; participatory research methods and their application (use and abuse) within development programmes; participatory programme evaluation; and the conceptualization and design of agricultural development projects.

- **Wieland Gevers**, MASSAf and ASSAf Executive Officer, previously he was Senior Deputy Vice-Chancellor responsible for planning and academic process at the University of Cape Town from 1992-2002. He was twice President of the South African Biochemical Society, and President of the Academy of Science of South Africa from 1998-2004. He is a Fellow of the Academy of Sciences of the Developing World, was Acting Chairperson of the Education Committee of the South African Universities` Vice-Chancellors Association during 2001-2002, and represented all South African Universities on the South African Universities on the South African Qualifications Authority from 1996-2002. Gevers was awarded the Welcome Gold Medal for Medical Research, and the Gold Medals of both the South African Society for Biochemistry and Molecular Biology, and the South African MRC. In 2004, Gevers was given the NSTF's "Achievements as an individual over a lifetime" Award.

STAFF

- **Rudzani Ramaite** is a Projects Officer at the Academy of Science of South Africa (ASSAf). She is also study director for ASSAf forum-type study on Science for poverty alleviation. Since joining the Academy, Rudzani has been involved in organizing a number of local and international workshops and conferences, she is also a co-editor of the ASSAf quarterly newsletter, *Science for Society*. Before joining the Academy in November 2005, she worked at the Centre for Environmental Economics and Policy in South Africa (CEEPA) that is located in the University of Pretoria (UP), Abbott Murex Kyalami SA. Rudzani received her Masters Degree in Microbiology from the University of Pretoria in 2004; she has published part of her Masters Thesis work as chapters in a book. She has an interest in water resources management, and has currently registered for a PhD in a related field.

- **Boitumelo Mabina** is a Projects Officer at the Academy of Science of South Africa (ASSAf). Boitumelo is a master graduate from the University of Free State specializing in Molecular Biology – Genetics in 2003. She also holds a certificate in Project Management from Standford College.She started her employment history at the AMPATH laboratories as a Medical Scientist for three years. She was then employed as at the academy as an Assistant Projects Officer from 2005. She is currently a study director for ASSAf consensus study.
- **Xola Mati** is a Projects Director and Director of the Scholarly Publishing Unit at the Academy of Science of South Africa (ASSAf) where he has worked since June 2004. His primary responsibility is to oversee the management of the four programmes of the Academy by the responsible staff which are a) Administration and Internal activities, b) Strategic Management of Research Publications, c) International Academy relations and d) National and Regional activities, under the supervision of the Executive Officer. Previously he was a Research Specialist at the Human Sciences Research Council (HSRC) and a Senior Researcher at the University of Cape Town (UCT). He holds an MA in applied language studies from the Stellenbosch University and a PhD in bilingual education from the University of South Africa (UNISA).

APPENDIX 2

Workshop Programme

ASSAf Committee on:
Science-based approaches to the alleviation of poverty

Science-based improvements of rural/subsistence agriculture

Date: Wednesday 18 October 2006 (09:00 – 16:40)
Venue: DST Auditorium, CSIR Campus, Brummeria, Pretoria East

Session 1 (09:00 – 12:00)

Chairperson: Siyabulela Ntutela, Department of Science and Technology

09:00 – 09:05	Welcome Robin Crewe, President, ASSAf
09:05 – 09:20	Introduction Sagadevan Mundree, Committee Chair, ASSAf
09:20 – 10:00	Ed Rybicki, Department of Molecular and Cell Biology, University of Cape Town: "Biotechnological approaches to crop plant development for adaptation to local conditions"
10:00 – 10:40	Mark Laing, Director of the African Centre for Crop Improvement, University of KwaZulu-Natal: "Crop plant breeding perspectives for small-scale farmers"
10:40 – 11:20	Florence Wambugu, CEO, Africa Harvest Biotech Foundation International: "Developing sustainable nutritional food security through agricultural biofortification of stable crops for small-scale farmers in Africa: The Africa Biofortified Sorghum Model"
11:20 – 12:00	Felix Dakora: Dean of Research, Cape Peninsula University of Technology: "Biofertilization approaches"
12:00 – 13:00	**LUNCH**

Session 2 (13:00 – 16:40)

Chairperson: Sagadevan Mundree

13:00 – 13:40	Ian Robertson, Agri-Biotech, Zimbabwe: "Achieving some of the potential 'clean' sweet potatoes in smallholders` farmer fields in Zimbabwe"
13:40 – 14:20	Martin Fey, University of Stellenbosch: "Soil science-based improvements in subsistence agriculture"
14:20 – 15:00	Tim Hart, Human Sciences Research Council: "Socioeconomics of subsistence farmers"
15:00 – 15:40	Diane Hildebrandt, Director of the Centre of material and Process Synthesis, School of Chemical and Metallurgical Engineering, University of Witwatersrand: "The best technology and poverty alleviation: A win –win situation for Africa"
15:40 – 16:40	General discussion and summing up Facilitator: Wieland Gevers, Executive Officer, ASSAf.

APPENDIX 3

List of tables and figures

SECTION 1

Biotechnological approaches to crop plant development for adaptation to local African conditions

Developing Sustainable Food Security through Agricultural Biotechnology: The ABS Project Model

SECTION 2

Developing Bio- and Agri-technologies for Poverty Alleviation in Rural South Africa

Achieving some of the Potential of 'clean' sweet potato in small-holder farmers' fields in Zimbabwe

SECTION 3

The Socioeconomics of Subsistence Farmers and the Contribution of the Social Sciences to Agricultural Development

Biofuels for Africa: Horses for Courses

APPENDIX 4

List of workshop attendees

Arnold, Ms Robyn	Write Connection CC
Bezuidenhout, Dr CC	North-West University
Blakeway, Ms Felicity	CSIR
Brink, Prof Danie	U.S.
Brown, Ms Bernadette	CSIR
Chakaya, Dr Ereck	CSIR
Chikwamba, Dr Rachel	CSIR
Crewe, Prof Robin	University of Pretoria
Dakora, Prof Felix	Cape Peninsula University of Technology
De Greef, Mr Willy	IBRS
De Villiers, Dr Stephanie	University of Stellenbosch
Dekker, Dr Len	Biodelta
Dithane, Mr Thabo	BSTEP
Dutton, Prof Mike	University of Johannesburg
Eloff, Kobus	University of Pretoria
Enow, Dr Andrew Achno	ICSU
Fey, Prof Martin	University of Stellenbosch
Frazer, Alexandra	Cape Biotech Trust
Gardinier, Dr Neil	CSIR
Gevers, Prof Wieland	ASSAf
Gundidza, Prof Mazuru	Total Transformation Agribusiness (PTY) Ltd
Guwa, Ms Nontando	ASSAf
Hart, Mr Tim	HSRC
Hildebrandt, Prof Diane	WITS
Hofmeyr, Dr Stroebel	SAAE
Ismael, Dr Yousouf	Dept of Agricultural and Food Economics
Jacobson, Dan	National Bioinformatics Network
Khumalo, Mr Lucky	DST

Koch, Dr Susan	ARC – PPRI
Kore, Prof	University of Pretoria
Kruger, Dr Bingle	SAAE
Kuna, Prof	University of Pretoria
Ledwaba, Ms Khanya	ASSAf
Mabasa, Ms Nondumiso	ASSAf
Madiba, Mr Jerry	DST
Mamabolo, MJ	Department of Agriculture
Masia, Ms Mavis	NACI
Mentz, Mr Jan	University of Pretoria
Mini, Dr Simphiwe	DST
Mlosy, Dr Christopher	CSIR
Mndawe, Jonathan	
Moroka, Ms Tshidi	CSIR
Mpele, Simon	NACI
Mundree, Prof Sagadevan	Plantbio
Munyai, Ms Rachel	DST
Ndala, Mr Stemmer	MINTEK
Ntutela, Dr Siyabulela	DST
O`Kennedy, Dr Maretha	CSIR
Onsando, Dr James	Africa Harvest Biotech Foundation International
Radebe, Mr Thabo	ASSAf
Rakate, Mr Edward	NACI
Ramaite, Ms Rudzani	ASSAf
Rampedi, Dr Moshibudi	LEDET
Rey, Prof Chrissie	WITS
Robertson, Dr Ian	Agri-Biotech & University of Zimbabwe
Rybicki, Prof Ed	University of Cape Town
Sehlapelo, Dr Bethuel	DST
Steenkamp, Laurie	SEDA
Taylor, Prof John	University of Pretoria
Van der Walt, Retha	North-West University
Van Eeden, Mr Jaques	Rockwezc
Van Jaarsveld, Dr Paul	MRC
Van Rensburg, LD	UWC
Wambugu, Dr Florence	Africa Harvest Biotech Foundation International

2006

Science-based Improvements of Rural/Subsistance Agriculture

Academy of Science of South Africa (ASSAf)

Academy of Science of South Africa