Foreword

During the past year, the Agriculture and Agroprocessing Sector Working Group engaged in several intense working sessions, with a mandate to ensure that future opportunities presented by research and technology will address the social and economic challenges South Africa faces with regard to the performance of the agriculture and agroprocessing sector. On behalf of the Sector Working Group we express our gratitude to the Department of Arts, Culture, Science and Technology for giving us the opportunity to make such a contribution to the growth of our country.

Our work focused on a variety of activities on the value chain, such as on-farm and beyond-the-farmgate activities, which include food processing, distribution, marketing and supportive industries. As chairperson of this Working Group, I was privileged to have worked with knowledgeable individuals from various subsectors of agriculture and agroprocessing. These individuals brought in a wealth of experience and expertise that facilitated our work quite significantly as demonstrated by the contents of this report.

At every milestone of our work we tested our views on a cross-section of stakeholders through workshops, interviews, lectures and opinion surveys. One of the most extensive consultation processes that we undertook and found very useful in informing our decisions was the Delphi survey. This allowed us to view the vision and perceptions of the stakeholders regarding the future of agricultural and agroprocessing research and technology development in the country.

Mostly, the quality of life of the majority of the citizens of this country, the new policies of governance, the nation's performance in global competitiveness, and future challenges in these areas often guided our choices in creating a healthy balance in the strategies eventually proposed in this report. It is in this light that each and every one of the important role-players in this sector - from government, the private sector, organised agriculture, labour and the civil society - need to investigate very carefully the meaning of the recommendations we make in this report pertaining to their business. We as a nation need to analyse this work and ask ourselves what future opportunities there are for both wealth creation and the improvement of quality of life.

I do believe that through this work, a first in South Africa, we begin to see the potential that agricultural research and technological innovation holds for this nation. We can reach new heights of global excellence for a long time to come. Let us all adopt a foresighting culture from now onwards to make this a winning nation.

Professor Johan van Zyl
Chairman: Agriculture and Agroprocessing Sector

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Abbreviations and Acronyms

ARC ..... Agricultural Research Council
CSIR .....Centre for Scientific and Industrial Research
DACST Department of Arts, Culture, Science and Technology
DEAT ..... Department of Environmental Affairs and Tourism
DoE.....Department of Education
DTI..... Department of Trade and Industry
DWAF ..... Department of Water Affairs and Forestry
FAO .....Food and Agriculture Organization
FRD .....Foundation for Research Development
HR .....Human resources
ICT.....Information, Communication Technology
IDRC ..... International Development Research Centre
IPR.....Intellectual Property Rights
MCST .....Ministerial Committee on Science and Technology
NAFCOCNational African Federated Chamber of Commerce and Industry
NAFU ..... National African Farmers Union
NARS .....National Agricultural Research System
NDA..... National Department of Agriculture
NGO..... Non-governmental Organisation
NRF .....National Research Foundation
NRM..... Natural Resource Management
NRTF..... National Research and Technology Foresight
NRTA.....National Research and Technology Audit
NSI.....National System of Innovation
PDA ..... Provincial Department of Agriculture
R&D ..... Research and Development
R&T .....Research and Technology
SABS .....South African Bureau of Standards
SACOB ..... South African Chamber of Business
SAAU .....South African Agricultural Union
S&T..... Science and Technology
STEEPSocial, Technological, Environmental, Economic and Political.
SWOT.....Strengths, Weaknesses, Opportunities and Threats
THRIPTechnology and Human Resources for Industry Programme
SMME ..... Small, Medium and Micro-enterprises
WRC .....Water Research Commission

Executive Summary

South African agriculture and agroprocessing in context

The Ministerial Committee on Science and Technology (MCST) commissioned the National Research and Technology Foresight (NRTF) project in the Department of Arts, Culture, Science and Technology (DACST) in 1997. It is the first time in the history of South Africa that such a study has been conducted.

The vision is to ensure that science and technology intervention brings an improved quality of life, competitive economy and a shared democratic culture to all South Africans. The Agriculture and Agroprocessing sector mission is:

"To determine a national research and technology (R&T) strategic framework for the agriculture and agroprocessing sector that would realise a commercially viable, sustainable and equitable socio-economic development along with public understanding of science and technology in South Africa for the next twenty years."

Agriculture (including forestry) and agro-industrial processing (agroprocessing) make a major contribution to the South African economy. While the relative contribution of agriculture to the country's Gross Domestic Product (GDP) is only about 4% to 5%, its impact is much larger, as it directly provides 10,5% of the country's jobs and creates employment for another 16% of the workforce in other sectors. In 1994, agricultural exports resulted in foreign exchange to the tune of R7 240 million. The manufacturing industry contributes about 37% to the GDP, of which25% comes from agroprocessing. In 1997, the turnover of the South African food and beverage processing sector was R72 648 million.

In a benchmarking process to compare South Africa's research and technology status and the impact of this R&T on socio-economic development, it became clear that South Africa contains elements of the developed world, both in technology and infrastructure. Yet these elements co-exist with a considerable lack of development, particularly in rural areas. This is also reflected in the country's expenditure on agricultural research, which is average compared to that of other developing countries, but less than that of developed countries. In contrast, the relatively small contribution of agriculture to GDP and that of manufacturing (which is higher) classify the country as relatively developed.

Value adding should become a focal area for investment and research and technology development will therefore have to focus on downstream consumer

requirements, both locally and internationally. This does not mean that primary producer practices are ignored. In fact, as the sophistication of the economy increases, so primary producer practices need to change in order to take account of the final market. International trade is an important component of total agricultural production and is therefore likely to influence the direction of technology development strongly.

In view of the above, agriculture and agroprocessing are important to South Africa and require a coordinated strategy for research, development and implementation to ensure the impact, sustainability and global competitiveness of the sector.

The Foresight process identified nine strategic technological nodes that would have to underpin the required development and competitiveness of thesector during the next twenty years, so that wealth generation and socio-economic development within the sector can be achieved. Investment is required in the following areas:

- Agroproduction systems including breeding technologies, focused and intensive production systems and extended, on-farm production life cycles, which could impact on industrial processing.

- Biotechnology used as a tool for a more rapid and efficient means to diversify and improve the food and other industrial product base. Biotechnology can be applied in combination with traditional breeding techniques for the elucidation of novel genes, for ease of processing, for improvements of crops and animals, and for legal use.

- Natural resource management and utilisation to support sustainable utilisation of natural resources (soil, water, air and genetic resources) in agriculture and agroprocessing activities. These include water-saving technologies, bio-solutions and monitoring technologies.

- Technology transfer is important for South Africa because of an identified weakness in its technology transfer system, particularly within the less developed agricultural sectors. This field includes training and extension, education, international technology transfer mechanisms and Intellectual Property Rights (IPR).

- Processing technologies to increase competitiveness within the global environment and to enhance wealth generation for all stakeholders, will require improved technological capacity within the fields of product preservation, handling and packaging technologies.

- An enabling environment focused on appropriate socio-economic research to optimise efficiency and benefits, strategic mechanisms to formulate andadjust

policy for R&D, access and availability to updated information in all subsectors and related activities and adequate asset development.

- Market development and maintenance to provide market information, consumer education, and continuous development of markets, all of which impact on technology development. A specific sector that needs this is SME producers and processors.

- Novel technologies with a future impact in South Africa were not identified by the Delphi survey as important, although they could have a significant impact on long-term wealth creation and competitiveness. They include the adaptation and use of novel materials and processes, interaction of technologies such as ICT (Information and Communication Technology) and biotechnology, ICT and mechanisation, adaptation of polymers and ceramics, miniaturisation, robotics. etc. Examples of these already emerging are odour sensors, autonomous robots with environmental awareness sensors, anthropomorphic robots used for factory jobs and intelligent materials with sensors.

- Systems modelling technologies give insight into the probability of events, which creates a capacity for risk management and planning. Modelling can therefore make it possible to understand most of the previously mentioned strategic nodes.

The following constraints to the developments required in the above nine strategic nodes were identified:

- Finance, i.e. scope and allocation of financial resources;

- Human resource capacity, i.e. the number of people and level of skills available in critical technological sectors; and
- Technology, i.e. lack of access, affordability, appropriateness and lack of a coordinated innovative culture.

Strategies to address each of the above constraints are provided.

Chapter 1: Introduction

The mission of the Agriculture and Agroprocessing Sector National Research and Technology Foresight is:

"To determine a national research and technology (R&T) strategic framework for the agriculture and agroprocessing sector that would realise sustainable socio-economic development and public appreciation of science and technology in South Africa up to 2020."

1.1 Background

The National Research and Technology Foresight (NRTF) project, housed within DACST, was mandated by the Ministerial Committee on Science and Technology (MCST). South Africa's interest in a foresight study started after 1993 when the International Development Research Centre (IDRC) of Canada, at the request of the Mass Democratic Movement, undertook a Mission to advise on the transformation of Science and Technology. The review found the S&T system to be too fragmented in its operation as shown by little or no collaboration between S&T role players. Furthermore, the obvious trend of declining public investment in research and development worldwide suggested that a new approach to the management of the entire research, science and technology system be established in South Africa. The report suggested the creation of a National System of Innovation (NSI) that would recognise all the role players in S&T as equally important and part of a single system in its approach to national problems.

As articulated in the science and technology white paper, the vision is to make sure that science and technology intervention brings an improved quality of life, a competitive economy and a shared democratic culture to all South Africans. The desired vision would be realised through an NSI underpinned by knowledge sharing, innovation for sustainable economic growth, employment creation, and equity through redress and social development. The NRTF project along with other DACST initiatives is a means to sustain, support, service, and manage the NSI.

Foresight's mission is to promote technical innovation and deployment, through a systematic process that identifies future opportunities for economic and social development for a given time horizon, which in the case of South Africa is twenty years.

Even though other countries have enjoyed the benefits of foresight studies, it is the first time in the history of South Africa that such a study has been conducted. It is salient

therefore to evaluate the South African perspective of foresight in relation to an international one.

Considering just a few international examples, foresight studies in terms of objectives, the foci, and approaches have varied according to the need of the country, for example, in the nature and extent of participation in the foresight process by wider communities. Japan's foresight process, for example, tended to involve S&T and industrial experts, whereas in the Netherlands, a broader community is usually involved. Methodologically, the Japanese process was different in that it often focused on Delphi surveys of future trends, while the UK process focused on a combination of these two foresighting tools. It is however important to mention a similar US study that lists critical technologies only, using a core of a selected few experts. By contrast, the South African Foresight study, even though informed by a many international lessons, tended to consider local dynamics so as to reflect the local context. It differed in the following areas:

- broader stakeholder consultation before and during the study;
- extensive use of macroscenarios and focused sector scenarios in the strategic thinking of sector-specific work and prioritisation;
- an extensive sector-specific situation analysis;
- use of larger and more representative working groups; and
- a country-specific Delphi survey.

1.2 The agricultural sector's main characteristics

1.2.1 Economic status and contribution of agriculture to the national economy

Although not often realised, agriculture makes a major contribution to the South African economy. It has upstream or backward linkages on the supply side and downstream or forward linkages on the manufacturing side.[1] While the relative contribution to the country's Gross Domestic Product (GDP) is only about 4% to 5%, this does not reflect its importance to the economy. If one takes into account the strong forward and backward linkages, its contribution is much larger as it creates approximately 1,6 jobs outside agriculture for every job in agriculture. It provides 10,5% of the country's jobs directly and creates employment for another 16% of the workforce in other sectors.[2] The Macro Economic Research Group reports that *"the Manufacturing-Agricultural Complex (MAC) accounted for 402 000 jobs in 1988, or 28 per cent of total recorded employment in manufacturing, 31 per cent of the manufacturing sector's production, 21 per cent of its capital stock and almost a quarter of manufacturing's contribution to GDP. Moreover, the MAC accounted for 23 per cent of exports, while absorbing only 9 per cent of manufacturing's imported inputs .[3]"* A direct investment in the agricultural sector creates twice as many jobs as an investment in the manufacturing sector.[4]

In 1994, agricultural exports resulted in foreign exchange to the tune of R7 240 million. Deciduous fruit, highly in demand in foreign countries, accounted for the largest exports. South Africa also exports groundnuts, subtropical fruit, wine, cut flowers and bulbs, mohair and karakul pelts, sugar, meat and wool to name just a few. In 1994 alone, 3,9 million tons of agricultural products were exported, with a third of that being horticultural products.

The sector's real contribution is far more substantial and crucial for sustained wealth creation, poverty alleviation, and welfare generation in the country considering that ±13 million people reside in and are dependent on economic activity in rural areas (AIPA, 1997). The role of agriculture should therefore be seen in a wider context, considering, for example, that it -

- Is a critical component of the food sector;
- has critical linkages with the broader economy;
- plays a critical role in regional development;
- is a major contributor towards human development, poverty alleviation, and the environment; and
- is a driver of industrial development.

1.2.2 The role of agro-industries (big and small)

Industry contributes about 37% to the GDP and is recognised as one of the major sectors contributing to economic growth. But this is not the whole story. As noted above, one quarter of this contribution comes from agro-industrial processing. Besides, agriculture and agroprocessing (especially foods, clothing, leather and leather products) tend to lead to a more equitable distribution of per capita income, also boosting trade and transportation. Moreover, these sectors all tend to create more low-skilled jobs.[5]

employment generators in the economy are found in the agro-industrial sector. They are: tobacco products, oils and fats, basic chemicals, meat products, animal feeds, other foods, dairy products, grain milling, sugar products, paper products and canning.[6]

The vital role of the agricultural and agroprocessing industry sector clearly indicates that agricultural investment is necessary for industrial, urban and regional development and to achieve food security, create jobs for all, generate and redistribute income and improve the quality of life of all South Africans.

1.2.3 South African Forestry

The South African forestry industry comprises some 1,3% of South Africa's land area and is based exclusively on fast-growing exotic tree species (pines, eucalypts and wattle). This industry has an annual turnover of R12 billion and meets about 95% of the country's demand for forest products. It is an export-oriented industry, with a net surplus of around R2 billion per annum. The forest industry's contribution to the gross value of

agricultural output is 7,3% (1996/97) and the forest products industry contributes 7,6% to the gross value of manufacturing output (1996/97). It is also a major employer - some 200 000 people, each supporting a number of dependants, have jobs or enjoy economic opportunity from forestry.

The industry comprises both large and small timber growers. The large companies (Mondi, Sappi and Safcol) essentially grow trees for the pulp and paper, saw-timber, mining timber and pole markets. In addition, there are many small growers (some in associa-tion with the large corporates). In KwaZulu-Natal alone, more than 10 000 small growers are involved in tree-growing schemes with large forestry companies. Other small growers are organised into cooperatives that market the products on their behalf(often on the international markets). With privatisation initiatives currently underway, all of the commercial forests will be under private ownership in future.

All the major forestry companies and most of the small growers are accredited either through the Forest Stewardship Council or through ISO 14001. Both are international benchmarks of sustainable forest management.

1.2.4 Fishery economic status

The fishing industry is mainly based on the marine resources along the South African coastline. About 28 000 people rely on this industry for an income. In 1995, the harvest out of fishing off a coastline of about 3 000 km totalled 580 000 tons (live weight) of fish, shellfish, seaweed and guano, with a wholesale value estimated at R1,7 billion.

1.2.5 Natural resources

Arable land potential in South Africa is low by world standards. Only 17 million hectares or 15 per cent is considered arable. Of this, four million hectares or less than three per cent is high-potential agricultural land. South Africa has very little irrigation potential. At present 1,2 million hectares are irrigated, with only an additional 250 000 ha which can be brought under irrigation. Non-arable land dominates most of the west and interior of the country, where the rainfall is below the 600 mm per annum required for reliable cropping. About 69 million hectares are used for extensive commercial animal production, based principally on the grazing of unimproved natural range land by cattle, sheep, and goats.

Given that demand for food will increase by roughly three per cent per annum, this will create greater demands on land resources. Land is a scarce factor of production and therefore cannot beunnecessarily degraded. Sustainable use of land resources in South Africa is therefore of prime importance. While total productivity increases, the losses associated with degradation remain.[7] Since 1947, total output is 2,5 times higher and total inputs are 1,2 times higher, while total factor productivity is 0,5 times higher.[8] Increased output can therefore be explained by input effects causing movement

along the production function and technology effects causing an expansion of the production possibilities. Resource degradation effects causing contraction of the production possibilities frontier are outweighed by input and technology effects. Consequently one can conclude that there has been a sustained growth in productivity, even with an obvious decline in the quality of the resource base.

1.3 The Foresight Programme

The agricultural and agroprocessing sector, along with the other eleven sectors of the NRTF project, was identified through an extensive process of consultation and workshops with all stakeholders all over the country. Stakeholders' inputs and the recommendations of DACST and the projects advisory board were to be considered in the process. The sector selection process was based on the socio-economic objectives, and also aimed at aligning technology policy with broad national goals. The broad frame of reference was agreed to be the major pillars for the growth and development strategy in South Africa. A working group was appointed from the stakeholders as described earlier. The group had a number of meetings in the form of workshops. The objectives of these meetings were to develop an understanding of the R,T&D needs, report on its conclusions and make recommendations. Deliberation in-between workshops to source specific information from identified experts and specialist individuals occurred at different levels through consultation and the Delphi technique (see Appendix A).

1.4 Agricultural and agroprocessing sector

1.4.1 Working group composition

The programme of this sector was the responsibility of a working group appointed by the Director-General of DACST late in 1997. The idea was to have a working group that is representative of a broader cross-section of sector stakeholders, i.e. government departments, the private sector, academic institutions, science councils, organised agriculture, farming and small business, civil society and NGOs. It is worth noting that working group members were identified and invited in their personal capacities as professionals or knowledgeable individuals in the sector. The names came from a wider consultative process that occurred at two levels. The names were sourced from the stakeholders themselves through a survey process, called co-nomination. Individuals who were frequently nominated were considered for selection. Gaps as far as gender, race and discipline are concerned were identified, after which direct nominations were taken by a further sourcing of names from various sector stakeholders where necessary. The names of the individuals and their areas of expertise appear in **Appendix A.**

1.4.2 Sector boundary conditions

The agricultural and agroprocessing sector shares some overlapping components with other sectors, such as biodiversity, manufacturing, and the environment. A consultative process to define the sector, with less duplication, was conducted to crystallise the sector boundary conditions. A series of round-table meetings across the country were conducted to define both the main foci and priority functional areas of the sector that allow the sector to stand out distinctly from otherrelated sectors. The working group had to discuss and agree on this framework before sector activities could start. This framework was quite useful in focusing sector discussions. A matrix to summarise the present landscape of the sector appears in **Appendix B**. The proposed main foci for the sector were -

- crops (field crops and horticulture);
- animals (including health, nutrition and range-land utilisation);
- fisheries;
- forestry; and
- natural Resources.

The main focus for agricultural R&T development will have to move away from a "make-and-supply" paradigm to a more "sense and respond" framework. End-user and customer needs will have to be the focus of R&D and not scientific laboratories per se. This partnership between end-users and scientists will provide the framework for scientific innovation in the agricultural and agro-processing industry in the future.

Priority sector areas that allow for an end-user focus were identified by the working group using many tools and much information. One such tool was policy, including policy on the long-term socio-economic development of the country, and expected future trends in research and technology development.

The working group concluded that the sector priority areas are -

- production, which can be divided into three categories:
  - use of physical resources (soils, water etc.);
  - use of inputs (feeds, remedies, fertilisers, seeds, chemicals, etc.); and
  - production practices (management).
- conservation and utilisation of natural resources.
- processing, recognising three levels:
  - beneficiation (stage 1);
  - manufacturing (stage 2); and
  - manufacturing discrete products (stage 3).
- support activities (marketing; extension; financing; information and institutional organisation), which will help the R&T system to sense and respond to market needs.

In preparation for further deliberation the working group recognised that a number of cross-cutting areas affecting research and technology development had to be taken into account. The most crucial of these were -

- extension and training (with a focus on end-user needs).
- marketing, which needs to consider the following three types:

  - informal;
  - formal; and
  - export.
- industrial products (edible and inedible).
- infrastructure development to support agriculture and agroprocessing.
- indigenous technology development and knowledge.
- business development in agriculture and agroprocessing.
- poverty alleviation and food security.
- job creation.
- technology transfer.
- support Industries.

1.4.3 Research and technology development framework

With regard to research and technology development, a representative frame-work comprising three interactive systems constituting a Research, Technology, and Development Complex (RTDC, Fig. 1) was considered. The working group had to focus on all the components of the RTDC in the identification of future research and technology opportunities. Please note that this identification should take place through the activation of the pull pathway.

Backward and forward linkages between these components are quite critical for analysis and further consideration of the RTDC. In a sense-and-respond system, links between the TU and other components should be forged as part of a strategic process.

1.4.4 Prioritisation of R&D

During the deliberations, the following criteria for the prioritisation of R&D were considered to be the most critical drivers to be borne in mind for the sector's R&D process:

- Sustainability of R&D thrust;
- Efficiency of research, technology development and delivery systems;
- Equity in terms of the broader national development objectives; and
- Competitiveness as a global player.

In the interests of the sector's effective contribution to the broader socio-economic development, critical areas in the sector were tentatively identified as requiring urgent intervention from the agricultural R,T&D community to enhance outputs of the sector. These areas were identified from an examination of the current sector needs, without pre-empting what the sector should look like in the next millennium.

1.5 Structure of the Report

The outputs of the comprehensive consultative process are reported in the chapters that follow. The next two chapters look at benchmarking the South African Foresight against that of other countries and the current status of R&D in South Africa. Chapter 4 introduces the concepts of scenario thinking, thus broadening the horizons of the Foresight process. The final chapters report on the survey results and conclusions reached, finally recommending an Agriculture and Agroprocessing R&D pathway for South Africa.

The report is intended for a wide readership and seeks to guide the strategic thinking of public and private organisations on their R&D priorities. Organisations and institutions that have a direct interest in agriculture and agroprocessing R&D are, amongst others:

- government departments, including DTI, DEAT, NDA, DACST and DWAF;
- science councils, for e.g. the ARC, the CSIR and the SABS;
- trade and industry, the agro-industry, SACOB, NAFCOC, NAFU and the SAAU;
- tertiary institutions;
- the NRF; and
- professional associations.

Chapter 2: Benchmarking

2.1 Background

The main purpose of the benchmarking process was to compare South Africa with a range of countries in terms of research and technology status and the impact thereof on socio-economic development. This exercise was not simple as South Africa does not perfectly fit within the "First World/Third World" or "developed/developing" framework. It was clear from the outset that South Africa contains elements of the developed world, both in technology and infrastructure, yet these co-exist with a considerable lack of development, particularly in rural areas. The range of countries used for the comparison should therefore be seen as a small sample, to illustrate particular points and place South Africa in perspective within the world community. This chapter should also be seen as an introduction to later chapters, where a detailed situation analysis is conducted. The intention of this chapter is therefore not a detailed benchmarking exercise, as the appropriate reports are available in separate documents. A general overview of South Africa's standing in relation to other countries with regard to the agricultural sector, and the role of technology in particular, is given.

A further objective of this exercise was to gain new insights into international agricultural research and technology trends, and to identify opportunities for development and priority setting in South Africa's agricultural research and technology system. A separate report, entitled "International Scan," contains the details.

South Africa's research and technology system exists within a national multi-policy environment to serve as a supportive framework for the advancement of science and technology activities. These policies can only make an impact if translated and applied at research and technology level. The vision of the reconstruction and development policy, created to ensure an improvement in the socio-economic standing of all sectors or the population, has been central to the development of a number of other policies and their implementation strategies. The following policies are a summary of those considered pertinent to the business of agricultural research and technology development.

Science and technology within the agricultural field can be seen in the same light as science and technology in general, and can be supported by the listed policies in the same way. The desired outputs can be summarised as:

- Promoting competitiveness;
- Enhancing quality of life, including wealth creation;
- Development of human resources; and
- The sustainable use of environmental resources.

2.2 Research expenditure

A fundamental indicator of technology innovation is the extent of expenditure on research, and how South Africa compares with other countries in this regard.

At present, South African expenditure on agricultural research is estimated at 1,04% of the agriculture GDP, which is average compared to that of other developing countries. It is slightly more than that of East Africa but significantly less than that of Europe (2,06%), the USA (3,7%) and Australia (4,02%).[9] Some benefit is gained from the European and USA research expenditure via basic research doneby multinational companies and later implemented with minor adjustment for local conditions. While the expenditure as a percentage of GDP is a useful benchmark, the size of the economies should also be taken into account, as this indicates the net size of expenditure. Clearly, South Africa has a total agricultural economy considerably smaller than Europe and the USA, but similar to that of Australia. Linked to research expenditure are two critical issues: human resource development to ensure a critical mass of skilled researchers, and maintenance of a world-class research capacity to support all the activities of agricultural research.

South Africa's R&D tends to be more adaptable in nature with less response time between expenditure and output than that of many developed countries. This trend, which suggests quicker rates of return on R&D expenditure, is less apparent in the basic research arena, as is the case in Europe.[10] This trend to a large extent explains the high 44% return rate on research expenditure in the primary agricultural sector.

2.3 Major economic trends

The greater the development of a country, the smaller the contribution of agriculture to the GDP tends to be. Manufacturing and services tend to increase in their contribution. In this regard, South Africa has the appearance of a relatively developed country, with an agricultural contribution to GDP of approximately 6%, as compared to China, Kenya and India with 32% to 33%, Argentina with 10% and the United Kingdom and Japan with 2% each. Agroprocessing tends to increase as development proceeds, and as this is listed in the manufacturing sector, an apparent decrease in the contribution to GDP of the agricultural sector occurs. This does not mean that the agricultural sector becomes unimportant, but on the contrary, indicates a maturity of the sector. As downstream value-adding contributes significantly to total GDP, and disproportionately to the primary agricultural production, the implication is that it is advantageous for a country to develop agricultural value-adding. The preceding statistics suggest that South Africa is in a better position than many developing nations, but it can improve considerably compared with the major industrialised countries.

If value adding is to become a focal area for development, then the research and technology trends will have to take account of downstream consumer requirements both locally and internationally. This does not mean that primary producer practices are ignored. In fact, as the sophistication of the economy increases, so primary producer practices need to change to take account of the final market. As previously indicated, international trade is an important component of the total agricultural production, and is therefore likely to strongly influence the direction of technology development. With South Africa tending towards the description of an industrialised, developed nation, the tendency towards value-adding is strengthened.

The population demographics of South Africa should not be ignored. A rapid urbanisation of populations is occurring in South Africa, again indicating a shift towards a developed economy. Population growth in South Africa tends towards less-developed countries overall, but particularly in rural areas. At present, the country can be placed between a developed and undeveloped economy. Similar discrepancies can be found within the agricultural sector, with a lack of homogeny in technological development and income. While there are a number of reasons for this, which will be further discussed elsewhere in this report, South African agriculture can again be described as falling between developed industrial and undeveloped. This also needs to be taken account of when considering socio-economic requirements, food security and appropriate researchand technology requirements. The agricultural sector plays a vital role in the economy of the country, when it is considered that approximately 13 million people reside in and depend upon the economic activity of the rural areas.

2.4 Major research and technology trends

Developed countries, such as the United Kingdom, are characterised by advancement through the development and utilisation of innovative technologies. In South Africa, the characteristics and trends in agricultural technology have been complex, and have been overlaid by socio-economic conditions. Two distinct sectors of agriculture are apparent, a high-technology developed sector and a resource-poor sector, which requires a different technology application profile for development. This may be similar to the situation in India. It is nevertheless notable that the latter country has policies that support innovative technologies to transform marginalised farmers into agents of poverty alleviation, and to ensure sustainable environmental management.

Within the more highly developed agricultural sector of South Africa, awareness and use of high levels of technology are advanced. However, most of the technologies have been found to be product and process technologies, with few support and information technologies. Approximately 30% of our technologies are imported, primarily from the more developed countries. South Africa therefore tends to be an adapter and user of technologies developed elsewhere, with a somewhat limited innovation base. However, the adaptation of the imported technologies has allowed

South Africa to process, transport and market products to discerning markets within South Africa as well as the most developed world economies. This has placed the South African agricultural sector well ahead of other developing countries, and comparable to developed nations, even though asector of the rural community is unable to participate because of various constraints. Technology, and in particular information systems, will need to be developed so that advantage may be taken of an as yet underutilised potential.

The skills base of South African agriculture does not compare well with that of developed nations. There appears to be an insufficient number of people with high skill levels. The more developed the sector becomes, the more critical this component will be when competitiveness, particularly in the higher technology area of value-adding is considered.

Trends in technology in the developed economies need to be considered. Populations of those countries are aware of product safety, storage, the influence of consumerism and integrated production as it affects the sustainable interaction of agriculture on the environ-ment. The importance of consumerism is clearly seen in the increasing popularity of notions such as "products of origin" and traceability requirements among consumers. Food safety and environmental and social characteristics of products are important consumer requirements. These factors dictate acceptability of products and production practices as well as technological processes, which become even more important when one considers the cross-border movement of products for trade and other purposes. In order to achieve these goals, many new and often innovative technologies will be necessary. The success of South Africa in relation to other producers of agricultural products will depend on the extent to which the local agricultural industry can harness the technologies needed to compete.

2.5 Strategic node comparisons

The Foresight process identified a number of strategic technology nodes, which are fully discussed in Chapter 6. Without wishing to pre-empt thediscussion, it may nevertheless be useful at this stage to place these issues in perspective within the international context.

2.5.1 Agroproduction systems

The agricultural production systems in South Africa have largely been locally developed to suit prevailing conditions. Where technologies have been imported (and, as stated before, approximately 30% of them are considered to be), some modification for local use is common. Little high or new and innovative technology appears to be locally developed. Equipment, plant and animal protection products are sourced and to a large extent even breeding is done elsewhere, with local customisation of technology.

2.5.2 Biotechnology

While various attempts have been made to find biotechnological solutions to problems in South Africa, with universities and the ARC being particular contributors, very few usable products have thus far emerged. South Africa does not, therefore, compare very favourably with the major industrialised countries. There are probably a number of reasons for this. First is the high level of investment required for R&D compared to a low level of investment in South Africa. Second is the long lag period before impact is perceived. And third is the lack of a local market for biotechnology products, which forces local biotechnology to try to target foreign, highly competitive markets. There are not enough joint ventures in the biotechnology industry to make up for low investment in biotechnology research and development. There is obviously also the potential rejection of biotechnology agricultural products as a result of bad press, which causes consumer fears.

Internationally, biotechnology is entering a growth phase. It has already impacted on many aspects of everyday life (for e.g. pharmaceutical, medical and, increasingly, agricultural products), and it has created wealth, employment and environmental benefits. Important factors in this success are enabling policies, access to finance, intellectual property rights, regulatory structures, good management, innovative, focused research, effective technology transfer and partnerships.

2.5.3 Natural resource management and utilisation

South Africa has considerable biodiversity, and while there has been some utilisation, there are a number of examples of other countries developing South African products. There appears therefore to have been a reticence to develop local products, and in this regard, South Africa must fall behind many other countries, both developed and developing.

2.5.4 Technology transfer

Contrary to often-held perceptions, commercial agriculture does not rely heavily on a publicly provided extension service but has been turning increasingly to an array of private services. The problem of technology transfer lies with the emerging and smallholder farming sector.

Today's public extension services resulted from the merging of two services, which had been aimed at commercial and homeland farmers separate and based on varying levels of expertise.

The number of extension staff employed in the public sector in South Africa is approximately 10 000. This includes extension officers previously employed by

homeland governments. Direct government expenditure on extension has been estimated at R515 million per annum, which is high by most countries' standards. It is roughly equivalent to 2,4% of the agricultural GDP and compares with 1,04% for the average African country, 1,2% for Latin America, andless than 0,5% for Europe and North America. Advisory services are also provided for commercial farmers by the private sector, including cooperatives, input suppliers, commodity organisations and farmer unions. These services are estimated to be at least as large as those provided by the public sector.

The aim of policy is to create an extension system that uses existing resources effectively to render a useful and efficient service to farmers. Rendering services to small-scale farmers is difficult, given the heretogeneity of the clients, the lack of communication between senior and junior staff and the urban background of many extension agents. While there are examples of the successful transfer of technology to small farmers, linkages between research and extension (and training) have generally been weak. It is essential that researchers understand and solve small farmers' problems and collaborate with extension officers to find methods of disseminating the results of their research. To this end, a far more pronounced approach to farming systems research and extension (FSR-E) is being considered. This will enable researchers to involve farmers in the adaptation of technologies under field conditions so as to maximise benefits to farmers. FSR-E is particularly important in South Africa as there is often a misconception that small farms are essentially large farms on a reduced scale. In any farming enterprise, production decisions are based on resource availability. Because of differences in access to resources, that is, land, capital, labour and information, choices regarding technology differ significantly between large- and small-scale farmers.

2.5.5 Processing technologies

Very few locally developed processing technologies exist. This is consistent with the primary product status of agriculture in South Africa, together with the tendency to import technologies with local adaptation and implementation. As the local agricultural economy progresses from a primary to a more tertiary status, this may change. At present, however, the status of processing technologies probably fits the description of the economy in general, falling between a developed and an undeveloped state. Unique aspects of the food manufacturing industry are that it is still very competitive and that many local manufacturing processes (for e.g. for wool, paper and animal products) are not internationally competitive. However, the food manufacturing industry industry has been able to compete on the international market for many years (for e.g. with fruit, fruit juices, lager beer, prepared vegetables and manufactured products) and has adapted new technologies to local circumstances, for example aseptic processing and packaging. The food manufacturing industry therefore has a mix of technology levels and skills available, and opportunities exist for companies to become or remain internationally competitive.

2.5.6 Enabling environment

As previously outlined, a number of policies exist which create the framework within which agricultural and associated processing technologies can develop. Many of these policies are relatively new, and as such their effects are still to be seen. When comparing them with policies of other countries, one again comes to the conclusion that the environment mirrors that of the economy in general, falling between developed and undeveloped.

2.5.7 Market development and maintenance

With some exceptions, South Africa has tended to market within traditional confines both locally and internationally. While in the past, both political and economic reasons must have contributed to this situation, there appear to have been less vigorous or aggressive campaigns than in some other countries, such as New Zealand.

2.5.8 Novel technologies

As previously stated, South Africa imports approximately 30% of its technology, and it tends to adapt or modify such technologies for local conditions. Development of genuinely new or novel technologies appears to be lacking, and as such the country must be rated behind most of the developed economies. There are even indications that the country lags behind some less developed economies, such as Israel.

2.5.9 Systems modelling

Systems modelling makes use of information and communication technology applications in simulations of agricultural systems such as natural resources, food processing systems and other complex systems for decisions support and ease of management. A number of organisations in South Africa are involved in systems modelling. While the resources are clearly not as large as those in the major developed economies, considerable work applicable to South African conditions is being conducted. South Africa may therefore compare favourably with the more developed economies.

2.6 Conclusions

The South African agricultural sector contains elements of both a highly developed, technology-based economy, and one that is less developed and resource-poor. This complicates the benchmarking analysis, and indicates that a variety of technology thrusts are probably required. The trend as a whole, however, is clearly one of a country placed between a developed and developing one, with movement towards one of further development. This is particularly so if one takes into account that large

numbers of rural, resource-poor members of the population have the potential, if the correct drivers are used, to move rapidly towards the developed sector. A rapid urbanisation will probably accelerate this process, withdemographic movement towards the manufacturing sector, thus decreasing the contribution of agriculture to the GDP.

Rates of return on research investment in primary agricultural production are due to technological spill-in effects, such as the tendency to use and adapt high-level technology very successfully. The fact that so much of our technology is imported shows that South African agriculture is reliant on others to develop new technologies, which again places the country somewhere between a developed and a developing nation. This trend would appear to dictate that development of innovative technologies locally, and will be necessary to maintain the current situation and improve the socio-economic development of the population.

It is also observed that while primary agricultural production is highly efficient and at an internationally competitive level, secondary processes, including processing and manufacturing, are less efficient in the local environment. To fully capture the added value of the downstream processes, technology development will have to be directed towards such processes to increase efficiency and enhance international competitiveness.

In order to focus on the areas of innovation, which will be necessary to harness the potential of South Africa and enhance development, an in-depth situation analysis of the agricultural sector of South Africa will be necessary. This was done, and is reported on in Chapter 3.

Chapter 3: SWOT Analysis

(Strengths, Weaknesses, Opportunities and Threats)

3.1 Process of SWOT

This section is the result of a rigorous process undertaken by the working group and was aimed at an extensive situation analysis of South Africa's agricultural R&D environment. The ultimate objective of this work was to ensure that research and technology intervention in South Africa addresses both weaknesses and threats while taking advantage of our strengths in capturing social and economic opportunities for the next twenty years.

The SWOT analysis focused on socio-political, economic, technological and environmental factors in South Africa as they impact on agriculture and agroprocessing. This process was carried out in two iterations, the first analysing or scanning the current environment, the second introducing futuristic thinking by using macroscenarios to cater for the uncertain nature (risks) of the unknown future. The key issues that were identified through the situation analysis, as concerns to the social and economic development of the sector, were tested for research and technology implications and then prepared as statements for the Delphi survey discussed in Chapter 5.

3.2 Current situation analysis

3.2.1 Technological issues

- **Value-adding technologies**

South Africa has weak cutting-edge, value-adding technologies for the eventual penetration of agricultural products to international markets. Furthermore, South Africa's linkage to international markets and R&D communities is relatively weak compared to that of the leading economies of the world. Problems associated with unclear intellectual property rights (legislation and enforcement) delays progress in this regard. Agriculture still depends mostly on outsourced research and technology development, even though the local infrastructure has been used effectively to either adopt or adapt foreign technology. On another level, limited seeding money and the diminishing skills base for value-adding technologies affect the development of such technologies even further. However, government- and private-sector partnerships through the THRIP and the Innovation Fund, using the developed R&D infrastructure, provide opportunities for more cutting-edge development throughout the value chain.

- **Continuous development of new products**

The weakness of value-adding technologies and also a lack thereof have had a negative impact on the consistent and continuous production of new agricultural products. The emphasis has been on primary agricultural products such as new cultivars and varieties rather than value-adding per se. The lack of commitment by the role players has resulted in a lack of funding for research to develop this area, even though South Africa's economic base is relatively strong. The lack in appropriate human resource development and market research has further impeded development in this area.

- **Biotechnology**

Biotechnology has contributed to the industrial revolution in Europe and America and has led to significant economic growth. With proper planning, biotechnology as a tool is creating opportunities for developing countries to diversify and improve the food base, while maintaining food security and economic growth. South Africa is ahead of many developingcountries in biotechnology but lags behind European and American countries because of limited expertise, the high costs involved and the potential of consumer resistance to genetically improved agricultural products. As a result, there is a lack of visibility pertaining to the efforts and products of biotechnology in South Africa. South Africa's strength in biotechnology (R&D) infrastructure, international interest and support for the country's biotechnology initiatives create an opportunity to develop the strength further so as to generate new market opportunities and address production constraints within the agricultural sector. The resource-poor agricultural sector and SMMEs could benefit tremendously from this.

- **Sustainable utilisation of indigenous and other genetic resources**

South Africa is rich in biodiversity and is ranked as the third richest country in the World, giving the country a comparative advantage. The utilisation of indigenous resources in South Africa is widespread but the development of new products for the market (internationally) is slow. International trends in the preservation of agro-biodiversity and genetic resources have been slow. The preservation technologies are less developed as the use of new technology is restricted. Sustainable utilisation and development of indigenous products, which are unique to the country, can be capitalised on only if appropriate technologies that can give South Africa a significant competitive advantage are developed. Practical use of indigenous knowledge and skills will create even more opportunities in this regard.

- **Technology transfer**

The large-scale/small-scale dichotomy in South Africa is different from that pertaining in most other countries, bringing a dimension that links socio-political, economic and technological issues. Agriculture is seen as one of the driving forces foreconomic

development in rural South Africa by creating employment opportunities and raising the income of rural households. The basis for transformation in rural areas is technology transfer, which requires a certain level of education in the farmer/entrepreneur, access to information by the farmer/entrepreneur, appropriateness of technologies within a given situation and access to education opportunities for the next generation. Mathematics, biology and business, which underpin agricultural education, are severely lacking in most schools and this results in serious constraints for a coordinated and unbiased human resource development plan within agricultural science and agribusiness.

3.2.2 Environmental issues

- **Soil degradation**

Soil degradation poses serious threats to the sub-Saharan African nations' food and agricultural production. This is a result of both climatic and human-induced activities that have an adverse impact on the soil base. South Africa is a signatory to the Convention to Combat Desertification and is obliged to develop and implement national, regional and subregional action programmes. Good natural resource management, research and technology development aimed at enabling the sector to cope with a sensitive environment, create areas of opportunity.

- **Water quality and availability**

Water quality and availability for agricultural use are imperative since they affect yields and soil degradation, which affects the quality of products. South Africa subscribes to the world food health and safety standards of the United Nations FAO, which have a set of requirements that must be complied with. Therefore, water quality within this context needs to be the subject of research and technology development. The new Water Bill presents both astrength and an opportunity for South Africa to ensure water availability for all farmers and consequent efficient use for agricultural production.

- **Integrated production systems**

The use of integrated production systems, especially of crops, in South Africa is not advanced. The white papers on agriculture and rural development support integrated production systems and identify such systems as important for sustainable agricultural and environmental management. Subsistence farming in rural areas is based on the concept of integrated production as this addresses food security issues. This area has become an opportunity for South Africa to explore as a future concern because food security and economic growth in rural areas must be ensured and sustained.

- **Technologies for water resource management**

Water is a scarce commodity, and this impacts on and limits the expansion of agricultural production. The new Water Bill brings new challenges to agriculture as it is only fourth on the list of priorities for water utilisation. Water resource management for agricultural use through recycling and optimisation, pollution control, waste-water management and energy-saving techniques in water use have a significant effect on agricultural production efficiency.

- **Biotechnology for waste management**

The waste management policy document articulates the problem of waste management as a high priority for South Africa. The cost of biotechnology as a tool for waste management and a lack of skills in this area prevent its extensive use to alleviate the problem and is poorly developed. Another potential weakness in addressing this problem is a lack of consultation across subsectors, resulting inan incoherent administration of the policy as it is spread across a number of policy documents belonging to different sectors of the economy.

- **Shift to less intensive natural resource use production systems**

The cost of agricultural inputs is rising and returns on farmers' investment are declining. Encouraging producers to employ production systems for less intensive use of natural resources provides a lucrative opportunity for improved agricultural production, conservation and sustainable use of biodiversity. Intensive research efforts should be directed towards the needed technologies.

- **Resource planning and management**

Appropriate resource allocation and use is the cornerstone of sustainable agriculture. Resource planning and management are linked to the size of operations, expected outcomes (income, product, yield), natural resource endowment (suitable land, water and climate) and market access. Technologies to ensure appropriate resource planning and management must be developed to ensure the long-term sustainability of different agricultural systems.

3.2.3 Socio-economic issues

- **Market development**

Linkages between R&D and the consumer are presenting a threat to the development of agricultural markets in South Africa. The development of products to cater for specific markets (certain market groups) can become an attractive opportunity for future market development. Aspects of market development that require attention are information systems on consumer choice, market segmentation

and technical matters such as packaging technologies and appropriate equipment for small-scale operations. At present themarket is segmented, with poor distribution systems to serve low-income consumers with inadequate consumer education. However, South Africa has managed to exploit market trends towards health, convenience and accessibility. The continued promotion of the health and nutritional characteristics of agricultural products such as food and fibre (e.g. wool) has made great strides. Increased efficiency in informal markets is an emerging trend in South Africa. A good capital base through collaborative funding, e.g. THRIP funding from the former FRD, has given an added advantage for market development in South Africa. The limited base of integrated skills in R&D, extension, technology transfer and training has caused some setbacks in market development.

- **Market acceptance for environmentally sustainable products**

Prescriptions by government resulted in environmentally sustainable products being affordable only to high-income groups and this poses a threat to the widespread use of these products by a broader market base. However, the challenge and opportunity are for the R&D community to develop cost-effective environmentally sustainable products. These products would be most opportune, especially for the input suppliers, farmers and agroprocessors, as they are becoming more in demand locally and globally.

- **Cost of entry into the markets**

Broader access to the markets (local and international) is limited by the cost of entry, resulting in significant barriers, especially for SMMEs. South Africa has recently seen the implementation of equity shares to help new entrants gain access not only to markets but also to land, skills and finance. Out-grower co-operatives also promote synergies between small and large growers to support each other and to facilitate access to a ready market for a specific cropcommodity. Subsidisation regimes among South Africa's competitors also impact negatively on market entry.

- **Centres of excellence**

A decreasing institutional capacity, skills base and funds are seriously threatening the sustainable capacity for the country to perform relevant and innovative R&D. This has been characterised by poor linkages between institutions involved in R&D and technology transfer (extension) resulting in a gap between R&D and practical application. South Africa's strength is its strong, world-class R&D infrastructure which, in spite of limited skills, creates opportunities for the development of centres of excellence in priority areas for agriculture. Competent universities and industry could form strong links around areas of competence creating an opportunity for the development of these centres.

3.4 Conclusion

A critical assessment of the current situation of agricultural R&D in South Africa shows that opportunities exist for a range of R&D interventions. The challenge is to assess the weaknesses inherent to the current R&D system and to address the threats from global economic trends which prevent agricultural growth and development. The current situation is informed by the South African policy environment (Chapter 2) and global economic trends (Chapter 1) which are not necessarily conducive to innovative R&D. Future economic trends and directives (local and international) will determine the innovation of R&D in South Africa.

Chapter 4: Scenario Thinking

4.1 Background

Long-term strategic planning and sound decision-making are based on the realisation that in times of changes, the future is highly unpredictable. A systematic and imaginative way of thinking is crucial to prepare for the future. One of the powerful tools for thinking ahead in an organised manner is scenario thinking, which also prepares the mind to recognise the signals of change before they fully unfold. Scenarios rely on historical data such as long-term demographic forces, while anticipating the surprising turns of a very complex world such as changes in political order and markets. These scenarios help the human eye to at least recognise the possibilities of change in the socio-economic environment of the country. Besides helping nations or communities see the future with different eyes, scenarios have managed to position leading corporations of the world, such as Dutch Shell, favourably in terms of strategic thinking and planning. It is in this light that the NRTF found it necessary to incorporate scenario planning as a crucial step in positioning South Africa's research and technology at the forefront of strategic development.

A set of four macroscenarios depicting four possible roads South Africa could take to 2020 are presented below. The scenario called The Frozen Revolution highlights the effect of the non-implementation of government policy on socio-economic upliftment, that is, it leaves the masses dissatisfied and key players fragmented and individually focused. The next scenario, The Innovation Hub, describes how South Africa's comparatively developed infrastructure creates opportunities for strategic regional development. The third scenario, called The Global Home, is about government embracing global liberalisation and facilitating private sector empowerment to respondto global market forces, in line with global trends and opportunities. The last scenario, called Our Way is the Way, depicts South Africa's perceived ability to challenge the conventional route to globalisation by rallying developing countries' support for the development of a significant South-South economic bloc. This approach results in isolation by the developed world.

These stories about the future have been used in the NRTF project to develop sector-specific scenarios that enabled the working group to generate strategies for the sector and to test the robustness of the developed strategies. These are published in a separate report obtainable from DACST.

The following are the four scenarios depicting possible pictures of the agricultural sector based on the macroscenario logics. (A summary is given in Table 4.2.5)

4.2 Scenarios

4.2.1 Scenario 1. The Frozen Revolution

Summary of the scenario

The Frozen Revolution scenario depicts a situation where the government is trying to address social and economic upliftment through endless policy formulation processes. Because of a policy paralysis, manifested in non-delivery, and engaging in populist projects, the masses are left dissatisfied. This ultimately leads to stagnation, a widening gap between the élite and the masses. For Science and Technology this means "hobby horse" projects, vote-catching projects with a continued reduction in resources leading to the demise of the S&T system.

It is the 8th of August 2004, exactly a year after general elections. We are tuned to People's Television for the eight 'o' clock news broadcast. The headline, "SHOCK WAVES IN AGRICULTURE" appears above the face of Dr Hoekom, the Honourable Minister of Agriculture.

Just a few months before our last elections, eminent scientists Drs Bono and Solomon of the University of the Northern Cape invented a new variety of maize called Ten-Minute Pap (TMP), through genetic engineering. This variety proved to have a high nutritional value, was easy to prepare and had a short growing time. It was also capable of combating indigestion in adults and flu in children. It was a world first! At the time, the Honourable Minister was losing favour with the agricultural unions because of the declining number of people in the sector. He quickly approved that the TMP be introduced immediately as it would improve the image of the sector and restore agriculture to a position of importance in the eyes of the population. Vast fields of TMP emerged everywhere. TMP became available in the Soweto and Hillbrow supermarkets. Housewives, health fundis, in fact everybody, including the white population, raved about TMP. Markets stretched from Cape Town to Nelspruit. Even people who have never eaten pap in their lives raved about TMP.

A few weeks ago, an unknown virus wiped out most of the TMP fields, causing massive job losses that resulted in poverty. TMP has started to disappear from the shelves to a point where consumers are fighting in the shops for the last few bags.

Community leaders, TMP users, workers and union representatives have all been unsuccessful in trying to meet the Minister of Agriculture, who is at present in Argentina, but we managed to get hold of the Director-General, Dr Nkani. This was her response to the crisis:

"I suggest that the population return to their traditional ways of eating maize. Why should people worry about TMP? This was a fly-by-nightproduct, so let's adjust to this hiccup. I promise that the financial support from the EU will be used, when it arrives,

to create a commission to investigate where the blame lies. Scientists have been summoned to identify possible projects to focus on solving these problems."

Now over to our Washington D.C. news reporter, who is with an international expert, Prof. Butterworth from the University of Wisconsin, USA:

"Professor, what is your view on this present crisis in South Africa's agriculture?"

"A delicate and complex situation exists in South Africa. When this variety was released, it was supposed to go through a rigorous process of evaluation for potential environmental risks and so forth. It seems to me that the Minister single-handedly made a swift personal decision on such a complex scientific matter. I think there is a lack of strategic focus in the R&D planning in South Africa, and issues such as climatic change, new diseases, international collabo-rations and innovation have been largely ignored. There is an almost total policy paralysis, which has resulted in an increase in crime in large areas of the farming community, food insecurity, unfocused rural development, environmental degradation and uncompetitive farming practices. Overseas investors have also warned the President and the Minister of Finance that the lack of commitment to agriculture, and especially to skills development, will have far-reaching implications for investment in the country. No wealth, no country!"

"Thank you very much, Professor. That will be the end of our news bulletin tonight. Until next time."

4.2.2 Scenario 2: The Innovation Hub

Summary of the scenario

South Africa has a comparatively development capacity for scientific and technological innovation. This capacity creates opportunities for strategic regional investment to build on an S&T skills base and knowledge that generate possibilities for a comparative advantage and a competitive edge regionally and globally. The innovation hub explores the building of collective regional strategic investment and indigenous technology capacity, excellence in scientific research and discourse, human resources development and policy instruments geared towards the socio-economic problems of the region.

"THAT USED TO BE AGRICULTURE"- In 2020, Chris van Toor, a Free State Farmer, along with his friends remembers the agriculture of the 1990s:

Chris: You know, Ma-Zondi, I was looking for my Palm-pad to check the latest market information on SADC and I couldn't find it. So in desperation I had to actually phone the co-op. It felt like days gone by.

Ma-Zondi: Talking about those days, Chris, let me tell you. You know, one day I woke up with intruders in my house. I got such a fright, I just froze! They took my cash, R1500,00, but luckily for me they were disturbed and just took off. Unbelievable!!!

Frans: You won't believe what used to happen to me! I had to leave at 05:00 in the morning to go to the market. I cannot believe it now being used to such a well-organised market. The infrastructure was poor and the variety of agricultural products was limited. In fact, you hardly saw any SADC country produce, let alone innovations. The old variety of cherries was still sold!

Chris: It's clear that things have changed. Some farmers were sceptical at the onset of change, and now, in 2020, our neighbours are really supportive and we work well with the private sector. Do you think the three of us would have been able to farm if the land redistribution programme didn't change in 2000 to allow us to participate? What about economic policies? To think that farming in 1998 was just farming and not a business to make money out of. Now agriculture has gained dignity and respect.

Frans: Remember how we struggled to get information and R&D for land reform beneficiaries? Man! If that hadn't happened, we would have been "drop-outs". I'm glad things have changed. We had the chance to study further in subjects that we could choose and not by sitting in a classroom either. Distance learning really helped the three of us.

Ma-Zondi: This morning as I was about to start my soil preparation, I came across an old plough I used to operate with horses! I remember my brother being very sceptical about my buying a computerised tractor, not knowing that I would be operating it so easily myself.

Chris: Well, imagine my surprise when I wanted to order some trees, and found that they had no disease-resistant trees (marula, you know). But you know, Ma-Zondi, not only mechanisation, but the entire approach to agriculture has changed.

Frans: What is really worrying is talking to other farmers' kids. They have no interest in farming. Remember how we use to be? They remind me of us back in 1998. No direction, and seeing agriculture as a no-win situation with no economic growth opportunities and never but never as a career.

Ma-Zondi: I was reading old newspapers this morning, and really things are so different! They were still trying to sort out the crime situation. And the economic policy - scary! At least now we have stability, which, if one thinks about it, was

greatly enhanced through the HR development and the regional investment framework.

Frans: Since 2010, information has become readily available. I remember how we talked to Zimbabwean and Namibian farmers regularly. I'm seeing my land, planted with fruit trees intercropped with hemp. You know, the marula seed they are processing to extract oil to use in cosmetics and the hemp for fibre. Things are so different.

Chris: I'm glad the new millennium brought along more mixed farming, better utilisation of natural resources, better education opportunities with especially the Agricultural University of Zambezi serving the whole region, more skilled people, regional co-operation with neigh-bouring countries, access to information and better marketing opportunities. I feel we are at the centre of innovation.

4.2.3 Scenario 3: The Global Home

Summary of the scenario

The global home scenario recognises global trends and opportunities which government embraces through acceptance of global rules and regulations. Government facilitates private sector empowerment to respond to global market forces. This leads to (1) significant initial economic growth; (2) some improvement in social development and (3) some dissolution of national identity and self-determination. S&T developments are focused on international trends with pockets of excellence, an inability to build on indigenous knowledge and a failure to address local social development needs.

A resource-poor farmer, Johannes Lijo, finds himself living in "The Global Home".

When Mr Lijo retired from military service in 2005 after 30 years of "long service and good conduct," he invested part of his pension in farming. Land available to him was only enough to resettle his grandchildren who have come back from the cities after realising that competition on informal trade markets is fierce from brothers and sisters from the continent and further afield.

He then used his retirement package money to source land that was being distributed to deserving citizens. To his shock, he was told that since there is stiff competition for limited agricultural land, only lucrative farming enterprises would be considered under the new land reform bill.

In his village of Tlholego, the community information centre provides the latest information technology but Mr Lijo has not lived in the village for the past 30 years

because he was working in Grootrivierdal. Therefore he was not aware of what the facility could offer, apart from a large number of youth who have just completed their fancy education in major towns and abroad. The latest information technology on offer was a range of products traded on the international markets, standards for export and marketing companies as well as the latest production systems. Because of his ignorance he did not realise that this information was under his nose. He organised a trip to Pretoria to find out exactly what is meant by lucrative farming enterprises.

With assistance from a national research organisation, he finally decides to take up protea production, as it is an export crop with good economic returns. Also, Tlholego's microclimate is suitable for its production. All other exotic crops proved to be difficult to grow as he did not have the necessary farming knowledge, the sophisticated technologyrequired, and the access to markets. After all, he believed that the government would only allocate land to him if his business plan made economic sense.

Mr Lijo got his land through a loan from the National Farmers Bank, and started to till his land. The research organisation assisted with the development of a protea variety that is suitable for low-input production, and that is pest- and disease-tolerant, drought-tolerant and peach in colour. He harvested his first crop in 2010 and was very happy with its performance on the EU market. For the first time he considered buying a computer for his own use.

Two seasons later (in 2012), he fails to receive a cheque and is told that his crop could not be sold as it was highly infected with disease. He goes to the community technology centre and asks for information about this new disease. The centre is helpful enough in getting him the information about the disease and the most effective bio-fumigant, which has only been released recently on the German market, where it is available.

Mr Lijo defaults with the bank because he can neither afford to import the chemical from Germany nor salvage the crop since the disease is soil-borne, requiring a fumigant for the soil, otherwise the land will have to lie fallow for five years.

Because of this experience he decides to send his daughter abroad to study agriculture, as he believes that the main reason for his failure was a lack of education and total reliance on domestic knowledge. His daughter, however, decides to study space food systems as she is quite interested in the food support programmes in the South African space programme.

4.2.4 Scenario 4: Our Way Is The Way

Summary of the scenario

"Our way is the way" highlights South Africa's belief in its ability to challenge the conventional route to globalisation by rallying developing country support for the development of a significant South-South economic bloc. This catalyses isolation of South Africa by the developed world. In terms of S&T it means the development of a skills base, a focus on development and self-sufficiency. Government focuses on innovation investment and there is less emphasis on a science base, as well as the gathering of scientific information by all means.

It's 2020. Miriam, who lives in a small house in Siyathandana Village in the Western Cape, sits on her tiny stoep and reflects . . .

Today, my son came to visit me. He drove into the courtyard, nearly running over two of my chickens which had been happily picking on their protea-pulp-enriched wild-flower seeds. He parked his new, biomass-fuelled car just in front of my solar-powered braai. These cars had been developed because of the huge amount of wood provided by the multi-skilling "Working for Water" project, which had been implemented to eradicate all the alien invasive vegetation that was sucking our country dry. The programme had allowed thousands of people to become skilled botanists, able to spot an alien pine or Hakea tree from hundreds of metres, and all the excess wood had then been used as fuel for our own national car, called the "Nelson".

Except for some crazy Englishmen, the rest of the world had not taken too much interest in our newly developed technology. First, black wattle wasn't this much of a problem elsewhere. In addition, the car wasn't really the fastest around, and it left a trail of smoke. But national pride had ensured its success inour own country, since the government had declared it every citizen's patriotic duty to help support indigenous technology. Imported cars are also highly taxed to protect the local car industry. Mind you, it was only the first nationally developed car since the "Ranger" which had been developed in the dark ages under CY Dimwit. My son is very proud of his car, anyway. It is a luxury model, specifically adapted to our conditions here in the countryside. As I said, the car is not very fast, but it can at least work as a tractor on the small farm my son owns. And that's just as well, since the government cannot maintain all the expensive roads in our rural areas. Yes, my son is a farmer. And I am proud of him. The government tells us every day how important he and others like him are in ensuring that everybody has enough to eat. He is mainly farming sweet potatoes, some cotton and has a small marula-tree plantation - and some dagga, but that's more for personal use and for friends!

Coming back to the car, I recently heard that we had run into an unexpected problem, because even if alien trees are growing fast, most of them have by now been removed, and our car risks running out of fuel. Since there are so many of these cars around, the government recently embarked on a replanting programme, and black wattle farming has been declared a national priority. That has the additional advantage of allowing for the redeployment of someof the previously trained botanists,

who had lost their jobs because nothing had been left to remove from our now pure indigenous fynbos and bushveld areas.

Ja, when I think back, SA has become a better place to live in. Sure, life is not always easy, but at least everybody has what they need to make an honest living. My solar-powered electricity supply allows me to stay warm in winter, at least if the sun is shining through enough. There were some initial problems when we embarked on our "SA is better" programme some twenty years ago and left some of the international organisations to go our own way. Forexample, we were taken by surprise when the rains started in winter instead of summer. If I remember correctly, the government had just embarked on a major indigenous crop improvement programme specifically for summer rainfall areas when this catastrophe struck. We then had to buy our food supply from some other countries for some time, and frequently went to bed hungry. At least everybody has a little piece of land, and our indigenous technology has made us something of a tourist attraction, bringing some money into our areas.

These tourists are funny people. They love to take photographs when we use our steam-powered mealie-crusher, and even go for a fun-ride on our Nelson. By the way, I heard on my "wind-up" radio today that we had some tremendous export successes. For example, it seems that the Japanese love our tasty chicken fed with Rooibos extract. They call it "health chicken". For us, it had just come out of necessity, since we had planted so much Rooibos during the years of the "Agriculture Indigenisation Programme" that we couldn't sell and I heard a rumour that some other countries are very interested in our locally developedsoil-tilling instruments. But instead of talking too much, I should rather start preparing some food for my son, he looks very hungry...

4.3 Merging SWOT with scenario thinking

4.3.1 Process of SWOT

SWOT (or situation analysis) was revisited using the scenarios as a backdrop in stimulating new thinking and future considerations. This exercise focused on emerging opportunities for research and technology development in South Africa for the next twenty years but also considered new threats and weaknesses per scenario and visualised them as opportunities. The response is arranged in terms of socio-economic, technological and environmental issues.

4.3.2 Technological issues

Regional diversity in agricultural production relating to water utilisation and availability was raised as a strength. However, the erosion of good scientists for R&D, the exclusiveness of science systems that are only relevant to South Africa and weak

regional skills bases are seen as weaknesses impacting on the technology development process.

Whilst the weak regional skills base is seen as a weakness in the greater regional context, it is also an opportunity for the South African-based scientists to work in the SADC region. Other opportunities that present themselves on the technological front are the use of international expertise and funding, utilisation of the local ethnic uniqueness in promoting the development of local SMMEs; linkages between R&D and farm production that will facilitate technology transfer and the use of indigenous technologies (e.g. animal traction) to capture a larger local and regional market. Traditional crops, inter-cropping strategies andhealing will need to be investigated for market potential, value addition and the international market to support and create opportunities. Joint ventures for selected commodities at the local and international level create more opportunities to source technology for the agriculture and agroprocessing sector.

The threats for this sector are the dumping of products, services, etc. on the local market, a loss of IPR internationally if it is not protected and reinforced by a legal framework and the likelihood that the market could be driven by science as opposed to market forces.

4.3.3 Socio-economic issues

One of the strengths of socio-economic development in the region is the regional diversity of agricultural production in relation to trade. Declining funds for R&D and an internally focused R&D system that is not orientated towards the global markets are seen as weaknesses.

From these weaknesses, several opportunities through innovative R&D can be realised. They include the promotion of local ethnic uniqueness for local SMME development, access to broad and new international markets by raising the levels of farmers through financial aid and education, moving the production of suitable crops, for e.g. maize, across regions and addressing food security in the region. More opportunities can be created through soft trade barriers, joint ventures for selected commodities at local and international level to obtain needed technologies and trading of R&D and its products. The most important resource is local indigenous knowledge that allows for the development of new products such as traditional crops, traditional intercropping strategies and traditional healing which can be investigated for future market potential and value-addition specifically for the international markets.

Globalisation facilitates the entry of multinational companies that compete for our markets and attempt to dump products, services, etc. on our local markets, which will affect the competitiveness of the sector. Negative, invisible trade barriers such as environmental regulations, phytosanitary regulations and social barriers will be used to

exclude local industry from global markets and international rules will also enforce liberalisation of trade which will affect the local economy severely by reducing market opportunities. Care should be taken that the market is driven by market forces and not science. The dependency of R&D on government funding can create isolated, science-driven institutions influenced by politics. If government does not create a sound legal framework to protect IPR, then this IPR can be lost to international groups. Intra-regional competition can occur if the production of certain crops is moved within the region; job losses and a decline in economic growth can result.

4.3.4 Environmental issues

Natural resource management brings new opportunities in technology transfer such as private extension, new products such as designer fertilisers, appropriate land use planning, rehabilitation of land, soil amelioration and water management technologies, e.g. irrigation, purification and water waste management. New markets will be created through the sale of technologies associated with water.

New opportunities in waste management are the utilisation and marketing of waste products derived from processing industries (i.e. mines, mills, processing plants etc.) and the need for good education and information systems to inform everyone about the effects of soil degradation, the benefits of sustainable land use, water quality and utilisation, and waste management. Waste management also creates a space for the revitalisation of land with technology from other countries and the re-emergence of indigenous and traditional technologies.

A threat to natural resource management is the exploitation by multinationals of mining, forestry and traditions. Systems are needed to guard against this. Policies will play an important role in directing natural resource management and therefore they should be environment-friendly.

4.4 Conclusion

The macroscenarios gave a futuristic guideline to the socio-economic, technological, environmental and political environment within South Africa. An analysis of these scenarios identified the possible strengths and weaknesses of South Africa in the future but also highlighted new opportunities and threats. The challenge is to create effective policies and systems to capture the opportunities and eliminate the threats in any given scenario. The development of technologies through R&D is a prerequisite for improved competitiveness and, therefore, increased economic growth.

Chapter 5: Delphi Survey

5.1 Background

The aim of the Foresight exercise, through its working group, is to assess emerging market opportunities and technological trends and inform decisions on the balance and direction of publicly funded science and technology for the next twenty years. It was recognised from the outset that it was not possible to have all the necessary expertise on a panel of a manageable size, especially considering the broadness of the sector. To gain the necessary commitment and consensus needed to make decisions and implement the Foresight product, it was crucial to do wide consultation with most stakeholders concerned with agriculture. A substantial amount of consultation was done through the working group members, associated individuals and the reference group. However, a much more structured dialogue with a cross-section of stakeholders was required to test preliminary strategies suggested by the working group. This intensive and continuous consultation process gives the Foresight process a unique characteristic compared to other, similar processes. This becomes even more pertinent to South Africa, whose science and technology system had functioned in fragmentation.

The method chosen to achieve Foresight's objective was the questionnaire-based Delphi Survey, a process in two iterations aimed at broader consultation of the stakeholders in the sector.

The main objectives of the survey were -

- to access the views of business, civil society, and science and technology communities on future developments in markets and technologies;
- to assist in gaining a commitment to results and consensus developments; and
- to inform stakeholders at large about major issues being addressed by the Foresight project.

The Delphi forms part of other, international studies such as Japan, Germany, the UK and Hungary, and is used either alone or to support other foresighting tools. The principles behind these international Delphi studies were also applied to the South African Delphi.

5.2 The approach

5.2.1 Identification of survey topics

The working group members worked both in subsector foci and in social, technological, environmental, economic and political (STEEP) subgroups to identify areas of principal need (such as problems, trends or issues) expected to underpin the

sector for the next twenty years. The working group applied these issues, trends or problems emerging from the STEEP to a logic chain, in terms of which the following were linked to each issue, trend or problem:

- List five problems/trends/issues that may influence the sector in the next twenty years;
- Identify possible new market opportunities that could arise from the trends or issues;
- Identify possible new products, processes and/or services to take advantage of some of the market opportunities; and
- Identify technologies, breakthroughs, scientific advances or innovations needed to underpin products, processes, services and products.

It must be noted that many issues and trends were identified by the working group and prioritised according to the criteria outlined below.

5.2.2 Formulation of Delphi statements

a) Further identification and testing of technologies, breakthroughs, scien-tific advances and innovations underpinning identified products, processes, services and products were finalised by an advisory pool of selected experts or knowledgeable individuals in the sector. The work was then ready for statement formulation by the working group.

b) The working group formulated Delphi statements. A Delphi statement had to be a concise statement of events, achievements or other phenomena upon which views are sought, an unambiguous expression of what, in the questioner's, view, had to be achieved. It had to incorporate any key conditions but exclude separate issues that warrant additional topics. To assist the working group in communicating which state of development they had in mind, the guiding notes to the questionnaire defined four items to be used:

Elucidation: to scientifically and theoretically identify principles or phenomena;

Development: to reach a specific technological goal for completion of a prototype;

Practical use: the first practical use of an innovative product or service; and

Widespread use: significant use, i.e. significant market penetration to a level where a product or service is in common use.

The WG was encouraged to be even more precise in their formulations through the use of quantitative representations in the statements.

5.3 Agriculture/Agroprocessing statements

5.3.1 Prioritisation criteria

Many statements resulted from a rigorous process of consultation in the working group and the reference group. All these statements are presented in a separate sector survey document. The statements were direct research and technology solutions linked to the STEEP problems, trends or issues identified by the working group members as key areas of concern for socio-economic development in the next twenty years across all disciplines in the sector. Some of the statements were pertinent to the issues of an enabling environment underpinning sector research and technology solutions for the next twenty years. The entire debate both by the working group and the stakeholders (reference group) became the centre of the survey.

When one considers the limited number of statements required for the survey, the issue of the **complexity** and **broadness** of the sector was raised. It became imperative that prioritisation criteria be formulated to screen the statements for the survey. It was agreed that certain criteria would used as guidelines in finalising Delphi statements. Each statement had to satisfy at least three of the following criteria:

a) Equitability (e.g. provides for small-scale farmers and future generations and creates a balance between social, economic and technological issues);
b) Competitiveness (e.g. gives a comparative advantage);
c) Food security (e.g. ensures national and household food security, incomes, accessibility of food, food quality and food distribution);
d) Efficiency (e.g. relationship between output and inputs, doing things better, increased productivity);
e) Environmental sustainability (e.g. as it pertains to food safety, health and physical environment); and
f) Job creation: (e.g. includes multiplier effects and money generation).

Please note: All research and technology components of each statement had to be tested for robustness, e.g. continuity, agility and relevance, as a key prerequisite for inclusion in the survey to ascertain long-term sustainability. The entire Delphi survey appears in ***Appendix C.***

5.4 Delphi results

This material will help the reader to understand how stakeholders in the sector at large perceive our ideas as represented by the survey. The results are analysed according to the confidence levels of the respondents e.g. High, Medium or Low, and/or combinations (see Table 5.4).

Table 5.4.1 indicates the Top Twenty Topics, reflecting three indexes:[1] Wealth creation (WC), Quality of Life (QL), and the Joint Index (WC+QL). These are used as a measure of respondents' perceived ultimate potential for the topic. The statements are in descending order as per the joint index. The Bottom Ten Topics are also provided for comparison. Also included in this table are respondents' perceived significant constraints associated with the topics. For e.g. F = financial, T = technological, HR = Human Resources, P = Policy, Soc/Cult = Social or Cultural. Please refer to the questionnaire for these.

The analysis was done at several confidence levels, such as high, medium and high and all respondents. It was evident from the data that a large degree of variability between the high and low level ofconfidence existed, while levels between high and medium were minimal. It became reasonable to adopt the results for the medium-to-high level of confidence and base decisions on these.

5.5 Survey Analysis

5.5.1 Characteristics of the top twenty statements

If one looks at the top twenty statements, it is clear that they cover most of the focus areas of the sector, i.e. production systems (2, 10, 16); farmer support (15, 16, 24); biotechnology (27, 33, 34); indigenous crops (37); industrial processing (44, 46, 54); legal and policy issues (59, 61) and common (67, 68, 69). A quick scan shows that the time frame for realisation for most of these statements ranges from less than five years to fifteen years.

5.5.2 Bottom ten statements

For comparison purposes the bottom ten statements have also been included in table 5.4.1 One of the interesting characteristics of these statements is that they contain mainly futuristic technologies such as robotics for harvesting and genetic engineering. With regard to some statements there is still strong social unacceptability of technologies such as food irradiation. Whilst these technologies have been considered as important for both wealth creation and improving quality of life in the short term, it is worth exploring them in the medium to long term.

5.5.3 Quality of life

The respondents seem to feel that farmer support, legal and policy issues, production systems and industrial processing are likely to make a major contribution to improving quality of life.

5.5.4 Wealth creation

The majority of top twenty statements reflecting the perception of a likely contribution to wealth creation fall in the focal areas of industrial processing including indigenous crops, production systems and farmer support. It is again apparent that because thetime frame for realisation is five to ten years, biotechnology is not perceived as a likely contributor to wealth creation in the short to medium term.

Overall analysis of the statements in terms of the five variables, viz. time frame for realisation, comparative standing, acquisition and wealth creation, will be discussed below.

5.5.5 Time frame for realisation

The respondents seem to feel that for most statements, the likely time frame for realising most of the technologies seems to be six to ten years, which is a medium- to long-term time frame. There are some statements reflecting realisation within 11 to 15 years.

5.5.6 Comparative standing

For most of the statements, the respondents seem to feel that South Africa is ahead of the Southern African and developing countries whilst South Africa is behind the developed countries.

5.5.7 Acquisition

There seem to be two main preferred acquisition strategies, viz. developing in South Africa and engaging in joint ventures. It is also evident that for those technologies in which South Africa is behind the developed countries, the preferred acquisition strategy is through joint ventures and developing in South Africa. Where South Africa is equal to or ahead of developed countries, the suggestion is that we develop in South Africa followed by engaging in joint ventures. There is also a third acquisition strategy, which is to import complete technology as well. This feature is true for the bottom ten statements. For the top twenty, the picture is slightly different. The most preferred strategy is to develop in South Africa followed by engaging in joint ventures and then customising existing technologies. These strategiescould be useful in guiding the Science and Technology system in formulating its international agreements strategy.

5.5.8 Constraints

In most statements, the major constraints as perceived by the respondents seem to be finance followed by human resources and technology. R&D follows but does not seem to be a major problem. This seems to suggest that the policy environment and socio-cultural issues are not perceived as major problems.

5.5.9 Summary

The surveys seem to be a useful tool in identifying emerging technologies and their potential applications in the economy and in providing societal solutions. There are a number of technologies that have been identified and these will be further explored in the next chapter.

5.6 Conclusions

This study was a useful reflection of the thinking patterns among South African agriculture and agroprocessing stakeholders. It was also important, however, to draw out emerging trends and their significance in the sector work and how they impacted on the interpretation of the results by the WG. Compared to other, international surveys, a response rate of 25% to 30% for the first round is regarded as good, while 20% is satisfactory. Given this background, the response rate for this sector was 28% for the first round and about 52% for the second round.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

This chapter presents conclusions and recommendations resulting from the situation analysis (Chapters 3 and 4), supported by wider consultation with stakeholders as outlined by the Delphi Survey results (Chapter 5). Judging from these results it is clear that the South African agricultural and agroprocessing sector is uniquely positioned: there are elements of both a developed agricultural sector and an underdeveloped sector, with a trend towards a more mature economy. Whilst there is an appreciation for and use of high-level technology particularly within the developed sector, the majority of innovative technologies are imported. If South Africa is to progress to a more developed state of agriculture and agroprocessing, as well as to increase wealth generation and the socio-economic standing of all stakeholders within the sector, a larger degree of technological innovation will be necessary. It is the intention of this chapter to outline the nine technological nodes expected to underpin the required development and competitiveness of the sector during the next twenty years so that the required wealth generation and socio-economic development within the sector can be achieved.

These strategic technological nodes generally have been found to contribute simultaneously to both wealth and improved quality of life, leading to balanced growth and socio-economic development. In indicating these critical areas for potential investments in agriculture and agroprocessing technologies, the intention is to advise the potential stakeholders within these broad areas of the advantages for investment without being prescriptivein terms of detailed methodologies. The critical areas to be outlined are not necessarily in order of priority nor is any particular weight given to the items They are a list of emerging nodes within the South African context.

6.2 Conclusions

6.2.1 Agroproduction systems

The primary elements within this strategic area are breeding technologies, focused and intensive production systems and also extended, on-farm production life cycles, with a possible impact on industrial processing.

- **Breeding technologies**

These are traditional breeding technologies in animal and plant production systems for the generation of novel and improved products. These may be primary or

secondary products required for ease of processing throughout the value chain. Particular emphasis should be placed on using these technologies to create pest and disease resistance, ameliorate environmental stress, and improve the quality of products, both in animal and plant production systems. Indigenous products should receive special attention as it is through novel, indigenous products that South Africa can create a comparative marketing advantage.

- **Focused and intensive production systems**

The purpose of focused and intensive systems is to enhance efficiency in the use of prime production factors (natural resources, labour, capital, and management) within specific subsectors. The technological requirements need to be focused on innovative methodologies for optimum resource utilisation.

- **Extended production life cycles**

This technology would be specifically attractive for rural and peri-urban production systems where labour and market flow constraints predominate, and would be useful for more consistent cash flows in terms of commercial agriculture and household food security. This applies to both animal and plant production systems

Key technologies:

- Development of focused and intensive agricultural production systems that are subsector-specific (e.g. hydroponics and broilers).
- Use of milk recording to improve the quality and quantity of milk or other milk products among participating herds.
- Development of livestock bloodlines that show inherent resistance to internal parasites.
- Traditional breeding techniques to produce oil seeds, plants, lean meat and animals.
- Use of breeding to produce novel agricultural products (e.g. fruits, vegetables, animals, trees, indigenous or traditional raw material) for new markets.
- New breeds of goats and sheep with good quality wool, meat and milk.
- Use of plant breeding for drought resistance in crops to reduce production risks in SA agriculture.
- Use of traditional breeding methods to introduce water and nutrient efficiency into important plants.
- Use of estimated breeding values (EBVs) to identify better breeding animals at a young age.
- Use of mechanisms to increase the length of the harvesting period of crops for rural and local markets.

6.2.2 Biotechnology

Biotechnology should be seen in a wider context, where it is used as a tool for a more rapid and efficient means to diversify and improve the food and otherindustrial product base, while maintaining the food security and economic growth. Biotechnology can be applied in combination with traditional breeding techniques for elucidation of novel genes, for ease of processing, for improvements of crops and animals, and for legal use.

It must be emphasised, however, that the future of biotechnology in South Africa, especially in the commercialisation of genetically modified organisms, has to be handled with sensitivity and a great of caution. Consideration should be given to consumer needs, including education and awareness programmes driven by all concerned role players, such as government, industry, NGOs, scientists, educationists and the media. International agreements, such as the "Biosafety Protocol" being formulated within the Convention on Biological Diversity (CBD) and other, national imperatives to ensure safe handling, transfer and disposal of genetically modified organisms and their products, have to be observed.

- **Biotechnology and traditional breeding**

Biotechnology can contribute to the efficiency of traditional breeding by expanding and manipulating the genetic resource base. It can be a support service, offering efficient tools in field selection using genetic markers and fingerprinting.

- **Elucidation of novel genes**

Most of the valuable and known genes used in genetic engineering at present tend to be protected by intellectual property rights, thus limiting wide access and application. Given South Africa's rich biodiversity, biotechnology creates an opportunity to elucidate novel genes that, through intellectual property rights, may generate strategic advantages.

- **Ease of processing**

Biotechnology could also be a tool to generate novel material and produce secondary products for ease of processing anywhere on the value chain. Furthermore, it could improve the efficiency of the process itself.

- **Improvement of crops and animals**

Biotechnology allows for the movement of novel and desirable genes to improve the quality of a wider array of animal and plant production capabilities.

- **Legal use**

Biotechnology provides opportunities as a diagnostic tool in issues of genetic and other legal disputes and the facilitation of international exchange of genetic material. Genetic fingerprinting, such as ALFPs (Amplified Length Fragmented Polymorphisms), microsatellites and other applications could be useful in the identification of genetic polymorphisms for international exchange and legal disputes.

Key technologies:

- Genetic engineering of novel microbes to produce food flavourants, colourants and preservatives.
- Research into novel genes (not protected by IPR) to introduce resistance into crops, especially cereals.
- Genetic engineering of micro-organisms (e.g. better yeast strains) to produce cheaper and quicker fermentation technologies.
- Research into suitable tissue-culture techniques for prolonged propagation, regeneration and preservation of cereal crops.
- Genetic fingerprinting (e.g. AFLPs, micro-satellites) to identify genetic polymorphisms for international exchange and legal use.
- Identification of microbes that will degrade or recalcitrate industrial polymers (plastics) for re-use.
- Research into crops or animal-specific promoters to hook up other useful genes for optimal expression of desirable genes.
- Development of N_2- (nitrogen-) fixing plants or crops using genetic engineering.
- Development of new tree varieties with desirable characteristics using gene manipulation, cell fusion, and other similar technologies in tree breeding.
- Introduction of sterility into exotic species to prevent proliferation through gene manipulation.
- Cryo-preservation of genetic resources, including nuts and oil seeds, for future propagation and breeding programmes.

6.2.3 Natural resource management and utilisation

This pertains to the technologies required for the sustainable utilisation of natural resources (e.g. soil, water, air and genetic resources) in agriculture and agroprocessing activities.

- **Water-saving technologies**

South Africa is considered a water-deficient country. It is imperative, therefore, to develop appropriate technologies to optimise water utilisation for agricultural and agroprocessing production. These technologies include "drip" and "deficit" technologies and efficient means of water transport, especially for rural agricultural use.

- **Bio-solutions and natural resource management (NRM)**

Bio-solutions and NRM create an opportunity to enhance the sustainable use of natural resources through the utilisation of biological products and organisms This is deemed to be an essential component of integrated production systems that enhance food safety and environmental protection. Thesetechnologies will also assist in ensuring a cleaner and healthier environment, both from an agricultural production and waste management perspective.

- **Monitoring technologies**

These are technologies to monitor natural resources locally and globally in order to support decision-making and land use planning as a key component of integrated natural resource utilisation, underpinned by appropriate remote sensing and information and communication technology. They should be applicable at international, regional, national, provincial and farm level.

Key technologies:

- Research into cover crops for intercropping systems in accordance with low-input agriculture.
- Use of biopesticides suitable for local ecosystems.
- Use of conservation tillage for sustainable environment and less erosion.
- Development of affordable global monitoring systems with high-resolution ability to monitor natural resources for precision farming.
- Use of satellite image analysis for land-use planning, drought monitoring and the development of regional trade scenarios.
- Adaptation of geographic information systems to access information on resource management technologies for full interactive use by rural, resource-poor and other users.
- Widespread use of "drip irrigation" instead of "overhead irrigation" to conserve water.
- Widespread use of "deficit irrigation" for water use efficiency.
- Use of biodegradable containers and wrapping materials that use bio-based materials.

6.2.4 Technology transfer

Technology per se is of little or no value without large-scale adoption by the end-user. Transfer plays a critical role in this process of adoption. This is important for South Africa because of an identified weakness in its technology transfer system, particularly within the less-developed agricultural sectors. This field includes training and extension, education, international technology transfer mechanisms and IPR.

- **Training and extension**

Enhanced training of extension personnel and farmers and improved technology transfer systems are identified as of critical importance for improved production, natural resource management, and wealth generation for all agricultural stakeholders.

- **Education**

Education forms the basis for human resource development to address the required future technologies, to enhance competitiveness and wealth creation and to ensure an improved quality of life in the agricultural and agroprocessing sector.

- **International technology transfer mechanisms**

In order to optimise skills and resource usage it would be strategically necessary to engage in international agreements pertaining to technology transfer. They would allow for the importation of certain technologies deemed uneconomical for local development, while at the same time concentrating resources so that a strategic advantage can be gained for local production enhancement and international trade.

- **Intellectual property rights**

Intellectual property rights are the key to successful technology exchange. Therefore an appropriate legal framework coupled with effective implementation is required. Effective IPR protection is also necessary as an incentive to the creation of an innovative environment. An effective IPR frame-work would allow South Africa to capitalise on its indigenous knowledge and technologies for future competitiveness, wealth creation and improved quality of life.

Key technologies:

- Adaptation of extension methodologies for South Africa's diverse situation to ensure effective linkages between researchers and extension farmers.
- Development of user-friendly teaching or training aids for resource-poor farmers.

6.2.5 Processing technologies

South Africa's economy is characterised by the export of primary products, resulting in a loss of potential in export earnings. Wealth creation is significantly affected by downstream beneficiation of products. South Africa's increased competitiveness within the global environment and enhanced wealth generation for all stakeholders are contingent upon a value-adding philosophy. This will require improved technological capacity within the fields of product preservation, handling and packaging technologies. Significant losses in agricultural products and resources occur post-harvest and in addition compromise food safety.

- **Preservation technologies**

Preservation will require innovative technologies to ensure freshness, prolonged shelf life and maintenance and enhancement of quality of bothtraditional and new indigenous products for commercial and rural use. This also creates an opportunity to enter new markets based on emerging and future trends and needs. Preservation techno-logies such as improved and specialised irradiation techniques, low-temperature technologies such as "snow-shooting," and novel and versatile drying technologies need to be developed or improved to fit all economies of scale.

- **Handling technologies**

The cost of product handling within the total cost chain is significant and will require innovative technologies to ensure the movement of product from producer to market at a minimum cost.

- **Packaging technologies**

Packaging technologies have the potential to protect products and prolong shelf life, enhance food safety and increase market appeal, thus contributing to wealth creation and improved quality of life. In order to create a competitive advantage both locally and internationally, innovation in the packaging of new and indigenous products where little or no technology is available presents a significant opportunity. Environmental trends applicable to packaging should be recognised.

Key technologies:

- Development of mini-seed harvesters and cleaners for small-scale production.
- Development of mini-threshing and milling equipment suitable for rural use.
- Use of a combination of extraction (e.g. industrial chromatography) and concentration technologies to separate or isolate nutraceuticals.
- Use of vitamin A and amino acid addition to staple foods through fortification in a metabolisable form to improve the nutritional status of a targeted population group.
- Development of appropriate packaging technologies suitable for pre-prepared foods to serve rural and new markets.
- Use of low-temperature-controlled technology (e.g. "snow shooting") applicable to all environmental conditions for the distribution of pre-prepared vegetables and fruits.
- Research into irradiation techniques (e.g. the use of gamma rays) for specific foods to improve their safety, availability and digestibility.
- Development of sophisticated fish de-scalers to remove scales from hake to improve quality for international markets.

6.2.6 Enabling environment

Science and technology should be supported by an enabling environment. This should particularly include agricultural research from a socio-economic perspective to optimise efficiency and benefits, and strategic mechanisms to formulate and adjust policy for R&D. An important component of an enabling environment is access to and availability of updated information in all subsectors and related activities. To create an enabling environment, adequate asset development is required. Included in the strategic assets are human resource, material, capital, knowledge and intellectual assets, relationships and the ability to change rapidly in accordance with perceived market or future trends. Innovative research and support for optimisation and development of these assets are necessary.

Key technologies:

- Widespread use of phytosanitary and sanitary norms through appropriate legislation and practices to protect agricultural resources.
- Research into legal and practical mechanisms to prevent loss of South Africa's agro-biodiversity, especially indigenous plants and animals.
- Widespread licensing and patenting of South Africa's agricultural indigenous knowledge and technologies for international markets.
- Legal protection and preservation of agricultural genetic resource base.
- Development of a strategic mechanism to formulate and adjust the policy for integrated agricultural research and development across all subsectors.
- Development of an IPR legal framework to protect new and existing SA agricultural and agro-processing products worldwide.
- Research into means of changing negative consumer perceptions on the dangers of food irradiation.
- Widespread use of imported biotechnology (e.g. applicable to livestock, flowers, fruit, vegetables, grain, etc.) for more cost-effective research and development.
- Research into key indigenous plants and their potential products for inventory and cataloguing.
- Research into general systems (e.g. rewards, efficiency, number of people per job, provincial roles, capacity building) to optimise efficiency and benefit to all stakeholders.

6.2.7 Market development and maintenance

Market development and maintenance are imperative for wealth creation and continuous, rational production. There is a correlation between market development and technology development because markets determine technology development needs. Therefore there is a need for market research and information, consumer education, and continuous development of markets. One of the factors that limit

market access is the cost of entry and maintenance. In both of these cases innovative technological solutions to either limit cost or circumvent barriers will be necessary.

Key technologies:

- Widespread use of agricultural socio-economic research (e.g. support, service, economic, trade, market development for social issues) for evaluation of potential policy impact.
- Practical franchising (national and international) of ethnic concepts (e.g. cuisine) to the international markets.
- Widespread use of accessible and appropriate market information packages for all agricultural subsectors.
- Practical use of prioritised cutting-edge technologies and global technology scanning.

6.2.8 Novel technologies

Although novel technologies were not identified by the Delphi survey as important for South Africa, particularly in relation to an improved quality of life, evidence from other countries shows that these technologies could impact on future wealth creation and competitiveness especially as they are pervasive throughout the sector. We would therefore be remiss to ignore the future impact of such technologies on the South African economy. These technologies include the adaptation and use of novel materials and processes, interaction between technologies such as ICT and biotechnology and ICT and mechanisation, the adaptation of polymers and ceramics, miniaturisation, robotics, etc. Examples of these already emerging are odour sensors with ability comparable to that of humans, autonomous robots with environmental awareness sensors, intelligent robots for unmanned plants, anthropomorphic robots used for factory jobs, and intelligent materials with sensors, storage capacity and effectors. Usually these technologies are underpinned by an intersection of multiple technologies.

Key technologies:

- Research into efficient means of water transportation, especially for rural agricultural use.
- Development of new technologies to preserve quality of natural or indigenous products for international markets.
- Development of technologies suitable for rural and small-scale processing to extract natural products (e.g. oil) from indigenous plants.
- Development of economic shelf-life technology at ambient temperatures for fish and other processed food products to open up distribution opportunities and markets in South Africa.

- Development of novel and versatile drying techniques to support rural industries also adapted to capital and human resources.
- Practical use of robots capable of harvesting and simultaneously sorting fruits and vegetables according to quality and size.
- Development of affordable, gender-friendly, mechanised technologies (e.g. tools, equipment and machinery) adapted to specific land, capital and human resources for economic growth.

6.2.9 Systems modelling

Modelling technologies give a futuristic insight into the probability of events, which insight provides capacity for risk management and planning. Modelling can therefore help us to understand the majority of the previously mentioned strategic nodes. Computer models combined with artificial intelligence dominate this node and are used to predict food production or processing systems for food safety throughout the value chain, conservation of natural resources, etc.

Key technologies:

- Practical use in South Africa of Internet-based systems to farm effectively (e.g. remote diagnoses of diseases and pests on plants.
- Practical use in South Africa of management systems using artificial intelligence and computer modelling to conserve natural resources for the ultimate harmonisation of agricultural-forestry ecosystem.

6.3 Recommendations

These recommendations are intended to outline the steps required to create an enabling environment within which to implement the identified strategic technological nodes successfully. They will present both the primary constraints and suggested strategies for effective advancement of the agricultural and agroprocessing research and technology expected to underpin socio-economic and competitive development for the next twenty years.

6.3.1 Constraints

- **Finance**

Finance is emerging as one of the primary constraints in the development of research and technology in this sector and across all subsectors. Major concerns are in the areas of the scope and allocation of financial resources. Funding can create incentives and disincentives for specific pathways as defined by underlying public and private objectives.

- **Human resource capacity**

The human resource capacity as defined by the number of people within the technological skills base as well as the level of skills in critical sectors is a serious constraint in South Africa. The lack of skilled personnel can be ascribed to a poor level of science education and a lack of career awareness at primary and secondary levels coupled with a perceived lack of financial incentives in agriculture impact negatively on the tertiary education base.

- **Technology**

Technological constraints have been characterised by a lack of access, affordability, appropriateness and an innovative culture in South Africa. Social perceptions and preferences also play a critical role in the acceptance and support of technologies.

Even though these constraints predominate, a minor yet significant role is played by the impact of a policy and legal framework, R&D infrastructure and markets on the development of research and technology in agriculture and agroprocessing.

6.3.2 Suggested strategies

6.3.2.1 Enhancing the culture of S&T innovation

a) Human resources for the future will be require the creation of extensive public awareness and a desire and enthusiasm for science and technology amongst all South Africans. In the interest of a coordinated approach, the Department of Education and DACST should take the lead in promoting and sourcing such awareness programmes. This should be a short-term activity laying the foundation for future progress.
b) The NDA and the DoE must engage actively in curriculum planning and implementation in order to prepare candidates for critical analysis of scientific concepts. Particular attention should be paid to teaching methodologies that promote multi-disciplinary skilling in the agricultural sciences. Included in science curricula should be an appreciation of the economic benefits of innovation.
c) To update the human resource base according to need there has to be continuous re-skilling and in-service training in appropriate technology use, development and transfer across the entire sector. This should be the responsibility of all stakeholders involved in research, technology and development, but DACST and the NDA should take the lead while collaborating with the PDAs.

6.3.2.2 Strategic approach to funding for innovation

There are several methods by which funding can be leveraged more efficiently for the maintenance and support of innovative technologies. The level of funding per se should not, however, be ignored. The following suggestions should be noted:

a) The science vote should ensure that the total public and private sector spending as a percentage of agricultural and agroprocessing GDP on research is on a par with that of the leading industrialised countries for the desired innovation and competitiveness to occur.
b) The following instruments of innovation aimed at mobilising private sector funding and ensuring that it is used efficiently need to be implemented:
   - incentives for innovation (e.g. tax breaks, seed money and grants, particularly on completion of projects);
   - local and international joint ventures;
   - partnerships;
   - strategic alliances locally and internationally;
   - equity holdings; and
   - collaboration, which should at least among important stakeholders include an industrial partner.

For the above responsibilities, DACST, the NDA and the DTI should act only as facilitators where required and should as far as possible refrain from involvement in research, which should be left to market forces. All departments concerned with agricultural research, and particularly the NDA, are expected to incentivise research for the public good, but only where industries or communities are clearly unable to contribute sufficiently.

6.3.2.3 R&D infrastructure for innovation

Infrastructure is often regarded as consisting of physical assets such as primarily buildings and equipment. However, the soft components of infrastructure are equally important. These can be defined as government, science councils, universities, industry and organised agriculture, all of which have a significant role to play in the development, utilisation and mainte-nance of technology. In order to coordinate and cost-effectively develop innovative solutions through the creation of linkages and networks across the sector, DACST needs to be the champion. The formation of an NARS will lead to the creation of a common vision of the realisation of agricultural technological objectives, underpinned by information and knowledge sharing, which is a desired component of a functional national system of innovation. Some of the benefits of an effective NARS would characteristically be a synergy of interaction followed by concerted efforts towards the development of centres and clusters of excellence for technological innovation. In the short term, the NDA should take the lead in setting up a NARS and facilitating all support systems.

The greatest benefit to the development of the agricultural and agroprocessing sector will accrue only if a common vision is created by all stakeholders through the identification and development of innovative technologies required by the future market place even before the market calls for such technologies. These processes will be supported by putting innovation at the centre of long-term strategic planning using foresight tools, technology forecasting, technology scanning and scenario planning for future competitiveness. In this way a capacity to anticipate the future needs of such markets and ensure the continuity of agricultural and agroprocessing enter-prises will give the South African industry a strategic advantage for sustainable socio-economic development.