



Risks, Livelihood and Vulnerability Programme - Working Paper

Agricultural Biotechnology and Small-scale Farmers in Eastern and Southern Africa

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Summary

The implementation of effective and successful agricultural development strategies that ensure food security in Sub-Saharan Africa represents one of the most crucial issues of the 21st century. African small-scale farmers, who are to a large extent both poor and vulnerable, are under pressure to produce more and better quality food, but are facing severe difficulties to do so. These difficulties include lack of infrastructure, management and husbandry problems, the degradation of their natural resource base, weak markets and other socio-economic constraints. Many African farmers are also confronted with challenging biological and environmental constraints including more recently the effects of global climate change. To reach maturity, food crops and livestock must be able to resist multiple stress factors, including low soil fertility and lack of fertilisers often in combination with drought and disease stress. The wide variation of agro-ecological conditions in Africa, means that crop genetics, linked to high quality breeding efforts and the development and dissemination of improved planting materials, remains one of the most effective means by which African farmers can be assisted. All over the world, and also in many African countries, breeders and scientists have been applying agricultural biotechnology, including genetic engineering, to a diverse range of crops and traits. Many of these agrobiotechnologies, including genetically modified (GM) crops, hold considerable promise for addressing productivity constraints, such as resistance to insect pests, diseases and environmental stresses facing farmers in Africa.

This study explores the conditions under which the introduction of agricultural biotechnology could result in net benefits to small-scale farmers and the rural population in Eastern and Southern Africa (ESA). The study examines the major production constraints and potential biotechnology applications for a large number of African crops relevant for resource poor small-scale farmers. It is concluded that many of the available applications in agricultural biotechnology are well suited to address an improvement in the specific traits and crops of

importance to small-scale farmers in Eastern and Southern Africa. The study however points out that the benefits of agricultural biotechnology in terms of improved seeds and cultivars has, so far, only to a very limited degree reached small-scale farmers. There is a big gulf between what agricultural biotechnology can do in principle and to what extent the technology has improved the situation for small-scale farmers in ESA. The study discusses in detail the barriers and challenges for the use of agro-biotechnology in solving the productivity problems facing small-scale farmers. These barriers include:

- The weaknesses of the public breeding systems in ESA which to only a very limited degree have been able to respond to and address the challenges facing resource poor small-scale farmers. This weakness is also manifested in an inability to harness the benefits of agro-biotechnology to the needs of small-scale and subsistence farmers in ESA.
- The high transaction costs experienced by both the public and the private sector in their efforts to disseminate potential agrobiotechnology and genetic engineering applications to address the needs of small-scale and subsistence farmers in ESA. These transaction costs are to a large degree a result of; (i) the impact of Intellectual Property Rights (IPR) where most of the patents and licenses are held by the private sector with the result that the public sector and poor farmers may not benefit from the technology because it is too expensive or not accessible; (ii) in the case of GM crops, challenging and costly requirements for generating biosafety data for regulatory approval which seriously stifles research and product dissemination efforts; (iii) negative public perceptions, and in some countries low market acceptance stifling investments in biotechnology R&D and subsequent commercialisation.
- The slow rate of introduction of biosafety regulatory measures, without which there

is no mechanism for giving approval for release of GM crops. The implementation of appropriate legal systems is further hampered by the lack of capacity in government and amongst scientists. This results in paralysis in decision making.

- Economic and supply constraints that limit the use of fertilizers and other agrochemicals, thereby limiting the full benefits of improved crop varieties.

On the basis of the above, the study also identifies a range of actions, not least in the policy arena, that could be taken by a range of actors in the region to enable agro-biotechnology to improve the productivity and livelihood of small-scale farmers. The insights gained in the report include, in brief, the call for policy makers in ESA to consider the following:

- Increased public investment in strong public research institutions and their abilities to harness the benefits of agro-biotechnology to the needs of small-scale and subsistence farmers in Africa¹.
- Increased support to dissemination and extension services on crops with low profit margin produced by the public sector but with high value for the poor and vulnerable. This would include the development of improved policies lowering the barriers for and improving the efficiency of public technology dissemination efforts. This could include the facilitation of product development partnerships, where private sector and NGOs could be engaged in new types of low cost technology dissemination efforts.
- Support to the integration of the "formal" and "informal" seed systems, where the breeding efforts by small-scale farmers are at least partly supported and integrated with the efforts in the public sector, using modern participatory

breeding approaches where agro-biotechnology² would play an important role. The introduction of new agricultural policies, including revisions of seed laws, is a prerequisite for such an integration.

- Supporting the efforts on facilitated access to proprietary agro-biotechnology, where African public sector institutions would be able to use patents and licenses held by the private sector benefiting the public breeding efforts for small-scale farmers. This would include the development of institutional and national intellectual property (IP) and technology transfer regimes and the capacity to manage IP and technology transfer issues.
- Supporting the public sector to engage in the development of generic key technologies which are available on an "open source" basis, and which can be adapted and used freely by public sector institutions to the benefit of small-scale farmers.
- Development of strategies to pool regional expertise to work in regional programmes and innovation platforms using agro-biotechnology on local crops of high relevance to small-scale farmers in ESA.
- Development of an integrated approach that would facilitate small-scale farmer access to a range of appropriate agricultural inputs in tandem with the supply of improved seed.
- Investments in efficient and, for the ESA countries, appropriate biosafety regulatory regimes and biosafety assessment capacity.

¹ Efforts that have a comparative advantage (in comparison to conventional technology) and potential to lead to increased yields of local crops and agricultural products and technology of importance to small-scale farmers and to the poor consumers in rural and urban areas.

² Such as marker assisted breeding/monitoring/characterisation.

1 Introduction

1.1 BACKGROUND TO THE STUDY

Sub-Saharan Africa remains one of the few regions of the world that is making slow progress towards attainment of millennium regional and national development targets (Sachs, 2005; Scones and Wolmer 2002) and since 1973 Africa is a net importer of food. A number of complex reasons³ account for this. One of them is the stagnation, and in some areas the actual decline, in the agricultural productivity of small-scale farmers. In recognition of the pivotal role of agriculture in Africa's development, and frustrated by insufficient progress, the continent, under the auspices of the New Partnership for Africa's Development (NEPAD) has developed a framework to enhance agricultural growth, the Comprehensive Africa Agriculture Development Programme (CAADP). The CAADP sets broad objectives for agricultural development in Africa⁴. Agricultural research, central in CAADP⁵, was endorsed by the 7th Ordinary Session of the Assembly of Heads of States and Governments held in July 2006, as a key mechanism to support agricultural productivity programs across the continent.

Africa's vision of agriculture as the engine of growth calls for a dual strategy: firstly to deliver improvement in the livelihood strategies of rural populations to achieve food security and incomes linked to markets, and secondly to increase growth in the agricultural sector so that it stimulates cross-sectoral macro-economic growth. The agricultural sector, including the multitude of industrial agro- processing industries, is of fundamental economic importance for most African countries. Accordingly, achieving the

projected CAADP agricultural output growth of 6% per annum will have catalyzing effects on economies all over the continent. Raising the productivity of the 15 million small farms on the continent using improved technology, services and policies (NEPAD, 2006) will be central in reaching the CAADP targets.

The so-called "Green Revolution", with its 'package of inputs' of high yielding varieties, agrochemicals, irrigation, and subsidies⁶, which led to dramatic increases in maize, rice and wheat production in the 1970s and 1980s in Asia and Latin America, did not take place in Sub-Saharan Africa. This, too, is due to a host of reasons. One of the main reasons is the weakness of the public breeding systems in Sub-Saharan Africa, which have been able, in only a very limited way, to respond to and address the challenges facing resource poor small-scale farmers (Conway, 1997; Djurfeldt et al., 2005). It is against this background that it is now commonly viewed as critical and urgent to produce resilient and high yielding varieties addressing the needs of African farmers. This is expressed strongly in the World Development Report 2008 by the World Bank (World Bank, 2007). The selection and combination of improved varieties and crop mixtures ought to improve overall robustness of farmer livelihood strategies (ASARECA, 2005).

Agricultural biotechnology is widely viewed as one of the key technological advancements that would enable Africa's agricultural innovation systems to meet more efficiently the needs of African farmers, which is the major focus of the CAADP (NEPAD, 2006). A key question to many developing country governments, including the donor community (Danish Board of Technology, 2003), is to what extent agricultural biotechnology can contribute to poverty reduction and sustainable development.

3 Historical, political, economic, social, technological and cultural.

4 It is within the CAADP framework, specifically pillar number 4, which focuses on agricultural research and increased productivity, that concerted efforts are being made from continental to country level.

5 As guided by the Framework for African Agricultural Productivity (FAAP).

6 Production and market price subsidies, guaranteed purchase of output by government, protected markets etc.

1.2 PURPOSE OF STUDY

The purpose of this study is to investigate to what extent agricultural biotechnology can assist small-scale and vulnerable farmers improve food security, rural livelihoods and contribute to sustainable development in ESA countries. The study is also meant to identify some of the main barriers and challenges for the use of agro-biotechnology in solving the productivity problems facing small-scale farmers. Lastly, the study aims to identify a range of actions, not least in the policy arena, that could be taken by a variety of actors in the region to enable agro-biotechnology to improve the productivity and livelihood of small-scale farmers.

1.3 ANALYTICAL FRAMEWORK AND METHODS

The *central hypothesis* of this study is that *under specific conditions* the introduction of agro-biotechnology could result in net benefits to small-scale farmers in sub-Saharan Africa. We have in this study explored what these specific conditions would be in the context of Eastern and Southern Africa (ESA) by mainly addressing the following three sets of questions and issues:

- **Prospects for biotechnology**
What are the prospects in ESA for the successful application of transferred agrobiotechnologies, including GM-technology for agricultural development and poverty alleviation, and for the promotion of national and regional research and development (R&D) efforts, in generating improved local staple food and cash crops?
- **Policy Options**
What realistic policy options and strategies are available to ESA governments to ensure that technology transfer and R&D efforts are dedicated to solving the productivity and livelihood problems facing small-scale farmers?
- **Institutional arrangements**
What institutional capacity has to be established and made operational, and what policies need to be implemented, at the national and regional levels, to ensure safety (both environmental and health), and facilitate the introduction of GM-local crops?

The study examines the major production constraints and potential biotechnology applications for a large number of African crops relevant for resource poor small-scale farmers.

In order to provide background data for the discussions and recommendations in the study, a survey was carried out in Tanzania on the various crop and livestock production constraints and potential biotechnology interventions. Researchers in a large number of agricultural research institutes in Tanzania under the Tanzania Ministry of Agriculture, Food Security and Cooperatives were interviewed by the study team. The researchers were asked about the major crop and livestock production constraints for farmers in Tanzania and their suggestions for potential biotechnology interventions. It should be noted that the constraints were limited to the crop/livestock breeding targets linked to biotic (diseases, pest etc) and abiotic production (e.g. climate conditions etc) constraints, and did not include any of the socio-economic challenges (e.g. markets, infrastructure, credits, tenure etc).

A similar study in Uganda, made by the National Agricultural Research Organization (NARO), Makerere University and Mbarara University of Science and Technology is also listed and discussed in this paper. These two studies in combination shows very explicitly the potential of agricultural biotechnology and how it can contribute to assisting small-scale vulnerable farmers improve food security, rural livelihoods and contribute to sustainable development in ESA countries.

In order to provide more detail of the processes and actions involved in creating an enabling environment for technology transfer, we have included a case study from Tanzania. This case study is included as an Annex.

We greatly acknowledge the impact biotechnology can have on animal health and livestock breeding, but the study focuses on crop biotechnology and in particular GM technology and its relevance for farmers in Eastern and Southern Africa.

2 Agriculture and the Gene Revolution

2.1 A TECHNOLOGY IN RAPID EXPANSION

Biototechnology, broadly defined, refers to any technique that uses living organisms or substances from these organisms to make or modify a product, improve plants or animals or develop micro-organisms for specific uses. Biotechnology is not a separate science, but rather a mix of disciplines, such as biochemistry, genetics, molecular biology, and cell biology.

Biotechnology consists of a gradient of technologies, ranging from the long-established and widely used techniques of traditional biotechnology (for example, food fermentation and biogas production), through to novel and continuously evolving techniques, such as genetic engineering and genomics. Biotechnology could also be seen as an integration of new techniques emerging from modern biotechnology with the well-established approaches of traditional biotechnology, such as crop and livestock breeding, food production, fermentation products and processes, and the production of pharmaceuticals.

The diversity of techniques that constitute modern biotechnology offers much promise to serve the pressing needs of sustainable development in the agriculture, industrial and health sector. For developing countries the challenge will be to develop biotechnology based innovation systems that are able to adapt relevant knowledge and technologies that can contribute to economic growth and also improve environment, health and livelihoods.

Agricultural biotechnology is becoming a progressively more important factor in shaping agricultural production systems world wide, including developing countries. Using advanced biotechnology tools, genetic resources can be more precisely characterized, efficiently improved and tailored to specific needs. The technologies can be used to support the development of sustainable production systems for food, feed and crops for industrial purposes, such as biofuel. Novel agroprocessing techniques using

biotechnology can add downstream value to crops and their byproducts.

Modern agricultural biotechnology, which includes disciplines such as genetic engineering, bioinformatics, structural and functional genomics, and synthetic genomics, is a comparatively young field of science. Thus, we have so far only seen the beginning of what promises to be a very exciting and maybe also revolutionary technology. It is important for developing countries to be part of this bioscience revolution, with its spectrum of techniques and opportunities. Countries without basic know-how will continue to be dependent on global actors and would miss the opportunity to steer technological development and to adapt and develop technologies to their own needs.

Biotechnology opportunities in the development of agriculture represent a complex and also vast topic with many uncertainties and there is rapid generation of new information. The possibilities that biotechnology offers may not yet be fully apparent, and it is likely that progress will take place far more quickly than current popular belief.

The boundaries between various types of agricultural biotechnology are disappearing, but in general the whole system of technology applications is becoming increasingly valuable to agricultural breeding systems all over the world, including those in developing countries.

Agricultural biotechnology is however not a solution or a means in itself and to a large extent depends on the existence of effective breeding programmes. Thus, agricultural biotechnology can never replace conventional breeding, but can be a vitally important tool in supporting sustainable agricultural production and breeding systems to be highly adaptive and effective in serving local needs.

2.2 COMPONENTS OF MODERN BIOTECHNOLOGY RELEVANT TO AGRICULTURE

The most common applications of agricultural biotechnology can be divided into some broad categories. Below follows a short description of these categories.

- *Molecular diagnostics* to aid crop production and protection. The use of molecular characterisation to provide more accurate and quicker identification of pathogens.
- *Vaccine technology*: the use of modern immunology to develop recombinant DNA vaccines for improving control of livestock and fish diseases. The technology for production of vaccines and antibodies in crops is developing rapidly.
- *Tissue culture* is a well-proven method for mass propagation of improved and disease free planting material for economically important crops and plant species with recalcitrant seeds.
- *Molecular breeding and marker assisted selection (MAS)*: the identification and evaluation of desirable traits in breeding programs by the use of molecular marker assisted selection (MAS). The majority of MAS techniques are based on applications of the Polymerase Chain Reaction (PCR) and amplification of selected genes or parts of genes and involves related technologies such as SSRs SNPs, AFLP, ISTR, RFLP and RAPDs⁷. Additional techniques such as Diversity Array Technology (DArT) based on DNA microarray technology, are applicable to genetic mapping and diversity analysis. These molecular breeding technologies enable the identification, mapping and evaluation of plants and animals carrying useful traits in a breeding population. These, in conjunction with conventional phenotypic

characterization, allow breeders to select crops with specific beneficial traits while avoiding the incorporation of undesirable traits in a precise way.

- *Genetic Modification (GM)*: the introduction of one or more genes, often across species barriers, conferring potentially useful traits into plants, livestock, fish and tree species. This results in a Genetically Modified Organism (GMO) which is synonymous with a living modified organism (LMO) into which genes conferring a new trait have been introduced.
- *Structural genomics*: the construction of genetic, physical and transcript maps of an organism. This involves the molecular characterisation of all genes in a species and the related assembly of data from genomic analysis into accessible forms useful to the various breeding systems. Linked to the new-found wealth of DNA sequence information, efforts are under way to determine protein structures of the derived protein sequences, thereby enabling targeted protein engineering.
- *Functional genomics*: sometimes referred to as molecular phenotyping, the aim is to utilise high throughput methodologies including proteomics, transcriptomics and metabolomics, to provide a more holistic view of the crop and its metabolic pathways that connect traits with their respective genes, thus greatly increasing the understanding of crop biology and opportunities to target interventions in breeding.
- *Bioinformatics*: computational tools are used to analyse biological data arising from structural and functional genomics. Bioinformatics uses the data to improve understanding of the biological processes in plants and animals.
- *Synthetic genomics*: the aim of synthetic genomics is the creation of synthetic cells to create “designer organisms”. One aim is the engineering of plants and microbes to produce biofuels.

⁷ SSR-Simple Sequence Repeats, SNP-Single Nucleotide Polymorphisms, RFLP-Restriction Fragment Length Polymorphism, AFLP-Amplified Fragment Length Polymorphism, ISTR-Inverse Sequence Tagged Repeats and RAPD-Randomly Amplified Polymorphic DNA

3 The Role of Agricultural Biotechnology in Eastern and Southern Africa (ESA)

3.1 THE CHALLENGES FACING FARMERS IN ESA

Implementation of effective and successful agricultural development strategies is needed for sustainable food production and to ensure food security for the more than 800 million people who do not have access to sufficient food to meet their basic needs. This is one of the most crucial issues in the 21st century. Those at risk include both rural and the urban poor. Developing country farmers are under pressure to produce more food at the same time as the sustainability of food production needs to be secured, but they are facing severe difficulties to do so. From the smallholder farmers' perspective yield stability may be more important than increasing average output. Achieving sustainable growth, both in terms of environmentally sound production and long term stable growth, in farm production is a very complex challenge, which needs an integrated holistic approach.

Population growth continues to be dramatic in most Eastern and Southern African countries and pressure to provide all people in the region with adequate food supply will be massive in the years to come. According to United Nations estimates of world population prospects⁸ the population of ESA is predicted to grow from 347 million in 2005 to 526 million in 2025. Feeding the growing population is not likely to be done most effectively through smallholders but by an increasing number of commercial farmers (World Bank, 2007). On the other hand, targets for reducing poverty and rural hunger may be reached through increasing small scale farmer productivity and also very importantly by increasing yield stability. Yield stability is very important, since crop failures can be fatal for vulnerable small-scale farmers. Consequently, it is crucial for ESA countries to promote growth in the agriculture sector, a growth which also includes small scale farmers and a growth which can be

used as an engine for further development. Agriculture innovation assisting these farmers to produce more under sustainable conditions is absolutely critical in order to achieve the MDGs.

Farmers in ESA are facing a host of difficulties and challenges including poor or non-existent infrastructure, management and husbandry problems, degradation of the natural resource base, weak markets, poor credit facilities and other socio-economic constraints. The severe effects of HIV/AIDS and malaria also present dramatic challenges, negatively affecting the availability of agricultural labour and the productivity of rural communities. Additionally, farmers are confronted with challenging biological and environmental constraints. The anticipated climate change is projected to have dramatic effects on agriculture world wide, and in particular for Africa. The implications for agriculture in Africa are serious, and capacity to assess effects and adapt agriculture to changing climate conditions will be crucial for African countries. The public agricultural sector has a key role to play in this regard.

3.2 THE LINK BETWEEN AGRICULTURAL RESEARCH AND POVERTY ALLEVIATION

There are many relevant insights into the concept of poverty with the basic agreement that poverty is multi-dimensional and context specific (Anandajayasekeram, 1999). Processes of impoverishment are highly dynamic and definitions of poverty shift not only geographically but also from individual to individual. While the notion of poverty may change over time, its core is the inability to fulfil the fundamental needs of human beings.

Donors and national governments in developing countries spend about US\$ 8 billion annually on agricultural research, and there is widespread evidence that this research has led to significant increases in agricultural productivity and incomes in those countries

⁸ <http://esa.un.org/unpp> based on medium variant analysis.

(Hazell and Haddad 2001; Kerr and Kolavalli 1999). But despite many decades of research and dramatic increases in food production, the effects of agricultural research on poverty remain complex and controversial. There is a huge body of empirical knowledge that has relevance to this theme, but it includes very few studies that meet acceptable standards of analysis. Without such studies it would be too easy to draw simplistic and misleading conclusions, like ceasing to maintain adequate levels of investment and support to agricultural research on the food problems of the poor.

It is recognized that agricultural research alone will not alleviate poverty and improve livelihoods, but that a cross-sectoral approach is necessary. Optimization of the role of agricultural research lies in recognizing its limitations and opportunities as a tool to achieve poverty alleviation, and a more proactive effort to develop links with those working on other aspects of poverty reduction. The failure rate of agricultural research and development processes in Africa in comparison with other regions has been attributed to the non-responsiveness of the National Agricultural Research Centers (NARS) to emergent challenges. Most African NARS do not fully operate as agricultural innovation knowledge systems but rather as universities with limited contact with farmers. This has led to a failure to contribute effectively to strengthening of livelihood strategies of the farming communities.

There is an extensive literature on the application of agro-biotechnologies and their relevance to farmers in developing countries. There is also a significant number of studies conducted by agricultural economists to measure farm-level impacts of the use of agro-biotechnologies, but very few of these studies are on farmers in Sub-Saharan Africa. Among crops and technologies and their impact in developing countries, case studies of genetically modified (GM) insect resistant cotton in China, South Africa and India have dominated the literature. A review of peer-reviewed applied economics literature on impact of GM crops (in particular GM cotton) in non-industrial countries was made in 2006 by IFPRI (Smale et al., 2006). This IFPRI study concludes that it is very

difficult to make any firm conclusions due to methodological limitations and brief time frames, but in general, the adoption of GM crops and traits included in the study benefited small scale farmers. The study also points out that these findings should not be generalised to other crops and traits and that future socio-economics studies will need to examine more closely issues of health, equity and poverty alleviation in relation to the adoption of agro-biotechnologies.

3.3 INCREASING PRODUCTIVITY THROUGH IMPROVED PLANTING MATERIAL

Current yields for cereals in Sub-Saharan Africa still average around 1 tonne per hectare, significantly lower than in South Asia and much lower than in OECD countries. The low productivity is due to many factors⁹, but one of the main problems, and the focus of this study, is the lack of access to local improved seed and planting material and the slow release of crop varieties appropriate to local agro-ecological conditions.

To reach maturity, food crops must be able to resist multiple stress factors such as drought, floods and low soil fertility, often in combination with high disease and pest incidence. The broad variation of agro-ecological conditions in Eastern and Southern Africa, low soil fertility, water stress and low use of agricultural inputs, means that crop genetics, effective breeding efforts and dissemination of more productive planting material and livestock remain as some of the most effective means by which farmers can be assisted. This is also expressed by IFPRI¹⁰ and FAO¹¹ (Hazell and Haddad, 2001; FAO, 2004) who conclude that developing country agricultural R&D systems (NARS) have to be more efficient in producing high yielding

9 Socio-economic constraints, weak markets, market access, lack of capital and financing, soil fertility problems and low fertiliser use, lack of irrigation and erratic rainfall patterns, management and husbandry problems, weak extension degradation of the natural resource bases.

10 International Food Policy Research Institute (IFPRI).

11 Food and Agriculture Organization (FAO).

crop varieties and cultivars with improved agronomic/nutritional characteristics. Building on this argument, organisations such as IFPRI (Pinstrup-Andersen et al., 2000), IFAD (IFAD, 2001), ISNAR (ISNAR, 2001), FAO (FAO, 2004), Rockefeller Foundation (De Vries, 2001) UNDP (UNDP 2001), African Development Bank (ADB 2001), African Union (AU, 2006), (World Bank, 2007), NEPAD (Juma et al., 2007) and a number of Academies of Sciences¹² argue that agricultural biotechnology could play an important role in assisting developing country NARS to be more efficient in producing high yielding and improved crop varieties and cultivars. Many of the available applications in agricultural biotechnology are highly suited to address improvements in the specific traits of importance to developing country farmers, such as increased tolerance to insect pests, diseases and environmental stress, all packaged into a seed. At this stage it is also important to add that for agro-biotechnology to be successful, it has to focus on smallholder productivity, not only focusing on crops that fit the agroecology of the various regions, but also those that fit into local social and economic systems.

3.4 AGRICULTURAL BIOTECHNOLOGY IS RELEVANT TO EASTERN AND SOUTHERN AFRICA

It is clear that farmers in ESA face many problems that biotechnology will not solve¹³, including lack of infrastructure, socio-economic constraints, weak markets, lack of credit and capital to buy agricultural inputs, management and husbandry problems and degradation of the natural resource base.

12 Brazilian Academy of Sciences, Chinese Academy of Sciences, Mexican Academy of Sciences, National Academy of Sciences of the USA, The Royal Society, Third World Academy of Sciences, Indian National Science Academy. (2000) Transgenic Plants in World Agriculture

13 There is a growing recognition in Africa that investments solely in technologies will not increase productivity, and do not offer meaningful solutions to farming problems, unless the problem of weak markets, infrastructure, socio-economic constraints, limited farm credits also are dealt with.

Agro-biotechnology is therefore very far from a panacea but can be a very important tool to address agricultural problems and opportunities in ESA.

For most people in developing countries, a better standard of living depends on increasing productivity in agriculture. Modern biotechnology research, together with appropriate policies, better infrastructure and traditional research methods have the potential to bring benefits to millions of poor farmers and consumers. Most would agree that agricultural productivity in ESA has to be improved, and that an important part of this productivity improvement will come through improved crop varieties. This implies a central role for the crop breeding systems in ESA. Breeding systems in ESA have a demanding task where they have to focus on crops that fit the agroecology of the various regions, but that also fit into social and economic systems. Moreover, local processing systems and consumption patterns often demand additional quality requirements in order for improved crop varieties to be adopted by farmers. To be successful, breeding programmes and agricultural research institutions in ESA must take into consideration these environmental variations and varietal preferences by farmers. Farmers' needs for specific traits are therefore an important component in shaping the breeding programme (be it drought resistance, pest resistance, improved quality). By analysing these requirements, selecting appropriate parental material and making selections under relevant conditions in close collaboration with farmers, new varieties with the right genetic make-up can be produced. A challenge for the breeding and seed dissemination system is however that in many ESA countries there is a poor uptake of already improved seeds, such as maize hybrids. The reasons for this need to be addressed, as this will also affect the uptake of cultivars improved through agro-biotechnology.

The question is to what extent agro-biotechnology is the best way to assist breeding systems to be more effective in meeting complex demands and the needs of small-scale and subsistence farmers?

Some have argued that the use of biotechnology has low priority when it comes to increasing

small-scale farmer productivity (Alterie and Rosset, 1999; De la Perrière and Seuret, (2000); van Aken, 1999; Greenpeace, 2004). It has been argued that agricultural problems today are not those of production, but are more socio-economic in nature. A more specific argument has been that the development of R&D capacity in biotechnology requires significant financial resources, and would not be the most optimal use of scarce resources. The argument has also been that there is a considerable scope for increasing crop productivity in African agriculture using conventional techniques and through the empowerment of small-scale farmers. Building on this, it has been argued that it may be more cost-effective for African countries to buy and import the practical applications of biotechnological strategic research (both the technology, its applications and improved crops) whenever they would be complementary to already existing conventional technology.

A large body of evidence (FAO, 2004; Bennet et al., 2006; Brookes and Barfoot 2005; Machuka, 2001; Pinstrup-Andersen and Cohen, 2000; Raney, 2006; Smale et al., 2006; Qaim, 2000;), however, confirms that agro-biotechnology has the potential to assist breeding systems to be more effective in serving small-scale and subsistence farmer needs with improved crop varieties giving higher yields¹⁴. Given the low adoption of high yielding planting material in many ESA countries, the potential for increased crop productivity, through improved planting material is significant. It can actually be argued that ESA has a potential advantage in relation to many other countries, for example European countries, which can only improve their yields marginally (since they already are on a high level). In ESA, crop yields are low, partly due to lack of high yielding planting material, and therefore a relatively modest improvement in productivity can have a significant local impact.

Another important argument in favour of agro-biotechnology is that crops developed through agro-biotechnology, in comparison

with the green revolution crops, require fewer changes in practices and extension services. The green revolution required in most cases a formidable network of agricultural extension experts to work closely with farmers helping them to change agricultural practices. In the case of crops developed through agro-biotechnology, including GM crops, the technology is inside the seed. If the technology is used on appropriate local planting material, the resulting crops wouldn't require any major changes in cultivation or additional management practices¹⁵.

In a broader perspective, economies in most ESA countries are mainly agrarian, with the agricultural sector contributing to the chief part of the gross domestic product (GDP), supporting the major part of the population. Many ESA countries will also in the foreseeable future continue to be agrarian economies, with relatively large farming communities. Given the increasing demand for food, feed and renewable bioproducts, it is imperative for countries in ESA to increase investments in the agricultural sector and in particular in breeding and seed supply systems that effectively serve the farming communities in ESA. Regrettably, many countries in Africa have disinvested in breeding and agricultural research. Investments in biotechnology for the breeding sector must therefore go hand in hand with investments in agricultural research in general and in particular an efficient breeding and seed supply and extension system.

The modern breeding sector is today heavily dependent on agricultural biotechnology and ESA countries will have difficulties in modernizing their breeding sectors without integrating and adopting agro-biotechnology. One of the key purposes of this study is a discussion of the conditions under which investments in public agricultural

14 Field trials and field trial applications for maize, banana, cotton, cassava, all in ESA countries, add to the evidence.

15 This is, however, to some extent "a case by case" situation, and would depend on breeding targets and local conditions. Some GM crops may require specific practices, such as refugia to prevent insect resistance development. There can be changes in regimes for herbicide application or pesticide spraying. Taking GM Bt crops as an example, there is also a need for extension experts to ensure that appropriate planting regimes are being followed to prevent the emergence of resistant insects.

biotechnology (including GM technology) would have the potential to lead to improved small-scale farmer productivity.

3.5 CURRENT APPLICATIONS AND THE PROSPECTS OF AGRO-BIOTECHNOLOGY IN ESA

All over the world, including many developing countries, breeders and scientists have been applying agricultural biotechnology to a diverse range of crops and traits. Many of these agro-biotechnologies have been developed with a commercial application in mind, but several also hold considerable promise for addressing key breeding targets of importance to small-scale farmers in Sub-Saharan Africa. Below follows a brief description of the potential of agro-biotechnology to remove some of the key constraints facing farmers in Eastern and Southern Africa.

3.5.1 Crop productivity constraints

Agro-biotechnology is already today a useful tool in addressing crop productivity constraints such as increased tolerance to insect pests, diseases (biotic stress) and soil or climate (abiotic) stress. Abiotic constraints are headed by the need for drought and heat stress, and mineral imbalances in soils (e.g. high aluminium levels or low phosphate levels).

One of the biggest threats to crop productivity in tropical areas, such as East and Southern Africa, is the emergent pests and diseases that are affecting both cash and food crops, many of them endemic in Sub-Saharan Africa (see Table 1).

Table 1: Crop disease incidence in tropical compared to temperate zones

Crop Species	Number of diseases	
	Temperate areas	Tropical areas
Sweet potato	15	187
Rice	54	500-600
Beans	52	253-280
Maize	85	125
Potato	91	175

Source: Securing the Harvest: Biotechnology, breeding and seed systems for African Crops, 2001 (eds J. De Vries and

G. Toenniessen, CABI publishing).

Thomson (2002) cited the major biotic constraints for Sub-Saharan Africa which included plant virus diseases (e.g. Maize Streak Virus, African Cassava Mosaic Virus); fungal infections; and Striga. East and Southern Africa have over the last ten years experienced an upsurge of new diseases as well as sporadic epidemics of diseases on important crops. Some of these diseases and pests include: Banana Bacterial Wilt, Black Sigatoka, Matoke Wilt on East Africa Highland banana, Turicum Leaf Blight (*Exserohilum turcicum*), Gray Leaf Spot (*Cercospora zeaemaydis*), Cassava Mosaic Virus Disease, Cassava Brown Streak Disease, Coffee Wilt (*Fusarium xylaroides*), larger grain borer etc.

Agricultural biotechnology offers opportunities to effectively monitor¹⁶ and manage pests and diseases. In fact, the accuracy of these tools has provided for their use in pest/disease tracking within and across different agroecologies (Milgroom and Fry, 1997). Griessel et al. (2004) have elaborated on biotic constraints to African food security that could be amenable to biotechnological solutions (see Table 2).

3.5.2 Improving food and feed quality

Agro-biotechnology already holds promise as a useful tool in improving food and feed quality, such as the development of crops with improved storage properties and nutritional characteristics (e.g. altered protein, mineral and vitamin content).

Research has shown (Thomson, 2002) that one of the most efficient ways to reduce malnutrition of the poor is by enhancing the iron, zinc and vitamin A content of basic food grains. In some cases this can be done through conventional breeding, but for some micronutrients, such as Vitamin A and the case of Golden Rice¹⁷, GM crops could be part of the answer.

¹⁶ Many biotic stress factors have been identified using a number of molecular and biotechnological tools.

¹⁷ A GM rice producing enhanced levels of provitamin A, for more information see www.goldenrice.org

Table 2: Biotic constraints to crop production in Africa and availability of biotechnology solutions¹⁸

Constraint	Genes or technology needed	Known genes	Being addressed		Commercialized	
			Outside Africa	In Africa	Outside Africa	In Africa
Grass weeds in wheat	Herbicide resistances	Yes	Insufficiently	No	Some	No
Parasitic weeds	Herbicide resistances	Yes	Research level	One case	No	One case
	Enhanced biocontrol	Some	Research level	No	No	No
Stem borer (maize)	Bt ¹⁹	Yes, not perfect	Yes	Yes	Yes	One case
Stem borer (sorghum)	Bt	Yes, not perfect	No	No	No	No
Grain weevils	Bt type gene	Not clear	No	No	No	No
	Classic biocontrol	Fungi known	No	Yes	No	No
Bemisia/TLCV	Anti-insect	No	No	No	No	No
	Anti-virus	Insufficient	No	No	No	No
Mycotoxins	Suppress vector - Bt	Yes, not perfect	Yes	Yes	Yes	Yes, one case
	Suppress fungus	No	No	No	No	No
	Degrade toxin	No	No	No	No	No

Source: Griessel et al., 2004.

The introduction of biofortified crops - varieties developed for improved nutritional content - is an important part of the CGIAR²⁰ research agenda. In the HarvestPlus program, coordinated by the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI), agro-biotechnology is heavily used to increase dietary intake of essential nutrients in staple foods.²¹

In Africa, the Biofortified Sorghum (ABS) project (funded by the Bill and Melinda Gates Foundation), a consortium of institutes, is using agro-biotechnology to develop 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 zinc²².

For crops with enhanced nutritional value, identity preservation/segregation mechanisms may be necessary in the market chain to preserve the value for the consumer. The cost of this needs to be balanced against the cost of nutritional post-harvest supplementation.

3.5.3. Facilitating sustainability

Agro-biotechnology could contribute to more sustainable agricultural practices, where crops can be tailored to lower degrees of agricultural inputs (e.g. pesticides, water), and to agricultural practices requiring less energy input (such as low tillage, perennial grains cultivation).

¹⁸ Prioritized constraints from an Africa-wide survey, not specific to ESA.

¹⁹ *Bacillus thuringiensis* (Bt) technology

²⁰ Consultative Group on International Agriculture Research.

²¹ <http://www.harvestplus.org>

²² For more information see www.supersorghum.org

This is not least true in the case of the adoption of genetically modified Bt cotton which has allowed cotton farmers, in both the developing and the developed world, to reduce their pesticide sprayings significantly (Huang et al., 2002; Brookes and Barfoot, 2005).

Work is also underway to develop genetically modified crops with an improved ability to absorb soil nutrients, which may assist in a more effective utilisation of fertilisers. There is also intensive research on the development of genetically modified maize and wheat more tolerant to drought.

3.5.4 Adding value to crop production

Development of crops and output traits with industrial applications (e.g. biofuels, starch, fiber, oils) is an increasingly important driver for agricultural development world-wide. Increasing oil prices and the insight into global warming threats has meant an increased demand for renewable resources. Developing countries could use agricultural biotechnology as a strategic base for environmentally friendly industrial growth where small-scale farming could potentially be made more profitable through the production of industrial (non food/feed) products such as:

- biofuels, fibers, starch products
- “green” chemicals”, biodegradable plastics, oils and lubricants
- detergents, enzymes, cosmetics, fragrances and flavors
- pharmaceuticals, antibodies and vaccines
- essential oils, flavors and fragrances

At present, biomass/biofuel resources in sub-Saharan Africa are utilised in an extremely inefficient manner at different levels, from the use of wood and charcoal for household cooking to major industries such as sugarcane and wood processing that generate significant biomass residues. Such residues are only the “tip of the iceberg” in terms of the overall potential, as they are readily available and are already economically competitive. However, even these are barely utilised due to the lack of infrastructure, poor market access, and institutions that do not or cannot promote innovation or strategic investment.

To determine the full potential, one must consider the vast opportunities for improving crop management cycles, breeding options, diversifying the genetic resource base, incorporating drought-resistant species, co-cropping strategies, and the introduction of crops that require significantly lower water inputs. Agro-biotechnology could greatly assist in the development of new biofuel crops.

3.5.5 The potential for agro-biotechnology in Tanzania

The results of a survey carried out in Tanzania²³ on the various production constraints and suggestions for potential biotechnology interventions are presented in Table 3. The table is a result of discussions with researchers in a large number of Agricultural Research Institutes (ARIs) in Tanzania, under the Department of Research and Training (DRT) in the Ministry of Agriculture, Food Security and Cooperatives (MAFS).

As can be seen from the table there is a whole range of opportunities where agro-biotechnology could assist in attaining key breeding targets for important crops in Tanzania. The table highlights the potential to use agro-biotechnology to develop crops with increased tolerance to insect pests, diseases and environmental stress, specifically adapted to Tanzanian conditions.

Consequently, supporting developing country breeding and agricultural production systems to adopt appropriate agro-biotechnologies can be an effective way of supporting sustainable growth in the agricultural sector and could effectively contribute to poverty reduction and in reaching MDG targets.

²³ Study made by Alois Kullaya, Emmerold Mneney, Mikochei Agricultural Research Institute (MARI) and Ivar Virgin, Stockholm Environment Institute (SEI).

Table 3: The major production constraints and potential biotech applications for priority crops and livestock in Tanzania

Priority crops	Main productivity constraints	Current available technologies/status	Potential Biotech intervention
Maize	-Grey Leaf spot (GLS)	-GLS resistant lines identified at Uyole	-MAS ²² for incorporating GLS
	-Maize Streak Virus (MSV)	-MSV resistant varieties under low altitude identified	-MSV and drought resistance in local varieties
	-Striga -Stem borers -Ear rot -Drought	-Ongoing efforts to use MAS for identifying drought tolerance	-Incorporate insect resistance genes, such as Bt ²³ in breeding programmes.
Rice	-Striga	-No good source of resistance available	
	-Insect pests -Rice blast -Rice yellow mottle virus (RYMV)	-Some sources of resistance identified	-MAS for Rice yellow mottle virus (RYMV)
Grain legumes	-Fusarium wilt in Pigeon peas -Insect pest of pigeon pea and cowpeas	-Some pigeon pea varieties show good resistance against fusarium wilt.	-MAS for resistance breeding
Sisal	-Availability of planting materials -Korogwe leaf spot	High yielding hybrids available	-Mass propagation through tissue culture
Sugarcane	-Sugarcane smuth	-No data on tolerant material	-Micropropagation of elite breeding lines through tissue culture.
	-Ratoon stunting -Yellow leaf syndrome -Stem borers	-GM- Bacillus Thurengiensis (bt) technology	-MAS and incorporate insect resistance genes, such as Bt in breeding programme
Cotton	-Insect pests e.g. Jassid	-Local germplasm resistant to insect pests like jassid identified	-MAS for incorporating resistance to jassids
	-Cotton bollworm (Helicoverpa armigera) -Fusarium wilt (Fusarium oxysporum and Bacterial wilt)	-GM-Bt technology -Varieties with good fibre quality identified	-Incorporate Bt- and herbicide resistance genes in breeding programme
Coffee	-Coffee berry disease (CBD)	-CBD and CLR resistant hybrid lines identified	-MAS for CBD and CLR
	-Coffee leaf rust (CLR) -Coffee wilt -Insects (scale, mealybugs, borer) -Nematodes	-No data on tolerant material	-Somatic embryogenesis for mass propagation of resistant genetic materials
Sweet potato	-Sweet potato virus complex		-MAS for resistance screening
	-Sweet potato weevil	-No good source of resistance available	-Development of molecular markers for disease diagnosis
Citrus	-Citrus greening disease	-An up to date data on the epidemiology of the disease is not available	-Molecular and serological tools for improved disease detection and indexing
Cassava	-Cassava Mosaic virus (CMV)	-CMV tolerant materials identified	-MAS for disease resistance and low cyanide content
	-Brown Steak Virus -Cassava green mite	-No data on tolerant material	-Development of molecular markers for disease diagnosis
	-Cassava mealybug	-Transgenic Cassava with altered starch composition	-Micropropagation of disease- free planting material through tissue culture

24 Marker Assisted Selection

25 Plants can be made more tolerant to certain insects through the incorporation of a Bacillus thurengiensis (Bt) gene encoding a specific toxin.

Phaseolous beans	<ul style="list-style-type: none"> -Bean stem maggot -Bean mosaic virus -Angular leaf spot disease -Bean common necrotic virus -Anthracnose -Heloblight -Insect pests (aphids, pod borers) 	<ul style="list-style-type: none"> -Sources of resistance to angular leaf spot and stem maggot identified 	<ul style="list-style-type: none"> -MAS for disease resistance screening -Development of molecular markers for disease diagnosis
Sorghum & millet	<ul style="list-style-type: none"> -Drought -Striga -Insect pests (borer, shoot fly, midge) -Diseases (charcoal rot, kernel smut, rust, ergot) 	<ul style="list-style-type: none"> -Some striga tolerant lines identified -Bt Technology -No data on tolerant material 	<ul style="list-style-type: none"> -MAS for drought and striga tolerance -Incorporate Bt or herbicide tolerance genes in on-going breeding programme
Potatoes	<ul style="list-style-type: none"> -Late blight (<i>Phytophthora infestans</i>) -Bacterial wilt (<i>Ralstonia solanacearum</i>) -Viruses -Potato tuber moth 	<ul style="list-style-type: none"> -Some sources of resistance identified -Various GM technologies for virus resistance available 	<ul style="list-style-type: none"> -MAS for resistance screening -Development of molecular markers for disease diagnosis
Banana	<ul style="list-style-type: none"> -Black sigatoka (BS) -Weevils -Panama wilt -Nematodes 	<ul style="list-style-type: none"> -Some BS resistant genetic material identified -GM technology for BS resistance being tested 	<ul style="list-style-type: none"> -MAS for resistance screening -Development of molecular markers for disease diagnosis -Micropropagation of disease-free planting material through tissue culture
Wheat	<ul style="list-style-type: none"> -Patchy stunting -Yellow Leaf rust -Stem rust -Drought 	<ul style="list-style-type: none"> -Some sources of resistance identified 	<ul style="list-style-type: none"> -MAS for drought and disease resistance screening -Application of molecular markers for disease diagnosis
Barley	<ul style="list-style-type: none"> -Barley yellow virus -Leaf rust -Leaf spot blotches -Drought 	<ul style="list-style-type: none"> -Some sources of resistance identified 	<ul style="list-style-type: none"> -MAS for drought and disease resistance screening -Application of molecular markers for disease diagnosis
Coconut	<ul style="list-style-type: none"> -Lethal disease, LD (phytoplasma) -Drought 	<ul style="list-style-type: none"> -Some sources of resistance identified 	<ul style="list-style-type: none"> -MAS for LD resistance and drought
Pyrethrum	<ul style="list-style-type: none"> -Low yields and pyrethrin content 	<ul style="list-style-type: none"> -High yielding hybrid clones with high pyrethrin content identified 	<ul style="list-style-type: none"> -Micropropagation through tissue culture
Cashew	<ul style="list-style-type: none"> -Powdery Mildew 	<ul style="list-style-type: none"> -Some sources of resistance identified 	<ul style="list-style-type: none"> -MAS for resistance screening -Micropropagation techniques
Pastures	<ul style="list-style-type: none"> -Low yields -Low nutritional quality 	<ul style="list-style-type: none"> -Some sources for yield increases and nutritional improvements identified 	<ul style="list-style-type: none"> -MAS for yield
Livestock	<ul style="list-style-type: none"> -Newcastle disease in chicken -Foot and mouth disease -Contagious Bovine Pleuro Pneumonia (CBPP) -Rinderpest -East Coast Fever (ECF) -Anthrax -Low genetic potential for milk and meat -Mastitis -Parasites -Genetic erosion in some local cattle breeds 	<ul style="list-style-type: none"> -Sources of disease resistance found only to a limited degree 	<ul style="list-style-type: none"> -MAS for resistance screening and improved yield -Application of molecular markers for disease diagnosis -Vaccine production -Embryo rescue and in-vitro preservation of endangered species

3.5.6 The potential for agro-biotechnology in Uganda

Uganda is one of the ESA countries that has built significant capacity in agricultural biotechnology, and research in agrobiotechnology has been conducted for more than 15 years. The agro-biotechnologies in use can broadly be clustered into two groups; (i) plant and cell tissue culture and (ii) molecular biology including transgenic approaches. This research has been undertaken by public institutions, mainly the National Agricultural Research Organization (NARO),

the Makerere University and Mbarara University of Science and Technology. Private sector agencies such as Med Biotechnology Laboratories and AgroGenetics Laboratories have also been active. The earliest applications of agro-biotechnologies in Uganda were in plant and tissue culture of banana in the mid 1990s. More recently advanced molecular biology tools including gene technology have been used. Table 4 below illustrates some of the ongoing and completed agro-biotechnologies being undertaken.

Table 4: Some ongoing agro-biotechnological research in Uganda and potential biotechnology intervention

Priority Crops Cluster	Main constraints	Current available technologies/status	Potential biotechnology intervention
Cereals such as maize, sorghum Rice	-Folia diseases of fungal and viral origins	-MAS for drought tolerance based on stay green trait.	-Incorporation input traits such as Bt and other disease and pest resistance
	-Insect pest damage (field and storage) -Drought tolerance -Striga	-MAS for resistance to leaf blight of sorghum and maize. - Herbicide resistant seeds to control Striga	-Incorporation value added traits for specialized food feed and industrial products Transgenic approach to Striga resistance
Grain legumes and oil crops	-Foliar diseases of fungal and viral origins -Insect pest damage (field and storage) Angular leaf spot disease	-MAS for resistance to bean anthracnose and bacterial wilt	-Incorporation of value added traits for specialized food feed and industrial products
Root and tuber crops	-Sweet potato virus complex -Sweet potato weevil	-MAS for resistance to sweet potato weevil	-Development of molecular markers for disease diagnosis.
	-Cassava Mosaic disease -Brown streak virus -Late blight P.infestans -Bacterial wilt (Ralstonia solanacearum)	-Transgenic approach to control of cassava mosaic disease -Diagnosis for P.infestans and monitoring of pathotypes frequencies	-Micropropagation of disease- free planting material through tissue culture.
Fruits	-Passion fruit woodiness	-Epidemiological and disease diagnosis	
	-Black sigatoka of banana	-Production of plantlets (tissue culture)	-Molecular and serological tools for improved disease detection and indexing
	-Banana bacterial wilt -Banana weevil	-Transgenic approaches for resistance to sigatoka and bacterial wilt. -Development of systems for genetic transformation	-Bt technology or other appropriate GM technology
Coffee, Tea	-Diseases -Coffee berry disease (CBD) -Coffee wilt	-Developing of inter-specific hybrids resistant to wilt	-Somatic embryogenesis for mass propagation of resistant genetic materials

Table 5: Percentage of national maize area planted with improved maize in 1999*

Country	Non Hybrid (Open pollinated varieties) (%)	Hybrids (%)
Angola	25	0
Ethiopia	2	4
Kenya	7	65
Lesotho	10	64
Malawi	4	7
Mozambique	8	0
South Africa	3	95
Swaziland	2	73
Tanzania	4	6
Uganda	50	5
Zambia	1	19
Zimbabwe	9	91

Source: CIMMYT Maize Research Impacts Survey, 1998/1999. Smale and Jayne (2003) give later figures for selected countries. Structural factors such as government seed subsidies impact on the observed utilization of improved varieties.

* These figures are estimates that include recycled seed. Levels of seed recycling are high in certain countries (particularly Uganda and Angola).

3.6 THE ROLE OF PUBLIC VS PRIVATE SECTOR IN SERVING THE POOR

Currently the use of improved seeds and planting material²⁶ is low in ESA. The situation is similar in many other ESA countries. It is for example estimated that in Tanzania less than 10% of farmers use hybrid seeds of maize²⁷. In Uganda about 11% of the total area dedicated for cereals such as maize is under improved varieties. There has been a marked increase in the proportion of farmers accessing improved seed with over 60% of farmers in the Lake Victoria Basin having up to 60% of maize under improved varieties (Sserunkuuma, 2004). This situation has also steadily improved with more agro-input dealers opening up stores and development of voucher systems that permit access to inputs on credit²⁸. Data shown in Table 5 reflects the percentage of improved maize in comparison to national maize areas in some selected countries. In general, this percentage

is much lower for self-fertilizing small grains (barley, rice, sorghum, wheat) and legumes (beans, groundnut) throughout the developing world²⁹. There are many reasons³⁰ for this, and a full discussion is beyond the scope of this report (Almekinders and Louwaars, 1999).

The low adoption of improved crop varieties tailored to local needs is partly due to the fact that the seed demand, and seed markets in many ESA countries, although steadily growing, are still weak and fragile. And, many farmers, for many good reasons, prefer their local seeds coming from the informal seed sector³¹ and are continuing the farm saving seed practices. Farm-saving is also common in Europe. At least in the case of maize, the seed market in ESA is almost entirely privatized, and those farmers who do purchase seed do so through

29 Louwaars (2007) provides data for the use of seed from the formal sector in India and compares them to Europe, and argues that low percentages of formal seed use does not mean a low use of improved varieties.

30 Farm saved seed practices, financial, infrastructure and communication constrains and cultural preferences (Almekinders & Louwaars, 1999).

31 Breeding and seed saving and exchange by and between individual farmers.

26 Including private and public sector breeding and seed supply initiatives.

27 Daily News; Tanzania as of 9.01.2002.

28 UNADA. Uganda Agro-input Dealers Association (www.unada.org)

private companies rather than public seed organizations. This is however not necessarily the case for other crops.

The low utilisation of improved seeds and planting materials is to a large extent also due to problems on the supply side. Seed production systems in ESA often work in an ineffective way and NARS of ESA often have difficulties in developing varieties that are in high demand by farmers. This is most unfortunate as there are many examples of high adoption and absorption of improved planting material when the formal seed sector has been able to develop varieties highly suited to local needs. In Uganda for example, the public seed sector developed Cassava Mosaic Virus resistant cassava and has together with civil society multiplied and disseminated them effectively within the country.

The food and agriculture market situation in many parts of Africa makes it possible to make a rough distinction between two³² different seed supply systems³³, one market driven system serving the larger and the medium scale commercially oriented farmers, and one system serving the small-scale and more subsistence oriented farmers³⁴. Improved seeds are used in both systems and many small scale farmers also access, save and re-use improved seed, especially for open pollinated varieties and some vegetative propagated varieties. However, many small scale farmers have difficulties in accessing certain improved varieties especially hybrids³⁵.

32 There are also a number of intermediate systems where farmers grow food for their own consumption on one part of their land using farm saved seeds and the other part of the land is used for commercial purposes, using commercially improved varieties.

33 There is a need to differentiate between the supply side to these farmers (two possible systems) and the market for their products which to a large extent is the same system, although different farmers have different opportunities to make use of this market system.

34 The divide between these two systems is particular clear in terms of the volume of seed handled.

35 It should not be forgotten that many small-scale farmers aspire to practice farming on a larger scale and would in many cases benefit from the opportunity to access a larger variety of improved seeds..

The commercially oriented system holds substantial opportunities for a market driven agricultural innovation process and a high adoption of modern technologies for seed development, diffusion and plant propagation. Whereas the commercial seed sector is largely dominated by transnational companies (TNCs), there are examples of emerging African local agro-input dealerships. The AGRA programme³⁶ of the Rockefeller Foundation has been particularly keen to support this process. Notwithstanding these recent developments, the TNCs dominate the global arena for elite cultivars and hybrids and especially GM-crops, from R&D to marketing. Their primary interest is in developing and marketing the elite seeds of a group of “global crops” (e.g. maize, soybean, oilseed rape/canola, cotton etc.) of importance to the farmers in those industrialised countries that have global-scale agricultural production and exports and in which control over the innovation in the value chain is feasible. A spin-off from this strategy is to market the same seeds in some key developing countries with large markets e.g. Argentina, Brazil, China, India and South Africa. The TNCs are, however, less interested in the low profit, country-specific and local-specific crops of crucial importance to small-scale farmers in developing countries.

It is thus unlikely that the private sector will play the leading role in the development of high quality varieties most relevant to the needs of the poor and vulnerable farmers, at least in the foreseeable future. Thus, the development and commercialisation of improved local varieties of crops such as sorghum, millet, cooking banana, cassava, yams, sweet potato, chickpea, cowpea, beans, etc. will depend heavily on public sector based crop-breeding programmes.

Utilisation and importation of elite cultivars from abroad will without doubt be helpful, but only to a limited extent³⁷. Given the

36 Alliance for a Green Revolution in Africa AGRA: A Strategic Partnership between the Rockefeller Foundation and the Bill and Melinda Gates Foundation. (www.africancrops.net)

37 Elite cultivars, not resistant to local conditions, pests etc.

different agro-ecological differences in ESA, the subsistence crop systems³⁸, the different cultural habits, and the use of a wide array of local varieties, breeding efforts are most effectively done locally through the various NARS in the region. Being close to the farmers and their problems, public-sector research institutions in developing countries have a key role to play.

Strengthening NARS in their ability to develop new locally adapted varieties with a higher frequency would therefore be of great value. The different crop and livestock breeding research programmes in ESA have been able to identify improved genetic materials with useful traits through conventional breeding, but this is a time consuming and fairly inexact process. Hence, breeders in the NARS would in turn be enormously helped if they could use elite cultivars with various preferred traits, including GM-traits, to improve local varieties, and improve local crop management systems. The elite cultivars would in this system be used as sources of important genes. Marker assisted selection (MAS) and genetic engineering can effectively be used to speed up the process and make it more precise.

3.7 THE IMPORTANCE OF DISSEMINATING TECHNOLOGY TO SMALL-SCALE FARMERS

A common problem in many African countries is the lack of delivery systems to get products to the poorest farmers. Seed certification, propagation and dissemination systems, including policy regimes, such as seed laws, genetic resource policies for technology dissemination, are in most ESA countries weak, dysfunctional and not optimal.

During the 90's the agricultural R&D sector and the whole farming sector, including the seed production and distribution systems in ESA countries, had to adjust to a more market driven approach. To a significant degree the rapid changes led to a gap between the R&D sector and the seed distribution actors. Under these new conditions it is clear that private seed dissemination actors are unwilling to

undertake the risk of seed production and marketing unless they see a real economic potential. Likewise, farmers will not invest in improved seeds or planting materials unless they are able to sell crop products. In addition, small holder farming systems in need of a particular variety of seeds are often unable to pay for them at rates which make it attractive for suppliers to enter the market. Even though the R&D systems are able to develop improved varieties which are highly suited for small-scale farmers, the problem of disseminating these new varieties is often insurmountable. Supporting developing countries to develop regional, national and local public seed production, certification, multiplication, biosafety and phytosanitary measures targeted to poor and vulnerable farmers is therefore crucial.

The question relevant to this study is how agricultural biotechnology research efforts and products developed by the public R&D systems in ESA could reach poor farmers and small farming systems?

The answer to this depends on the specific type of crop and market system. There is the fully commercial crop sector³⁹, where seed dissemination is dominated by the private sector. There is also the intermediate crop sector where the private sector will reach certain types of farmers with improved varieties, but far from all, directly⁴⁰. Lastly there are crops where the profit margin is very low, or almost impossible to make profitable, for which the private sector is not expected to play any role but rather it is the public sector which is faced with seed and cultivar development. The latter two cases suggest an active role for the public sector to disseminate agricultural biotechnology research efforts to poor, small-scale farmers. In this context, the question can also be raised as to whether the production of seeds and planting materials is a role for the public sector or the private sector. Public research institutions in Africa

39 This includes the commercial maize farmers adapting hybrid maize varieties and the horticultural market.

40 Technology may trickle down to remote and resource-poor farmers which could be reached through various public- private partnerships.

38 Including the farmer-saved seed practices.

do not generally have the management skills and financial resources to upscale from small- to large scale testing and to large-scale commercial seed production. Therefore, in order to facilitate improved delivery of seeds there is a need to make use of product development partnerships, involving the private sector and NGOs.

3.8 SUPPORTING PUBLIC BREEDING INSTITUTIONS TO ASSIST SMALL-SCALE FARMERS

Few countries in the world, if any, have really been able to make their agriculture more productive without major investment in public breeding efforts. The modern breeding sector is today heavily dependent on agricultural biotechnology and developing countries will have difficulties in modernizing their breeding sectors without integrating and adopting agro-biotechnology.

Agricultural biotechnology could play an increasingly important role in assisting public breeding institutions of developing countries to become more relevant to small-scale farmer needs. Technology could assist the public sector to be more efficient in producing high yielding and improved crops for further distribution to subsistence oriented farmers. It could also assist in the development of more productive and disease - resistant livestock. Modern participatory breeding using agro-biotechnology could also assist in the much needed integration of the "formal" and "informal" seed systems, where breeding efforts by small-scale farmers, to a greater extent could be supported and integrated with the efforts in the public breeding sector.

Investment in strong public research efforts will be essential for harnessing the benefits of agro-biotechnology to the needs of small-scale and subsistence farmers in developing countries. Being close to the farmers and their problems, public-sector research institutions in developing countries have a key role to play. At the same time it is important to keep in mind that a prerequisite to invest in agro-biotechnology is that a country has a functional public breeding sector. Agro-biotech investments have to be based on broad crop productivity improvement programmes,

including sustainable management/ husbandry, efficient extension and integrated pest management strategies. Unfortunately, the public sector in many ESA countries is facing severe problems in attracting funds⁴¹ and competent staff, and plant breeding in the public sector is generally not seen as a very desirable career. This, coupled with the fact that advanced graduate training and training of high quality breeders is in general not publicly funded⁴², has led to a diminished number of African plant breeders. A significant effort to train plant breeders from ESA countries, using both conventional and biotechnological tools, is being made by the African Centre for Crop Improvement in South Africa⁴³. Crops included in the programme include; sorghum, millets, rice, maize, cassava, sweet potato, dry beans, cowpea, pigeon pea, groundnuts, and soybeans.

At the same time, the role of the public sector is changing in ESA countries. Most ESA countries have issued several policies and strategies at macro level, that have firmly established the transfer from centrally planned economies towards more market oriented and decentralized systems in which private investment could play a dynamic role in the economy. With regard to the agricultural sector this has meant policies stimulating a growing role for the private sector in rural development, and also in plant propagation and seed dissemination, something which in many countries used to be state driven. However, the necessary mechanisms for the implementation of new government policies are in many ESA countries not in place. This has led to a situation where state driven seed dissemination efforts have been scaled down but where the private sector has been unable

41 Largely due to effects of the structural adjustment programmes of the 1990's this prevented staff recruitment.

42 Most donors view plant breeding as a long term process and are not willing to invest in the process or training as such.

43 Following first phase support from the Rockefeller Foundation, the African Centre for Crop Improvement ACCI is currently supported through the Programme for a Green Revolution in Africa with funding from the Bill and Melinda Gates Foundation.

to fill these gaps. As a result, the development and dissemination of agro-biotechnologies is still very much a public sector affair. But, while a number of ESA institutions have initiated research on various aspects of biotechnology, most of them are unable to effectively disseminate these technologies to the farmers. As a consequence, the development of public-private product development partnerships, where public and private actors collaborate in the development and dissemination of agrobiotechnology and seeds, is therefore greatly needed in ESA. Support to both the public and the private sectors in engaging in these partnerships will also be crucial, as will be the need to address the role of public or private extension services in the introduction and effective use of improved crops.

4 Agricultural Biotechnology R&D Activities in ESA

4.1 OVERALL AGRO-BIOTECHNOLOGY ACTIVITIES IN ESA

In Africa, there is a growing recognition of the need to invest strategically in biotechnology. As a result, biotechnology research has been initiated at several universities and government supported institutions in the region. There are also different funding agencies and international biotechnology programmes operating or being planned at regional or international level. These include the Rockefeller Foundation, BIO-EARN, ASARECA, BECA, INIBAP⁴⁴ Several CGIAR⁴⁵ centres (IITA, CIAT, CIMMYT and ICRAF) are also actively working with the National Agricultural Systems (NARS) in the region on various crop and animal breeding biotechnology programmes.

The adoption of biotechnology at the national level in Africa is mainly focused on the medical and agricultural sector, and so far there are only limited activities in the field of environmental and industrial biotechnology⁴⁶. Unfortunately, biotechnology is still an underdeveloped resource for the improvement of crop production in ESA. Even though many countries in the region have a fairly large

number of individuals trained in agricultural biotechnology, many of them are unable to utilize their knowledge due to the lack of infrastructure and R&D funding. A specific study of the agricultural R&D system in Tanzania is enclosed as Annex A.

South Africa is the leading country in the region with several agricultural biotechnology research institutions involved in state of the art R&D and is the eighth largest producer in the world of genetically modified (GM) maize and cotton. The Agricultural Research Council (ARC) has a number of advanced agricultural biotechnology research projects⁴⁷. The Council for Scientific and Industrial Research (CSIR) has developed transformation systems for maize and sorghum⁴⁸. The University of Cape Town has developed a GM control system for Maize Streak Virus (MSV), which is currently being tested in field trials. The University of Pretoria's Forestry and Agricultural Biotechnology Institute (FABI) focuses on plant and tree pathogens, but also on the development of crops with resistance to biotic and abiotic stresses⁴⁹. The University of the Witwatersrand is developing virus-resistant cassava. In addition to these examples, a number of universities are developing molecular systems for agriculture and there is a rapid growth in agro-biotechnological expertise, not least in bioinformatics. The Department of Science and Technology (DST) provides support to the Biotechnology Innovation Centre PlantBio, which has a mandate to fund plant biotechnology projects with potential commercial value.

44 East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development, (BIO-EARN), Association for Strengthening Agricultural Research in Eastern and Central Africa, (ASARECA), Biosciences for Eastern and Central Africa (BECA), International Institute of Tropical Agriculture, International Network for the Improvement of Banana and Plantain

45 Consultative Group on International Agricultural Research Centers such as International Institute of Tropical Agriculture, International Network for the Improvement of Banana and Plantain, International Centre for Tropical Agriculture, The International Maize and Wheat Improvement Centre.

46 With South Africa being an exception. South Africa has, for example, a fermentation facility for industrial production of the amino acid lysine, using locally developed technology. The BIO-EARN Programme is also addressing environmental/ industrial biotechnology.

47 Investigating virus tolerance in vegetables and cereals, bacterial control in fruit production and the production of high-value proteins in crops. The ARC has carried out many field trials with GM technology transferred to local varieties and with technology developed in-country, e.g. fungal tolerant strawberries.

48 The CSIR, South Africa is investigating fungal control mechanisms for these crops.

49 The University of Pretoria, supported by US Department of Energy, plays a leadership role in a new international project to sequence the Eucalyptus genome,

Apart from South Africa, there are also examples of national agricultural research systems⁵⁰ in ESA which have been active in adapting the new technologies, in particular in Kenya, Tanzania and Uganda. In Kenya, the Kenya Agricultural Research Institute (KARI) is leading the way. KARI has recently developed a well equipped biotechnology research laboratory and is the first African country other than South Africa to plant genetically modified (GM) maize for field trials⁵¹. In Uganda the National Agricultural Research Organization (NARO) is planning to conduct field trials of genetically modified (GM) insect-resistant Bt cotton and herbicide-resistant GM cotton. Uganda recently decided to import genetically modified, fungal resistant sweet banana plant materials from Belgium for field trials, which are currently being conducted.

One of the main problems for the region is the lack of adequate government funding for institutional capacity building activities and funding for skilled permanent staff and PhD students. Available and limited human and financial resources are generally spread too thinly over the existing physical infrastructure. Consequently, even if some of the research facilities are of acceptable standard, they often lack the critical mass of trained individuals. Hence, due to low staffing⁵² and lack of operational funds, many laboratories operate below capacity. Limited access to databases, information updating, international networks and scientists are other serious problems for the institutions in the region. In addition, current R&D activities are largely confined to research laboratories and are very seldom commercialised and applied in relevant sectors of society. This is partly due to the very weak links between public research and private sector operations in the countries.

Another serious problem in most African countries has been the lack of conducive biotechnology policies and regulatory

frameworks, weak management as well as poor collaboration and priority setting, which many times has led to resources being spread too thinly and inadequately over too many programmes. However, many countries in Africa are now in the process of formulating and drafting biotechnology policies and national biosafety regulatory frameworks in order to promote safe application of biotechnology according to national priorities⁵³.

4.2 THE USE OF GENETIC ENGINEERING IN ESA

4.2.1 Global status of genetically modified crops

Currently GM agriculture is widely used globally by more than 10 million farmers. In 2006, GM crops covered more than 100 million hectares (James, 2006), which is roughly 8% of the total global cultivated land area. Virtually all maize, soybean, and most of the cotton on the world grain markets are today genetically modified. Not only countries like the United States, Argentina and Brazil, but also China, India, the Philippines, South Africa, Vietnam, and Nigeria are investing in GM agriculture. The global area of biotech crops has been increasing steadily at a sustained growth rate of 13% during the last ten years. It could therefore be anticipated that this technology will probably increase in importance in the future. Development has so far been on globally commercialised crops with a focus on large scale productive farmers in the North and South however significant GM breeding efforts directed to small-scale farmers in developing countries are also under way.

Potential concerns relate to ethical questions, socio-economic impacts and risks, food safety issues and environmental concerns related to introgression of transgenics into non-GM crops and wild relatives, which vary from country to country depending on the

50 Such as Kenya Agricultural Research Institute (KARI) and National Agricultural Research Organisation (NARO) in Uganda.

51 <http://www.SciDev.net>

52 Including laboratory technicians, who are an important resource in biotechnology research.

53 Morris (2008) highlights the problems that can arise when national biosafety frameworks are developed that are not aligned with regional or sub-regional policies, and are delinked from agricultural trade and research priorities.

transformed traits and the available gene pools of different crops and risks in centres of origin. Biosafety regulations and implementation capacity are important to manage such perceived risks. In most developing countries however, the available expertise, institutional capacity, capital and legal structure to deal with GM crops is insufficient.

4.2.2 Impact so far

Most of the current agricultural biotechnology, and in particular GM R&D is being directed by institutions and companies for whom the yield and robustness of African food staples, especially those grown by farmers who retain seed, is not a major motive. In general, commercial GM seed suppliers show little interest in crops where they cannot protect their IP and/or where the cost of achieving regulatory compliance is not justified by the market size. However, an expanding body of literature reporting on the actual farm-level economic impacts of GM crops in developing countries is now available (Brookes and Barfoot, 2006; FAO, 2004; Huang et al., 2001; Smale et al., 2006; Traxler et al., 2001).

A recent extensive study on the economic and environmental benefits by Brookes et al. (2006) also shows a large number of impressive benefits from a decade of GM crop production (1996-2004). The benefits from the use of GM technology, could, in short, be summarised as follows,

- Economic benefits at the farm level amounting to a cumulative total of \$27 billion.
- Reduced pesticide spraying by 224 million kg
- Reduction of the environmental footprint associated with pesticide use by 15%.
- Reduction of the release of greenhouse gas emissions from agriculture, which is equivalent to removing four million cars from the roads each year.

There has been lively discussion among scientists and within the civil society on the potential negative effects of GM on the environment and on human and animal health (Greenpeace, 2004; International Council for Science, 2003; Friends of the Earth, 2003; Nuffield Council on Bioethics, 2004;

Van Aken, 1999). It is important to note that agriculture, as any other economic activity, affects the environment and it is therefore to be expected that the use of GM crops will to some degree also affect it. The International Council for Science expresses it as follows; "...the effect of genetic technologies may be either positive or negative – they may either accelerate environmentally damaging effects of agriculture, or they may contribute to more sustainable agricultural practice and the conservation of natural resources. It is a matter of application and choice..." (ICSU 2003).

Some negative effects⁵⁴ on biodiversity have been observed in connection with the use of herbicide resistant GM crops, due to a lower presence of weeds affecting biodiversity and wildlife (Firbank, 2003; Squire, 2005). In contrast and as mentioned above, the use of Bt cotton has dramatically decreased the use of highly toxic insecticides on a world wide basis, which has a very positive effect on the environment and the health of farmers. Generally, the environmental effects will depend on the specific GM application, the agricultural system and the agro-ecological system in which it is used. There have so far been no widely accepted scientific reports on documented deleterious environmental effects of the commercialized GM crops. For ESA countries it is important to assess environmental impact of the potential use of GM crops in comparison with present agricultural practices, other technology options and potential benefits.

There is so far no evidence of any negative health impacts from the consumption of GM foods or food containing GM crop ingredients. This should be seen in the light of the fact that GM crops have been cultivated commercially in the United States since 1995 and that a large portion of internationally traded commodity crops such as maize, soybean and canola is today genetically modified.

54 On the other hand, herbicide resistant GM crops can increase crop productivity and lower the demand for tillage and could therefore potentially be a more energy efficient and climate friendly crop production system in comparison to conventional practices.

Table 6: GM crop status in Africa

Status	Countries	Type of crops
Countries with commercial plantings of GM Crops	South Africa	Bt-maize, herbicide tolerant maize, herbicide tolerant soya and Bt Cotton
Countries having reported field trials of GM Crops	Burkina Faso; Egypt; Kenya; Morocco; Senegal; South Africa; Tanzania; Zambia; Zimbabwe	Bt-maize, Bt-Cotton, Virus resistant Sweet potato, low nicotine GM tobacco.
Countries engaged in GM Crop research and development	Benin; Burkina Faso; Cameroon; Egypt; Ghana; Kenya; Malawi; Mali; Mauritius; Morocco; Namibia; Niger; Nigeria; Senegal; South Africa; Tunisia; Uganda; Zambia; Zimbabwe	Mainly on disease resistance and pest resistance

Source: African Biotechnology Stakeholders Forum (ABSF). http://www.absfafrica.org/pages/biotech_status.html

4.2.3 Examples of GM crops addressing the needs of the poor in ESA

Tissue culture and marker assisted breeding is used by many NARS and on a number of crops in Africa, including banana, maize, cassava. (Eicher et al., 2006). Interestingly enough there are also a number of publicly driven R&D projects aiming at developing GM crops suitable for African conditions.

South Africa is so far the only country in Africa with commercial plantings of GM crops, but in several African countries there have been field trials of GM crops and there are also a significant number of African countries involved in some type of GM crop research, (see Table 6 above)

The Bt cotton and Bt maize in South Africa are the first examples in Africa where GM crops have been commercialized. The case of Bt cotton has been most studied (FAO 2004; Smale et al., 2006) and the majority of studies show that Bt cotton has significant benefits for farmers, compared to conventional cotton. The most notable changes observed are a reduction in pesticide use, an upward yield trend and a decrease in the cost of production. South African small-scale farmers also benefited from the use of Bt cotton and the success of the South African small-scale farmers in the Makathini flats using Bt cotton has been especially highlighted (Bennet et al., 2006; Hofs et al., 2006).

There are a number of examples of R&D projects using advanced agrobiotechnology

Table 7: Some of the most important ongoing GM crop R&D efforts on Sub Saharan Crops

Biotechnology Crop	R&D effort	Some of the Involved actors
Insect and virus resistant sweet potato	R&D designed to developed varieties GM sweet potato resistant to virus diseases and potato weevils	Kenya Agricultural Research Institute(KARI), Monsanto, the International Potato Center (CIP) and Auburn University (United States)
Insect resistant Maize (IRMA)	R&D designed to develop GM Bt maize for Africa, where the Bt trait is backcrossed into African adapted varieties.	CIMMYT, Kenya Agricultural Research Institute(KARI).
Disease and insect resistant banana	Development of GM transgenic banana with resistance to diseases, but also tissue culture applications for dissemination of disease free banana seedlings	National Agricultural Research Organization (NARO), CIRAD, IITA, Catholic University of Leuven (KUL) and University of Pretoria.
Biofortified Sorghum	Using genetic engineering developing biofortified sorghum with improved elevated levels of vitamins, micronutrients and essential amino acids.	Gates Foundation, Africa Harvest, African Agricultural Technology Foundation(AATF), Council for Scientific and Industrial Research(CSIR), University of Pretoria, Du Pont, Pioneer Hi-Bred, UCLA.
Insect resistant Bt Cowpea	Development of GM Bt Cowpea.	CSIRO, Australia, IITA, UCLA-Davis, Purdue University, Michigan State University, University of Zimbabwe.
Virus resistant cassava	Development of GM Cassava resistant to Cassava Mosaic virus.	Kenya Agricultural Research Institute (KARI);, Danforth Center (United States).
Insect resistant Cotton	Testing different GM Bt cotton varieties in Africa (e.g. South Africa, Burkina Faso, Tanzania).	Monsanto and the respective national agricultural research centres in ESA countries.

Source, Mainly Eicher et al., 2006

including genetic engineering specifically focusing on improving cultivars of specific relevance to small scale-farmers in ESA countries. Some of the most important examples are listed in table 7.

Apart from the above examples there are also GM crops in the CGIAR R&D pipeline of significant relevance to ESA countries. A common denominator, for more or less all these initiatives and potentially valuable technologies is that they build on fairly complex R&D consortia arrangements, integrating many actors in many countries. This is often necessary to access all relevant technologies and know-how and to be able to address and overcome all the technology dissemination barriers facing biotechnology crops and in particular GM crops.

Another observation that can be made is that most of these, potentially very valuable R&D efforts are at least some 10-15 years or longer from reaching small scale farmers in ESA, This is due to the many complex scientific, legal, economic and political barriers to the development of GM crops and long delays in developing and implementing national biosafety regulations and guidelines (Eicher et al., 2006).

5 The Challenges

5.1 PUBLIC RESEARCH FOR THE POOR

There is fairly strong agreement on what type of biotechnology research would be helpful in assisting small-scale farmers and in poverty alleviation (FAO 2004, Pray et al., 2003). In short this would be biotechnology and plant breeding research on commodities and traits that meet the needs of the poor. There is also a broad consensus that public research institutions will continue to be important actors in adapting the technology for the poor. It is also further recognised that public-private partnerships are needed so that public research and small local or regional companies can get access to research tools and genes that will assist the poor.

However, in reality, there is a wide gap between what agricultural biotechnology can do in principle and to what extent the technology has improved the situation for small-scale farmers. The sections below discuss the changing conditions for agricultural research and the different challenges for public institutions to adapt agro-biotechnology for the local needs of small-scale farmers in ESA. The barriers to successful use of agro-biotechnology in solving the productivity problems facing small-scale farmers are many, and include:

- The weaknesses of the public breeding systems in many developing countries which only to a very limited degree have been able to respond to and address the challenges facing the resources of poor small-scale farmers. This weakness is manifested in an inability to access and adapt agro-biotechnology to the benefit of small-scale and subsistence farmers.
- The high transaction costs experienced by the public sector in their efforts in disseminating potential agro-biotechnology applications to meet the needs of small-scale and subsistence farmers.
- The lack of adequate legal and biosafety frameworks to support the introduction of products derived from agro-biotechnology.
- Poor access to farming inputs that are necessary to improve productivity.
- Poor infrastructure and weak market systems that discourage small-scale farmers from increasing their production.

5.2 GREEN REVOLUTION VERSUS THE GENE REVOLUTION

Agricultural innovation is today increasingly carried out by the private sector, and public research projects are conducted in a different policy and market environment. The Green Revolution was driven by public institutions for local markets, and was operated through subsidies and protected markets. Agricultural innovation today is to a large extent driven by the private sector, exercising a much more stringent IP protection. Agricultural markets are also, with some exceptions⁵⁵, to a much lesser degree under government control and less influenced by subsidies.

Since the late eighties, there has been enormous investment by the private sector in agro-biotechnology. Monsanto can be taken as an example of this. Monsanto invests today 10% of its total revenues in agrobiotechnology R&D, which in 2006 amounted to over US\$ 550 million worth of investments in agrobiotechnology⁵⁶. This could be compared with the entire CGIAR system which in 2006 invested some US\$ 450 million in agricultural R&D generally, of which only a small proportion is directed towards agrobiotechnology R&D.

The reason for the R&D push in the private sector is partly due to the widening scope of patent protection for genetic resources, patentability of genes, plants, biotechnological processes and equipment, and in some countries plant varieties (e.g. the United States),

55 For example, the subsidies within the European Union, not least through the Common Agricultural Programme (CAP)

56 Personal communication with Mattias Zetterstrand, Monsanto representative in Sweden.

and increasing protection levels of plant breeders' rights systems. This development has made it possible for the private sector to reap the benefits of their investments in R&D. The high level of investment required to ensure competitive outcomes also pushes research in the direction of the high value commodity crops and associated high value traits. Interestingly enough, the use of GM technology has to some extent made private sector breeding actors more competitive in relation to public sector breeding. This can be seen on highly competitive seed markets such as for soybean. The increased demand for GM soybean has benefited the private sector actors producing GM varieties as opposed to public sector breeding actors concentrating on non-GM soybean.

The public breeding sector in many countries, not least in developing countries, finds itself in a difficult situation, where it is expected, in spite of dwindling financial resources, to respond to various market demands, long term national policies, changing agro-ecological conditions and private sector interest. It also needs to be able to attract highly qualified and motivated staff. The national agricultural research systems (NARS) in some countries hail the introduction of IPRs (notably plant breeder's rights) to make up for reduced public investments in research, but this may bring about changes in research priorities away from the interests of smallholder farmers.

5.3 CROP BIOTECHNOLOGY UNDER AN INCREASING PROPRIETARY CONTROL

Part of the reason for higher transaction costs is due to international conventions and treaties that together with rapid developments in biotechnology have led to new conditions for worldwide access to, and use of, genetic resources and biotechnological techniques. Technology, DNA sequences, research tools and output traits are today largely under commercial control. Major developments in this respect arise from a sequence of court cases in the USA that extended the patent system to life forms in the 1980s, and from the WTO agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) and

subsequent trade agreements that expanded the IPR systems geographically. However, most agro-biotechnologies are currently not protected in the majority of developing countries, but this situation may change rapidly with harmonization and mechanisms that facilitate application of protection in many countries at the same time⁵⁷.

This has led to a situation where public sector R&D institutions, including the CGIAR system, are using technologies controlled by the private sector. This may not pose a serious problem as long as the institutions limit their use of proprietary technology to research (depending on the extent of the research exemption in the national IP-laws), but when products of this research reach the dissemination and commercialisation stage, the freedom to operate may have to be negotiated with the IP right holder. Ownership issues and management of Intellectual Property (IP) is therefore becoming an important part of research collaboration, technology transfer/dissemination and commercialization in the whole agricultural sector.

For many public R&D institutions this may mean high transaction costs (for negotiations or license payments) or denial of access to potentially useful technologies, which in some cases may result in poor farmers not benefiting from the technology because it is too expensive or not accessible. This is a serious challenge which has to be dealt with, but prospects for North-South technology transfer may not be all that bad. After all, public crop and livestock breeding institutions in many developing countries may not be in such a weak position to negotiate favourable conditions for technology access⁵⁸ and may be increasingly able to produce and protect their own

57 South Africa is a party to the International Patent Cooperation Treaty (PCT) and many international companies file their patents there because they can get an early priority date in a non-examining country.

58 Given that they have access to local markets, and often have valuable local crop varieties adapted to specific agroecological conditions.

inventions. There are also examples⁵⁹ of GM-technologies being transferred to developing countries for use by poor farmers at either no cost or at low cost. The GM sweet potato technology donated by Monsanto to Kenya Agricultural Research Institute (KARI) is one example of this. The ‘Golden Rice’ case is another good example, where the owner of the Golden rice technology, Syngenta, allows the inventors of the technology to sublicense the technology to public research institutions in their breeding efforts for small scale farmers⁶⁰. There is also the recent establishment of the African Agricultural Technology Foundation (AATF) which will facilitate and fund the transfer of advanced agricultural technologies, including GM-technologies, to African countries.

The debate concerning benefits and risks connected with an increased proprietary control of DNA sequences, research tools and output traits in a developing country perspective, has been fierce. The proponents of this development have argued that it has led to a marked increase in investments in agricultural R&D, and the generation of technologies and traits which ultimately will be of high value to developing country farming systems, including those in ESA. Some studies show that the strengthening of agricultural IPR⁶¹ may increase incentives to invest in agricultural research as long as

the most important requisites⁶² are in place (Louwaars et al., 2006). The strengthened IPR situation may also create incentives for the private sector, universities and individuals to market and disseminate the technologies. These conclusions may only be valid in situations where the commercial infrastructure through agricultural input markets is available (which is not always the case in ESA).

Opponents have argued that the whole development may be negative for small-scale farmers and public breeding systems in developing countries (Alterie and Rosset, 1999). The argument has been that the strong IP systems on seeds and seed technology is ill suited for most of the seed production and farming systems in the developing countries including ESA⁶³. The public seed production systems struggle to live up to the challenging mandate to provide seeds for a large number of crops, including “orphan” crops (with weak or non functional food markets). Another argument has been made (World Bank, 2006; Louwaars et al., 2006) that public breeding institutions may find it very attractive to their position and resources to target the more commercial farmers and through a management of IP and strategic partnerships and by doing so, increase revenues. Such a development may draw their attention and resources away from the breeding of crops with lower commercial value, e.g. cowpea, millet, sorghum, sweet potato etc (Louwaars, 2007).

There is ample evidence that there is a willingness, particularly with the larger companies, to provide access to technologies on very favourable terms through humanitarian licenses (see e.g. the websites of ISAAA and AATF). However, after a recent agreement on liability and redress in the framework of the Cartagena

59 GM sweet potato technology donated by Monsanto to Kenya Agricultural Research Institute (KARI), the ‘Golden Rice’ case and the insect resistant maize (IRMA) for Africa.

60 Syngenta, owner of the Golden rice technology, has given the inventor Ingo Potrykus and Peter Beyer at the Swiss Federal Institute of Technology in Zurich a humanitarian licence enabling them to sublicense public research institutions and low-income farmers in developing countries, to the full set of necessary technologies. Humanitarian licences mean the use in developing countries (low-income, food-deficit countries as defined by FAO) and resource-poor farmer use (earning less than US\$10,000 per year from farming). Under the agreement, technology must be introduced into public germplasm. Reusing the harvested seed in the following planting season is allowed and the farmer is the owner of his seeds

61 Including strengthening of Plant Breeders Right (PBR).

62 Countries with a functional seed and input market allowing private sector to compete and with good legal institutions.

63 The bulk of the seeds in ESA is still produced and exchanged by farmers and this informal seed system provides a wide variety of highly diversified varieties (but low yielding) adapted to various local conditions.

Protocol⁶⁴, this willingness may be reduced. When the original supplier of a technology may be held responsible for any mishap in the application of the technology in terms of environmental or food safety, inventors are likely to become more hesitant in providing access to technologies to parties that they cannot control (Sullivan, 2005). There is however no quantitative analysis of this expected result.

5.4 TECHNOLOGY DISSEMINATION AND PUBLIC-PRIVATE COLLABORATION

Public institutions are often not the best agents for technology dissemination and commercialisation. These are activities often more suitable for private sector and market actors⁶⁵. Collaborations between private and various public sector R&D institutions therefore have an increasingly important role to play in the dissemination and transfer of appropriate agro-biotechnology applications for small-scale farmers.

In the case of GM crop commercialisation, public institutions are in a particularly challenging situation. GM crop commercialisation involves very high costs and requires substantial capacity to meet the registration and biosafety regulatory requirement of GMOs, based on the need to perform extensive testing for environmental, food, and feed safety. Such costs are another bottleneck of the application of advanced biotechnologies (GM modification) to the often quite specific needs of smallholder farmers.

An important task for the governments of developing countries is therefore to create conditions and an enabling environment for technology transfer and product development partnerships. The involvement and close collaboration between the public and private sectors as well as other market actors are often crucial in order to facilitate a successful dissemination and commercialisation of public R&D efforts (Brenner, 2004).

There is also a need for public R&D institutions to raise awareness of opportunities and obligations in the context of exchange of genetic resources, know how and technology. Consequently, institutions in ESA countries need the capacity to develop appropriate institutional frameworks and policies for access and development, and management of IP and technology transfer.

Lastly, it has also been argued (Pray, 2003) that after all, the main problem for developing countries to access the new agro-biotechnologies is not the result of IPR barriers as described above, rather the lack of research and management capacity in developing countries, to successfully use these technologies. This would certainly be the case for most countries in Eastern and Southern Africa, which are still suffering from too few R&D institutions and private actors able to absorb, develop and disseminate these agro-biotechnologies in their own local markets.

5.5 EMERGING BIOSAFETY REGULATORY FRAMEWORKS

There are concerns about the potential health risks from GM food consumption and potential environmental problems such as the introgression of transgenes into non-GM crops and wild relatives. The potential for introgression into wild species is higher where the crop is grown close to its centre of origin and where there are many wild relatives. Biosafety regulations and the development of capacity for scientifically based risk assessment and risk management are important here. Issues related to the socio-economic effects of GM agriculture have also given rise to intense debate on, for example, its impact on agricultural practices, market risks, ownership, and technology dependence issues. Consequently, for countries interested in developing or adopting GM technology, the development of a biosafety regulatory capacity with an ability to compare and balance the benefits and risks of the new GM technologies against other conventional technologies, is crucial. Most developing countries have implemented, or are in the process of implementing, national biosafety regulatory frameworks in response to, among other factors, the ratifying of the

64 The Cartagena Protocol on Biosafety

65 Including NGOs, cooperatives etc.

Cartagena Protocol on Biosafety. However, there is still a general lack of hands-on expertise, institutional capacity, capital and legal structure to deal with biosafety decision-making on GM crops in an effective and efficient manner.

The development of biosafety regulatory systems is not always straightforward and in some countries is surrounded by controversy. The way these systems are implemented affects biotechnology development and adoption. The governments in ESA are now responding to the challenge of developing biosafety regulatory systems which are functional and stimulate technology transfer and local innovation of local GM crops on one hand, and public confidence on the other hand⁶⁶. Supported by biosafety technical assistance programs such as the UNEP-GEF biosafety implementation projects and the USAID-supported Program for Biosafety Systems (PBS), many ESA governments are now in a position to perform science-based reviews of applications for small-scale (field trial) or large-scale (commercial) releases of GMOs in their countries.

A key issue for the ESA Governments is that once⁶⁷ they have biosafety regulations in place, they need to ensure an efficient and science based implementation of these regulations. The processes of carefully balancing and weighing the potential benefits against the potential risks of GM-crops, and of arriving at a decision to approve or reject the application for biosafety-clearance, presumes the existence of relevant and adequate capacity in several specific areas of knowledge. Biosafety implementation is shaped by the scope and the quality of available competence in the disciplines of biological and environmental sciences, plus the aptitude for inter-ministerial regulation and government-scientist collaboration. As put by McClean et al. (2002), “a thin, weak, or limited knowledge and skills base

tends to produce regulations that are highly protective (at the expense of innovation), poorly defined or inconsistent, comparatively rigid, and /or narrowly interpreted. A deep and broader knowledge, skills and capacity base will foster more latitude in the regulatory development and more flexibility in regulatory implementation”. As demonstrated by Morris (2008), many countries in ESA implementing the Cartagena Protocol in this type of protective fashion, are insufficiently sharing scientific competence within the region, and are not aligning their approaches with regional research and economic policies.

The interest of the transnational companies (TNCs) in testing and commercialising GM technologies in many developing countries has been both negative and positive in terms of GM crop acceptance. Transnational companies such as Monsanto, Pioneer Hybrid and Delta and Pine Land, among others, have been the first to commercialise GM crops in most countries. Being the first, they have provided a real test case for the involved local R&D institutions and the regulatory authorities in their risk assessment deliberations and in the management of applications, informing the public, monitoring GM trials and handling of permits. In this regard these TNCs have contributed substantially to the development of the biosafety regulatory system and the corresponding implementing capacity at the regulatory institutions. However, the TNCs actions have also sharpened the disagreements between local actors and stakeholders and contributed to a politicized debate. A debate where many actors may have been more concerned about the TNC global dominance of the GM crop market and their commercialisation efforts than about the actual biosafety issues surrounding the introduction of the various GM crops.

The debate on GM crops has contributed to the development of a comparatively strict biosafety regulatory system with a demand for high quality biosafety data. The actions of the leading actor in the field, Monsanto, are also highly interesting since they encompass many of the critical aspects and challenges for the public R&D institutions in the commercialisation of their GM crop innovations. Monsanto is probably the company, which at the global level has the

66 Balancing between heavy criticisms from some stakeholders and NGOs arguing that the system is non-transparent and too permissive and criticism from R&D institutions and private sector for being too precautionary and cumbersome.

67 These regulations are not even in place yet in some of the countries.

richest experience in providing high quality assessment data and in complying with different kinds of biosafety regulatory demands all over the world. The Monsanto process of “pulling” GM crops such as Bt corn and Bt cotton through the biosafety regulatory system has contributed to the high standard in the quality of biosafety data (e.g. toxicological data, pollen dispersal studies) required by the regulatory authorities worldwide. The provision of the data has probably been costly for Monsanto, but the company has a substantial biosafety regulatory department and access to a large amount of data from all its GM crop field tests world-wide. The problem is that local public R&D institutions will have great difficulties⁶⁸ in generating and providing all the necessary data in the same manner as the TNCs⁶⁹.

It has been calculated that the costs in taking a single transgenic event through regulatory procedures, including greenhouse and field tests and food safety and animal tests, can cost up to US\$4 Million. (Cohen, 2005). A publicly funded project to gather the regulatory data for Bt potatoes in South Africa, is estimated to have cost significantly less (US\$800-850 000). This is in part because the salaries in public institutions are less, but also because university facilities were used for production of protein for toxicology studies (Hector Quemada, personal communication to J Morris). Many universities and research institutions do not use full cost accounting models, so the real cost is probably considerably higher. The regulatory process is also time consuming, adding some 5-10 years in comparison with that for non-transgenic crop approval. There are thus few public institutions which can absorb such cost⁷⁰, and the long biosafety assessment processes are to a large extent discouraging

68 For example, toxicological feeding studies can be very costly and public R&D institutions usually do not have the necessary budgets or the skills to acquire all the necessary data.

69 Who, for competitive reasons would not like to disseminate the biosafety data. The data would however be part of a publicly available application dossier, except for Confidential Business Information – which usually is not biosafety related.

70 Few public granting institutions are today willing to invest in assisting public institutions to “pull through” a GM product into the whole biosafety regulatory process.

scientists in the public domain from engaging in GM technology. It can be anticipated, however, that these timeframes and associated regulatory costs will decrease as familiarity and publicly available risk assessment data increase.

As indicated above, there is a risk that the strict regulatory system and implementation with a strong precautionary approach, may lead to a market situation where only the TNCs are able⁷¹ to comply with regulatory demands, and where the local developing R&D institutions and companies (including the CGIAR system) have difficulties competing with the TNCs in their development of GM crops for the local market. This could lead to a situation whereby the public R&D efforts directed to the needs of local small-scale farmers will never be made available to these farmers. Consequently, should the governments in ESA be interested in the dissemination of locally developed GM crops to local farmers, they have three options (which may in fact be complementary approaches). The first option would be to lower the criteria for the provision of biosafety assessment data during the assessment of locally developed GM crops. The second option is to strengthen the local competence of regulatory bodies to assess risk and empower the local R&D actors’ ability to comply with the regulatory demands. This would probably necessitate increased funding to undertake biosafety assessment studies and biosafety capacity building in public R&D institutions. A third option is for the ESA governments to agree to work together and in the first instance adopt a regional approach to biosafety risk assessment, and the sharing of data and expertise. In future this could potentially be extended to incorporate regional risk management and decision making.

5.6 THE SOCIO-ECONOMIC CHALLENGES

The socio-economic challenges for developing country farmers in relation to their adaptation and adoption of new

71 Even the large transnational companies, such as Monsanto are finding this increasingly difficult.

crop technologies have been a topic of intensive debate, especially in the case of GM-technology. There is great difficulty in determining socio-economic impacts of the introduction of agrobiotechnology on farming communities a priori. There is lack of adequate methodologies to do this at the early stages of risk assessment, when technologies are to be tested, and yet, in many cases, also in ESA countries, it is increasingly required as part of the risk management and decision making process.

In the case of GM technology, the potential socio-economic risks faced by small scale-farmers in developing countries that may adopt the current commercial crops are related to:

- Potential monopoly control that the TNCs' developing country agents/ subsidiaries/joint-ventures exercise on the price of the GM-seeds.
- The need to buy GM-seeds for every new planting season to maintain high-yield levels and fulfil farmer's agreements with the seed-selling companies,
- Profitability margins being squeezed between increasing seed costs and declining harvest prices
- Possible loss of existing robust crop varieties and technologies, thereby reducing the diversity, flexibility and resilience of farming systems, and increasing vulnerability to events that could lead to famine.
- Loss of export markets in cases where the importing country does not accept GM crops/products as is the case with some EU countries.

Most of these concerns are not unique to GM-crops. To some extent, they are the same as the concerns raised when hybrid seeds and elite cultivars were introduced some decades ago. One new component, however, is the stronger IPR protection accorded to GM-technologies and GM-crops. Additional concerns have to do with the ongoing globalisation and liberalisation of markets, and the changes in agricultural systems and how this is impacting on rural societies. Turning these arguments

around, it could be said that developing country farmers can benefit from improved commercial seeds, even if they cost more,⁷² provided they are able to produce more and find a market for their products at reasonably profitable prices.

Studies of the benefits arising from biotechnology which have been commercialised actually show that farmers, in most cases, pass on most of the total benefits⁷³ to society. For example, in the case of Bt cotton in South Africa it was shown (Pray et al., 2003) that farmers passed on about two thirds of the total benefits to society. The immediate socio-economic benefits of Bt cotton to small-scale and subsistence farmers in South Africa are fairly well documented. Adoption rates among small-scale farmers are at 90% in certain cotton growing areas (Bernsten 2001; Bennet et al., 2006; Ismaël et al., 2001; Kirsten and Gouse, 2002). In order to accurately monitor long term socio-economic effects on the introduction of GM cotton on issues such as farm level impact, health, equity and poverty alleviation, future socio-economics studies will need to collect more data over a longer period.

5.7 THE NEED FOR POLICY REGIMES IN ESA

The so called green revolution made a drastic impact on crop productivity world-wide, and the breakthroughs made⁷⁴ during the 60's and 70's, are still required to ensure⁷⁵ that the benefits of the agro-biotechnology revolution are fully realised. The green revolution in Asia was not only due to new crop varieties and technologies but to a large extent was driven by government policies. It has been argued that the green revolution bypassed Africa,

72 Farmers will buy GM-seed only if the cost is justified by the returns. GM seed prices may vary from area to area, so that they are priced to be competitive and reflect the potential benefit for that area.

73 Measured as farmers' profits plus the profits of the supplier of the technology.

74 Such as fertilizers and crop hybrids.

75 Thus. Agro- biotechnology is not a substitute for the first green revolution, but rather builds on the efforts made during this period.

not only because of inappropriate farming systems or due to technology barriers, but also ineffective policies (Djurfeldt, 2005).

The importance of consistent policies and strategies can be exemplified by developments in China. Farmers in China are today using agrobiotechnology, including GM technology, extensively. China has also been able to very successfully integrate agrobiotechnology in its agriculture R&D programmes with a large number of biotechnology crops in the R&D pipeline. These achievements are however a result of substantial investments in agrobiotechnology R&D and policy development made by China in the late eighties. Thus China is now reaping the benefits of a policy framework developed some 15 years ago. The same is also true for countries such as India, the Philippines and South Africa.

The point is that well developed policies and long term country strategies matters (Paarlberg 2001; Bhagavan and Virgin, 2004). For ESA countries, with their scarce resources and serious agricultural challenges, carefully crafted policies and strategies towards making use of the opportunities provided by the bioscience revolution in addressing poverty, hunger and long term economical growth, will be crucial. The last section of this study focuses on what we think are key policy options for adapting agro-biotechnology to the needs of small-scale farmers in ESA countries.

6 Policy Options for Adapting Agro-Biotechnology to the Needs of Small-scale Farmers

6.1 APPROPRIATE POLICIES AND STRATEGIES MAKES A DIFFERENCE

We have, in earlier sections, shown that agro-biotechnology and also GM technology can be highly useful to the needs of small-scale farmers in ESA, but that there are serious barriers which make it difficult for the technology to reach these farmers.

We have also argued that long term strategic investments, conducive long-term policies, effective and efficient national regulatory systems and various incentive systems are important factors in order for countries to benefit from agricultural biotechnology. The experiences of countries like China, India the Philippines and South Africa corroborate this.

Below follows a list of possible measures, not least in the policy arena, that could be taken by a range of actors in the region to enable agro-biotechnology to improve the productivity and livelihoods of small-scale farmers.

6.2 POSSIBLE ACTIONS WHICH WOULD SUPPORT THE ADOPTION OF AGRO-BIOTECHNOLOGIES BY ESA COUNTRIES

6.2.1 Establish desired outcomes and mechanisms for the monitoring of progress

In order to provide strong leadership and to follow up on priorities and strategies⁷⁶, ESA national governments could develop a commonly agreed set of prioritised desired outcomes and a system where the progress made towards achieving these outcomes is regularly monitored. The recent report by the NEPAD/AU High-level Panel on Modern Biotechnology would be the starting point

for developing a common vision. This would include;

- A definition of clear objectives in terms of the contribution of agro-biotechnology to poverty alleviation and food security, backed by poverty reduction strategies.
- A definition of clear desired outcomes of public investments in agrobiotechnology R&D, including decisions on the type of R&D biotechnology investments needed (guiding donors and other actors interested in assisting long term capacity building)
- The development of monitoring mechanisms, consisting of a mix of independent⁷⁷ and institutional reviews and progress reports.
- A determination of the relative importance of achieving food security through local agricultural production versus the importance of production of cash crops for income generation (to be traded for food imports if desired).
- A definition of the relative importance of the private and public sectors in achieving desired outcomes.

In determining priorities and assessing the relative risks and benefits connected with the use of various technologies (agro-biotechnology vs traditional technologies and GM vs non-GM agrobiotech) broad based consultation should be done with all stakeholders, including the urban and rural poor.

6.2.2 Strengthen Public R&D Capacities

Since the crop biotechnologies at the international level, developed by the TNCs, are particularly focused on commercial markets, the role of public research and development is imperative for the contribution of these technologies to the reduction of rural poverty.

⁷⁶ ASARECA has developed a priority investment areas and strategic partnerships key crops of regional relevance

⁷⁷ Not part of the system.

- Support institutional strategies that are consistent with the objectives, and monitored through appropriate oversight mechanisms.
- Increase public investments in strong African public research institutions and their abilities to harness the benefits of agro-biotechnology to the needs of small-scale and subsistence farmers in Africa⁷⁸ through research and breeding.
- Assure optimal needs orientation of public research through broad participation in priority setting and various phases of research.
- Develop mechanisms to strengthen collaboration among ESA countries and sharing of facilities and expertise to facilitate R&D agro-biotechnology in the region. This includes an increased use of R&D platforms, such as the NEPAD centres of excellence, and regional funding/research agencies such as ASARECA.
- Promote organisational reforms in public institutions to facilitate the broad based participation in regional and international research consortia and technology transfer. This involves institutional structures and mechanisms for networking, R&D management, contract arrangements, financial accountability, transfer of funds and exchange of staff. It would also involve institutional policies on management of Intellectual Property (IP).
- Support facilitated access of proprietary agro-biotechnologies for use by the poor, including extended research exemptions and inclusion of licensing mechanisms for this particular use in intellectual property (IP) laws; this would include a support to institutional and national IP and technology transfer capabilities, as well as a support to “technology brokers” such as AATF.
- Support public sector engagement in “open source” platforms for enabling and applied biotechnologies⁷⁹.
- The establishment of an agro-biotechnology innovation prize to be funded by ESA governments, possibly through donor agency funds.
- Perform regular studies on the economic, environmental and health effects of the adoption of agro-biotechnology derived products in ESA countries. Such studies would help answer some of the concerns and questions about safety and socioeconomic effects of the use of agro-biotechnology and support future policies. These studies should be done by interdisciplinary consortia of ESA scientists and possibly linked to a peer review by high quality international experts.
- Build capacity to undertake biosafety research to address uncertainties regarding health and environmental risks of GM crops, and to generate all the data required to assure the safety of newly developed GM crops.
- Develop an integrated innovation chain and a continuous development of methodologies to ensure that there is seamless development from the laboratory to greenhouse to field to farmer. Biotechnologists and breeders need to interact throughout the process.

6.2.3 Improved technology dissemination and agricultural innovation systems

R&D efforts can only lead to development and improve livelihoods if R&D results are disseminated and commercialized and eventually result in products/processes/technologies that benefit society. A key question facing ESA countries is how a biotechnology innovation system and bioresource value chain could contribute to development and poverty alleviation. ESA countries need to strengthen the

⁷⁸ Measures that have a comparative advantage (in comparison to conventional technology) and potential to lead to increased yields of local crops and agricultural products and technology of importance to small-scale farmers and to the poor consumers in rural and urban areas.

⁷⁹ This may include support to CAMBIAS BiOS project or other CGIAR initiatives.

formal agricultural innovation systems and support technology and knowledge dissemination to small scale farmers. In the case of agrobiotechnology, this would mean innovation chains from the laboratory to the market, supporting linkages between R&D actors, farming community, private sector entrepreneurs and agro-processing industries. Public sector institutions would need specific assistance to reach poor and vulnerable farmers to enable biotechnology innovations to contribute to poverty alleviation. Support in this area may include the following.

- Support to the integration of the “formal” and “informal” seed systems, including modern participatory breeding approaches where agro-biotechnology⁸⁰ might play an important role. This would in many countries necessitate revision and harmonization of national seed laws, and plant breeders’ rights laws.
- Increased support to effective extension services, particularly focusing on improved crops with low profit margin produced by the public sector but with high value for the poor and vulnerable. Support would include activities such as farmer-field-schools, seed fairs etc., but also public information campaigns for successful applications of biotechnology.
- Increased public awareness campaigns on biotechnology in general, allowing farmers and consumers to access science and evidence based information, enabling appropriate technology dissemination.
- The weak innovation systems in most ESA countries have so far not been able to address crop value addition chains. There is a need for a “gap” analysis, including studies on rules/policies, actors missing and possibly the introduction of specific “innovation actors” able to step in to catalyze action.
- Lowering the barriers for and improving the efficiency of public technology dissemination efforts, including the facilitation of product development partnerships, where private sector and/or possibly NGOs could be engaged in new types of low cost technology dissemination efforts. Government and donor funded venture capital initiatives are needed to catalyze public-private partnerships and technology dissemination. The public sector also needs to strengthen its ability to negotiate with the private sector to draw up and manage contracts.

- Supporting the local public and private actors to meet and discuss collaboration opportunities and development of consortia for technology transfer, adaptation and R&D (such as IRMA, BIO-EARN). This could be done through technology fairs and workshops, etc. On a more structured level this would involve the development of business incubators and science parks.
- Designing capacity building and awareness programmes⁸¹ to stimulate entrepreneurship and business development, involving different actors (public sector, NGOs and private sector). These programmes could be geared to increasing trust between the different actors, and visualising different models and ways of working together.
- Assisting the local private sector in engaging in technology dissemination and R&D collaboration. Governments in the ESA should stress the importance of putting into operation policies to encourage innovation and private sector investments in research and development. This could be done by education and training⁸², informing private sector of opportunities as well as putting in place mechanisms to reduce business risks for the private sector⁸³ engaging in technology dissemination to small-scale farmers (including tax incentives, credit facilities, venture capital and transparent liability arrangements).

80 Marker assisted breeding/monitoring/characterisation.

81 Could be workshops or seminars.

82 Training on entrepreneurship and business management.

83 Many of the local private sector actors in ESA are currently financially weak.

- Putting in place strategies and mechanisms for promoting up- and out-scaling of technologies mainly by the private sector.

6.2.4 Investing in biosafety

Investments in efficient and appropriate biosafety regulatory regimes and biosafety assessment capacity are needed. The governments of ESA countries need to develop the following:

- Strengthen the inter- and intra-ministerial collaborating mechanisms appropriate to the implementation and compliance-monitoring of policy, legislation and the biosafety regulatory regime.
- Harmonize national policy, legislation and implementation of biosafety regulations, regionally and internationally, within the provisions of the Cartagena Biosafety Protocol and other relevant international agreements to which the countries in the region are signatory. Where possible, existing laws and legal authority should be used to establish a regulatory framework.
- Establish a functional and transparent administration of applications for the development, testing and release of GM organisms, including (i) administering applications for GM activities; (ii) handling enquiries about GMOs and biosafety; (iii) producing guidance and application procedures for stakeholders; (iv) training of biosafety regulatory personnel within and outside the government; (v) facilitating assessment of applications through administration and formation of review committees (vi) establishing credible decision making mechanisms (vii) establishing monitoring mechanisms (viii) coordinating intergovernmental information sharing on GM activities and where appropriate shared risk management and decision making.
- Impartially assess risks and benefits of the proposed development, testing, use and release of GM organisms based on scientific methods. This

requires scientific and regulatory skills including a capability of collaborating with scientific bodies regionally and worldwide, on the validation of known data and methodologies.

- Develop mechanisms for risk management/risk monitoring and risk communication. This would include; (i) the ability to coordinate inspections and report on GM activities; (ii) follow-up on non-compliance (iii) create and update the national biosafety database, ensuring its reliability, (iv) promote the regional sharing of biosafety information, and (v) developing risk communication strategies for different stakeholders.
- Mechanisms to facilitate handling of trans-boundary movement of GMOs within the context of regional trade agreements, especially in light of the relatively high levels of informal trade in ESA countries.
- Assure cost- effectiveness of the above operations avoiding prohibitive costs on innovators. Developing countries should build on assessments and experiences⁸⁴ made in more developed countries.
- Disseminate balanced information on the benefits and risks of GM products with the view of improving public awareness on GM technologies.

6.2.5 Assisting small-scale farmers in adopting agro-biotechnologies to their needs

Small-scale farmers need to be assisted in such a way that they can adopt and use promising technologies according to their needs. This could be done through:

- Developing mechanisms for client-oriented research by strengthening the farmers' ability to demand desired

84 For instance through accessing the regulatory reviews made in leading OECD countries or in other relevant countries in the world in the process of acquiring experience in handling GM organisms, e.g. India, the Philippines, Indonesia.

products and effectively give input to public sector breeding targets.

- Support to mechanisms that facilitate farmer access to credit for improved seeds, fertilizers and agrochemicals as well as market access to facilitate the uptake of public R&D outcomes.
- Training of farmers in making their farm more productive and managing new improved varieties.
- Farmer empowerment in terms of training as well as access to and management of resources.
- Improving market opportunities and promoting internal and intra- regional trade by removing non-tariff barriers.
- Improvement of local varieties and landraces that the farmers are already familiar with.

6.2.6 Consistency of the above policies and their implementation

The adoption of a product chain approach from biotechnology research to application in breeding and finally to use by smallholder farmers requires long-term vision. Consistency of policies over extended periods of time is therefore imperative for a successful application of the technologies for development objectives. This need for consistency applies in the development and adoption of the intended policies themselves and also the mechanisms for the adaptation of such policies to changing conditions and needs. This could be done through:

- Development of conducive policy environments framing the use and dissemination of agro-biotechnology. This would include pro-poor policies on seed development, harmonized and possibly revised genetic resource policies and seed laws, incentives and clear guidelines for public-private partnerships, clear Intellectual Property

(IP) policies⁸⁵, and structures at national and institutional levels that promote technology transfer and technology development.

- Harmonization of genetic resource policies (e.g. seed laws, Plant Variety Protection (PVP) systems etc) and actions to enable the “formal” and “informal” seed systems to reinforce each other.
- Definition of priority areas for biotechnology research guided by a long term vision which would act as guidance of public investment of biotechnology research in public-sector institutions. A short-, medium-, and long-term strategy on how governments in ESA could support the agricultural sector to benefit from the bioscience revolution would also be important. Specific attention should be given to investment in technology that would reach small-scale farmers.
- Development of policies and methodologies for determination of the likely development cost versus broad economic benefits to be derived from specific opportunities, to facilitate the process of priority setting and ensure that investments will be cost-effective.
- Identification and highlighting of the most strategic actions, including government actions, that would lead to increased investments, technology transfer and agro-biotechnology product development in the agricultural sector.
- Provision of a clear, transparent, practical and sustainable biosafety regulatory and compliance-monitoring framework, which ensures that the regulation and applications are applied,

85 There are many examples world-wide that visualize constructive development of country/ institutional specific IP systems for technology and seed dissemination. Much can be learned from IP systems developed at institutions in other countries in the world, including countries such as Egypt, South Africa, and Thailand.

reviewed and monitored in a science based and predictable manner.

- Consistency of policies towards biotechnology and biosafety across government departments, particularly those responsible for agriculture, environment, science and education. This will help to ensure an integrated and holistic approach to the development of agro-biotechnology from both an investment and a regulatory perspective.
- Consistency of national policies with those of sub-regional and regional trade, economic, agriculture and innovation communities. The policies of ESA organizations such as SADC and COMESA need to reflect and be aligned with a common vision in the member states.

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Annex A

Impact of Agricultural Biotechnology on the Rural Population of East and Southern Africa: The Case of Tanzania

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1 Crop Breeding Programmes and Capacity in

1.1 INTRODUCTION

The Directorate of Research and Training (DRT) in the Ministry of Agriculture, Food Security and Cooperatives (MAFSC) is the major institution of the National Agricultural Research System (NARS) in Tanzania. It is composed of the Coordination Unit at the Ministry Head Office, seven Zonal Agricultural Research and Development Zones² under which there are 16 Agricultural Research Institutes (ARIs). The main objectives of the crops research programme under the DRT during the last decade as indicated in NARM³ have been to: (a) to carry out high-priority, demand-driven research on food and cash crops to increase on-farm production through improved varieties with high genetic potential (b) disseminate technology packages to target end users in order to improve productivity of food and cash crops; and (c) to sustain production, as well as rationalize processing and marketing in order to increase economic returns to farming as an enterprise.

To enhance production, commodity improvement programmes of the different NARS institutions focus on, e.g. breeding research to develop high yielding varieties with traits demanded by the farmer/clients and markets. Broadly, the major objectives have been to improve yield, product quality, and resistance/tolerance to biotic and abiotic stresses. During the period between 1999 and 2004 thirty one varieties of different crops were developed and approved for release by the Variety Release sub-committee (Table 1).

1.2 HUMAN RESOURCES CAPACITY

According to the Medium-term Programme (MTP⁴) report of 2003 of the Ministry of Agriculture Food Security and Cooperatives, the NARS has a critical mass of skilled scientists, technicians and support staff for developing the necessary information and technologies required by the sector stakeholders. By the end of 2003/04 the two major NARS organizations (DRT and DLRT⁵) had 343 scientists, eighty seven percent of whom had academic qualifications above the first degree. Among these only about 40 are plant breeders. However, further analysis shows that a large proportion of the NARS staff is approaching retirement age, and a good number of them are involved in administrative functions. For example, more than 50% of the research scientists in the three major NARS institutions (DRT, DLRT and SUA⁶) are more than 45 years old, and will retire in the next 10-15 years. The low proportion of young scientists in the DRT and DLRT is due to the 10 years freeze on employment, loss of staff occurring through brain drain and the impact of HIV/AIDS. From this analysis it can be concluded that, while in the past deliberate efforts had been taken to train an adequate number of scientists in various agricultural fields, (including breeding), deliberate efforts need to be taken to ensure this capacity is maintained and strengthened. It is therefore necessary to recruit and train new scientists with expertise.

2 These represent broadly 7 agro-ecologies: Eastern, Southern, Northern, Western, Southern Highlands, Central and Lake Zone

3 NARM - the National Agricultural Research Master Plan was published in 1991 (URT 1991). It specifies priorities at zonal and national levels which guided agricultural research under the DRD and the DLRT over the past decade.

4 MTP, 2000: medium term Plan, National Agricultural Research System (NARS) of the United Republic of Tanzania

5 DLRT = Directorate of Livestock Research and Training

6 SUA = Sokoine University of Agriculture

Table 1: List of crop varieties released from 1999 – 2004 by different Agricultural Research Institutes in Tanzania

Crop	Name of Variety	Year released
Maize	Staha ST	2001
	Kilima M1	2001
	Stuka 1	2001
	Lishe K1	2001
	Lishe H1	2001
	Lishe H2	2001
Sorghum	UH615	2001
	Macia	1999
	Hakika	2002
Rice	Wahi	2003
	TXD 85	2000
	TXD 88	2000
Wheat	TXD 306	2001
	Chiriku	2002
Barley	Kusini	2001
Cassava	Kigoma Red	1999
	Hombolo 95/005	2002
	Mumba	2002
	Naliendele 90/034	2003
Sweet potatoes	Jiihada	2000
	Mavuno	2000
	Vumilia	2000
	Simama	2000
	Sinia	2000
Beans	Wanja	2002
	Uyole	2003
Soybean	Uyole Soya 1	2002
Cowpeas	Vuli-2	2003
Pigeon peas	Komboo	1999
	Mali	2002
	Tumia	2003

1.3 CURRENT STATUS OF PHYSICAL INFRASTRUCTURE

During the last six years the DRT invested considerably in improving, updating and maintaining the physical infrastructure in its research institutes. The department procured many key facilities for creating good working and living environment for the research community. However, some of the major bottlenecks still facing the ARIs include:

- Ineffective management of vehicles and other facilities, which, often results in ineffective use and thus creating artificial shortages;

- Outdated laboratory facilities in some research institutions;
- Poor communication facilities (telephone, fax, e-mail and internet services) at various institutes. This has a direct negative bearing on information sharing and interaction among scientists and institutes within the country, regionally and globally;
- Inadequately equipped libraries, which lack current scientific literature. This has a bearing on the quality of reports and research proposals.

1.4 CURRENT SITUATION FINANCIAL RESOURCES

Currently in Tanzania R&D activities being conducted by the different NARS institutions get their funds from the following three main sources:

- Central Government allocations or grants. The Government has not been able to fund agricultural research adequately due to financial constraints. During the last 10 years, the Government allocation to agricultural research is estimated at 0.36% of agricultural GDP⁷ (MTP, 2003). Although the government allocation for research has been improving over time during the last few years, this allocation remains far below the recommended amount of 1% of agricultural GDP to be spent on research.
- Donor subventions from bilateral and multilateral donors. In recent years, however, there is a declining trend in donor support to agricultural research and the agricultural sector as a whole.
- Cess and levies. Local taxes collected as cess are used to fund research for commercial crops such as cashew, tea, tobacco, coffee and cotton. The actual amounts contributed to research largely depend on the levy collected, which in turn depends on the commodity prices and production.

7 GDP = Gross Domestic Product

Other potential sources of funds include contract research, contributions by local government authorities or private sector through the Zonal Agricultural Research Funds and revenue retention or cost recovery. The potential of these sources is still untapped due a number of reasons, including inadequate capital and entrepreneurial skills of the research institutions.

The different problems notwithstanding, the breeding programmes have been able to produce a number of improved varieties, some of which have been commercialized. In order to meet the increasing demand for better varieties, there is however, a dire need to strengthen this capacity by recruiting and training new breeders as well as providing adequate infrastructure and financial support. In addition it will be important for research institutes to improve their intellectual property (IP) as well as financial management skills and capacities.

2 Status of Agro-biotechnology and GM-local crops in Tanzania

Crop improvement in Tanzania has largely depended on conventional breeding methods. However, the scenario is now changing, with some NARS institutions having started integrating biotechnology in their crop improvement programmes.

2.1 CROPS IMPROVED THROUGH TISSUE CULTURE WITH FARMERS

In Tanzania there are two crops produced through tissue culture (TC) that are being grown by some farmers. Sisal is being produced at Mlingano Agricultural Research Institute through a joint venture with the private sector. There are also some farmers who are growing TC bananas. These have been produced through collaboration with GTL⁸ in Kenya under the support of ISAAA and introduced in the country by Horti Tengeru. In addition, SUA, MARI and Kizimbani Research Station in Zanzibar have distributed limited quantities of TC banana to some farmers.

2.2 CROPS UNDER IMPROVEMENT THROUGH AGRO-BIOTECHNOLOGY IN TANZANIAN NARS

Currently five ARIs under the DRT are implementing a project on “Molecular marker-assisted and farmer participatory improvement of cassava germplasm for farmer/market preferred traits in Tanzania”. This project is funded by the Rockefeller Foundation (RF), and seeks to use new tools of molecular marker-assisted selection (MAS) and farmer participatory breeding to develop pest and disease resistant cassava varieties upon which many rural communities in Tanzania depend for their food security and livelihoods. Local cassava varieties selected by farmers from the three major agro-ecologies, namely Eastern, Lake and Southern Zones of Tanzania have been crossed with genotypes from CIAT, Cali, Colombia that are resistant to Cassava Mosaic Disease (CMD), Cassava

Bacterial Blight (CBB) and cassava green mites (CGM). Molecular markers for CMD, CBB and CGM were then employed to identify the resistant F1 progenies. These are now being further subjected to on-farm evaluation in a participatory manner to identify those preferred by farmers and market. This project also aims to understand the mode of resistance of Cassava Brown Streak Disease (CBSD) and to develop quantitative trait loci (QTLs) to be used in future breeding purposes.

The DRT is also implementing another RF funded project on “Genetic enhancement to increase productivity in rice through breeding for resistance to Rice Yellow Mottle Virus (RYMV) disease in Tanzania”, the objective of which is to use MAS and farmer participatory breeding to develop pest and disease resistant rice varieties.

Other projects being implemented by the DRT include: the development of capacity for indexing banana virus diseases, and mass propagation of disease free cassava varieties that are resistant to the Ugandan variant (UgV) of Cassava Mosaic Virus. The breeding programme has identified about 11 resistant clones. These will be mass propagated through TC for distribution to farmers after being indexed for UgV using molecular tools to ensure that they are clean.

2.3 CROPS MOST SUITABLE FOR AGRO-BIOTECHNOLOGY

In Tanzania a comprehensive priority setting for biotechnology R&D has not yet been done. The last priority setting was done more than a decade ago. However, under the Agricultural Sector Development Programme (ASDP), which officially commenced in July 2006, farmers’ problems and priorities are being captured through participatory methods and these become the basis for the preparation of the District Agricultural Development Plans (DADEPs). In addition country-wide participatory zonal research priority setting exercise to identify the specific research and development requirements for the farmers in the different agro-ecological zones will also be conducted. The aim is to establish

8 GTL = Genetics technology Ltd

a research agenda that moves beyond technology and provides farmer-oriented, demand-driven responses to priority problems in the field. However, without the intention of pre-empting the outcome of this exercise, but based on previous needs assessment surveys - including those by Virgin (2002)⁹ and Mneney et. al., (2002)¹⁰ in the Eastern, Southern Highlands, Lake and Central zones, the following preliminary suggestions are made for the short and medium term.

- Application of tissue culture techniques for the mass propagation of important cash and food security crops. The cash crops include high yielding and/or disease resistant sisal, coffee and pyrethrum varieties. In terms of food security crops, priority could be on mass propagation of improved banana varieties to satisfy different market niches, as well as production of disease-free cassava and sweet potato planting materials. To accomplish this, it is important to develop strong partnerships between the public institutions and the private sector. The arrangement could be such that the public TC laboratories produce the in vitro plantlets in the laboratory, and the private companies would be involved in raising the plantlets in the nursery and marketing of the same;
- application of MAS to improve resistance/tolerance of maize and sorghum to biotic and abiotic stresses;
- application of MAS to improve resistance/tolerance of cassava and sweet potato to biotic and abiotic stresses;
- conducting confined field trials to test the efficacy of some GM crops such as Bt cotton against the American red boll worm, Bt maize against stem borers,

transgenic cassava against Cassava Mosaic Disease and transgenic papaya against Papaya Ring Spot Disease. The implementation of this will depend very much on the operationalization of the national biosafety regulatory framework as well as the Plant Breeders' Rights through which the owners of the GM crops can protect their varieties. .

9 Virgin, I. (2002): Long-term strategies for strengthening agricultural biotechnology research and development capacity in Tanzania. Short-term consultancy for Department of Research and Development (DRD), Ministry of Agriculture and Food Security (MAFS) Tanzania

10 Mneney E.E., A.A. Mpunami and J.S. Kasonta (2002): Needs assessment and priority setting in agricultural biotechnology: A case from the Eastern and central zones in Tanzania.

3 Transfer of Technology and National R&D Capacity

3.1 AGRO-BIOTECHNOLOGY CAPACITY IN TANZANIA

The application of biotechnology in Tanzania can be considered to be in its initial stages. In terms of agricultural biotechnology there are several public R&D institutions that have started integrating biotechnology in their research and development agenda. They include:

- ARI Mikocheni, which has adequate facilities for tissue culture¹¹ and for basic molecular marker techniques for germplasm characterization and disease diagnosis. The Institute has been conducting studies on genetic diversity and fingerprinting of different crops such as coconuts, cashew, coffee, sweet potatoes and cassava. It has four biotechnologists with PhD (1 plant breeder and 3 pathologists) and seven other researchers who are pursuing their post graduate training (3 PhDs and 4MSc). There are also about six technicians, most of whom can work independently without extensive supervision.
- ARI Mlingano has established, in collaboration with KATANI Ltd. a tissue culture laboratory for micropropagation of sisal. This laboratory is manned by two researchers (MSc) and two technicians. All are well conversant with in TC techniques.
- ARI Uyole, ARI Ukiriguru and Horti Tengeru. These laboratories have been built by the Government to promote mass propagation of pyrethrum, coffee and banana and other crops through tissue culture. Each of these laboratories has one researcher and two technicians.
- Kizimbani Research Station in Zanzibar is involved in banana micropropagation, and it is manned by two researchers and one technician.
- Sokoine University of Agriculture (SUA) is a public university, the main mandate of which is teaching, research, consultancy services and extension in agriculture, veterinary medicine, natural resources, and related fields including food science and technology, forestry, meteorology, environmental science and nature conservation, aquaculture, bee keeping, wildlife management, agribusiness, biotechnology and laboratory sciences.
- SUA has established a tissue culture laboratory for both research and training purposes. They include laboratories for tissue culture and micropropagation, microbiology, molecular biology, immunology, pathology, biochemistry and biotechnology research. The SUA has also established an ultra modern seed pathology laboratory and the Genome Sciences Centre for research in functional genomics and bioinformatics. The Genome Sciences Centre accommodates a wet lab, facilities for printing, hybridizing and scanning microarray system, and the computer infrastructure necessary for data storage, manipulation and analysis. At the university there are nine scientists and a number of qualified technicians who are engaged in different biotechnology research activities.
- The National Plant Genetic Resources Centre (NPGRC) based at the Tropical Pesticides Research Institute (TPRI) in Arusha has recently established a tissue culture laboratory for long term in vitro conservation of plant genetic resources. The NPGRC has four researchers (2 PhD and 2 MSc) who are involved in biotechnology and biosafety related activities.
- The Tanzania Coffee Research Institute (TaCRI) has established a tissue culture facility with an annual capacity of producing more than 250,000 plantlets of high yielding, diseases resistant coffee varieties through somatic embryogenesis. Currently the laboratory is manned by

¹¹ The TC laboratory has an estimated capacity of producing about 500,000 plantlets of different crops per year

one qualified research scientist (PhD and two technicians). The TaCRI is responsible for coffee research and technology transfer to support the rejuvenation of coffee industry in Tanzania.

3.2 MAIN CONSTRAINTS

Some of the main constraints and challenges for promoting agricultural biotechnology R&D in Tanzania include:

- Lack of a national biotechnology policy and a functioning national biosafety framework. The Government of Tanzania has been working on this issues (see Section 4);
- Lack of clear priorities and expectations for agricultural biotechnology. A number of the on-going activities have been through initiatives taken by individual scientists and/or institutions. The approach to biotechnology development has therefore been rather ad hoc and un-coordinated;
- Lack of a critical mass of well trained and experienced experts (scientists and technical staff) and inadequate infrastructure capacity;
- Inadequate financial capacity of the national breeding programmes;
- Inadequate capacity for seed production and marketing system. After the collapse of the Tanzania Seed Company (Tanseed) there has not been adequate capacity to multiply breeders' seed coming from public research institutions. Generally these institutions do not have adequate management skills and financial resources to upscale from small- to large-scale commercial seed production. To improve the situation, the Government has established a Seed Agency that will take care of seed production.

3.3 CROP EXTENSION PROGRAMMES AND CAPACITY

During the early 1990s, agricultural services consisted primarily of centralized, supply-driven public services organised

around three main domains, namely research, training and extension. The technology transfer model, inherent in the Training and Visit (T&V) extension system, was found to be unsustainable due to the high costs of service delivery. Furthermore, extension approaches barely took into account the concerns, needs and involvement of farmers. The majority of the farmers, as a result, either did not access the services, or often found them irrelevant. The situation worsened, largely due to Government dominance in the management of extension, while coordination with the private sector, church-based organizations and other NGOs - as well as farmer-led initiatives - was often minimal.

From the late 1990s, extension services were decentralised in line with the Local Government Reform Programme, now administered by the Local Government Authorities (LGAs). These changes in the policy environment created room for private sector participation in the provision of agricultural services. To increase the interaction between advisors and farmers, the initiatives combined the use of group approaches and training of farmer motivators. Farmer Field Schools (FFS) have been established in a number of pilot districts, and various stakeholders regard the FFS as a promising, cost effective method for client-oriented extension services, which responds to their demands, empowers them through group training and participation, and provides effective links between farmers, research and extension.

With the shift of extension services to the Ministry of Local Governments the Directorate of Research and Training in the Ministry of Agriculture, Food Security and Cooperatives established in the seven zones Zonal Agricultural and Extension Liaison Units (ZRELU) and Zonal Communication Centres in charge of research and extension linkages. The research institutes collaborate closely with their respective ZRELUs in conducting on-farm trials and in the dissemination of technologies, including improved varieties from the research institutes to local farmers.

One of the main problems facing the extension service in the country is limited financial ability and human resource capacity of most LGAs to support extension services.

Therefore, to sustain these initiatives, grassroots institutions should also share some of the costs, e.g. for running FFS. Recruitment

and training of additional extension staff will also be necessary.

4 Status of Biotechnology Policy and Biosafety

4.1 NATIONAL BIOTECHNOLOGY POLICY

In 2002 the Government of Tanzania established its National Biotechnology Advisory Committee (NBAC) with the mandate of advising the Government on all issues pertaining to safe development and application of biotechnology. This Committee spearheaded the development of the national biotechnology policy, which is now at its advanced stage of completion. The main objective of the policy is to ensure that Tanzania has the capacity and capability to capture the proven benefits arising from health, agriculture, industry and environmental applications of biotechnology while protecting and sustaining the safety of the community and the environment. Once the biotechnology policy has been approved, it will be necessary for the Government to formulate an implementation strategy and plans that will lead to the attainment of the specific objectives, which are to:

- develop a coordinated biotechnology strategy;
- link R&D and industrial capacity for biotechnology in Tanzania;
- develop innovative financing mechanism for biotechnology;
- develop Intellectual Property Rights of biotechnology inventions, innovations and services;
- apply biotechnology to the conservation and development of genetic resources;
- develop adequate institutional and human resources capacity for biotechnology;
- establish public – private sector partnerships and linkages;
- promote public awareness about the nature, benefits and risks of biotechnology ;

- develop priority areas for biotechnology R&D in the relevant sectors;
- strengthening national and international collaboration; and
- develop strategy and give guidance on ethical issues associated with biotechnology.

4.2 NATIONAL BIOSAFETY FRAMEWORK

In 2002 the Government started developing the National Biosafety Framework (NBF) with technical and financial support from the UNEP/GEF. The NBF is based on the Environmental Policy and the Environmental Management Act (2004). The main objectives of the NBF are to:

- establish science-based, holistic and integrated, efficient, transparent and participatory administrative and decision making system so that Tanzania can benefit from modern biotechnology while avoiding or minimizing the inherent environmental, health and socio-economic risks; and
- ensure that the research, development, handling, transboundary movement, transit, use, release and management of GMOs are undertaken in a manner that prevents or reduces risks to human and animal health, biological diversity and the environment.

The NBF seeks to establish a) Institutional Biosafety Committee (IBCs) at all institutions that are involved in the import, export, handling, contained use, release or placing on the market of GMOs or GM products to institute and control safety mechanism; b) Ministerial Competent Authorities to review relevant sector specific biosafety applications; c) National Biosafety Committee with multi-sectoral representation to review all

applications and make recommendations to the Biosafety Focal Point for decision making. Arrangements are now being made to operationalize the framework through inter alia, drafting of the relevant biosafety regulations, formation of the different relevant committees, training in risk assessment and risk management, conducting public awareness workshops for different stakeholders and procurement of some infrastructure facilities for biosafety research.

4.3 INSTITUTIONAL BIOSAFETY CAPACITY

Since the NBF is not yet operational, none the institutions that are involved in biotechnology research in the country has an institutional biosafety committee to foresee biotechnology R&D activities. As an example ARI Mikocheni (MARI) does not yet have sufficient capacity, competence and experience in biosafety assessment and management. However, at the Institute there are three scientists who have attended short courses and workshops related to biosafety risk assessment and management organized by the BIO-EARN programme. In addition, two scientists are members of the Agricultural Biosafety Scientific Advisory Committee (ABSAC). This committee was established by the Ministry of Agriculture, Food Security and Cooperatives in 2004 as the ministerial competent authority responsible for advising the Ministry on all issues pertaining to safe application of biotechnology. It will also conduct scientific biosafety reviews for contained and confined research in GM plants and make recommendations for approval by relevant authority. Currently ABSAC draws its powers from the Plant Protection Act (1997). In January 2005, through the technical and financial support from the Programme for Biosafety Systems (PBS), the ABSAC members were trained on how to conduct biosafety reviews for confined field trials. Despite these efforts, it is fair to say that these scientists have limited expertise and they lack experience in biosafety issues. In terms of infrastructure MARI has adequate IT facilities, which can also be used for biosafety data management, analysis and

information exchange. The Institute is now in the process of refurbishing an existing building into contained laboratory for conducting research in genetic engineering.

4.4 BIOSAFETY STRATEGIES/ POLICIES TO ENSURE SAFETY OF LOCAL GM CROPS AND IMPLEMENTATION CAPACITIES

The currently available commercial GM crop varieties like Bt Cotton and Bt maize developed by multinational companies are likely to be less adapted to local conditions in Tanzania. In view of this, it is important that we develop capacities of transforming our improved local varieties that are preferred by farmers. Another approach would be to introgress the genetically engineered trait (e.g. Bt genes) from the foreign varieties through a back crossing programme. To ensure the environmental, health and socio-economical safety of local GM crops the following suggestions are made:

- Establishment of good collaboration with multinational companies and/or advanced laboratories which own the technologies/ gene constructs;
- Prospecting for local genes;
- Development of a strong capacity in IP management regimes;
- Development of a strong infrastructure and human capacity in GM technology in Tanzania;
- Provision of adequate funding, not only for doing the transformation but also for conducting biosafety analysis;
- Stimulating awareness through training of and communication with different stakeholders (government ministries/ agencies, private companies, NGOs, media);
- Promoting strong public – private sector partnerships and linkages;
- Establishment of an efficient biosafety monitoring system to ensure compliance;

- Avoiding introduction or planting of GM crops in biodiversity hot spots;
- Development of an efficient, well coordinated national biotechnology network that has strong regional and international linkages under the motto, 'no one can do it alone'.

To implement the above national policies and strategies, it will be important to establish the different committees prescribed by the National Biosafety Framework because nothing can be done if they are not in place. It will be important to make sure that the different committees have the right composition and the right mix of disciplines. Secondly, since the members of the different committees are likely to have limited or no experience in biosafety issues, it will be crucial that tailor-made training opportunities are provided to members so that they can make informed decisions based on science and knowledge.

In addition to training, it is essential that the research institutes are adequately equipped with infrastructure facilities for contained and confined biosafety research. The facilities include biosafety cabinets and green houses that correspond to the required biosafety levels. Other facilities that will be required are for safe handling and disposal of hazardous chemicals and waste.

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The Stockholm Environment Institute

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