The economics of cultivar improvement research in the South African wheat industry

by

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DECLARATION

I, Christiaan Johannes Stander, hereby declare that this dissertation is my own work and has not previously been submitted to any other institution for purposes of any other degree.

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ABSTRACT

The economics of cultivar improvement research in the South African wheat industry

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Research and Development (R&D) has a long history in South African agriculture and has led to growth in both agricultural output and yields over the past few decades. Various wheat breeders, both private and public, have contributed greatly towards varietal improvement which impact can be noted in the yield growth in the South African wheat industry. Research into improved wheat varieties cannot exist, however, without sufficient funding and investment in this form of agricultural R&D. In turn, in order to improve the accountability of research into agriculture and more specifically investment in varietal improvement research, information with regard to the economic benefits of varietal improvement research is needed. The benefits of wheat varietal improvement research internationally have featured in a number of studies, but little is known about the true impact of varietal improvement research on South African agriculture and more specifically the wheat sector. The total stream of benefits from research investment by private and public wheat breeders must be calculated by using relevant methods and up-to-date data on yield levels, production and area planted to the different wheat cultivars released by private and public wheat breeders.

Wheat production in South Africa continues to play an important role in the agricultural sector despite the fact that the area planted to this important grain crop has followed a downward trend since the mid 1990s. In 2008 wheat production was the tenth highest contributor to value added in agriculture and covered 20% of the area planted to field crops. Until 2002 South Africa was the top producer of wheat on the African continent, a position currently held by Ethiopia (FAO, 2009). Despite this, wheat continues to play an important role as a staple for many in South Africa.

Three wheat breeders account for the biggest market share of varietal improvement in South Africa: Sensako, the ARC-SGI, and Pannar. It can be noted that Pannar only entered the wheat-breeding market in the mid 1990s, with both publicly developed cultivars and those developed by Sensako being present from the 1970s. All these wheat breeders spend large sums of money annually to ensure their cultivar releases can compete in a highly competitive environment. Measuring the return on this form of investment relies heavily on the availability of certain data. Experimental yields are the only reliable sources of relative yields and must be obtained for all of the varieties planted in all of the production areas. From these yields an index of varietal improvement can be constructed to calculate the growth in yields from a value in the base year (1980). By calculating a k-shift from this index, the total benefits can be estimated by multiplying the k-shift value with production and price data.

The benefits due to varietal improvements are captured in various studies and consistently indicate that the benefits of varietal improvement research are far greater than the expenditure on research. The question that is often raised is: Can all of these benefits be attributed to varietal improvement alone? And if not, what percentage can be assigned to varietal improvement research? There is also the issue of the yield levels of the counterfactual or "without" scenario. Would yields have remained at their levels in the base year if no research had been conducted? Or would technology improvements have spilled over from various other sources? For the dissertation, different assumptions based on expert opinions were made with regard to the attribution of benefits to different factors. This allowed benefits to be allocated to other factors, besides varietal improvement, that had a positive impact on yield growth on an experimental and ultimately a commercial level.

In this study, the benefits due to varietal improvement research were investigated and found that the benefits due to varietal improvement amounted to R13.798 billion. Further, these benefits can be attributed to the role played by different institutions (such as the ARC, Sensako and Pannar). The study established that 61% of the benefits could be attributed to the ARC, 34% to Sensako and 4% to Pannar. The ARC-SGI held the greatest share of benefits attributable to varietal improvement and had more hectares planted to their varieties than any other seed company. Sensako contributed more benefits in the irrigation areas with the ARC-SGI contributing the most in the dryland and winter production areas.

It must also be said that the amount of benefits calculated, R13.798 billion, assume no spill-over effects of genetic material from other countries. If 20% was to be attributed to spill-over effects from other countries the benefits related to the research in South Africa on wheat varietal improvement would amount to R9.157 billion. Assuming spill-overs from other countries did occur, and attributing some of the benefits to better farming practices adopted by producers in South Africa, the study established that out of R23.289 billion in total benefits, R9.157 billion can be attributed to varietal improvement research, R9.474 billion to better production practices by farmers and R4.658 billion to spill-over effects from other countries.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Total expenditure on research and development (R&D) in South Africa amounted to R18.6 billion in 2007/08, which is a sharp increase from the R16.5 billion spent in 2006/07 (CeSTII, 2009). Of this amount, the government sector accounted for 22.8% (R3.8 billion) and 21.7% (R4 billion) of R&D expenditure in South Africa for 2006 and 2007 respectively. The biggest share of total R&D expenditure in South Africa is, however, provided by the business sector and accounts for 57.7% of total R&D expenditure. The remaining 43.3% is shared by government with 21.7% and foreign and other sources with 19.4% (CeSTII, 2009). As a result, gross expenditure on R&D amounted to 0.93% of the Gross Domestic Product (GDP) in 2007/08, a slight drop from 0.95% in 2006/07. Of the R4 billion spent on R&D by the South African government in 2006, roughly R280 million was spent on agricultural R&D.

On average primary agriculture contributes about 3% to South Africa's gross domestic product (GDP) and in 2008 contributed R68 billion to the South African economy, which increased from R38 billion in 2002 (GCIS, 2010). Expenditure on R&D in this important sector is on average 2.5 to 3 percent of the contribution made by the agricultural sector towards the GDP. This figure differs annually and is to an extent dependent on the given agricultural year. In 2007, expenditure on small-grain research amounted to R36.7 million, nearly doubling in nominal terms after 2000 when R18.8 million was spent (Liebenberg, 2009). These figures are an indication of the government's efforts in terms of small-grain research. Unfortunately, little information is available on the contribution, and thus the return on investment, of R&D in small grains. This is the case for both private and public wheat breeders involved in small-grain – and particularly wheat cultivar – improvement research in South Africa.

Varietal improvement research in the South African wheat sector has long been the aim of both public and private wheat breeders. Annually, new wheat varieties are developed and released to improve not only yields, but also pest resistance and grain quality. The Agricultural Research Council – Small Grain Institute (ARC-SGI) situated in Bethlehem in the Free State Province has been at the forefront of public varietal improvement research in the wheat industry and since 1970 has released 43 wheat varieties at an average of 1.2 cultivars per year. Prior to 1970, the ARC-SGI was a division of the Department of Agriculture and it was only in the 1970s that an institute was established. When considering the private sector, two dominant role-players can be identified: Sensako and Pannar. These two wheat breeders account for the largest market share held by private wheat breeders in the wheat cultivar market and have in recent years been dominant forces in wheat varietal improvement.

Establishing the economic impact of varietal improvement by public and private wheat breeders may assist in promoting ongoing investment in this form of R&D. A number of other indirect benefits exist as a result of the adoption of new wheat varieties. Dixon, Nalley, Kosina, La Rovere, Hellin and Aquino (2006) identified four main benefits of adopting improved wheat varieties. Firstly, improved wheat varieties impact on field-level yield and stability, and secondly, the intensification of food crops "often leads to the release of land, water and labour resources for on-farm diversification". Thirdly, the impact is felt at people-level due to higher and more stable yields resulting in improved household food security and higher household income. Fourthly, as a result of intensification and diversification, poverty is reduced, with an off-farm effect on the local economy. Dixon *et al*. (2006) also stated that South and East Asia witnessed a 225% increase in wheat yield levels from 1961-64 and 2000-04, while Sub-Saharan Africa saw a 117% increase over the same period. When considering yield growth in the South African wheat sector in general, it can be observed that commercial wheat yields have increased by nearly 300% since 1970 (Author's own calculations based on the Abstract of Agricultural Statistics released by the Directorate: Agricultural Statistics, 2009). Breaking this figure down into different decades, shows that yields increased most during the 1990s with an increase of 137% from 1990 to 2000. During the 1970s wheat yields increased by 27%, while from 1980 until 1990 yields increased by 19% and from 2000 yields increased by 11%.

Attributing the growth in wheat yields to different factors is difficult, as many factors have had a positive impact on South African wheat yield levels. The majority of growth in wheat yields on a commercial level throughout the 1970s and 1980s can mainly be attributed to better wheat production practices and improved farm management as farmers implemented moisture conservation in the dryland production areas and farmers in the irrigated areas moved away from flood irrigation to pivot irrigation. (These two factors had the greatest impact on commercial wheat yields in South Africa.) The 1990s were characterised by the deregulation of the South African agricultural sector and the abolishment of the Wheat Board in 1997. As a result, farmers had to be more efficient in production, because wheat prices were no longer fixed and supported. This had a positive impact on yield levels and, together with varietal improvement, accounts for the largest share of growth in yields in the 1990s. The 1990s also saw private wheat breeders becoming more competitive in varietal improvement and led to R&D in wheat varieties shifting from public wheat breeders to the private sector. As a result, all role-players, both public and private, had to ensure the development of wheat cultivars demanded by a free market environment. It is thus fair to say that due to a more competitive wheat-breeding market environment, role-players had to become more efficient and thus growth in wheat yields prior to 2000 can mainly be attributed to varietal improvement.

The growth in South African wheat yields from the 1970s can be seen in Figure 1.1 and it can be observed that both wheat and maize yields have followed an upward trend since the early 1970s. Note the change in rate-of-yield increases in the 1990s in both wheat and maize. Various factors contributed to the volatility of these yields. Some of these key factors are discussed in Chapter 2.

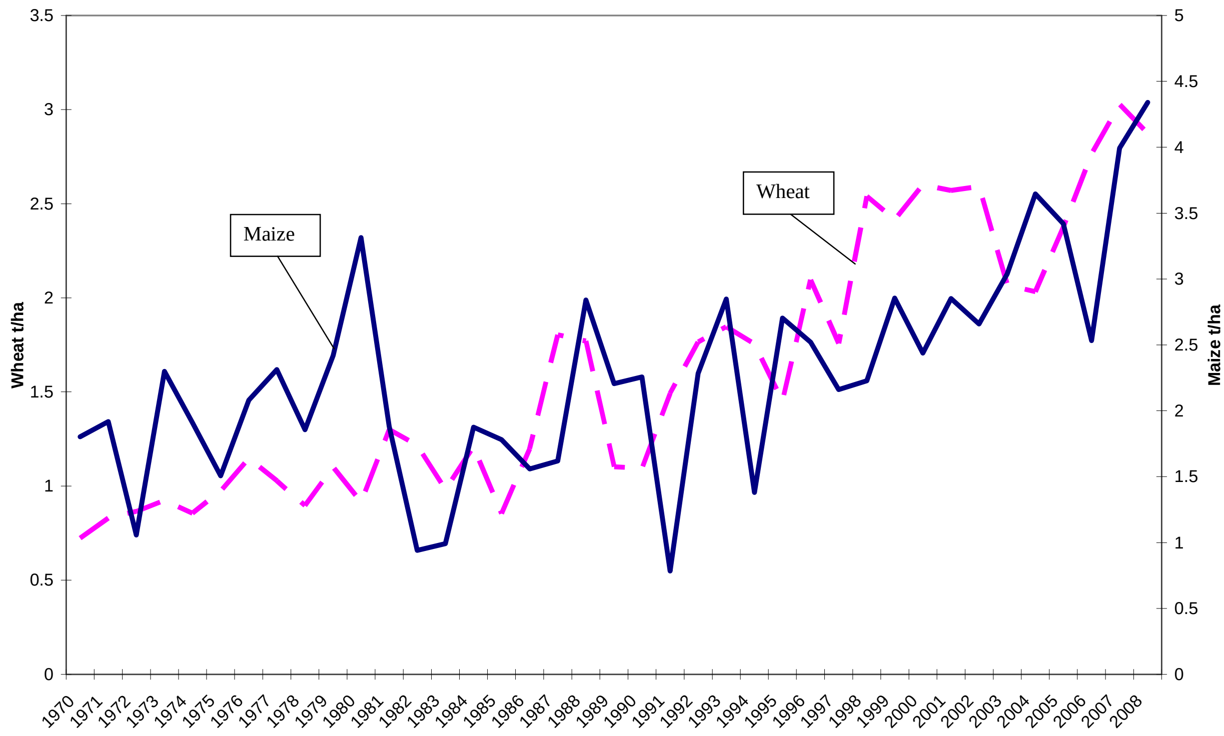


Figure 1.1: Average maize and wheat yields in South Africa (t/ha): 1970-2008

Source: Department of Agriculture, Fisheries and Forestry, Directorate: Agricultural Statistics (2011)

1.2 PROBLEM STATEMENT

In order to improve the accountability of research into agriculture and more specifically investment in varietal improvement research, more information on the economic benefits of varietal improvement research is needed. To date there has been no study calculating the contributions made by wheat varietal improvement research in South Africa, and thus the return of all the years of expenditure on varietal improvements is not known. Although benefits as a measure of yield increases in the wheat industry exist, no monetary value has yet been assigned to these increased yields. In any case, it can be argued that the estimate of the shift in yield levels does not accurately indicate the true contribution made by new varietal releases. Methodologies used to estimate shifts due to varietal improvements fail to capture the effects on a commercial level and at times undervalue the true shift. As a result no good measure of the effects of varietal improvement in the South African wheat industry exists.

The total stream of benefits from research investment by private and public wheat breeders must be calculated by using relevant methods and up-to-date data on yield levels, production and area planted to the different wheat cultivars released by private and public wheat breeders. To complicate matters further, to date there has been no study documenting the precise area cultivated to wheat cultivars in the different wheat-producing areas. As a result, some methodologies have relied on other variables besides area cultivated, which is the best measure of adoption rate by producers. In turn, some methodologies may not allow for the calculation of a shift in yield levels or production, but rather estimate a shift due to wheat varietal improvement research.

The actual shift in yield levels due to varietal improvement needs to be calculated on an industry level, and all cultivars released by both private and public wheat breeders must be included. In turn, the area planted to all of the varieties cultivated in South Africa since 1980 must be estimated in order to capture the true benefits of the adoption of new wheat varieties in the South African wheat industry. Benefits must be attributed to private and public wheat breeders and weighed against the costs of varietal improvement research in order to calculate the net returns of research.

1.3 RESEARCH OBJECTIVES

1.3.1 General Research Objectives

The general objective of this dissertation is to determine the benefits associated with varietal improvement research in the South African wheat industry attributable to both private and public research wheat breeders. Different cultivar production data for the various production areas are analysed to calculate the benefits associated with new varietal releases for selected wheat breeders.

1.3.2 Specific Research Objectives

The specific objectives of this study are:

- To determine the changes in South African wheat yields attributable to improved varieties released by private and public agencies;
- To attribute the benefits of varietal improvement to the different wheat breeders due to increased yields brought about by new wheat varietal releases;
- To determine the benefits associated with varietal improvement research from the perspective of the ARC-SGI;
- To identify the role of public research wheat breeders such as ARC-SGI in varietal improvement research;
- To assist in improving the accountability of investment in varietal improvement research and agricultural R&D in general; and
- To analyse the effects and make recommendations to contribute towards better private and public varietal improvement initiatives.

1.4 JUSTIFICATION OF THE PROPOSED STUDY

This study aims to contribute the following: Firstly, this study is the first *ex post* study quantifying the benefits of varietal improvement research in the South African wheat sector including both the private and public sectors. Secondly, the study emphasises the contribution made by the ARC-SGI to varietal improvement research. Lastly, the study lays a foundation for further research with regard to the estimation of the economic benefits of varietal improvement research and the benefits derived from agricultural R&D in South Africa.

1.5 DELINEATIONS AND ASSUMPTIONS

The study focused on the growth of wheat yields in the South African wheat industry brought about by all of the varietal improvement initiatives. Breeding for all attributes, such as increased yield, quality improvement and pest resistance, was included. Wheat production data was obtained for all the major wheat-producing regions and then analysed at provincial level. Experimental trial data for all the different wheat cultivars was aggregated to provincial level. All the cultivars developed by the ARC-SGI over the past thirty years were identified and the benefits associated with these specific cultivars were established. Different counterfactual scenarios were identified to account for possible contributions made towards yield growth by other sources besides varietal improvement research.

1.6 METHODOLOGY USED IN THE DISSERTATION

The aim of the dissertation is explained in the section above, but special emphasis must be placed on the methods used in the chapters to follow. Various methodological approaches were considered before deciding on a specific approach.

It is important to distinguish between the aims of different methodological approaches to correctly answer crucial research questions. There are two questions that are of most importance in this study. Firstly: What are the benefits associated with varietal improvement research? And secondly: How can these benefits be calculated and attributed to different wheat breeders? By calculating a k-shift (See Alston, et al., 1998) using indexes of varietal improvements, research benefits were calculated. The k-shift calculates the growth in yield levels due to varietal improvement brought upon by research after accounting for other factors contributing to the growth in output over time. By multiplying this value with price and quantity data, total benefits brought about by cultivar development could be calculated. This is the major factor that influenced the choice of methodological approach, as many approaches assume or estimate a k-shift. By means of the approach followed in the dissertation, the actual k-shift brought upon by varietal improvements in the South African wheat industry could be calculated.

To be able to calculate the k-shift, experimental trial data and production data on all of the wheat varieties cultivated in South Africa was needed. Experimental trial data was obtained from the ARC-SGI. Production data on the various cultivars was obtained from the 1980-1997 winter grain statistics reports of the Wheat Board (1997) and from 1998-2008 wheat crop quality season reports of the South African Grain Laboratory (SAGL, 2009). Experimental trial data forms an important part in the analysis, as experimental yields can be the only reliable source of yield levels and yield growth.

1.7 OVERVIEW OF THE DISSERTATION

The dissertation consists of a total of seven chapters. Chapter 2 considers the economic context of wheat production in South Africa and provides an overview of the South African wheat industry with regard to production and yield trends. A short description of the major policies and government intervention in the South African wheat industry is also provided. The purpose of this chapter is to emphasise the economic importance of wheat production in South African agriculture. The role that government has played over the past few decades will also assist in understanding the shift in production trends in the wheat industry.

Chapter 3 provides a timeline of varietal improvement in South Africa and takes a historical look at the different wheat varieties developed by public wheat breeders and later the ARC-SGI. The role that both public and private wheat breeders have played over the past few decades is also analysed. The different wheat varieties released by public wheat breeders is discussed and a complete list of all of the wheat varieties released over the last 30-40 years is provided.

The estimation of the area planted to the different wheat varieties released by both public and private wheat breeders is described in Chapter 4 and the results obtained from the estimation are reported. Market shares and trends with regard to the different wheat cultivars, private and public, are also included.

Chapter 5 discusses the relevant methodologies followed in calculating the benefits of varietal improvement research in the South African wheat industry and more specifically for the ARC-

SGI. Mention is made of other relevant methodologies that were considered for the analysis. All of the estimations and assumptions made are also described. The aim is thus to provide a detailed discussion of the estimation of benefits and the variables used in the calculation.

Chapter 6 reports the actual results obtained from the analysis, and the methods described in Chapter 5 are implemented here. The results from the analysis are analysed and the benefits of varietal improvement research for the ARC-SGI and public wheat breeders are calculated. The k-shift due to varietal improvement is estimated and a monetary value is given to this shift to illustrate the importance of varietal improvement research in the South African wheat industry.

Chapter 7 consists of conclusions and relevant recommendations with regard to varietal improvement research for both private and public wheat breeders. These recommendations assist not only in priority setting with regard to agricultural R&D, but also in the promotion of this form of investment. The aim is to make recommendations with regard to the current performance of private and public wheat breeders in order to improve varietal improvement initiatives and market share.

CHAPTER 2

SOUTH AFRICAN WHEAT PRODUCTION IN CONTEXT

2.1 INTRODUCTION

Wheat production in South Africa continues to play an important role in the agricultural sector despite the fact that the area planted to this important grain crop has followed a downward trend since the mid 1990s. In 2008 wheat production was the tenth highest contributor to value added in agriculture and covered 20% of the area planted to field crops. Until 2002 South Africa was the biggest producer of wheat on the African continent, a position currently held by Ethiopia (FAO, 2009). Despite the fact that the production of wheat has followed a downward trend, it can be noted from Figure 2.6 that commercial wheat yields have followed an upward trend and more so from the mid 1990s. From a South African perspective, the wheat industry can be described as a dynamic part of the South African agricultural sector, and various shifts – in both production and area of production – have been recorded over the past few decades. Due to the fact that improved wheat varieties are developed for different production and ecological areas, production shifts have had an impact on varietal releases and especially adoption rates of cultivars in the different production areas.

In order to create a proper context for the study, this chapter provides an economic overview of the wheat industry in South Africa. Wheat production, yield trends and area cultivated are the main focus, and emphasis is placed on the provincial distribution of wheat production. A summary is given of the geographical location of these production areas to distinguish between the summer and winter production areas. Production shifts recorded over the past few decades are also described.

A brief overview of government intervention in the South African wheat industry is included to emphasise the dynamic nature of the wheat industry and to identify the impact that deregulation has had on this important industry.

2.2 POLICIES AND GOVERNMENT INTERVENTION IN THE SOUTH AFRICAN WHEAT SECTOR

The South African wheat sector has a long history of government intervention, which came to halt in 1997. This section aims to provide a very brief description of the most significant policy shifts that impacted on the wheat sector. Table 2.1 lists these policy shifts, followed by a brief description.

Table 2.1: Historical deregulation of the wheat-to-bread value chain

1935	Establishment of the Wheat Industry Control Board
1937	Implementation of a single-channel fixed price system
1939	Introduction of a bread subsidy
1991	Termination of the bread subsidy together with the control on the price of both bread and flour
1995	Introduction of tariffs to replace quantitative import control
1996	Abolishment of the Wheat Board

Source: NAMC in Meyer (2002:22)

At the beginning of the 20th century the Union of South Africa was established, leading to the focus being put on wheat production in order to supply cheap food for a developing South Africa (Meyer, 2002:22). At the time, according to Meyer (2002:22), South African producers were only producing half of the wheat required to satisfy demand in South Africa, and measures thus had to be put in place to increase production. The Wheat Industry Control Board was established in 1935 to control the flow of wheat. It was in 1937, according to Meyer (2002:23), that the sole right to sell wheat was granted to the Wheat Board by means of the Wheat Control Scheme. A Wheat Control Scheme meant that South African producers would receive a fixed price determined by the Wheat Board before the planting season commenced. This price was paid to the farmers at delivery to the co-operative, regardless of where the delivery was made (Vink & Kirsten, 2000:3). Being in a controlled market, world prices were not taken into consideration when determining the wheat price. It was only after 1991 that the Wheat Board took the world wheat price into consideration in determining the South African wheat price (Meyer, 2002:23).

In 1997 the Wheat Board was abolished, which meant that South African producers were exposed to international markets where prices are determined by market forces. Due to uncertainty in the market, a major decrease in the area planted to wheat in South Africa was recorded in 1998 (Figure 2.6). Ever since the early 1990s, domestic supply seldom satisfies domestic demand, forcing South Africa to import. As a result, the wheat price tends to hover around import parity price levels.

Considering the discussion above from a varietal improvement perspective raises the following questions: “What impact did a controlled market environment have on efficiency?” and “What were the effects of the movement away from this controlled market environment?” Vink and Kirsten (2000) gathered information that supported the argument that deregulation, in balance, has in fact led to a net welfare gain to commercial agriculture. With respect to a comparison between the periods 1990-1994 and 1994-1998, their conclusions might have confirmed this argument and recorded positive growth in foreign investment, growth in new company registrations in the agricultural sector, lower food price inflation, and an increase in the general level of investment in agriculture. Can the dramatic growth in wheat yields in the mid 1990s be attributed to deregulation? One possible scenario is that due to a more competitive environment with no predetermined prices, producers had to utilise their best possible land for wheat production, impacting positively on commercial wheat yields.

After deregulation, a decrease in the area planted to wheat in South Africa was recorded. Despite this, production has remained relatively stable due to the positive growth in wheat yield levels. The following section provides an overview of wheat production in general and the major trends associated with this sector.

2.3 MAJOR TRENDS IN WHEAT PRODUCTION IN SOUTH AFRICA

2.3.1 Overview and Area Distribution

Wheat stands firmly as one of the most important grain crops in the world and the second most important grain crop in South Africa after maize. Since the abolishment of the Wheat Board in 1997, producers have become more exposed to international markets, leaving prices to be determined by market forces (NAMC, 2003:158).

The wheat industry in South Africa consist of two major parts, namely the primary industry consisting of 5 000 - 6 000 commercial wheat producers, and the secondary industry consisting of the milling and baking industries (NAMC, 2003:159). The major areas of wheat production include the Western Cape, Free State, Northern Cape and North West provinces. These areas are located in winter and summer wheat production areas and wheat is produced both on dryland and under irrigation.

The production of wheat in South Africa is mainly for human consumption, with only a small percentage of poorer quality wheat being marketed as stock feed (NAMC, 2003:158). Table 2.2 indicates the provincial share in wheat production share bearing in mind that wheat is produced in both winter and summer rainfall areas. It can be noted that production is broken down into the nine provinces of South Africa for the period prior to 1994 based on the locality of the major production regions. These provinces formed part of the previous four provinces known as the “Cape”, “Transvaal”, “Free State” and “Natal” provinces. The Western Cape area, located in a winter rainfall area, used to be the primary location for the production of wheat. From the 1970s, production of wheat shifted more to the Free State Province (summer rainfall area) and other irrigated areas (FPMC, 2003:158). From the table below it can be noted that in 2008 production shifted back to the Western Cape, making it the province with the largest area planted to wheat in South Africa. Later in the chapter these shifts in production are put into context and other changes are described.

Table 2.2: Percentage area planted to wheat by province

Production Year	Province									
	Western Cape	Northern Cape	Free State	Eastern Cape	Kwazulu-Natal	Mpuma-langa	Limpopo	Gauteng	North West	Total Hectares
1980	28.77%	3.89%	49.76%	5.63%	0.16%	1.79%	5.68%	0.21%	4.10%	1 623 000
1981	33.46%	3.20%	43.31%	6.84%	0.12%	2.83%	5.18%	0.12%	4.93%	1 787 000
1982	29.83%	5.15%	45.44%	6.60%	0.11%	2.74%	6.27%	0.17%	3.69%	1 974 000
1983	28.01%	4.86%	48.02%	6.23%	0.10%	2.53%	5.67%	0.15%	4.41%	1 809 000
1984	31.51%	4.59%	45.77%	6.69%	0.11%	2.21%	5.69%	0.28%	3.15%	1 922 850
1985	33.49%	2.39%	47.79%	4.99%	0.30%	2.76%	5.88%	0.36%	2.03%	1 957 675
1986	34.58%	2.71%	44.64%	5.77%	0.44%	1.84%	5.93%	0.46%	3.63%	1 936 000
1987	35.49%	2.63%	42.77%	7.44%	0.62%	1.29%	5.11%	0.46%	4.18%	1 729 000
1988	38.17%	2.66%	49.86%	2.08%	0.75%	1.68%	0.46%	0.98%	3.35%	1 985 000
1989	32.90%	2.37%	56.37%	1.81%	0.65%	1.51%	0.60%	0.86%	2.92%	1 830 000
1990	27.98%	2.57%	60.82%	1.97%	0.71%	1.37%	0.55%	0.87%	3.17%	1 550 632
1991	21.58%	3.42%	66.47%	0.38%	0.41%	1.35%	0.23%	0.19%	5.98%	1 433 966
1992	22.84%	3.75%	66.00%	0.49%	0.38%	1.19%	0.23%	0.15%	4.97%	747 300
1993	44.82%	7.36%	40.32%	0.80%	0.61%	0.97%	0.27%	0.31%	4.54%	1 064 798
1994	39.26%	4.93%	49.71%	1.43%	0.40%	0.73%	0.97%	0.21%	2.36%	1 039 491
1995	38.27%	5.32%	49.59%	1.55%	0.35%	1.16%	1.04%	0.28%	2.45%	1 363 150
1996	29.40%	4.11%	60.08%	1.21%	0.26%	0.77%	0.84%	0.21%	3.13%	1 293 800
1997	31.15%	5.26%	54.26%	1.31%	0.39%	1.31%	1.55%	0.14%	4.64%	1 382 300
1998	28.94%	4.70%	57.15%	0.94%	0.42%	1.59%	1.23%	0.22%	4.81%	745 000
1999	40.27%	4.70%	44.30%	0.67%	0.67%	1.21%	1.21%	0.27%	6.71%	718 000
2000	43.18%	5.99%	41.78%	0.56%	0.84%	1.53%	1.11%	0.56%	4.46%	934 000
2001	36.99%	6.00%	47.43%	0.46%	0.93%	2.14%	1.61%	0.54%	3.91%	973 500
2002	35.44%	4.57%	51.36%	0.30%	1.13%	2.57%	1.54%	0.38%	2.71%	941 100
2003	38.68%	5.74%	46.75%	0.37%	0.91%	2.50%	1.81%	0.27%	2.98%	748 000
2004	43.45%	6.48%	42.78%	0.33%	0.94%	1.20%	1.07%	0.27%	3.48%	830 000
2005	42.65%	6.16%	42.48%	0.48%	0.80%	1.89%	1.87%	0.30%	3.37%	805 000
2006	37.52%	6.02%	47.20%	0.50%	1.12%	2.24%	1.37%	0.31%	3.73%	764 800
2007	38.18%	5.23%	47.07%	0.37%	0.92%	1.96%	2.35%	0.26%	3.66%	632 000
2008	51.42%	6.65%	34.02%	0.60%	0.95%	0.79%	1.74%	0.27%	3.56%	748 000

Source: NCEC (2009)

Historically, South Africa has been a net importer of wheat, with only a few good production years resulting in a net surplus being produced. Although the total area of production has decreased, yields have increased. A major decrease in area planted was recorded from the 1997/98 season to the 1998/99 season. This can mainly be attributed to uncertainty in the market due to the abolishment of the Wheat Board in 1997 coinciding with a record harvest in the United States of America (Meyer, 2002:14). The South African wheat industry’s first year under free trade resulted in downward pressure on wheat prices (Meyer, 2002:14) leading to a decrease in wheat production in this specific season.

Winter rainfall area

The two production areas in Figure 2.1 are located in the Western Cape Province, which is presently the top wheat-producing area in South Africa. These two areas are not the only areas of wheat production in the Western Cape, with some wheat being produced in the central areas of the province. Wheat production in the Swartland and Rûens area are under dryland conditions and thus depends on sufficient rainfall for a good harvest.

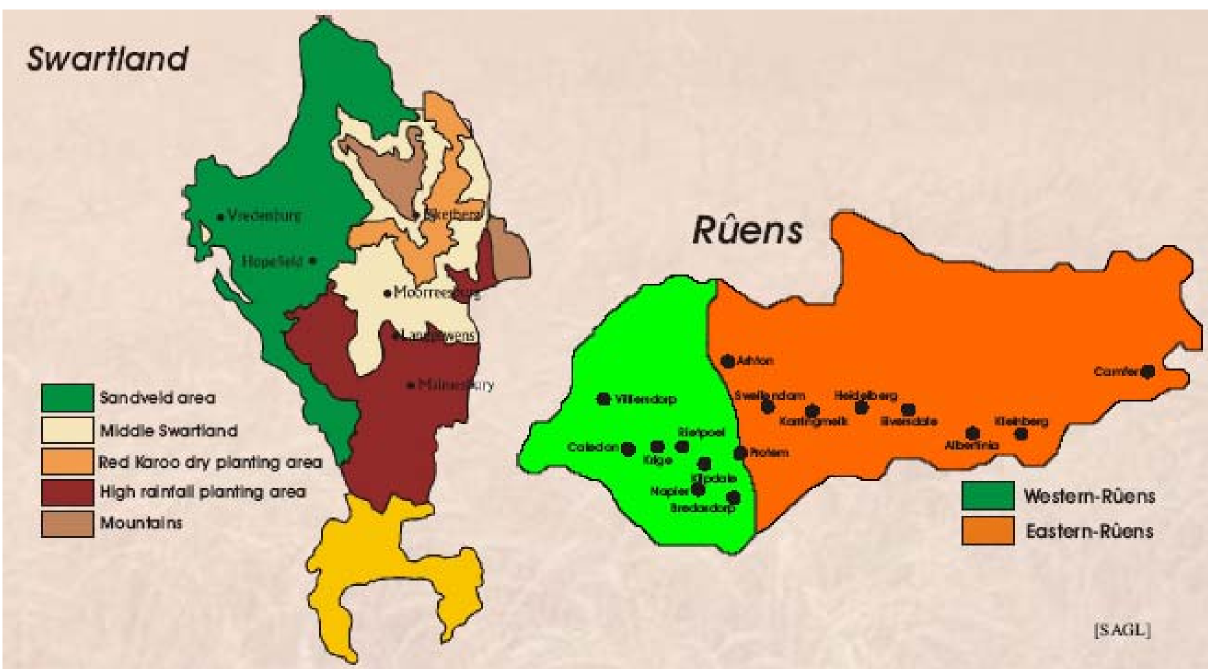


Figure 2.1: Winter wheat production area

Source: SAGL (2009)

Summer rainfall area

There are both dryland production and irrigation areas in the central and northern parts of the country that fall in a summer rainfall area. The Free State Province is the largest area of wheat production under dryland conditions in the summer rainfall area, with production in the Gauteng, Mpumalanga, North West and Limpopo provinces being mostly under irrigation. These areas can be seen in Figure 2.2 and Figure 2.3 respectively. The majority of wheat is, however, produced under dryland conditions.

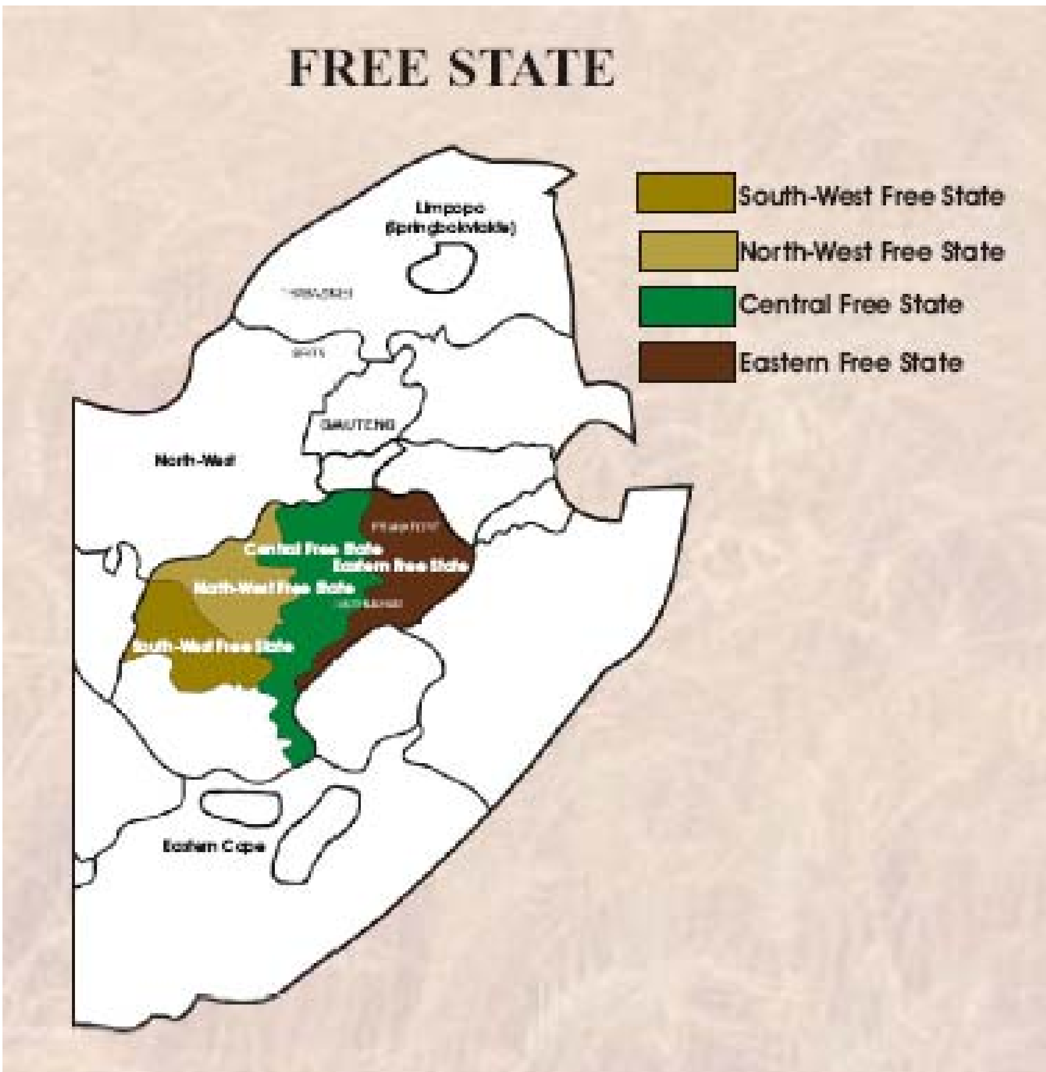


Figure 2.2: Free State – Summer production area

Source: SAGL (2009)

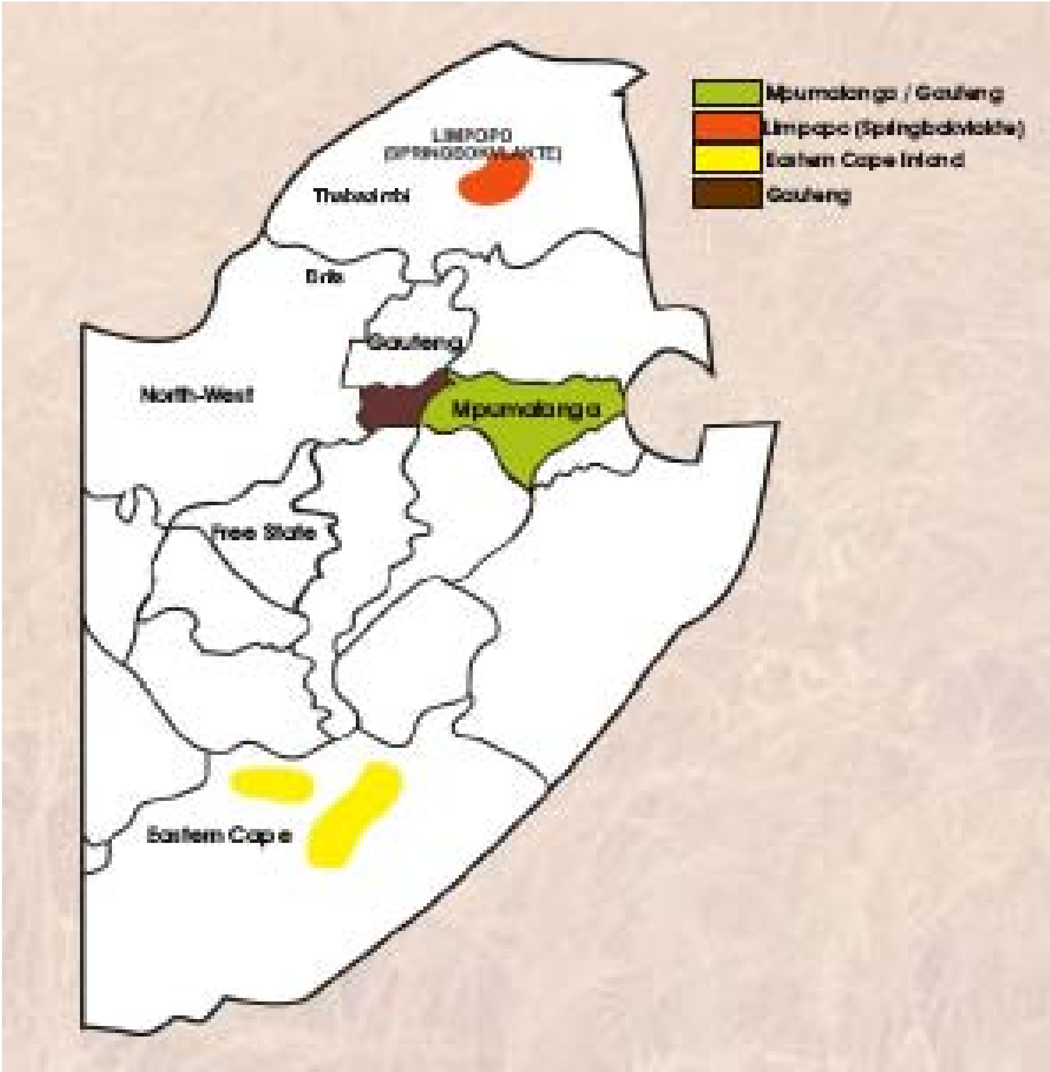


Figure 2.3: Other summer production areas

Source: SAGL (2009)

Various irrigation schemes are located across South Africa and can be seen in Figure 2.4. Wheat production under irrigation can be high yielding, with yields reaching up to ten tons per hectare (ARC-SGI, 2009). Adequate water supply is limited, however, and restricts producers from moving away from dryland production to an irrigation production system.

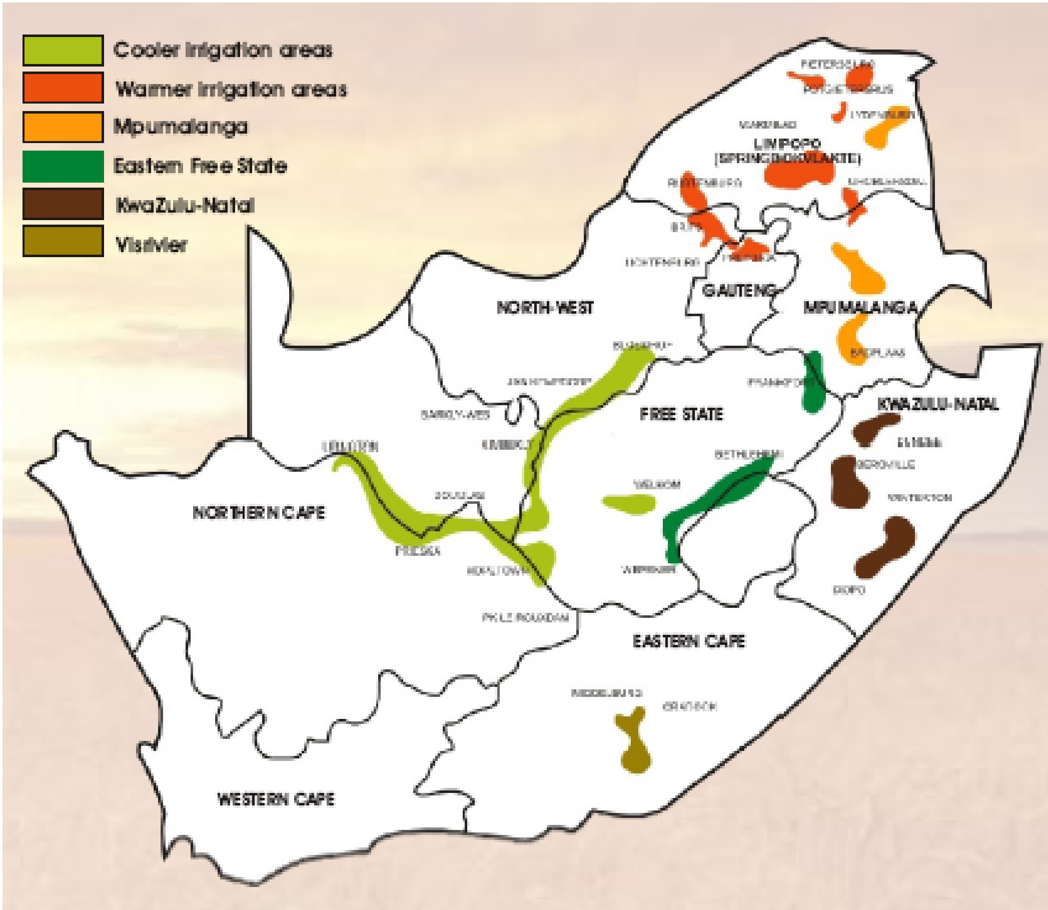


Figure 2.4: Irrigation areas in the South African wheat industry

Source: SAGL (2009)

2.3.2 Production: Shifts and Trend Analysis

South Africa consists of 36 crop production regions with wheat being produced in 32 of these regions (SAGL, 2009). These areas are also used in the analysis in the chapters to follow. The Western Cape, consisting of six of these crop production regions, accounted for the largest share of wheat production in 2008 with a total of 350 000 hectares planted and 840 000 tons of wheat produced at an average of 2.4 t/ha. This was followed by the Free State with 280 000 hectares planted and 560 000 tons of wheat produced at an average of 2 t/ha.

As mentioned previously, in the 1970s wheat production shifted from the Western Cape to the Free State and various irrigation schemes throughout South Africa, causing the Western Cape to lose its status as the primary wheat-producing area in South Africa. This has had a huge impact on the release of various cultivars due to ecological differences between the Western Cape, the Free State and other irrigation areas. Figure 2.5 indicates the shifts in production that have occurred in the South African wheat industry on a provincial level. The shift in the 1970s mentioned above is evident where the shares in production of the different provinces for 1980 are illustrated. The majority of wheat produced in this year was in the Free State and not in the Western Cape. It can also be observed that a further shift occurred and less wheat was produced in the Western Cape and the Free State's share of production increased in the 1990's. Interestingly the Western Cape is currently the province with the largest share of wheat production and accounts for 47% of wheat produced in South Africa. It is evident that wheat production has shifted back to the Western Cape area, with the Free State shifting back to its market share of the 1980s.

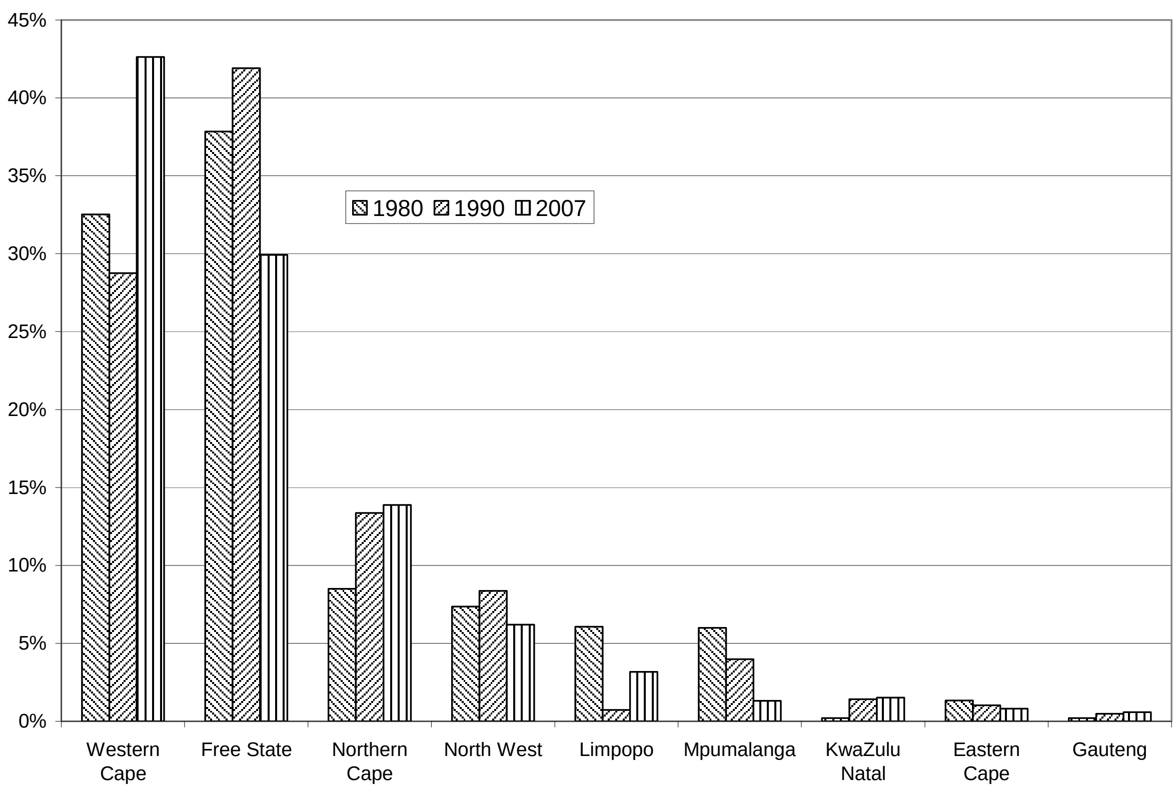


Figure 2.5: Provincial distribution of wheat production in South Africa: 1980, 1990 and 2007

Source: NCEC (2009)

2.3.3 Yield Trends in Wheat Production

South African wheat yields have followed an upward trend since the late 1980s, as is noted in Figure 2.6. This is true for a large number of crops in many countries (Pardey & Wright 2002 in Pardey, Alston, Chan-Kang, Magalhães & Vosti, 2004:1) with R&D accounting for a large share of the benefits (Alston *et al.* 2000 in Pardey *et al.* 2004:1). The rate of wheat yield growth is also significantly different prior to South African agriculture's process of deregulation. This might have impacted positively on efficiency as mentioned in Section 2.2 and promoted the flow of better genetic material from other research stations abroad into South Africa, thus accelerating yield growth. Figure 2.6 indicates the decrease in area planted to wheat and at the same time the increase in yields resulting in fairly constant wheat production in South Africa for the period 1980-2008.

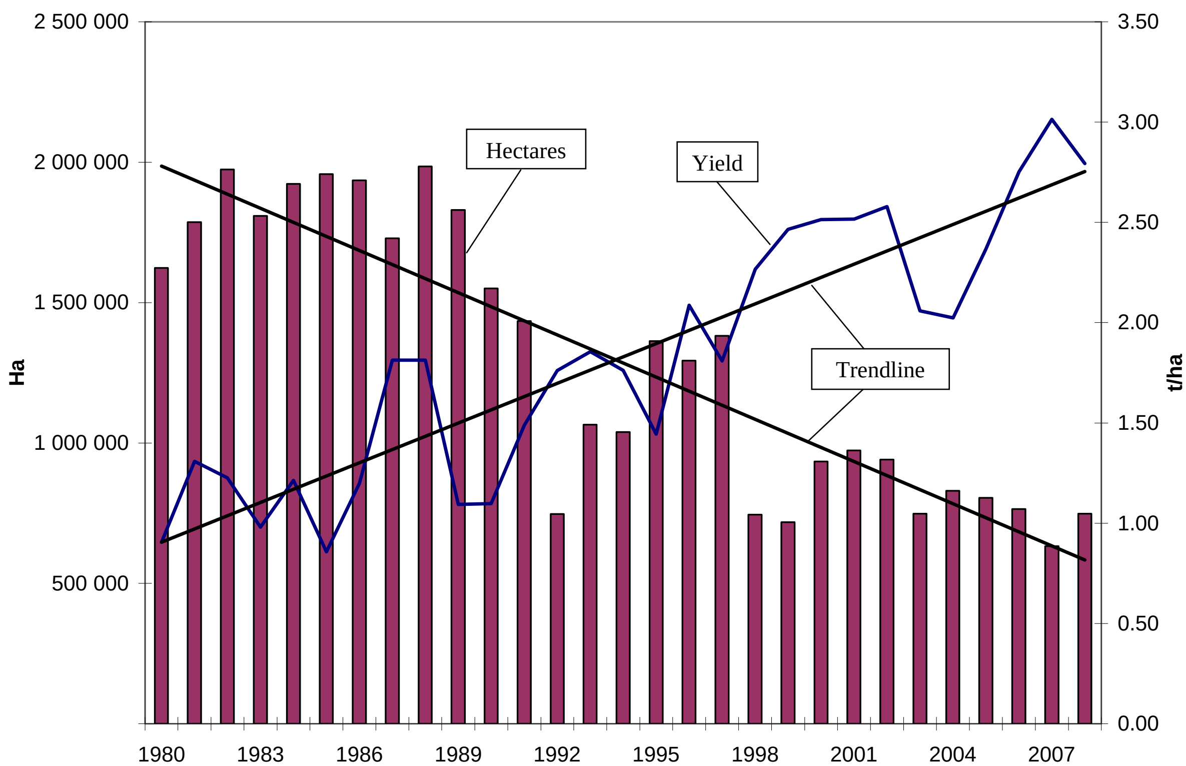


Figure 2.6: South African wheat yields vs. area harvested: 1980-2008

Source: NCEC (2009)

2.3.4 Wheat Consumption in South Africa

Figure 2.7 illustrates the production and consumption of wheat in South Africa, and it can be observed that since 1989 production has seldom satisfied domestic demand, forcing South Africa to import and thus confirming the net import status of South Africa's wheat industry.

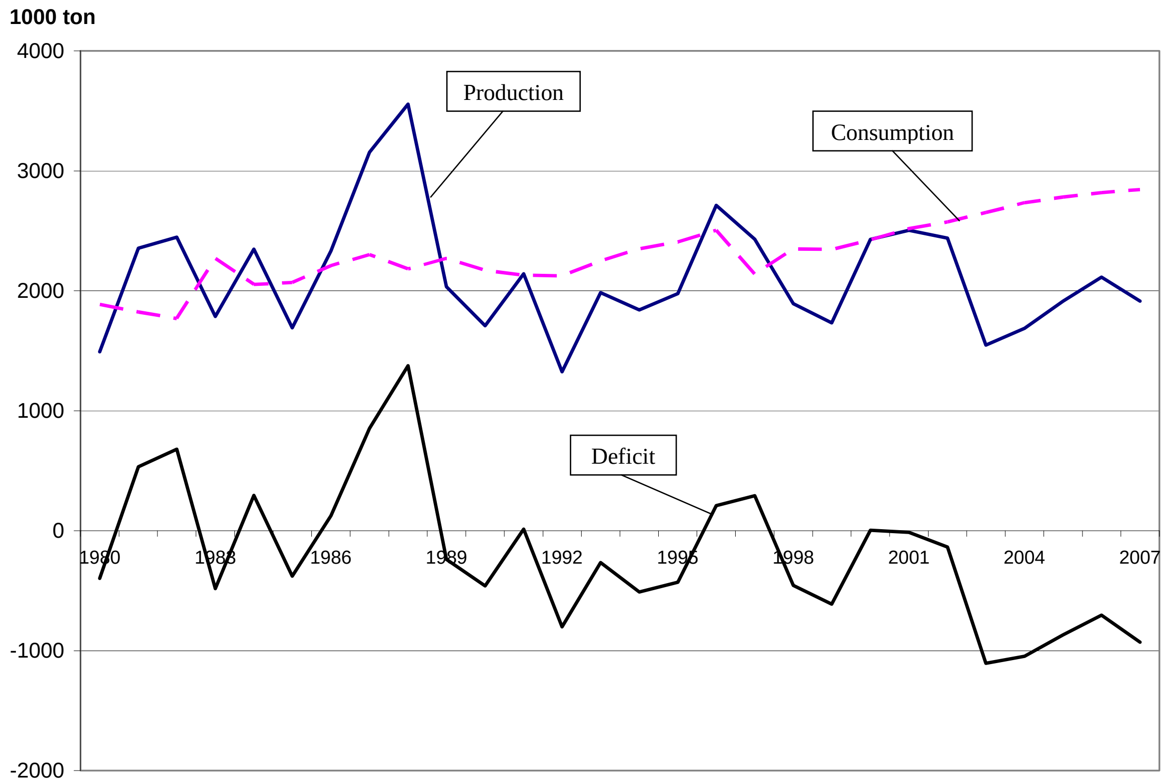


Figure 2.7: Production vs. consumption of wheat in South Africa

Source: Directorate: Agricultural Statistics (2009)

From Figure 2.7 it can also be noted that the deficit between the production and consumption of wheat has increased sharply since 2001. As a result, more wheat has to be imported to satisfy domestic demand. It can be anticipated that wheat consumption will increase in future as a result of population growth and increased demand for bread as a staple food in South Africa. Measures must thus be put in place to promote wheat production and ensure that domestic supply meets domestic demand.

2.4 SUMMARY

Chapter 2 provided evidence of the importance of the wheat industry and the role that it plays in South African agriculture. The historical analysis of both production and yield trends indicates that the wheat industry has long been a dynamic part of South African agriculture. The provincial distribution of production indicates the diversity in locations in which wheat can be produced. Despite this, South Africa has seldom produced enough wheat to satisfy domestic demand.

The first part of Chapter 2 provides an overview of the major policy shifts in the wheat sector and describes the role that government has played in the wheat sector. The South African wheat sector has a long history of government intervention, which came to halt in 1997 after the abolishment of the Wheat Board. The various policies that were introduced have had a major impact on production. Some may argue that the movement away from a regulated market to a relatively free market has impacted positively on the efficiency of producers and has led to increased availability of better genetic material from international research wheat breeders.

The next chapter provides some background to varietal improvement research in South Africa and identifies the three major wheat breeders in the wheat-breeding industry. All the cultivars released by the ARC-SGI are also identified and listed, and expenditure on small grain research is discussed.

CHAPTER 3

VARIETAL IMPROVEMENT RESEARCH IN THE SOUTH AFRICAN WHEAT INDUSTRY

3.1 INTRODUCTION

Cultivar improvement research in South Africa dates back to 1912 when the first interspecies crosses were made to introduce rust-resistant genes into wheat (Pakendorf in Pretorius, Pakendorf, Marais, Prins & Komen, 2007:593). Since then, varietal improvement research has received immense attention and new varieties are constantly being developed by public and private wheat breeders. The focus of varietal improvement research has also shifted dramatically from the early days, moving away from only gains in yields and towards the breeding of disease resistance in the wheat plant and grain quality improvements. Historically, most of the new improved varieties released originated from public wheat breeders, with private wheat breeders only becoming more prominent in the 1970s.

Besides varietal improvements, management and chemical procedures are also put in place to assist in combating diseases that affect wheat and to assist in research with regard to improved wheat varieties. Varietal improvement research is, however, the most effective measure against wheat diseases considering the cost of pest management practices in wheat production and the possible gains due to the adoption of a new wheat variety. This has also been the case over the past four decades, with various wheat breeders releasing new cultivars annually. These cultivars have been developed not only to assist with pest management, but also to improve yields and the quality of the wheat produced.

Chapter 3 consists of three major parts: Firstly, an overview with regard to varietal improvement is provided and all varieties released by the ARC-SGI are listed. The role of the ARC-SGI with regard to varietal releases is reviewed and other leading wheat breeders are identified. Secondly, contributions made by varietal improvements on a national level are discussed. This section also describes the role of the institute and the efforts needed to develop and release a new variety.

Thirdly, government expenditure on R&D in agriculture and specifically with regard to research in small grains is discussed.

3.2 BRIEF HISTORY OF VARIETAL IMPROVEMENT RESEARCH IN SOUTH AFRICA

The cultivation of wheat dates back to 1652 when the first Dutch settlers cultivated crops for passing ships and the population in the Cape (Du Plessis in Pretorius *et al*, 2007:593). Cultivar improvements have since then played a part in the wheat sector as a means to combat disease and for overall crop improvement. Both private and public wheat breeders are constantly busy developing new wheat varieties. In the private sector, Sensako and Pannar are the most prominent wheat breeders in terms of market share in the varietal improvement of wheat. These firms have research stations across South Africa and produce cultivars for various ecological areas. In later chapters, the market share of each of the three largest wheat breeders is calculated in order to assess and discuss the current market situation.

As mentioned earlier, the ARC-SGI is the primary focus of the dissertation. As a public research institute, the ARC-SGI has always been prominent in terms of cultivar releases in the wheat sector. The first major cultivar release by the ARC-SGI, know at the time as the Small Grain Centre, occurred in 1970 with the release of the cultivars “Barta”, “Belinda” and “Betta”. The ARC-SGI has since then released a total of 43 cultivars. The most cultivar releases occurred in the 1970s with a total of 15 cultivars being released during that decade. From the figures in Section 4.5 (Chapter 4) it can be noted that the cultivar “Betta” was planted for many years in the Free State and has been one of the ARC-SCI’s most successful dryland cultivars.

For the analysis in later chapters, selected cultivars released prior to 1970 by the public wheat breeders (Department of Agricultural Technical Services) were also included due to the fact that many cultivars developed in the 1960s and 1970s were still being planted as late as the 1990s. These cultivars were included in the calculation of the benefits and the estimation of the market shares for the ARC-SGI, as they had been developed by a public institution.

Table 3.1 lists all the cultivars released by the ARC-SGI, as well as their production and preferred ecological areas.

Table 3.1: Cultivars developed by the ARC-SGI and other public wheat breeders

No.	Cultivar	Year of Release	Main Area of Production	Ecological Area
1	SCHEEPERS	N/A	Free State	Dryland, summer rainfall area
2	SCHEEPERS 69	N/A	Free State	Dryland, summer rainfall area
3	T4	1964	Transvaal & Cape Province	Summer & winter irrigation
4	INIA	1969	Transvaal & Cape Province	Summer & winter irrigation
5	BARTA	1970	Free State	Dryland, summer rainfall area
6	BELINDA	1970	Free State	Dryland, summer rainfall area
7	BETTA	1970	Free State	Dryland, summer rainfall area
8	BENITA	1974	Free State	Dryland, summer rainfall area
9	MEMNON	1974	N/A	N/A
10	SONDEREND	1974	Cape Province	Dryland, winter rainfall area
11	AERIE	1975	Cape Province	Dryland, winter rainfall area
12	ELIZE	1975	Free State and Transvaal	Dryland, summer rainfall area
13	HELENE	1975	Transvaal and Cape Province	Dryland, summer and winter rainfall area
14	ELRINA	1976	Cape Province	Dryland, winter rainfall area
15	LIESBEECK	1976	Cape Province	Dryland, winter rainfall area
16	DIPKA	1978	Free State and Cape Province	Dryland, summer and winter rainfall area
17	GOURITZ	1978	Cape Province	Dryland, winter rainfall area
18	FLAMINK	1979	Free State	Dryland, summer rainfall area
19	HELENE S13	1979	N/A	N/A
20	PALALA	1980	Transvaal	Dryland, summer rainfall area
21	WILGE	1980	Free State	Dryland, summer rainfall area
22	GAMTOOS	1983	Transvaal and Cape Province	Dryland, winter rainfall and irrigation area
23	KAREE	1983	Free State	Dryland, summer rainfall area
24	PALMIET	1983	Transvaal and Cape Provinces	Summer irrigation
25	MOLEN	1985	Free State	Dryland, summer rainfall area
26	TUGELA	1985	Transvaal and Cape Provinces	Summer irrigation
27	MARICO	1992	Transvaal and Cape Provinces	Summer irrigation
28	TUGELA-DN	1992	Free State and Transvaal	Dryland, summer rainfall area
29	KARIEGA	1993	Transvaal and Cape Provinces	Summer irrigation
30	BETTA-DN	1994	Free State and Transvaal	Dryland, summer rainfall area

No.	Cultivar	Year of Release	Main Area of Production	Ecological Area
31	HARTS	1994	N/A	N/A
32	LETABA	1994	N/A	N/A
33	MOLOPO	1994	N/A	N/A
34	GARIEP	1995	Free State	Dryland, summer rainfall area
35	LIMPOPO	1995	Free State and Transvaal	Dryland, summer rainfall area
36	CALEDON	1996	Free State	Dryland, summer rainfall area
37	ELANDS	1999	Free State	Dryland, summer rainfall area
38	STEENBRAS	1999	Transvaal and Cape Provinces	Summer irrigation
39	BAVIAANS	2001	Cape Province and Transvaal	Dryland, winter rainfall area and summer irrigation
40	KOMATI	2002	Free State	Dryland, summer rainfall area
41	OLFANTS	2002	Transvaal and Cape Provinces	Summer irrigation
42	TARKA	2002	N/A	N/A
43	BIEDOU	2003	N/A	N/A
44	DUZI	2006	Transvaal and Cape Provinces	Summer irrigation
45	KROKODIL	2006	Transvaal and Cape Provinces	Summer irrigation
46	MATLABAS	2006	Free State	Dryland, summer rainfall area
47	NOSSOB	2006	N/A	N/A

Source: ARC-SGI (2009)

The other public cultivars developed prior to 1970 and included in
Table 3.1 are “Scheepers”, “Scheepers 69”, “Inia” and “T4”. “Scheepers” and “Scheepers 69” are both dryland cultivars. “Scheepers 69” has been an important cultivar in South Africa and was cultivated by producers for more than 35 years, with some areas being planted to this dryland cultivar as late as 2000. “Inia” and “T4” were primarily produced under irrigation and were popular in all of the irrigated areas and some dryland areas.

In order to correctly analyse the wheat-breeding environment, it is important to understand how the South African public and private wheat breeders and the environment in which they operate have changed over the years. For many years, Sensako had the responsibility for the multiplication of seed developed by the public wheat breeders, specifically the ARC-SGI, which in those days was part of the Department of Agricultural Technical Services. Prior to 1970, Sensako reproduced all developed cultivars and supplied these to the various co-operatives in the different wheat-producing areas. The seed was supplied at a price subsidised by the then Wheat

Board Research Fund (Van der Merwe & Hatting, 2007:1). However, this policy came to an end with the abolishment of the Wheat Board, and the seed companies listed in Table 3.2 now have the licence to reproduce and market new wheat varieties developed by the ARC-SGI. Today, the ARC-SGI still does not market its own cultivars, but rather gives private wheat breeders the licence to do so.

Table 3.2: Wheat breeders responsible for the marketing of the ARC-SGI's wheat, barley and rye cultivars

Institution	Wheat	Barley	Rye
Advance Seed		Maluti	
Advanta Africa			Falcon
Agricol		Kompasberg**	Rex*
All-Gro	Inia, Kariega, Marico, Olifants, Steenbras		
Pannar	Baviaans, Caledon, Gariep	Drakensberg	Kiewiet*
Sensako (Monsanto)	Betta-Dn, Elands, Limpopo		
WPK Landbou		Kompasberg**, Tafelberg**	

Source: Van der Merwe et al. *(2007)*
Notes: *Plant breeder rights held collectively with the University of Stellenbosch
**Plant breeder rights held by Zylem (Pty) Ltd

Wheat breeders are protected by the Plant Breeders Act, 1976 (Act 15 of 1976), which states that any unauthorised reproduction and marketing of protected cultivars is against the law. Plant breeder's rights are only valid for twenty years (Van der Merwe & Hatting, 2007:2). Interestingly, the cultivar "Inia" has no plant breeder's rights attached, but can only be reproduced and marketed by All-gro.

The varieties listed in Table 3.2 are cultivars developed by the ARC-SGI that are currently marketed in the various production areas by the different private wheat breeders. The ARC-SGI is also responsible for seed multiplication of their own cultivars. Research stations in Bethlehem, Vaalharts, Rietrivier and the Western Cape enable the ARC-SGI to reproduce seed from their developed cultivars (Van der Merwe & Hatting, 2007:3). Currently the majority of the ARC-SGI's irrigated cultivars are distributed by a division of the Magaliesberg Grain Co-operative (MGK) known as All-gro, which has the sole right to market the majority of the ARC-SGI's irrigated cultivars. From the results reflected in Chapter 4, it can be noted that this initiative with All-gro has led to a steady increase in market share for the ARC-SGI in some of the irrigated areas. This is due to effective marketing in these areas, ensuring the adoption of new wheat cultivars by producers.

Figure 3.1 indicates wheat cultivar seed sales by agri-businesses and co-operatives for 2009. The cultivars “SST 027” with 17.95%, “SST 88” with 15.19%, and “SST 015” with 12.69% are the top three cultivars in terms of seed sales for 2009. These three cultivars, all developed by Sensako, account for 46% of seed sales across South Africa. The share of Sensako cultivars in the South African wheat seed market is estimated to be around 78.9% (SAGL, 2009). The ARC-SGI cultivars account for 18.5%, which is a 1.5% increase from the previous year. The ARC-SGI cultivars included are listed in the note to Figure 3.1. Note that it is the cultivar “Duzi”, developed in 2006, that accounts for the largest share of seed sales in 2009 for cultivars developed by the ARC-SGI.

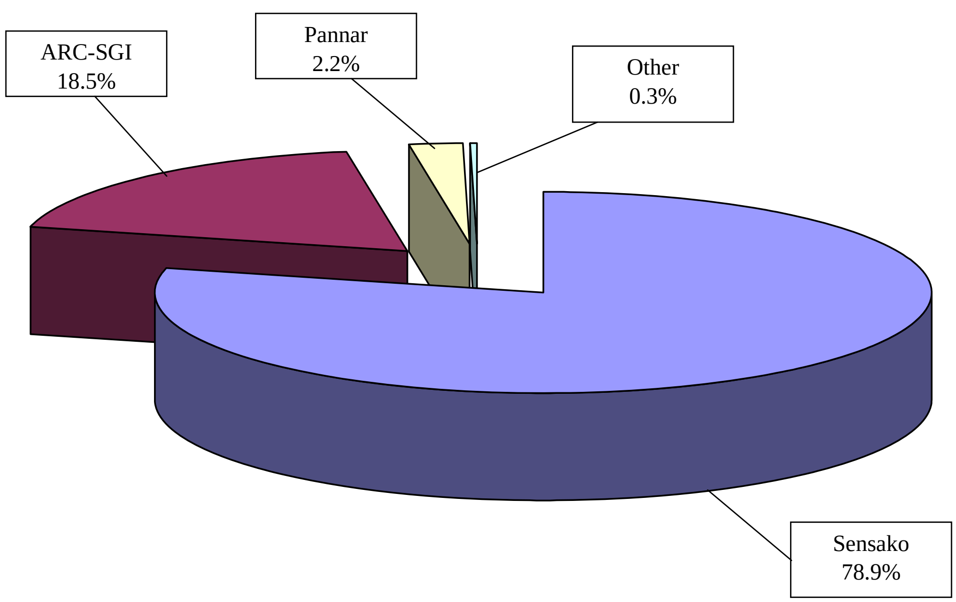


Figure 3.1: Percentage of seed sales by commercial grain silo owners: 2009

Source: SAGL (2009)
Notes: *ARC cultivars include Duzi: 6.10%, Elands: 2.98%, Komati: 2.59%, Krokodil: 1.85%, Kariega: 1.12%, Matlabas: 0.97%, Olifants: 0.76%, Gariep: 0.58%, Betta DN: 0.53%, Tugela: 0.46%, Steenbras: 0.28%, Baviaans: 0.22%, Inia: 0.04% and Marico: 0.004%

The "other" cultivars that make up the remaining 0.3% include cultivars developed by Afgri and smaller private wheat breeders. It is important to note that Figure 3.1 is based on seed sales and not area planted to the different varieties. As a result, these percentages are not an accurate estimation of market share, as producers retain seed to plant in the next production season. This issue is discussed further in the next chapter.

Sensako, the ARC-SGI and Pannar are identified as the three major role-players in the South African wheat-breeding industry, as reflected by the results discussed in Chapter 4. Pannar only entered the wheat-breeding market in the mid-1990s, with the Small Grain Centre (the predecessor to ARC-SGI) being present from the 1970s. Sensako was also established in the 1970s when farmers felt the need to establish their own wheat- and maize-breeding programmes. Different co-operatives in the central region of South Africa decided to collaborate and Sensako was established. In 1999 Monsanto bought the majority of Sensako and the remaining shares were purchased in 2000. The initial aim of Monsanto was to obtain a maize-breeding programme in South Africa and not a wheat-breeding programme. As a result, shortly after the purchase of Sensako, Monsanto sold the wheat-breeding division of Sensako to private individuals.

The organisations in the wheat-breeding industry identified above compete for market share in a highly competitive environment where the adoption of newly developed cultivars is heavily dependent on effective marketing in all of the production areas. In turn, a well-developed breeding programme must be in place to ensure that the best genetic material is used. These elements, which ensure that a role-player is competitive and an adequate market share is captured, rely heavily on expenditure on R&D. The next section provides some background information on investment in this form of agricultural R&D and more specifically government spending on R&D in small grains.

3.3 R&D SPENDING ON SMALL GRAINS IN SOUTH AFRICA

The focus of the dissertation is small grains, and thus the small grain industry's share of the total R&D basket is an important aspect. The figures that are reported in this section were obtained from the ARC and include total spending on R&D on small grains (Liebenberg, 2009). From Figure 3.2 it can be noted that spending on small grain research by government has followed an upward trend since 1980. Figure 3.2 indicates real vs. nominal prices of expenditure on small grain research. The GDP deflator, obtained from the South African Reserve Bank (SARB), was used to deflate the expenditure values.

A total of R385 million has been spent, in nominal terms, since 1980 (Liebenberg, 2009). The year 2006 recorded the highest spending on small grain research, with a total of R39 million being spent in nominal terms and R26 million being spent in real terms (Base year 2000). The upward trend in small grain R&D spending is encouraging, but some agencies in the wheat-breeding industry may feel that the amounts spent on small grain research are not satisfactory. As a result, research into the development of new technologies such as genetically modified (GM) wheat cultivars, for example, may not be feasible due to a lack of investment.

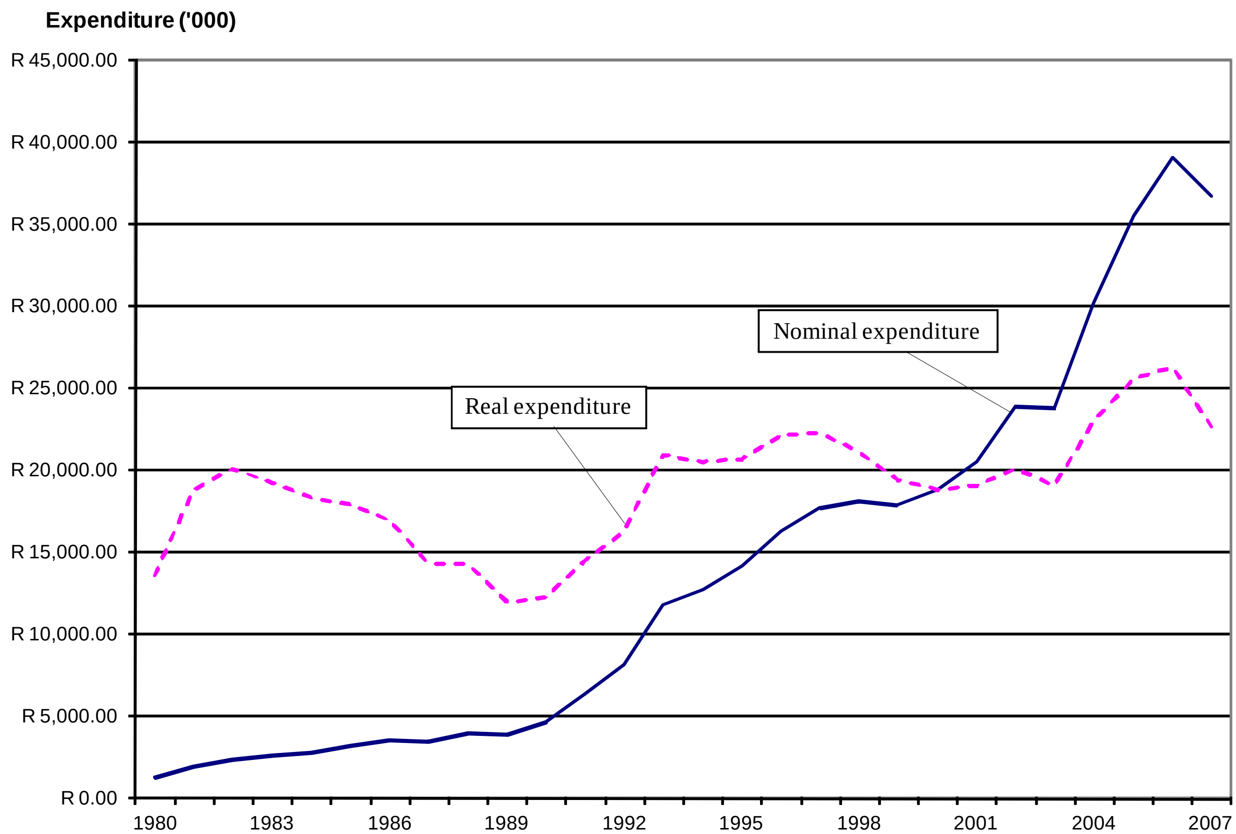


Figure 3.2: Public spending on small grain research in South Africa: 1980-2007

Source: Liebenberg (2009)
Note: Real expenditure is calculated by deflating nominal expenditure with the GDP deflator (Base year = 2000). Real expenditure is thus inflation adapted.

Generally, the trends in Figure 3.2 show signs of positive growth in public small grain research expenditure, but it is of great importance that spending continues to grow so as to ensure economic and technological growth in this important sector.

3.4 SUMMARY

The discussion in this Chapter illustrated that varietal improvement research in South Africa has a long history in South Africa and the contributions made, both private and public, have changed the wheat industry dramatically. The role that the different wheat breeders have played over the past few decades is captured in the literature studied, and the key changes recorded in these wheat breeders are highlighted.

The different market shares as indicated by commercial seed sales provided by the South Africa Grain Laboratory (SAGL) cannot be assumed as current market shares due to the fact that farmers retain seed for the following season's planting. For this reason, a true indication of market share and thus cultivar adoption can only be indicated by actual production per cultivar and hectares planted per cultivar. Chapter 4 provides a detailed discussion of cultivar adoption and calculates the market shares of the various wheat breeders based on the actual area planted to the different cultivars. Furthermore, Chapter 4 provides more insight into the methodological approach followed to estimate actual area planted per cultivar and consequently to estimate current market shares.

CHAPTER 4

ESTIMATING AREA PLANTED TO DIFFERENT WHEAT CULTIVARS

4.1 INTRODUCTION

In the context of this study and for a better understanding of the wheat cultivar breeding system, some important information is needed. Although this chapter is intended to broaden the context, it also forms an important and critical part of the methodological approach followed in the dissertation. As mentioned previously, experimental yield data was obtained from the ARC-SGI to assist in the estimation of yield growth and the benefits brought about by research. However, various calculations were necessary in determining the variables used in the analysis. This chapter therefore describes all the necessary calculations in the data analysis and the necessary steps in the estimation of the area planted to the different wheat varieties, as used in the calculation of the benefits.

Data on area planted to the different wheat cultivars is crucial, as it is the best measure of adoption by producers. Relying on seed sales by silo owners as a measure of estimation is helpful, but does not paint a true picture of wheat area plantings due to the fact that producers can retain seed to plant in the next season. One method that may assist in the estimation of the area planted is surveys. This is, however, a lengthy and expensive process and may lead to biased information being supplied by producers. Due to the difficulty of obtaining reliable information on wheat plantings and market shares, the Wheat Board, and later the SAGL, resorted to identifying cultivars from deliveries made by the producers to the various delivery points in all the production areas. Samples were taken and analysed to establish exactly which cultivars were most prominent in a given production area. This is the best estimate of the market share of a given cultivar in a given region, but does not solve the problem of identifying the area planted per cultivar per region, because this percentage of production in a given region cannot be directly converted to area planted. Thus a higher yielding cultivar will indicate a higher adoption rate than a lower yielding one, despite the fact that precisely the same area is planted to the respective cultivars. Using cultivar evaluation trial data the area planted to the different cultivars were estimated and in the process we estimated the market share of various wheat breeders as discussed below.

4.2 METHODOLOGY TO ESTIMATE AREA PLANTED PER CULTIVAR PER REGION

By combining the wheat production statistics per cultivar supplied by the Wheat Board and later the SAGL and the experimental yields of all of the cultivars planted commercially, an estimation of the area planted to the different varieties could be made. At first an average experimental yield for all of cultivars planted commercially was calculated across all the experimental trial sites of the ARC-SGI. These included both irrigation and dryland trials conducted in all the provinces. These trial results were then aggregated and the average experimental yield was calculated for the three main production areas (winter, dryland and irrigation areas) for the period 1980-2008.

Using the share of the cultivar in the production of wheat in a specific year the volume in tons was calculated for all of the cultivars planted within a region. This divided by the adjusted experimental yield gives an estimated area planted under the cultivar in the region. The average provincial experimental yield that was calculated is typically higher than commercial yields, and if used in the calculation would underestimate the actual area planted to a given cultivar. Hence, the average provincial experimental yield had to be adapted to account for the lower actual commercial yields. This factor was estimated as the ratio between the estimated hectares planted based on the average provincial experimental yield and the actual hectares planted in that region or province. This proportion indicates commercial yields as a percentage of experimental yields or the percentage by which commercial yields are lower than experimental yields.

The experimental index was calculated by multiplying the average provincial experimental yield of a cultivar by the proportion of area sown to that cultivar, thus weighting it with adoption. This method is discussed further in Chapter 5.

Table 4.1 presents the results for the dryland production area if the methodology as described in the paragraph above is applied to the 1987/88 data.

Table 4.1 thus serves as an indication of how the data points for all the years and all the provinces were estimated. Column 1 lists the different cultivars that were planted in the dryland production area according to the Wheat Board's winter grain statistics report for the period 1987/88, while column 2 indicates the given cultivar's share of production as a percentage of total production in the province. By using the known number for total wheat production for the province, the physical tons produced per cultivar could be estimated (column 3). Column 4 lists the weighted average provincial experimental yields for each of the cultivars as obtained from the experimental trial data. By dividing column 3 with column 4, an estimate was made as to the amount of hectares produced per cultivar, assuming that commercial yield is equal to experimental yield. This is rarely the case, however, and so to make provision for this, the experimental yield was adjusted by a factor to account for the lower commercial yield (column 6) as explained previously. The factor, 0.612174, can thus be interpreted as the percentage by which the commercial yield is lower than the experimental yield and is the ratio of the sum of the hectares in columns 5 and 6. Thus the commercial yield of the Free State in the 1987/88 production season was 61.22% of the experimental yield or 38.78% lower than the experimental yield for this period. It is important to note that these adjustment factors were estimated for every year and every province.

Table 4.1: Illustration of how the area planted per wheat cultivar was established

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Region: Free State				**Factor: 0.612174**	
Cultivar	**Percentage of total production**	**Production (tons)**	**Experimental yield (t/ha)**	**Hectares (Production / Exp yield**	**Hectares (Production / Exp yield*Factor)**
Betta	24.53	407079.8	3.388846	120123.42	196224.5
Karee	15.21	252467.8	3.455192	73069.09	119360.1
Molen	8.73	144826.5	3.300952	43874.15	71669.46
Scheepers 69	26.89	446222.1	2.800667	159327.09	260264.6
SST 107	13.09	217239.7	2.863509	75864.85	123927
Tugela	11.56	191797.2	3.459858	55434.99	90554.37
Sum	100.0	1 659 633		527693.59	862 000

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (2009)

Thus, column 6 shows the estimated area planted per cultivar for the 1987/88 production season in the dryland production areas. For example, it is estimated that 260 264 hectares were planted to “Scheepers 69”, 196 224 hectares to “Betta” and so on (column 6). These hectares planted to the respective cultivars add up to the total area planted in the dryland production areas for 1978/88 (862 000 hectares).

The procedure explained above was essential in the estimation of the area planted per cultivar, and various assumptions had to be made due to data being unavailable because of institutional changes. These assumptions are described in Section 4.3 to follow.

4.3 ASSUMPTIONS MADE IN THE ESTIMATION OF AREA PLANTED PER CULTIVAR

The year 1980 was selected as the base year for the analysis, and data from the Wheat Board, the National Crop Estimates Committee (NCEC) and the ARC-SGI was obtained for 1980 onwards. In some instances, cultivars developed prior to 1970 were still being cultivated in the 1980s, but not included in the ARC-SGI cultivar evaluation trials, and assumptions had to be made with regard to the yields of these cultivars. For these cultivars, yield was estimated by utilising site/regional experimental averages and, if site-specific trial data was not available, site-specific yields located closest to the specific area were used. The aim was to calculate the average of the experimental yield data for three major areas: winter (Western Cape), dryland (Free State) and Irrigation (Northern and Eastern Cape, KwaZulu Natal, Mpumalanga, North West Province and Limpopo). These areas were used to group all production data together, because earlier data on these three production areas had been published. For the years after 1994, following changes in the country’s provincial setup, data for the other provinces was aggregated to these three production areas.

The Wheat Board’s winter grain statistics for 1982-83, 1995 and 1997 include no data on the area planted to the different varieties. The lack of data relating to 1995 and 1997 is probably due to structural changes in agriculture at the time, as well as the process of deregulation in the years following. After this period, the function of collecting cultivar production data had to be assigned to another institution. The function was transferred to the South African Grain Laboratory (SAGL) in 1998 and the first report was published in 1999. This report contained little information, however, and reported only on some areas of production. As a result, only the SAGL reports dating from 2000 could be used. Currently the SAGL releases complete and detailed reports on all of the major wheat production areas.

Table 4.2 lists all the assumptions that had to be made due to the absence of data as described above. Note that for some years prior to 2000, the SAGL failed to report on smaller wheat production areas and so year-on-year assumptions were made.

Table 4.2: Assumptions made in the estimation of area planted per cultivar

Year	Province	Assumption made
1982	All Provinces	Areas planted to different varieties were adapted by a factor of national production
1983	All Provinces	Areas planted to different varieties were adapted by a factor of national production
1995	All Provinces	Areas planted to different varieties were adapted by a factor of national production
1997	All Provinces	Areas planted to different varieties were adapted by a factor of national production
1998	Kwazulu-Natal	Percentage values of cultivars for 1996/1997 were used
	Guateng	Percentage values of cultivars for 1996/1997 were used
1998	Mpumalanga	Percentage values of cultivars for 1996/1997 were used
	Limpopo	Percentage values of cultivars for 1996/1997 were used
1999	All Provinces	Areas planted to different varieties were adapted by a factor of national production
2000	Eastern Cape	Percentage values of cultivars for 1999/2000 were used
2001	Kwazulu-Natal	Percentage values of cultivars for 2000/2001 were used
2002	Eastern Cape	Percentage values of cultivars for 2001/2002 were used
2003	Eastern Cape	Percentage values of cultivars for 2002/2003 were used
2005	Eastern Cape	Percentage values of cultivars for 2004/2005 were used
2006	Kwazulu-Natal	Percentage values of cultivars for 2005/2006 were used
2007	Eastern Cape	Percentage values of cultivars for 2006/2007 were used
	Free State: South-western Production Area	Percentage values of cultivars for 2006/2007 were used
	Free State: South-eastern Production Area	Percentage values of cultivars for 2006/2007 were used

4.4 ADJUSTMENT FACTORS OBTAINED IN THE ESTIMATION OF AREA PLANTED

As mentioned in the previous section, the experimental yields obtained from the ARC-SGI were adjusted by a factor to account for the fact that commercial yields are in most cases lower than experimental yields. These factors are a good indication of efficiency at farm level, as they indicate the extent to which commercial yields were lower than experimental yields in a given production year. These factors may vary with other variables that influence production and yield levels, but may provide new insights into the attribution of growth in efficiency to various external factors.

From Figure 4.1 it can be noted that the commercial yields as a percentage of experimental yields in the winter production area followed an upward trend from roughly 30% in 1980 to more than 60% in 2008. This trend suggests a substantial growth in on-farm efficiency. This could be as a result of major technological, biological and perhaps institutional changes in this production area over the past few decades, but in all likelihood is simply the effect of farmers planting less on marginal fields.

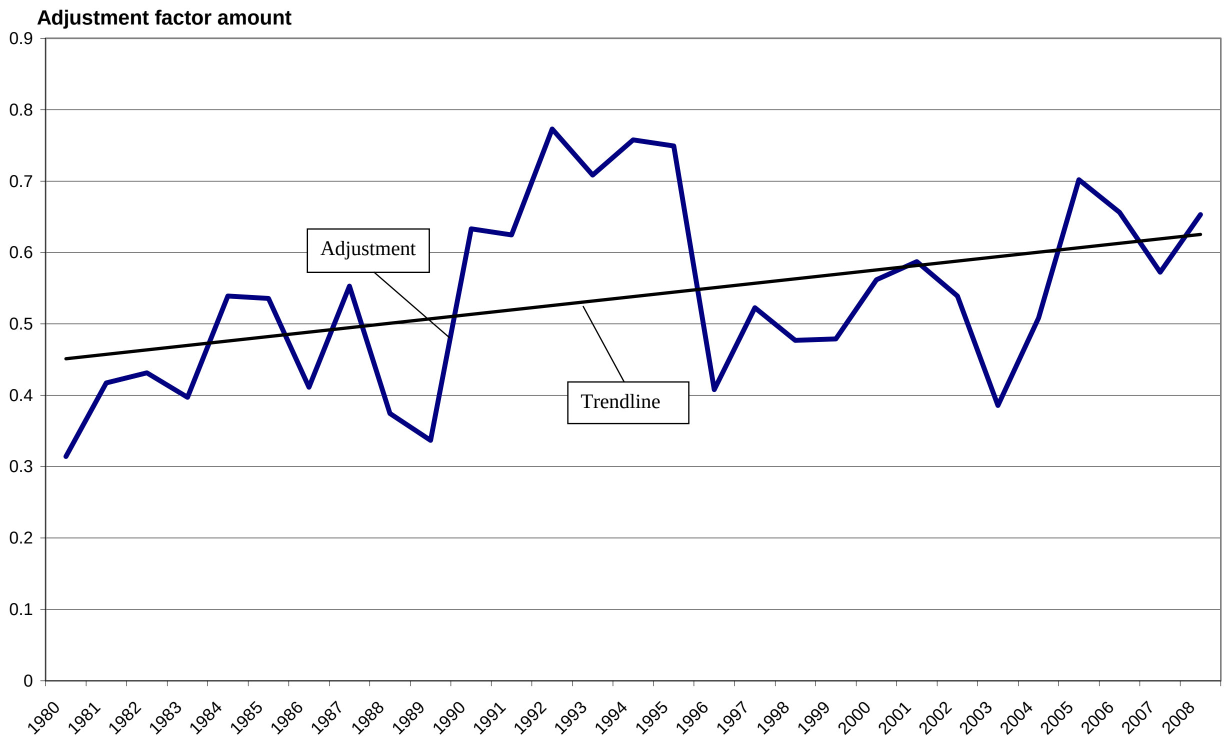


Figure 4.1: Adjustment factor for the winter production area: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

As seen in Figure 4.2, there is some volatility in this adjustment factor. The reason for this is due to yield levels that fluctuate due to changing weather conditions. These poor yields were not reflected as prominently in the experimental yields as in the commercial yield levels, thus explaining the major decrease in the adjustment factors for some years. Mention must be made on the fact that for the years 1980 – 1995, the Northern Cape and Eastern Cap (primarily irrigation areas) where included in the data reported by the Wheat Board. There was no alternative but to include these all three these production areas for this period. Later in the dissertation, provision will be made for this in attributing benefits.

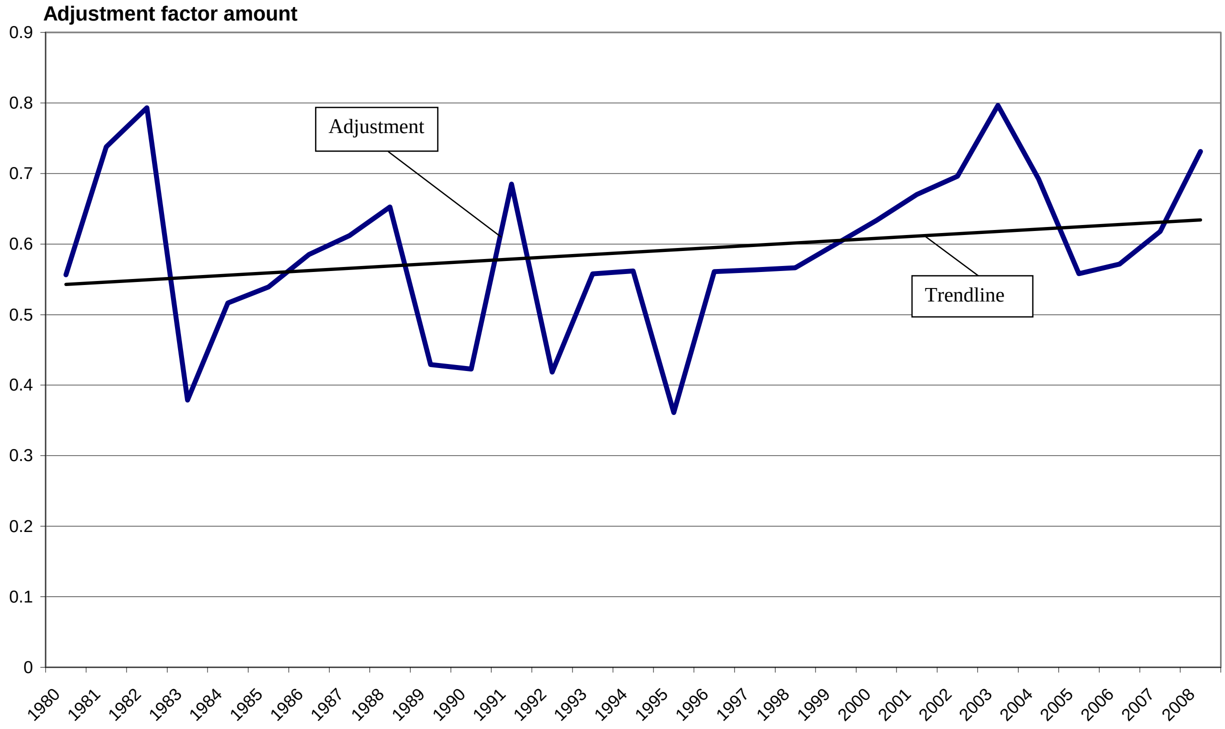


Figure 4.2: Adjustment factor for the dryland production area: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

Although an irrigation area, poor weather conditions in the irrigation production areas can still have a negative impact on commercial yields and thus production. It can also be seen that the irrigation production areas showed increased commercial yield levels as a percentage of experimental yields, rising from just above the 30% level to almost than 90% in 2008, thus suggesting only a 10% difference in experimental and commercial yields 2008.

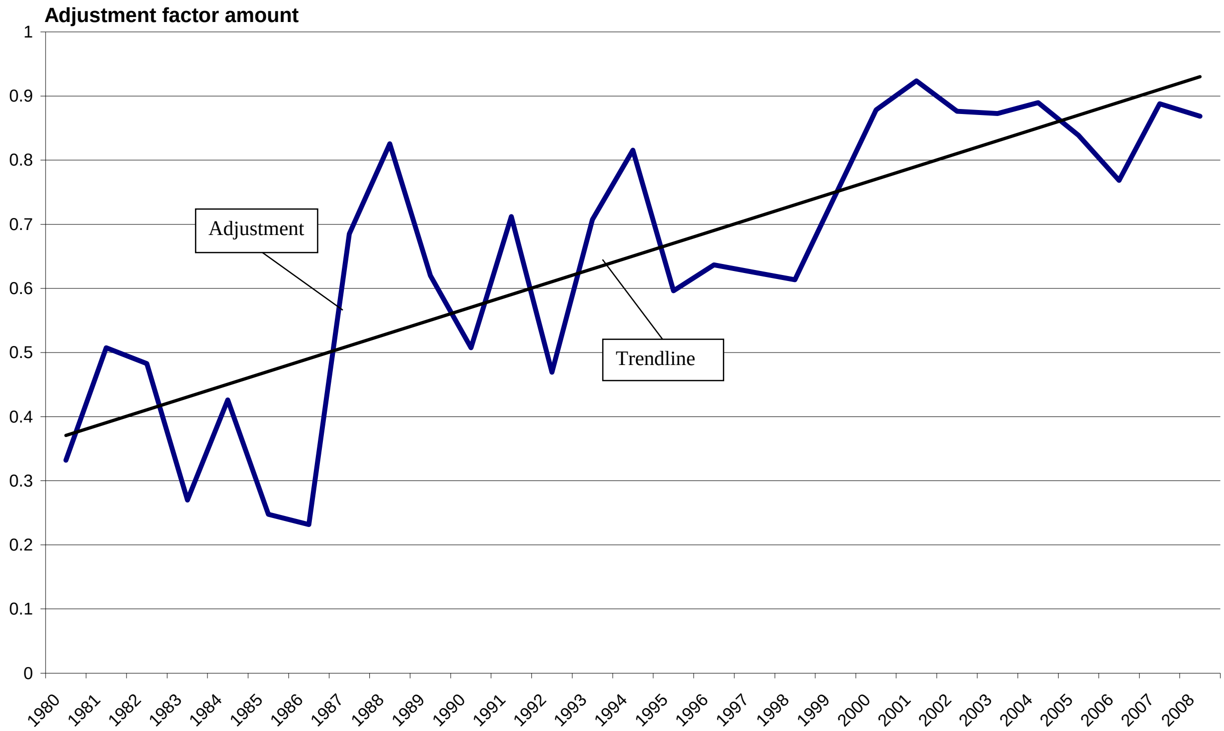


Figure 4.3: Adjustment factor for the irrigation production areas: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

Figure 4.4 indicates the estimated adjustment factors for South Africa. These factors were calculated by weighting the three production areas discussed above by their respective shares of wheat production in South Africa. From Figure 4.4 it evident that South African wheat producers have become more efficient and are currently recording commercial wheat yields much closer to the cultivars' potential than two decades ago. Although both experimental and commercial yield levels have increased, commercial yield levels have increased more as a percentage than experimental yields, confirming an increase in efficiency levels. In Chapter 5, commercial and experimental yields are presented as an index to illustrate growth and will supply the necessary evidence of increased efficiency in the South African wheat producer.

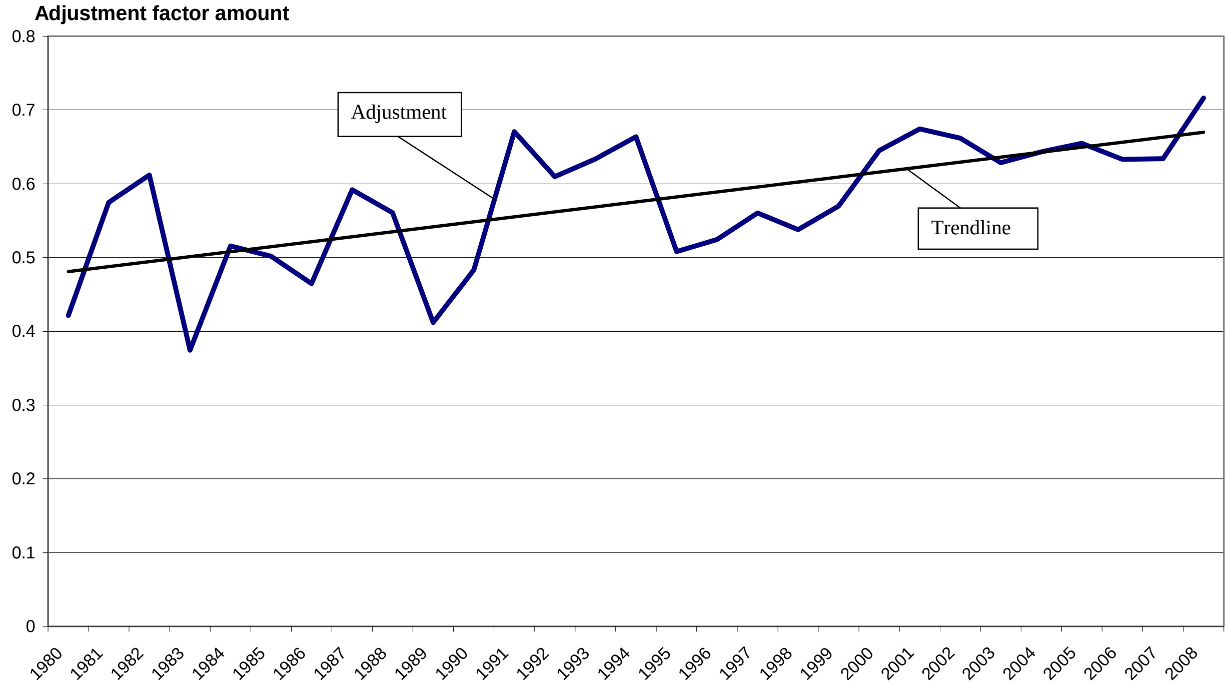


Figure 4.4: Adjustment factor for South Africa: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

4.5 AREA SHARE RESULTS FOR PRODUCTION AREAS: AREA PLANTED TO DIFFERENT WHEAT BREEDERS' CULTIVARS

The aim of the figures presented in Section 4.5 is to report on the cultivars that comprised the largest share of production in all of the production areas. It can be noted that only three role players are prominent in the analysis as they have close to 100% of the wheat market share. Cultivar adoption of cultivars produced by smaller private sector companies was extremely low and was not recognised in this dissertation and thus not reported.

By following the methodology explained in Section 4.3, it was possible to estimate the area planted per cultivar for all of the regions. These calculations indicate which cultivars were most prominent and through adding the cultivar the relative market share of the breeding company/institution.

4.5.1 Area share of planted cultivars: Dryland Production Area

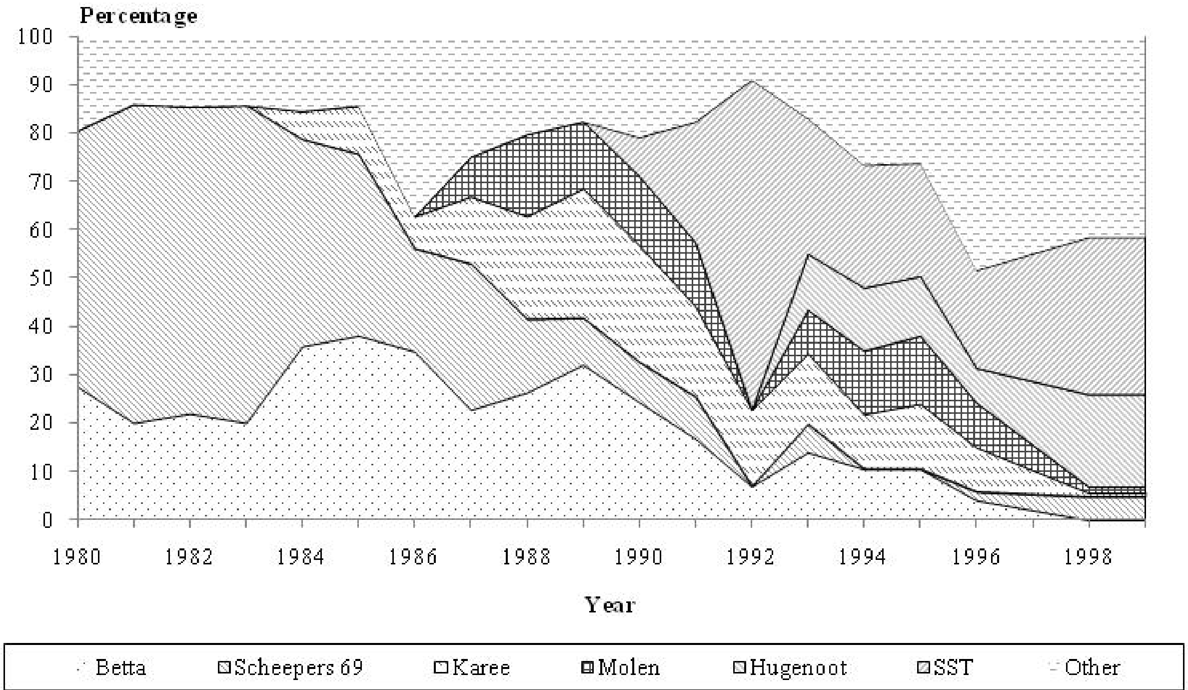
In Figure 4.5 (Panels a and b) the trend in area planted by cultivar is shown. Due to the large number of cultivars involved the changing patterns are shown for two separate periods. In Panel a, the two decades from 1980 to 1999 is shown. The cultivars “Betta”, “Scheepers 69” and “Karee” were all developed by public wheat breeders, with “Betta” and “Karee” being developed by the ARC-SGI.

Most of the ARC-SGI’s cultivars were prominent in the 1980s with up to 58.8 percent of the dryland area being planted to ARC-SGI cultivars in 1989. This share dwindled to about 8 percent toward the end of the 1990’s, but rebounded to grow back to about 40 percent in 2002 (see Panel b). It has fluctuated about this level until the end of the period. The province where the ARC-SGI has always had the largest market share is the Free State Province.

A notable feature of the latest decade is the growing presence of Pannar cultivars in most of the dryland production areas. The ARC-SCI has since the 1980s held the largest market share in the dryland production area and continues to do so. “PAN3349”, “PAN3377” and “PAN 3118” account for the largest share in production for Pannar, with Sensako holding only a small percentage of market share in the important dryland production area.

The 1990s saw increased competition between agencies in the wheat-breeding industry and a dramatic increase in the development and release of privately developed cultivars. As a result, market share was more evenly distributed, with market share shifting to private wheat breeders than public wheat breeders. This is especially true after 1997 when the Wheat Board was disbanded. The 1990s also saw the entry of a new private role-player, Pannar, with the release of its first dryland cultivar in the mid 1990s. In the 1990s the most prominent cultivars of the ARC-SGI’s were “Molen”, “Betta“ and “Karee”, with Sensako’s “SST124” being most prominent in the Free State. Pannar’s “PAN 3211” held the majority of Pannar’s market share in the dryland production area in the last decade.

Panel a: Wheat cultivars planted in dryland production area: 1980 – 1999



Panel b: Wheat cultivars planted in dryland production area: 2000 – 2008

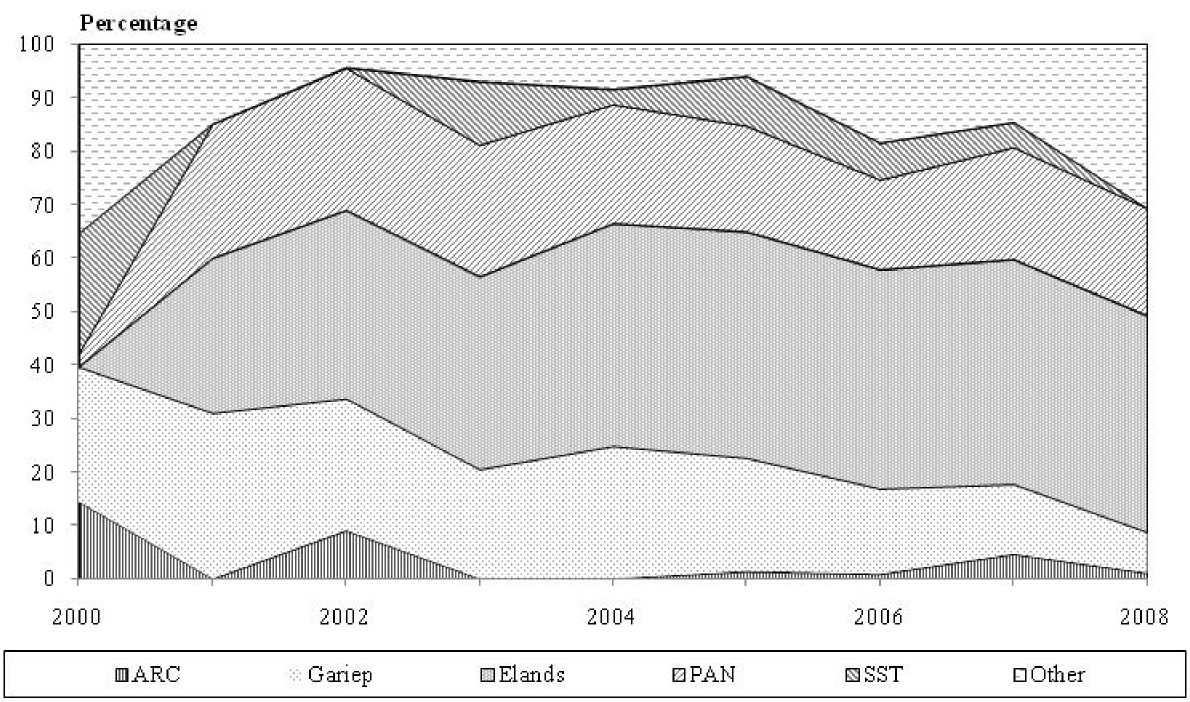


Figure 4.5: Major wheat cultivars planted in the dryland production area: 1980-1990

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

Note: SST cultivars aggregated as SST. Pannar cultivars aggregated as PAN

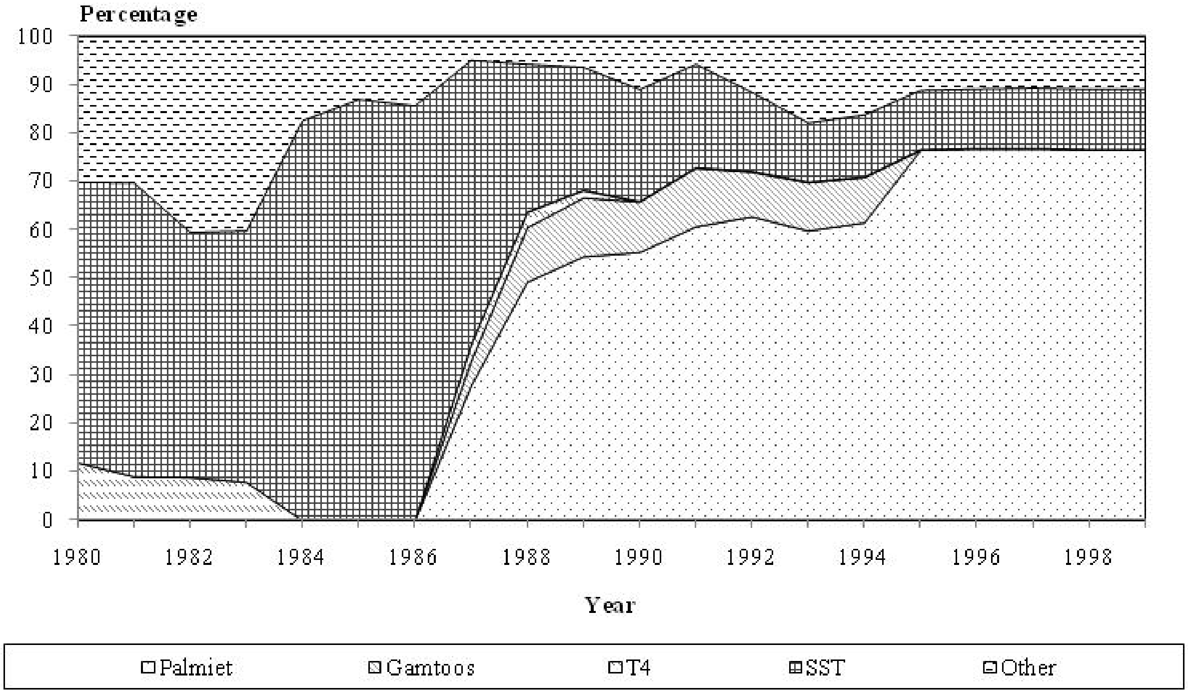
4.5.2 Area share of planted cultivars: Winter Production Area

The trend in area planted by cultivar for the winter rainfall area is reported in Figure 4.6 (Panel a and b). Statistics on the cultivar composition of the wheat harvest in the winter rainfall area became unavailable from 1998 through 2000 and it was decided to maintain the 1997 shares in the analysis. To simplify the data presented in Figure 4.6 Sensako's SST cultivars were aggregated to limit the number of variables presented in the graph.

"Palmiet" became the most prominent ARC-SGI cultivar cultivated in the winter production area during the first two decades, with "Kariega" and "Marico" (not shown individually) also contributing to the ARC-SGI's market share. Sensako's SST-cultivars ("SST44", SST16", SST66" and "SST3") held the leading position until 1986 when "Palmiet" was introduced. The position between the ARC and Sensako switched again soon after the turn of the century. Sensako regained its leading position in 2001 in the winter production area, with a nearly 90% market share with "SST57", SST65", "SST825" and "SST88" being most prominent in the Western Cape.

Whether the estimated trends since 1997 are a true reflection of the relative status of the different wheat cultivars is questionable. With the closure of the Wheat Board wheat quality tests were disrupted for a year. Hereafter the results on the cultivar composition of the harvest by region ceased to be reported as detailed as needed. Only the most prominent cultivars are mentioned and in the case of the Western Cape (regions 1 through 6) no information was available for five consecutive years. More detailed (tube specific) data is available, but this was not available at the time of this study.

Panel a: Wheat cultivars planted in winter production area: 1980 – 1999



Panel b: Wheat cultivars planted in winter production area: 2000 – 2008

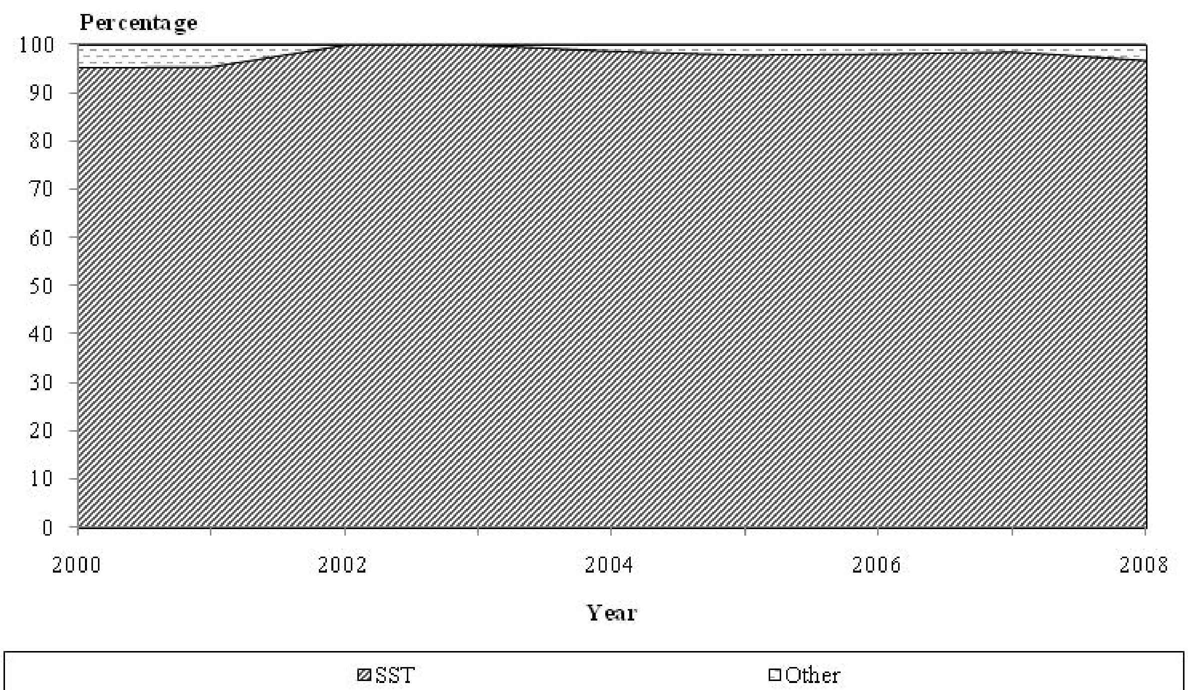


Figure 4.6: Major wheat cultivars planted in the winter production area: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

Note: SST cultivars aggregated as SST

4.5.3 Area share of planted cultivars: Irrigated Production Area

In Figure 4.7 the trend in area planted by cultivar in the irrigated wheat farming areas is shown. In 1980 a large number of cultivars with small individual shares in the area planted represented almost 57 percent of the area planted. This situation changed drastically in 1981 to represent only 23.5 percent of the planted area. A probable reason for this is that drought of the early eighties may have reduced the ability of farmers to plant from retained seed from the 1980 harvest. Initially the public sector developed cultivars “Inia”, “Elize” and “T4” made up 38.1 percent of the area planted to wheat under irrigation. Of the public sector developed cultivars, “Elize” was developed by the ARC-SGI and the other two originated from genetic material sourced internationally, but released and marketed by the Department of Agricultural Technical Services. “Inia” was one of the most prominent cultivars in all of the production areas and accounted for a large area planted over two decades.

During the 1990s the cultivars “Inia” and “Palmiet” continued to be planted in the irrigation production areas, but with the release of “SST822”, “SST825” and “SST86”, by Sensako the SST cultivars taken together began dominating the market. These cultivars continued to be dominant up to 2005 when “CRN826” (released in 2003 by Monsanto) began to be adopted by farmers in the irrigation areas – reaching 46.1 percent of the area planted to wheat in 2007. “SST 835” was introduced in 2007 and is currently responsible for the majority of the area planted to Sensako cultivars.

Currently “Duzi” (released in 2006) accounts for the largest share of plantings of ARC-SGI cultivars in the irrigation production areas.

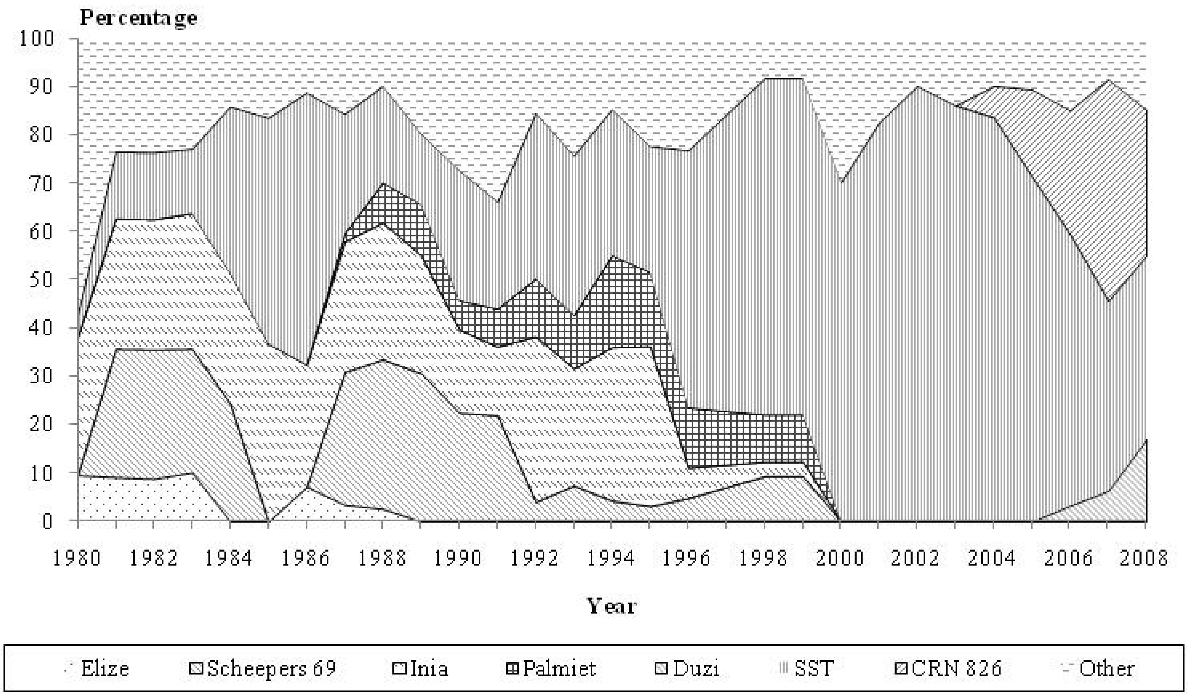


Figure 4.7: Major wheat cultivars planted in the irrigation production areas: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

Note: SST cultivars aggregated as SST

4.6 MARKET SHARE RESULTS PER WHEAT BREEDER FOR DIFFERENT PRODUCTION AREAS

By aggregating the area planted by cultivar data according to the supplier thereof the relative market share of each breeder can be determined. The winter production area was heavily dominated by the ARC-SGI from the mid-1980s to the mid-1990s. However, from Figure 4.8, it is evident that after the abolishment of the Wheat Board, the ARC-SGI lost the majority of its market share and has not recovered since, mainly due to the abolition of the subsidy on ARC released cultivars. From the figure below it can be noted that Sensako as close to 100% market share as opposed to a 12% market share in the early 1990's.

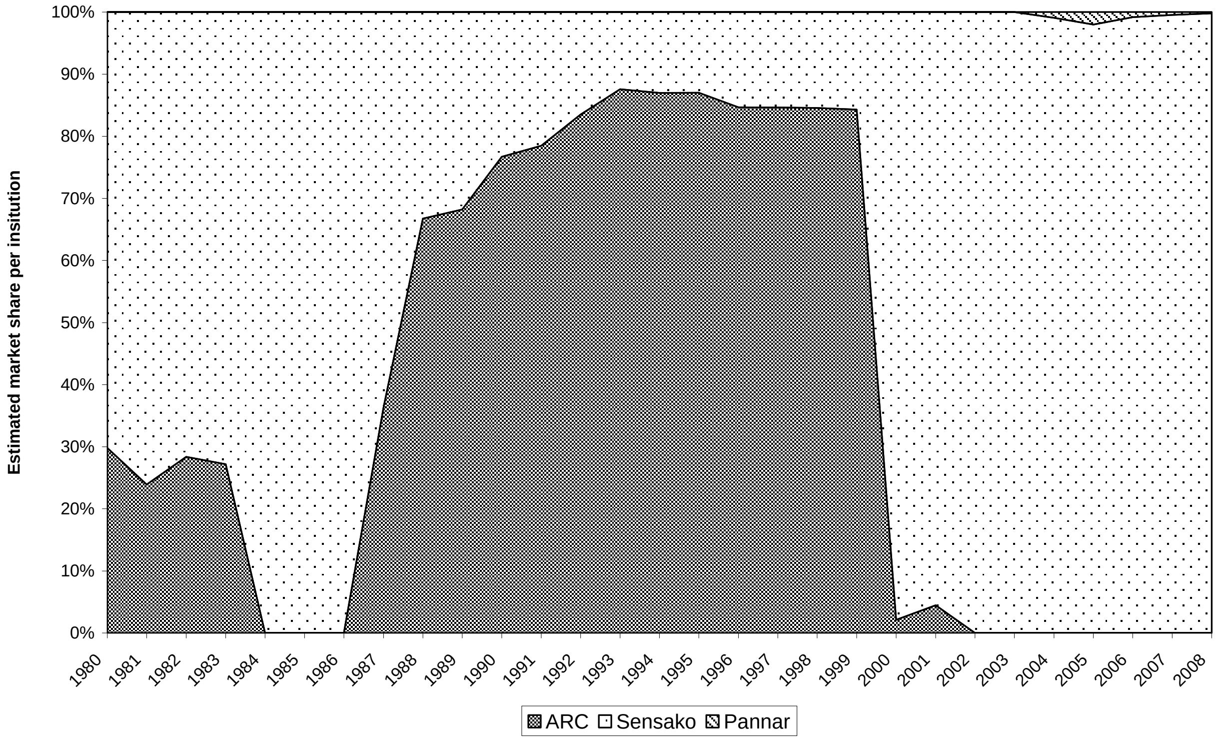


Figure 4.8: Estimated market share of wheat breeders in the winter production area: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

As mentioned previously, the dryland production area is the only region where the ARC-SGI is still dominant and holds the largest market share as shown in Figure 4.9. Pannar has also grown in market share since its introduction into the wheat-breeding industry in the mid-1990s. The ARC holds 53% of the market share in the dryland production area with Sensako holding 18% and the remaining 29% belonging to Pannar.

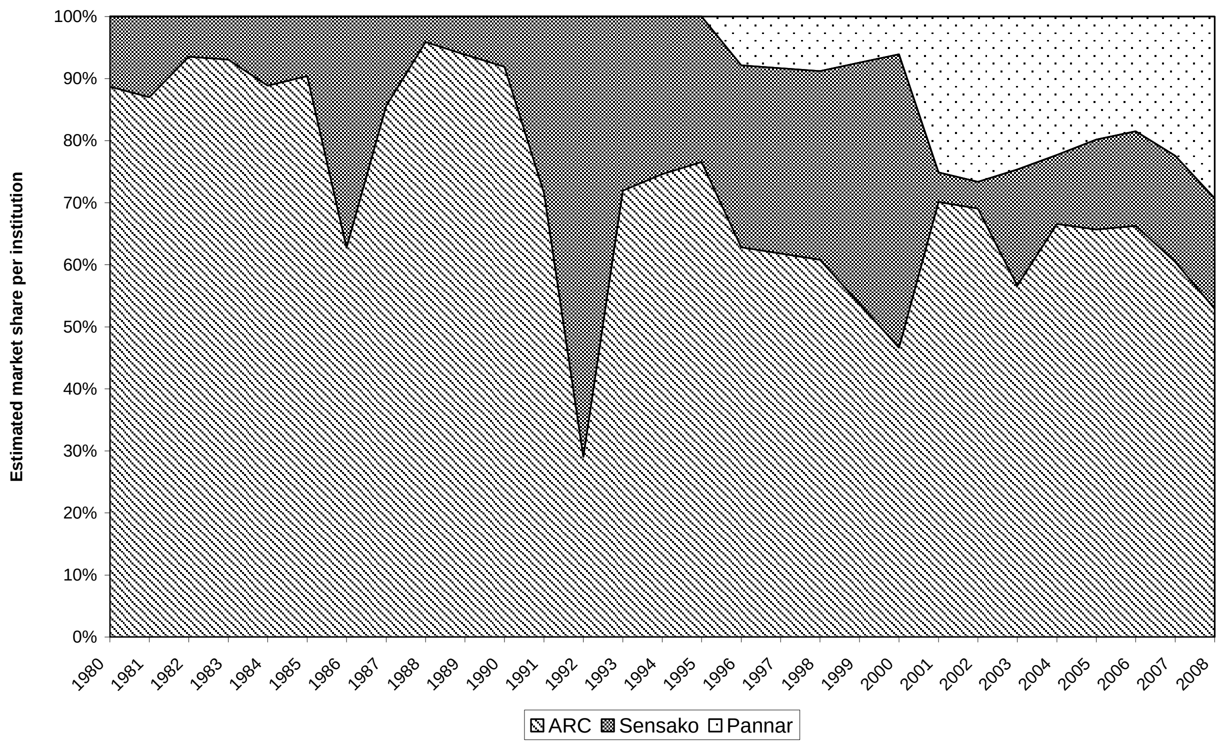


Figure 4.9: Estimated market share of wheat breeders in the dryland production area: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

The irrigation production areas were also dominated by ARC-SGI cultivars throughout the 1980s and 1990s. This changed, however, and from the beginning of 2000, Sensako has held the largest market share in this important production area. As noted from Figure 4.10, since 2007 the ARC-SGI has retained some of its previous market share. The ARC currently holds 29% of the market share in the irrigation production areas while Sensako has 69% and Pannar only 2%.

Figure 4.10: Estimated market share of wheat breeders in the irrigation production areas: 1980-2008

Source: Author's own calculations based on cultivar production data supplied by the Wheat Board (1997) and the SAGL (2009)

From the figures above it can be noted that Sensako has in recent years held the major share in terms of cultivars planted in South Africa's wheat production areas. The ARC-SGI has held little market share in most of the irrigation areas for the past decade. Market share estimations for 2008, however, show an increase in ARC-SGI's market share in these irrigated areas. However, there has been no increase in market share in the Western Cape Province where 40.20% of South Africa's wheat was produced in 2008 and where the ARC-SGI has basically no real market share.

4.7 SUMMARY

Chapter 4 provided a description of the methods used in the estimation of the area share per wheat cultivar in all production areas. As a result, an estimation of the market share of the different seed companies could be made. Data on percentage production per cultivar for all production areas was obtained from the annual reports of the Wheat Board and the SAGL and assisted in the estimation. The estimation of the area share by variety data assisted in capturing the adoption rates of new wheat varieties by farmers. These adoption rates are crucial for the calculation of the index of varietal improvement, as will be shown in the later analysis.

Chapter 4 also provided the current provincial estimated market shares of the ARC-SGI, Sensako and Pannar – information used in the calculation of the market share for the whole of South Africa. These market shares are based on area planted to an institution's cultivar and provide new insights into the adoption of different wheat breeders' cultivars in the three wheat producing areas. From Chapter 4 it can be noted that Sensako is dominant in two of the three production areas. The dryland production area is the only area where Sensako does not hold the majority market share.

Final thoughts and results on market shares and benefits are provided in the final chapter. The provincial market shares are aggregated to provide an estimate for the whole of South Africa. Chapter 5 to follow provides an overview of the relevant methodology considered for the dissertation. A detailed description of the chosen methods is provided in Chapter 5.

CHAPTER 5

EVALUATING YIELD RESPONSE TO VARIETAL CHANGE

5.1 INTRODUCTION

The evaluation of yield response to varietal change can be quantified by using various methodological approaches. The methods explained in this chapter have been used in various studies (Brennan, 1984; Pardey *et al*., 2004; Zentner & Peterson in Barkley, 1997). A number of other studies followed a similar methodology in the calculation process, but to date no standard measure exists for the measurement of yield gains (Morris & Heisey, 2003:244). There are also various factors that need to be taken into consideration before deciding on a relevant methodology. According to Morris and Heisey (2003:244), three main problems must be addressed in order to correctly calculate the impact of varietal improvement, namely measuring the adoption of modern varieties (MVs), estimating the benefits attributable to the adoption of these MVs, and assigning credit to different breeding programmes that participated in the development of the MVs. These three factors are attended to and discussed in Chapter 5, with logical solutions to these problems being provided.

This chapter consists of an overview of different methodologies and the approach chosen for this dissertation. An explanation is given of the various estimations and assumptions made in the analysis, and the relevant methodology is explained.

5.2 ECONOMIC EVALUATION OF VARIETAL CHANGE: INDEXES OF VARIETAL CHANGE

Pardey *et al.* (2004) conducted a study at the International Food Policy Research Institute (IFPRI) to assess and attribute the benefits from varietal improvement research in Brazil. To a degree this dissertation follows a similar methodology to calculate the benefits with regard to wheat cultivar improvement research in South Africa. The methods used in the study by Pardey *et al*. (2004) are based on an approximation that was first used by Griliches in 1958. According to Pardey *et al*.

(2004:20) Griliches measured the total benefits that arose from the varietal improvement of hybrid corn in the USA. One of the assumptions made was that the total Gross Annual Research Benefit (GARB) is approximately equal to the value of the additional output, calculated by multiplying the value of production (*PQ*) with the proportional gain in yield (*k*), due to the adoption of new resistant varieties (Pardey *et al*., 2004:20). Thus GARB can be written as: *GARB* = *kPQ*, where *P* equals the price and *Q* the quantity of the crop produced in the different production areas. According to Pardey *et al*. (2004) this is a highly intuitive measure and is open to criticism. However, this is the best means of approximating the research benefits in light of the lack of information regarding the size or nature of supply shifts due to new crop varieties.

Making use of the preceding approximation to GARB avoids the need to calculate the price and quantity effects due to research, as with the economic surplus methods (Pardey *et al*., 2004:21). If a distinction is to be drawn between benefits to consumers and producers respectively, this advantage is lost. Should spill-over effects occur to neighbouring production areas, the question should be raised: Are these technological improvements influencing world production, which determines the price effects of new varieties? If this is in fact the case, this price change needs to be calculated in order to measure the total benefits to the country. In this dissertation it is assumed that South Africa's varietal innovations have had no impact on global market prices. This is a fair assumption given that South Africa is a net importer of wheat and is one of the smaller players in the global wheat industry.

5.2.1 Research and Development Lags

The relative flow of research costs and benefits associated with the development of a new wheat variety is presented in Figure 5.1. The vertical axis represents the flow of benefits and cost in a specific year, and the horizontal axis represents years after initiating a research project. From the figure, three lags can be identified: The research lag, the development lag, and the adoption lag. Initially, there is only expenditure during the research into the development of the resistant varieties (3 to 10 years) (Pardey *et al*., 2004:21). The research lag is followed by a development lag of a few years, which usually consists of field trials, certification and approval of the variety, and the multiplication of the seed (Pardey *et al*., 2004:22). Lastly the adoption lag occurs where it can be observed that benefits become positive. In most cases the flow of benefits will decrease due to the fact that new varieties are developed and adopted. This flow of research costs and benefits is a constant process that is repeated as new varieties are developed.

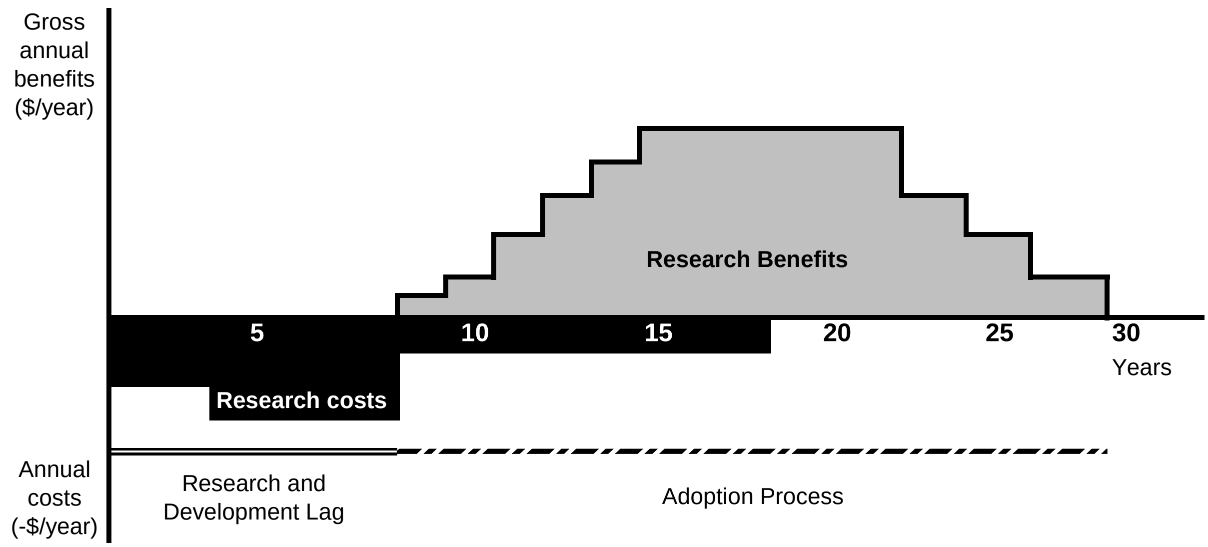


Figure 5.1: Research benefits and costs over time

Source: Pardey et al. *(2004:22)*

5.2.2 Indexes for Calculating Varietal Improvement

Pardey *et al*. (2004:24) measured varietal improvement by comparing individual varieties, or indexes that aggregate across different varieties, with some base or index. Using experimental data has its advantages, according to Pardey *et al*. (2004:24). Many of the variables that generally influence yields are held constant and, due to the fact that the variation in experimental treatments is less, differences in yields attributable to varietal effects can be better recorded. This is the case in this dissertation, as experimental data was obtained from the ARC-SGI's annual experimental trials planted at different locations in the different wheat-producing areas. It is important to note that experimental yields are usually higher than producers' yields, but the aim was to calculate the difference in yield between an old and a new variety due to varietal improvement and not yield level.

If a full set of observations of experimental yields by region for every new variety that was developed and adopted is not available, another route may be followed to calculate the benefits.

This can be done by means of a regression model, and the section below describes the necessary steps in estimating both experimental and industry yield data.

5.2.2.1 Estimation of Experimental Yield Data

Pardey *et al.* (2004) adopted the method used by Venner in 1997 and James in 2000 to estimate experimental and industry yield data. Given the data for new varietal releases in all of the research stations in the major wheat-producing areas, Pardey *et al.* (2004:29) were able to estimate a regression model of the following form:

$$Y_{klm} = \sum_{i=1}^{I} \alpha_i DV_i + \sum_{j=1}^{T} \beta_j DA_{j(k)} + \sum_{s=1}^{S} \delta_s DS_s + \sum_{t=1}^{T} \gamma_t DT_t + \Theta_{r(l)} W_{r(l)m} + \varepsilon_{klm} \qquad (5.1)$$

In Equation 5.1 Y_{klm} is the recorded experimental yield of a given variety *k* at site *l* (in region *r*) in a trial conducted in year *m*; DV_i is a dichotomous dummy variable set equal to 1 for variable *i* and zero otherwise; $DA_{j(k)}$ is a dichotomous dummy variable if variety *k* with a 1 for release of the variety in year *j* and zero otherwise; DS_s is a dichotomous dummy variable for the different areas where research stations are located with a value of 1 for site *s* and zero otherwise; DT_t is a dichotomous dummy variable for time and is assigned a value of 1 if the variety is released in year *t* and zero otherwise; $W_{r(l)m}$ can be described as an index of weather in region *r*, that contains site *l* in year *m*; and ε_{klm} is the residual term from the model. It is important to note that dummy variable DV_i is assigned to each of the *I* total varieties in the data set, $DA_{j(k)}$ is assigned to each of the *T* years covered by the data set, DS_s is assigned to each of the *S* total number of sites in the data set, and DT_t is assigned to each of the *T* years covered by the data set.

By using this regression model, fitted values can be calculated for the experimental yields for each variety in the sample, for every year and site. The model is expressed below:

$$\hat{Y}_{ist} = \hat{\alpha}_i + \hat{\beta}_{j(i)} + \hat{\Theta}_{r(s)} W_{r(s)t'} \qquad (5.2)$$

Given that variety i was in fact released in year j, $\hat{\beta}_{j(i)} = \hat{\beta}_j$. As in Pardey *et al.* (2004:29), the estimates of variety-specific fitted yields on regional levels can be obtained by taking the average of the fitted yields across all the sites within a specific region. Substituting the fitted values for yields for all varieties by region and year into equations 5.3 and 5.4 below, the yield indexes can be calculated. This is done for both the actual and base values:

$$\hat{Y}_{rt}^{a} = \sum_{i=1}^{n} Y_{irt} \hat{\pi}_{irt} \quad (5.3)$$

$$\hat{Y}_{rt}^{b} = \sum_{i=1}^{n} Y_{irt} \hat{\pi}_{irb} \quad (5.4)$$

These estimated yields can then be substituted in equation 5.5 to calculate an estimated k value:

$$\hat{k}_{rt} = \left(\frac{\hat{Y}_{rt}^{a} - \hat{Y}_{rt}^{b}}{\hat{Y}_{rt}^{a}}\right) \quad (5.5)$$

From this estimation of k the total benefits from varietal improvements in region r in year t can be calculated as:

$$B_{rt} = \hat{k}_{rt} P_t Q_{rt}$$

5.2.2.2 Estimation of Industry Yield Data

The section above focused on the estimation of experimental data and differs from the estimation of industry yield data as it is necessary to know the fraction of each variety, i planted in region r in year t (π_{irt}), in order to formulate a regression model. According to Pardey *et al.* (2004:29) the annual average yield (across all varieties) for a region, *r*, must be regressed against the fraction of the area planted to the different varieties and other variables as can be seen below:

$$Y_{rt} = \gamma_{0r} + \sum_{i=1}^{I} \gamma_{ir}\pi_{irt} + \sum_{s=1}^{S} \beta_{r(s)}(W_{st} - \bar{W}_{r(s)t}) + \varepsilon_{rt} \tag{5.6}$$

$\bar{W}_{r(s)t}$ is yet another weather variable and resembles weather averaged across sites (denoted by *s*) in region *r* in year *t*. Pardey *et al*. (2004:29) described this model as region-specific in which parameters and data are specific to region *r*. It is, however, possible to estimate the same model for several regions. Some parameters may even be equal over different regions (for instance weather effects or the variety response parameters) (Pardey *et al*., 2004:30). From equation 5.6, a calculation of the expected yield of a variety, *i* in region *r* in year *t*, can be illustrated as follows:

$$\hat{Y}_{irt} = \hat{\gamma}_{0r} + \hat{\gamma}_{ir} + \sum_{s=1}^{S} \hat{\beta}_{r(s)}(W_{st} - \bar{W}_{r(s)t}) + \varepsilon_{rt} \tag{5.7}$$

The 'hats' as usual indicate that these values are estimated values. Pardey *et al*. (2004:30) further indicated that the expected value in a normal year, with regard to the weather, can be illustrated as:

$$\hat{Y}_{irt} = \hat{\gamma}_{0r} + \hat{\gamma}_{ir} \tag{5.8}$$

This in short is the methodological approach in the estimation of varietal improvement in the absence of experimental yields for the different wheat varieties. In the case of this study, this was not the case, and experimental yields for all varieties across all production areas were available from the ARC-SGI experimental trials. As a result, no regression model had to be run to estimate these values. Given the nature of the data, it was possible to use actual values, which is therefore a major attribute of this dissertation and certainly improves the accuracy of the calculations.

5.2.2.3 Calculations with a Full Set of Experimental Yields

Pardey *et al*. (2004:25) defined an "index of experimental yield performance" in a certain region at a given period. Given the actual adoption pattern and the experimental yields, the index can be written as:

$$Y_{rt}^{a} = \sum_{i=1}^{n} Y_{irt}\ \pi_{irt}\ , \qquad (5.9)$$

Where: $\pi_{irt} = \dfrac{A_{irt}}{A_{rt}}$ and $A_{rt} = \sum_{i=1}^{n} A_{irt}$

In the equation above Y_{irt} can be described as the experimental yield of variety i in region r in year t, and π_{irt} is the proportion of area in region r sown to variety i and, as can be noted, these values are actual and not estimated. A similar equation can be formulated for the base year scenario, which is a measure of what yields would have been in the absence of varietal improvements:

$$Y_{rt}^{b} = \sum_{i=1}^{n} Y_{irt}\pi_{irb} \qquad (5.10)$$

Where: Y_{rt}^{b} is an index of experimental yield in the absence of any varietal improvements and π_{irb} the proportion of area in region r sown to variety i in the base year. The proportional increase or gain due to varietal improvements can then be illustrated as:

$$k_{rt} = \left(\frac{Y_{rt}^{a} - Y_{rt}^{b}}{Y_{rt}^{a}}\right) \qquad (5.11)$$

By using the k-shift value calculated in Equation 5.11, the total benefits can thus be calculated as follows:

$$B_{rt} = k_{rt} P_t Q_{rt} \qquad (5.12)$$

From Equation 5.12 the total benefits due to varietal improvements are estimated, but these benefits must still be attributed to the different role-players in the wheat-breeding industry. This can be done by simply assigning attribution weights to all of the organisations. *Pardey et al*. (2004) explained that two different approaches can be followed. With the first approach, all of the credit for a variety is given to the breeder that developed it, while with the second approach, weights can be assigned if genetic material is shared by two role-players. Equation 5.13 below shows the attribution of total benefits to different wheat breeders.

$$B_{rt}^{E} = B_{rt} \sum_{i=1}^{n} Ei\pi_{irt} \tag{5.13}$$

E_i is the fraction of the benefits attributable to a wheat breeder depending on the share in the development of a wheat cultivar. Due to the confidentiality of wheat cultivar pedigree data in South Africa, all of the benefits of a developed cultivar are attributed to the breeder of that cultivar.

Auer (1963), Heady and Auer (1966) and Silvey (1978,1981) in Brennan (1984) and Zentner and Peterson in Barkley (1997) also used an index of varietal improvement to calculate research-induced shifts, but calculated the average yield increases of new varieties relative to a base year variety. As in the methods described above, a weighted average yield was used in this instance. Weighted by the proportion of area planted to the different varieties, this weighted experimental yield captures both yield and adoption effects. Brennan (1984) measured the contribution of new wheat varieties to increasing wheat yields and implemented both a varietal improvement index and an index of varietal newness first used by Johnson and Gustafson in 1963 (Brennan, 1984:178). One drawback of the index of varietal newness, as identified by Brennan (1984:178), is that the index does not give an indication of yield effects, but rather the adoption rates of new wheat varieties. In this study, this would have prevented the estimation of benefits due to varietal improvement because no k-shift could have been estimated. Despite some limitations, Brennan (1984:183) concluded that the index of varietal improvement is the best option to estimate varietal improvement. Brennan (1984:184) constructed the varietal improvement index by expressing the new wheat varietal releases' yield as a percentage of an existing variety that was planted throughout all of the years included in the sample. To an extent this study also made use of this approach, but new wheat varieties are expressed as a percentage of the weighted average yield of all of the varieties in the base year.

Barkley (1997) followed the same approach as Brennan (1984) and captured the average yield increases of eight Kansas semi-dwarf varieties relative to a base year variety. This method, as with the methods followed by Brennan (1984) and Pardey *et al*. (2004), captures two sources of change. Firstly the higher yield due to varietal improvement is captured and secondly, the adoption of these cultivars by producers is also captured in the area planted to the variety.

5.3 COST CALCULATION IN VARIETAL IMPROVEMENT RESEARCH

When calculating the costs associated with a specific research project, different conceptual issues need to be understood in order to correctly calculate and compare these costs to benefits. One of these is the costs associated with the development of one new variety. There are often three to ten years between the initiation of the research and the release of the new variety (Pardey *et al*., 2004:31). Although a huge amount of time is spent on the development of a new variety, there is no guarantee that this variety will be released. Costs can also be divided into different components, which include labour, capital and operational costs. Pardey *et al*. (2004:31) also identified the fact that agricultural research is a labour-intensive undertaking. Not only plant breeders, but also agronomists, plant pathologists, entomologists and support staff are needed to carry out varietal improvement research. Pardey *et al*. (2004:31) described the quantification of all of the necessary costs involved in varietal improvement research.

5.3.1 Labour Costs

By developing an inventory of all the staff at different research stations, a crop-and activity-specific set of labour costs can be estimated. This classification is done according to the individual's discipline (i.e. plant breeder, pathologist, etc.) and the individual's qualification (PhD, MSc or BSc). The time spent on plant breeding is estimated and it is assumed that 100% of the time was spent on crop improvement research. This assumption is not made for agronomists, entomologists and other role-players who are occupied with other research not directly involved in crop improvement.

By using salary data, w_{qct}, for qualification class, *q*, each crop, *c*, and each year, *t*, Pardey *et al*. (2004:32) were able to estimate the share of labour cost dedicated to crop improvement research:

$$SCI_{ct} = \frac{\sum_q w_{qct} s_{qct} L_{qct}}{\sum_q w_{qct} L_{qct}} \quad (5.13)$$

From Equation 5.13, s_{qct} can be described as an estimate of each respective labour class devoted to crop improvement research in a given year.

5.3.2 Operating Expenditure

Operating costs include the cost of field and laboratory chemicals, fuel and any other supplies needed to conduct crop improvement research (Pardey *et al*. 2004:33). Making use of budget data for all of the research stations, an estimate of the share of operating expenses directly related to crop improvement research can be calculated. This is done by using the median of the operational cost shares for each research station or institute, together with the total operational costs for each institute, for each year.

5.3.3 Capital Expenditure

The annual cost of capital can be calculated by using data on the value of the initial capital stock at the different institutes and relevant capital items obtained throughout a research year (land, buildings and other physical assets like machinery). By using the same shares of the amount of labour and operating costs used for crop improvement research, the value of the capital stock used for crop improvement research can be illustrated as follows:

$$S_{ct} = \sum_k (1 - d_k) S_{kc(t-1)} + \sum_k I_{kct} \quad (5.14)$$

From Equation 5.14 $S_{kc(t-1)}$ is the stock capital and I_{kct} the investment capital of class *k* for crop *c* at time *t*; d_k is the annual depreciation rate of capital and is assumed as 0% for land. Robinson and Barry in Pardey *et al*. (2004:33) distinguished between two parts of the annualised user cost of capital: depreciation costs and opportunity costs due to earnings forgone from resources that are tied up in durable assets. From this Pardey *et al*. (2004:33) illustrated the user cost of capital as:

$$UC_{ct} = \sum_{k} S_{kct}(d_k + r_k) \qquad (5.15)$$

5.4 COMPARING BENEFITS AND COSTS

In order to compare different projects in different timeframes, aggregation over time by means of relevant capital budgeting methods is needed. This, according to Pardey *et al*. (2004:35), is the essence of comparing projects with different time patterns and benefits. It is important to apply capital budgeting techniques purely because of the time value of money. Future benefits are discounted and past benefits are compounded relative to current benefits.

5.4.1 Net Present Value

When using the Net Present Value technique, an investment can be seen as profitable if the net present value is positive.

$$PV(B)_t = \sum_{j=0}^{n} B_{t+j} / (1+i)^j \qquad (5.16)$$

The present value of a stream of benefits, in year *t*, over the next *n* years, can be expressed by Equation 5.16 (B_{t+j} is the benefit in year *t*+*j* and *i* is the interest rate used to discount future benefits). By comparing the stream of benefits with the costs (*C*) of a given project, the net present value can be calculated by:

$$NPV_t = PV(B)_t - PV(C)_t$$
$$= \sum_{j=0}^{n} (B_{t+j} - C_{t+j})/(1+i)^j \qquad (5.17)$$

Thus it is evident that if the present value of the benefits exceeds the present value of the costs, the net present value is positive and the investment profitable.

Important issues mentioned by Pardey *et al*. (2004:35) are that a distinction should be drawn between the costs and benefits being calculated. These costs and benefits can be either social or private and may not affect the formula used to calculate them, but the way in which they are measured. Another factor that needs to be taken into consideration is the discount rate *i*, which should be consistent with the measures of both costs and benefits.

5.4.2 Benefit-Cost Ratio and Internal Rate of Return

The Net Present Value technique is most popular in evaluating investments, but other capital budgeting instrument like the benefit-cost ratio and internal rate of return are often used because they are more readily comparable across different investments (Pardey *et al*. 2004:36). As the name indicates, the benefit-cost ratio is simply a ratio of the present value of benefits to the present value of costs:

$$BC_t = PV(B)_t / PV(C)_t \qquad (5.18)$$

From Equation 5.18 it can be noted that if the present value of benefits exceeds the present value of costs, the benefit-cost ratio is greater than one and thus, as with the net present value, the investment is profitable.

The final technique described in this dissertation is the internal rate of return (IRR). IRR can be described as the discount rate that yields the net present value equal to 0 (Pardey *et al*. 2004:36). Thus:

$$0 = \sum_{j=0}^{n} (B_{t+j} - C_{t+j})/(1+IRR)^{j} \qquad (5.19)$$

An investment with a NPV > 1, given a discount rate of *i*, will thus have an IRR>*i* and will thus be profitable.

5.5 CONCLUSION

Chapter 5 provided a concise description of the relevant methodologies that were considered in the dissertation. These methods are similar to an extent, but the key differences, as explained above, assisted in the selection of a relevant method for the dissertation. Although most methods can be used for the analysis, some are more suitable and must be used to prevent biased results.

From the literature studied above and from careful inspection of the data acquired, it is clear that the construction of a varietal improvement index is the best method for the analysis in this dissertation, because actual cultivar production data was obtained and thus the area share per cultivar could be calculated. Growth in yield relative to a base year is also captured well by an index as in Zentner and Peterson (1997), cited in Barkley (1997). The calculation of a counterfactual scenario, as in Pardey *et al*. (2004), and the use of an index value of the yield of one variety planted throughout all of the years in the sample, as in Brennan (1984), could not be used for this South African scenario. This is due to the extended observation period of the study (1980-2007) and higher adoption rates by South African farmers, and simply because no cultivar was planted throughout all of the years included in the analysis.

The index of varietal improvement has thus been constructed as growth in yield relative to a weighted average yield value calculated for 1980. The k-shift was then calculated from this index and used to estimate the benefits by multiplication with production and price data obtained from the Abstract of Agricultural Statistics of the Directorate: Agricultural Statistics (2009). As mentioned in previous chapters, the net benefits of varietal improvement were only estimated for the ARC-SGI (public institutions). The benefit-cost ratio was the only capital budgeting instrument used and total costs were calculated from budget data for 1980-2007 obtained from the ARC-SGI.

CHAPTER 6

MEASURING THE BENEFITS OF WHEAT VARIETAL IMPROVEMENT RESEARCH IN SOUTH AFRICA

6.1 INTRODUCTION

The benefits of varietal improvement research have been captured in various studies and have consistently been shown to be far greater than the expenditure on such research. The question that is often raised is: Can all of these benefits be attributed to varietal improvement alone? And if not, what percentage can be assigned to varietal improvement research? There is also the issue of yield levels of the counterfactual or "without" scenario. Would yields have remained at the same levels in the base year if no research had been conducted, or would technology improvements have spilled over from various other sources?

Morris and Heisey (2003:248) mentioned that a common mistake made by impact assessment studies is to assume that yields would have remained the same as in the base year in the absence of research. A more realistic approach is to assume that, even in the absence of research, yields would have increased by a factor of the realised yields due to other sources of varietal improvement. Estimating a value for varietal improvement in the absence of research is very difficult and no proven method exists to assist with this issue. The best way to deal with this issue is either to assume that no varietal improvement would have happened in the absence of research or technological improvements, or to assign a best guess estimate to this value. Morris and Heisey (2003:248) advised that a subjective judgement is needed to ensure that the gains realised in the counterfactual scenario are accounted for.

As mentioned earlier in Section 5.2.2 (Chapter 5), the aim of the study was to analyse yield growth and not yield levels. Experimental yield levels are generally higher than commercial yield levels, but are the only reliable indicator of yield growth. This is due to the fact that experimental trials are expertly managed to eliminate yield variability and ensure that optimal yields are realised in line with the cultivar's potential. Experimental trials are also the only yield by cultivar records in South Africa. As mentioned by Brennan (1984:182), "The only reliable sources of relative yields are variety trials". Conclusions are thus drawn on experimental yield growth, but commercial yield growth is also reported as a comparison with the experimental yields and to observe whether the growth in new varieties' yields is captured by commercial yields.

This chapter therefore applies the methodology discussed in Chapter 5 to wheat improvement research in South Africa with some deviations. Most importantly, no regression was done to estimate the yield indexes because:

1. The ability to use commercial yields as a proxy for the weather index would suffer from a number of caveats in the South African setting, not the least the absence of reliable observations of district level wheat production over the length of the study period.
2. As a probable alternative, site specific weather data could be used, but this were not available at the time of this study. Annual observations – where available – has no bearing on the distribution during the growing season, also;
3. Weather stations at district level are not uniformly available for all wheat producing districts and, where available, would again not adequately reflect the effect of precipitation during the growing season.

Using a regression model to estimate yield indexes, given the required information is available, is definitely a possibility for future studies.

Here the indices of varietal change for the three major production areas are illustrated and a k-shift value is calculated from these indices. These shifts due to varietal improvement are assigned a monetary value to indicate the gains due to varietal improvement. The inability to fit the regression model, thus introduces the issues mentioned in the introduction and in the previous chapter with regard to the attribution of benefits to research and is addressed by means of an expert opinion survey, weights are assigned to research-induced shifts and shifts brought about by other factors. To address the shift in production area by excluding marginal land is addressed by using the experimental k-shift index. Finally, a conclusion is drawn with regard to the economic benefit of research into varietal improvement.

6.2 INDEX VALUES FOR VARIETAL IMPROVEMENT IN DIFFERENT PRODUCTION AREAS

The figures to follow indicate the contributions made by varietal improvement in the three production areas in South Africa. The k-shift was calculated for the three production areas, and later in the chapter benefits for the three regions are calculated.

Figure 6.1 indicates the index of varietal improvement calculated from the area weighted average experimental yields of all of the cultivars planted in the winter production area and a commercial index indicating growth in commercial yields in the winter production area calculated from data on production and area planted. These two variables are expressed as an index to better capture the growth in yields. Note that the commercial index is much higher than the experimental index and indicates that commercial yields have increased more, as a percentage, than experimental yields, probably largely due to production shifting away from marginal fields. Figure 6.1 indicates that experimental yields increased by 31% (1980-2007), with some years indicating above-normal yields. Commercial yields, however, increased by more than 173% after 1980. This can be attributed to a lower base year value for commercial yields due to much lower yields realised by producers in 1980. Figure 6.1 also suggests that commercial yield growth in the winter production area may also be attributed to other factors besides varietal improvement.

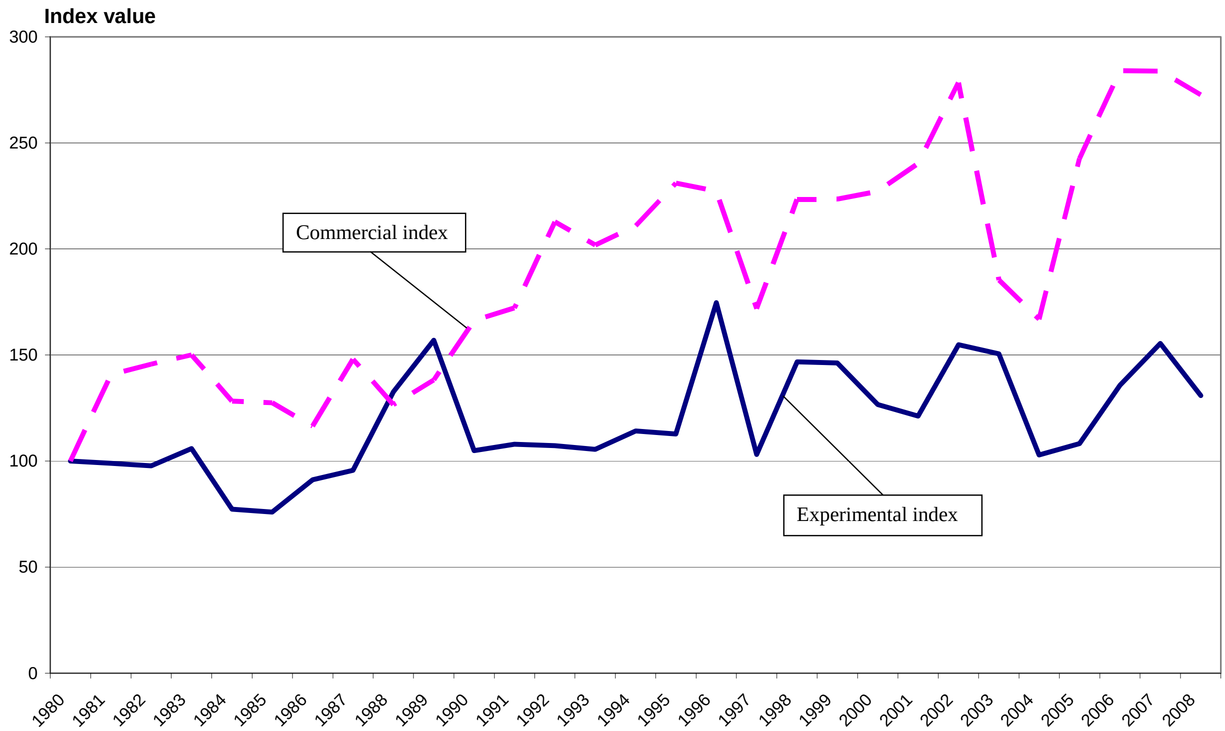


Figure 6.1: Index of varietal improvement vs. Index of commercial yield levels for the winter production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Note: Index: 1980 = 100

Figure 6.2 indicates the weighted average experimental and weighted average commercial yields of all of the varieties cultivated in the winter production area. From this figure it is clear that experimental yields have always been higher than commercial yields, but the growth in commercial yields has been higher than in experimental yields since 1980. This then explains the reversal of the two graphs in Figure 6.1 and Figure 6.2.

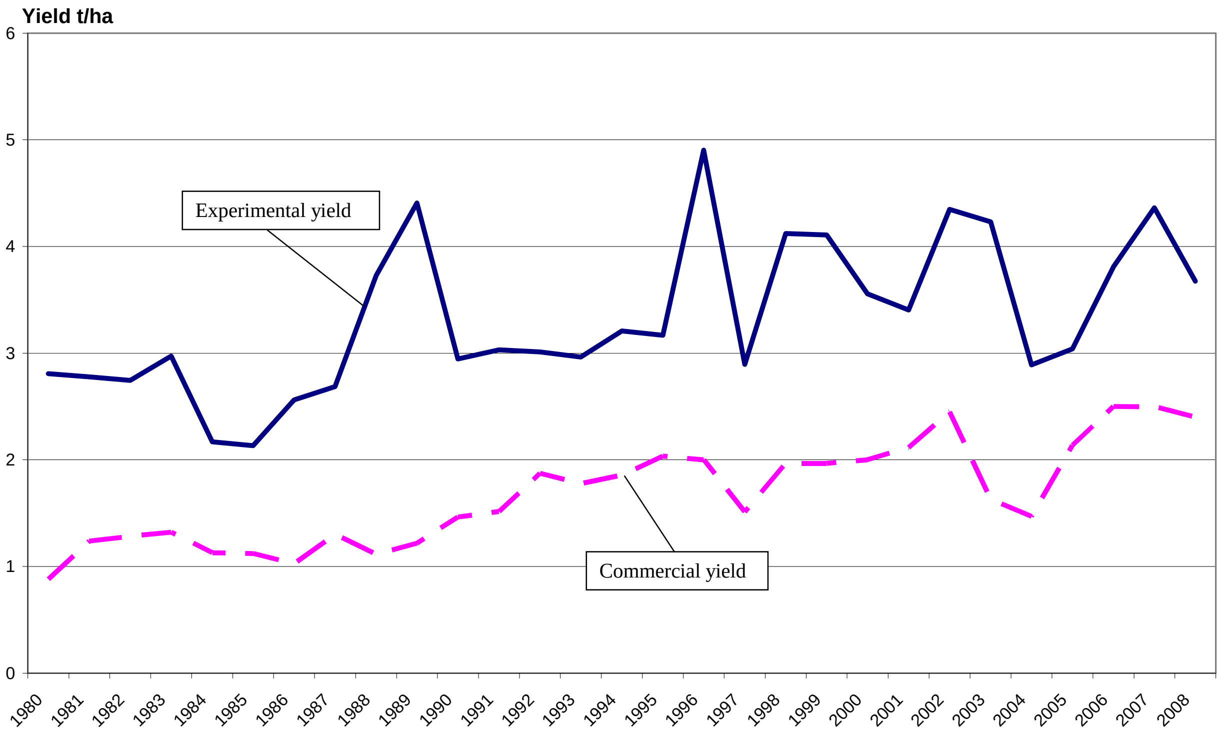


Figure 6.2: Weighted average experimental yields vs. Weighted average commercial yields in the winter production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Figure 6.1 and Figure 6.2 suggest that during the 1980s and 1990s, farming and irrigation practices in the winter production area improved dramatically, thus impacting positively on commercial yields in this production area. However, a very important question needs to be raised: To what an extent did these improved practices impact on experimental yields and should provision be made for increases in experimental yields due to improved practices? This important question is answered and discussed later in the chapter.

Figure 6.3 show the index of varietal improvement and the index of commercial yield levels for the dryland production area. It is clear that commercial and experimental yields have since 1980 followed a similar trend in yield growth. Over a period of 27 years, commercial yields increased by a total of 153% and experimental yields by 109%.

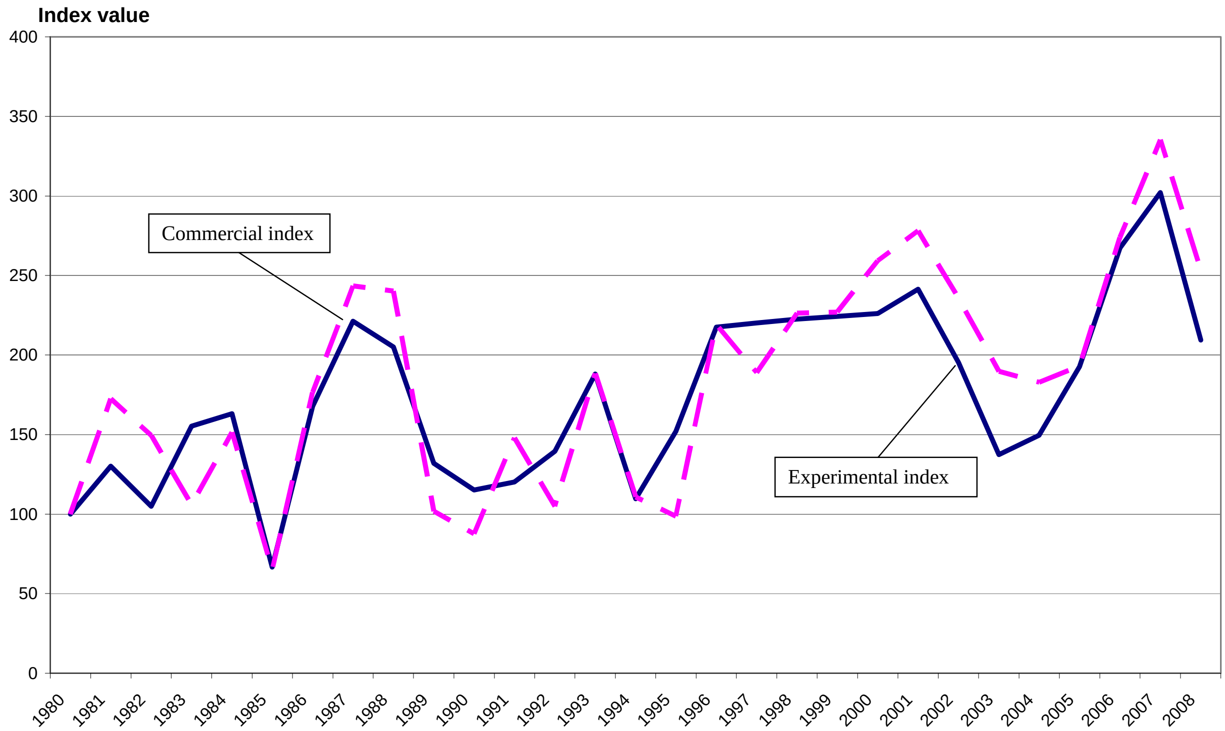


Figure 6.3: Index of varietal improvement vs. Index of commercial yield levels for the dryland production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Similar to the winter production area, experimental yields in the dryland production area have always been higher than commercial yields. This is clear in Figure 6.4 below. It is also noted that commercial and experimental yields in 1980 were roughly 0.79 t/ha and 1.42 t/ha respectively and increased to 2.65 t/ha for commercial yields and 4.29 t/ha for experimental yields in 2007. Also, Figure 6.3 and Figure 6.4 show that yield levels have been more erratic in the Free State production area, which can be attributed to the fact that wheat is mainly produced under dryland conditions. This increases the risk for yield variability dramatically. Despite this, varietal improvements have been captured by the commercial market in the sense that as new varieties were released and experimental yields grew, commercial yields followed the same growth pattern. Improved farming practices are to a lesser extent responsible for major yield increases in this dryland production area, but will be accounted for later in the chapter.

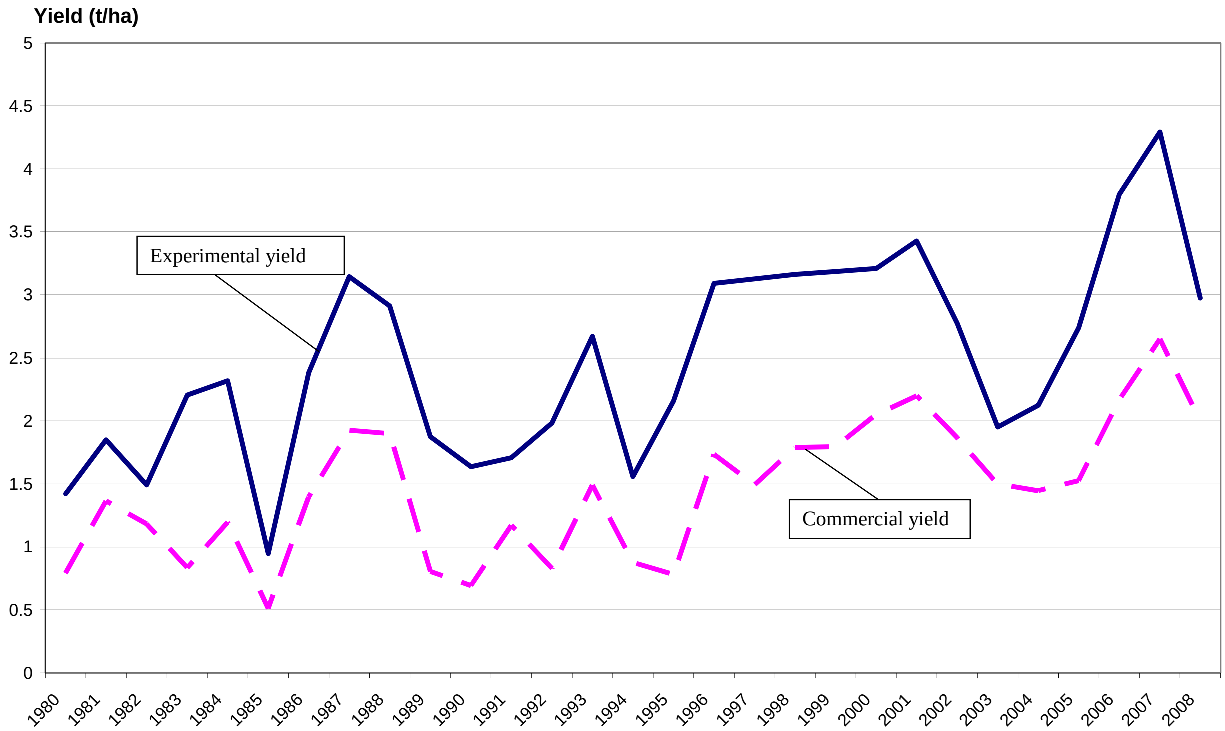


Figure 6.4: Weighted average experimental yields vs. Weighted average commercial yields in the dryland production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

The irrigation production areas have since the 1980s recorded remarkable growth in wheat yields. From Figure 6.5, it can be seen that experimental yields have increased by 194% while commercial yields have grown by 405% since 1980. It is argued that the shift from flood irrigation to a pivot irrigation system has had a major impact on yields in the irrigation production areas, on both an experimental and a commercial level. The introduction of new technology such as pivot irrigation is adopted by all of the role-players and provision has to be made for the growth in experimental yields due to improved irrigation practices.

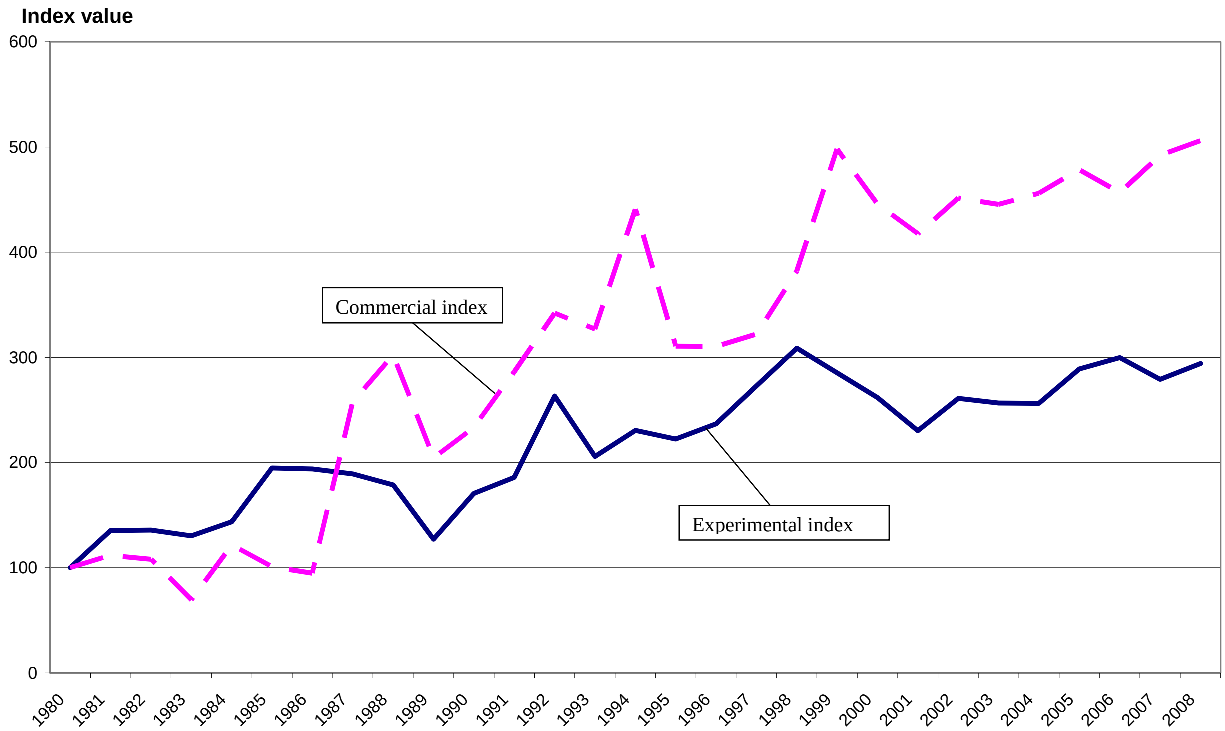


Figure 6.5: Index of varietal improvement vs. Index of commercial yield levels for the irrigation production areas

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

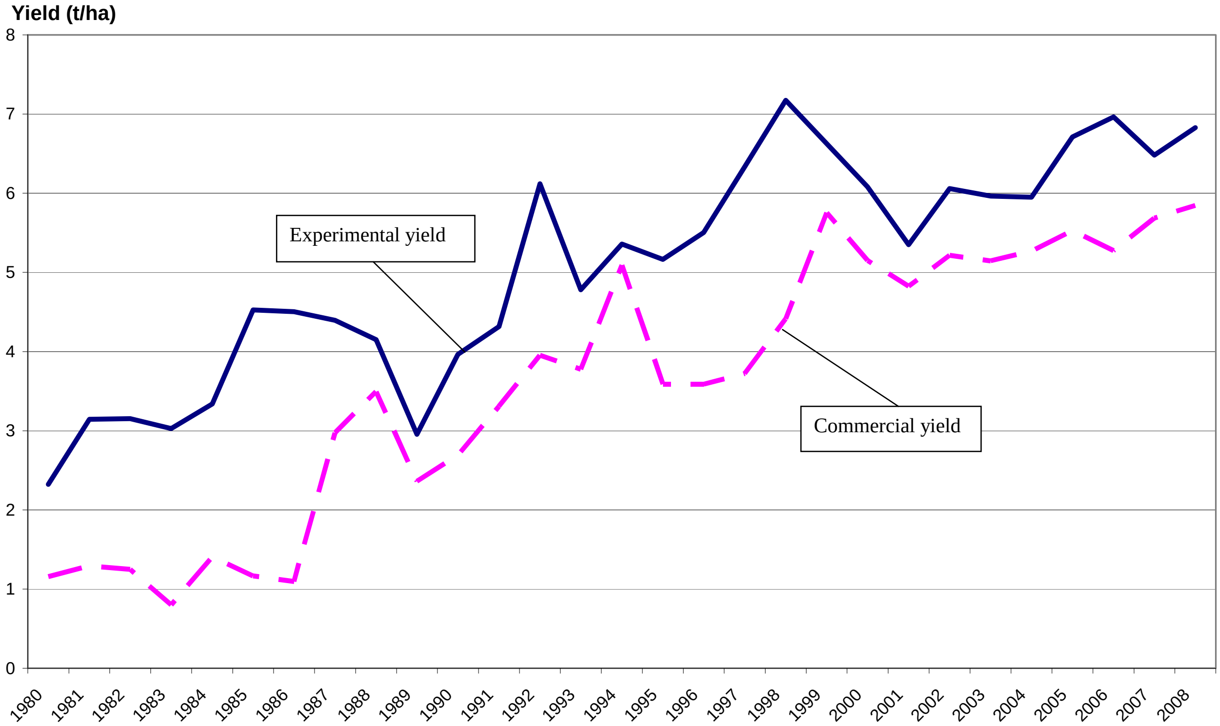


Figure 6.6: Weighted average experimental yields vs. Weighted average commercial yields in the irrigation production areas

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

By using the weighted average yield levels of the three production areas, weighted average experimental and commercial yields for South Africa could be calculated. Note that these yield levels were calculated by multiplying the weighted average yield levels of the four provinces by their share of South Africa's total wheat production. It is evident from Figure 6.7 that commercial yields in South Africa have grown more than experimental yields, as was suggested by the provincial figures. In total, South African commercial wheat yields grew by 209% after 1980, while experimental yields grew by 86%.

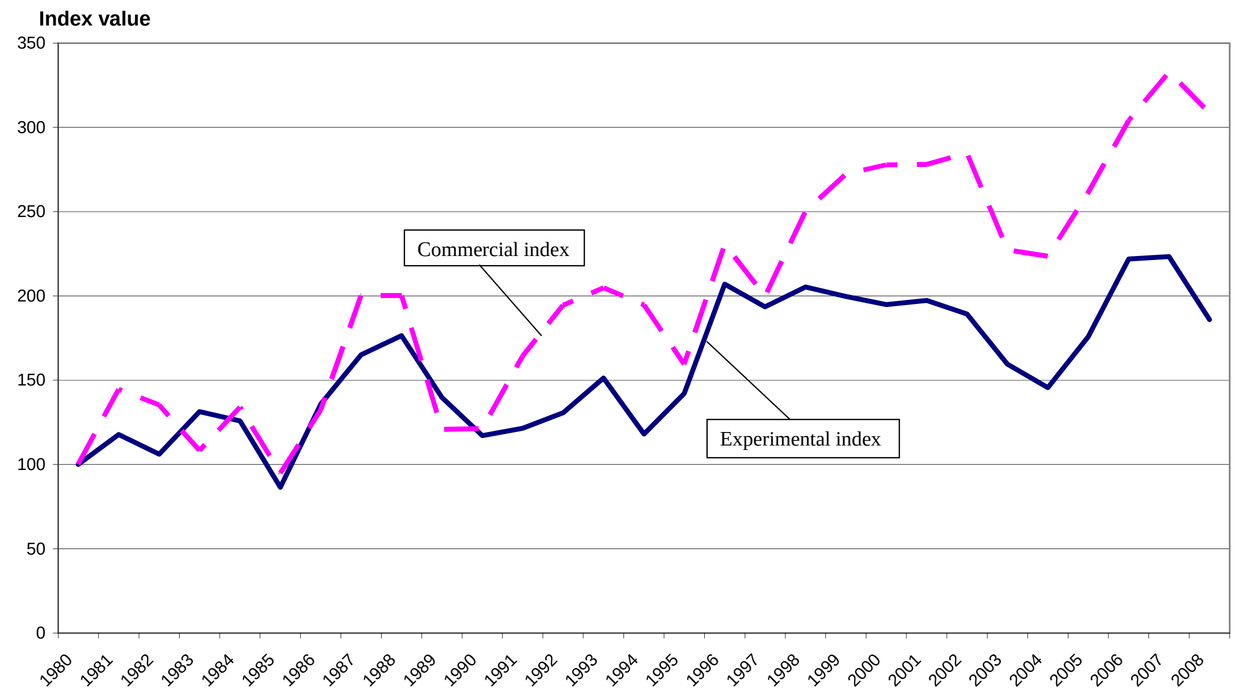


Figure 6.7: Index of varietal improvement vs. Index of commercial yield levels for South Africa

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Figure 6.8 further indicates that South African commercial wheat yields increased from a weighted average yield of 0.91 t/ha in 1980 to 2.79 t/ha in 2007 and that experimental wheat yields increased from a weighted average yield of 2.14 t/ha in 1980 to 4.65 t/ha in 2007.

Figure 6.8 is the perfect illustration of the South African wheat producers' increasing efficiency. Note how the gap between commercial and experimental yields has gradually narrowed over the last 27 years and especially since 1997. This confirms the shift in efficiency as a result of the producers' ability to better utilise resources and their application of better farming and irrigation practices. Concealed in the major yield increases on a commercial level are the gains due to varietal improvements. The percentage growth of experimental yields is thus reflected in the commercial yields, but only as a percentage of the total increase in commercial yields.

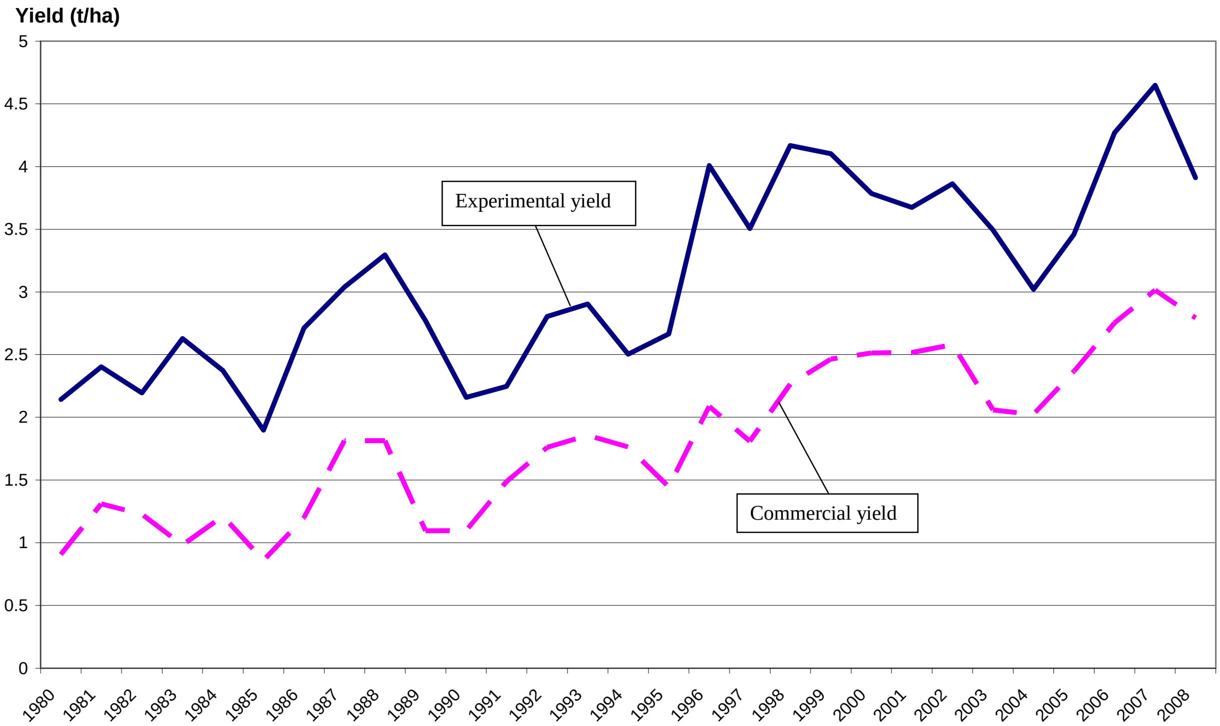


Figure 6.8: Weighted average experimental yields vs. Weighted average commercial yields in South Africa

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

6.3 K-SHIFT VALUES AND CALCULATION OF BENEFITS

It is of great importance to note that in this study, experimental yields and thus the growth in experimental yield levels were used to calculate the k-shift values as explained in Section 5.2.2.3. Not only are the yields of all of the cultivars commercially planted available from experimental trials, but experimental yields are also a more reliable source of yield levels due to lower variability brought about by better management practices used in experimental trials.

From the index of varietal improvement illustrated in selected figures above, the actual k-shift was estimated by calculating the growth in the index value relative to the base year (1980). Note that the adoption of new varieties already captured in the indexes as the weighted average yields of all of the varieties was calculated by multiplying the experimental yield for each year with the proportion of area planted to the variety. As a result, both the growth in yield and the adoption of new cultivars are captured in the weighted average yield, and thus the index, for each province.

Figure 6.9 shows that for a few years after the base year (1980), the k-shift that was recorded was negative, suggesting a negative contribution with regard to varietal improvement in the winter production area. This can be attributed to new cultivar releases coinciding with a dryer than normal production year. As a result a lower yield was realised and, due to the fact that the yields are weighted by the area planted to capture adoption, a lower weighted yield was recorded. This was also the case in 2004 and 2005 when abnormally low yields were recorded in the Swartland and Rûens production areas. As a result, the weighted average yields for the whole winter production area were lower than recorded in previous years.

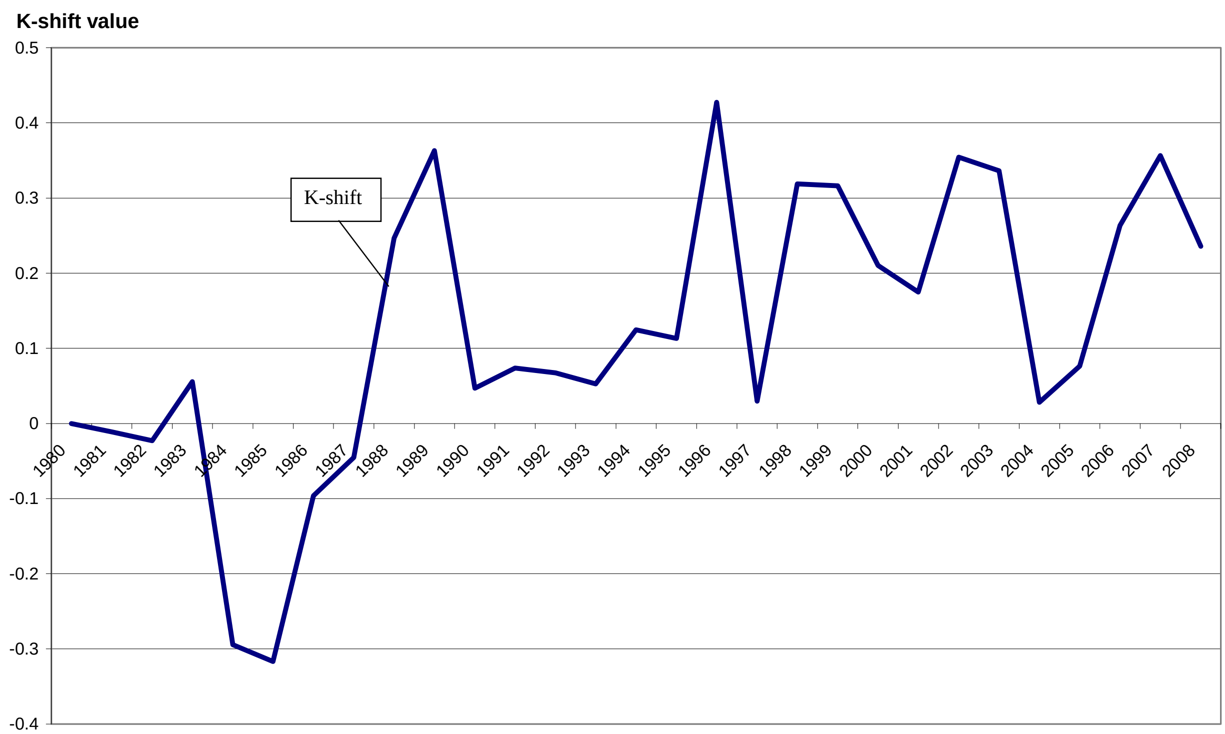


Figure 6.9: K-shift for the winter production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Revisiting the literature cited in Chapter 5, an estimate can be made of the benefits due to the increase in yield (k-shift). Following Equation 5.12, the benefits can be calculated by multiplying the k-shift value with the price of wheat and the quantity produced in the given area.

Table 6.1 shows the yearly k-shift value for the winter production area, the real basic price for wheat, the annual production in the winter production area, and the benefits realised. The total benefit for the winter production from 1980 until 2007 is estimated at R2.625 billion in real terms.

Table 6.1: Calculation of benefits with the calculated k-shift values: winter production area

Year	Real Wheat Price (Rand)*	Quantity**	K-shift value***	Benefits (Rand)
1980	R 2,273.69	622,664	0.00	R 0
1981	R 2,320.17	861,000	-0.01	R -16,107,815
1982	R 2,488.53	914,000	-0.02	R -37,692,775
1983	R 1,990.08	911,936	0.06	R 74,271,529
1984	R 1,940.25	919,392	-0.29	R -430,361,787
1985	R 1,805.61	963,073	-0.32	R -442,325,983
1986	R 1,788.29	928,991	-0.10	R -124,310,763
1987	R 1,678.75	1,102,076	-0.05	R -74,659,141
1988	R 1,273.03	1,026,956	0.25	R 277,437,259
1989	R 1,406.37	883,411	0.36	R 383,430,015
1990	R 1,385.25	734,083	0.05	R 40,244,783
1991	R 1,499.77	735,632	0.07	R 68,701,256
1992	R 1,499.22	921,509	0.07	R 80,118,095
1993	R 1,420.04	1,019,886	0.05	R 64,565,408
1994	R 1,245.64	1,140,693	0.12	R 149,920,757
1995	R 1,241.69	1,123,234	0.11	R 133,785,894
1996	R 1,310.52	806,000	0.43	R 451,417,475
1997	R 1,026.19	605,000	0.03	R 18,414,939
1998	R 941.59	590,000	0.32	R 177,033,457
1999	R 1,045.22	610,000	0.32	R 201,670,559
2000	R 1,165.35	691,000	0.21	R 169,159,619
2001	R 1,320.38	730,000	0.17	R 168,564,713

Year	Real Wheat Price (Rand)*	Quantity**	K-shift value***	Benefits (Rand)
2002	R 1,321.08	891,800	0.35	R 417,185,315
2003	R 1,147.28	530,000	0.34	R 204,357,230
2004	R 830.70	520,000	0.03	R 12,147,217
2005	R 746.55	645,000	0.08	R 36,742,703
2006	R 1,025.38	730,000	0.26	R 197,078,745
2007	R 1,464.50	812,000	0.36	R 423,808,422
Total Benefits				R 2,624,597,129

Source: Author's own calculations based on data from the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

Notes: *Abstract of Agricultural Statistics (Directorate: Agricultural Statistics, 2009). Deflated with GDP deflator (SARB,2009)

**Quantity produced in the winter production area (NCEC, 2009)

***Calculated by using Equation 5.11

Once again, mention must be made of the fact that production under dryland conditions can cause yields to be more unstable, as is the case in the dryland production area. As mentioned previously 1985 was an exceptionally poor rainy season, which contributed directly to the smaller shifts in this year.

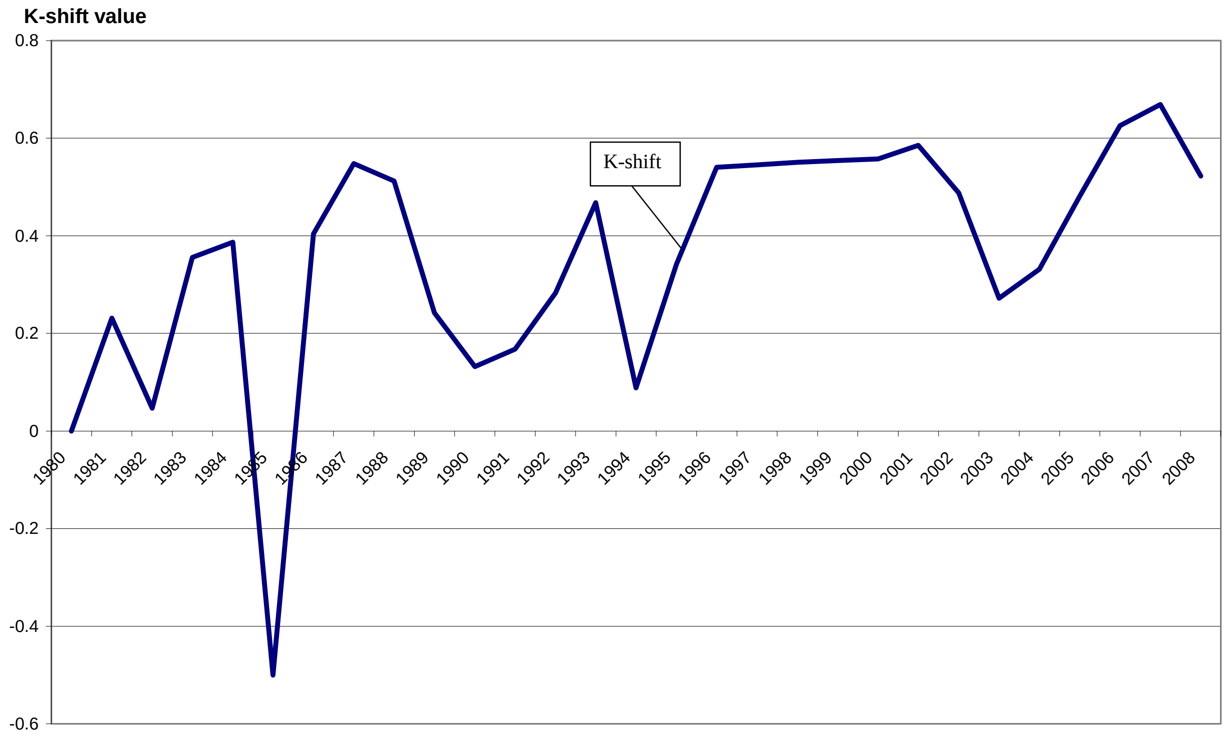


Figure 6.10: K-shift for the dryland production area

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

The same method used above for the calculation of benefits for the winter production area was used for all of the provinces. The k-shift figures are presented in the figures to follow and the tables with the estimated benefits for the remaining provinces and for South Africa can be found in Annexure A. From these tables it can be seen that the benefit for the dryland production area is estimated at R12,720 billion and for the irrigation production area at R7,945 billion. The total benefit to South Africa is estimated at R23,289 billion in real terms

The irrigation production area is perhaps the most consistent in terms of yield growth, as can be seen in Figure 6.11. For the years 1988 and 1989, a dramatic reduction in yield levels was recorded and was reflected in both experimental and commercial yields.

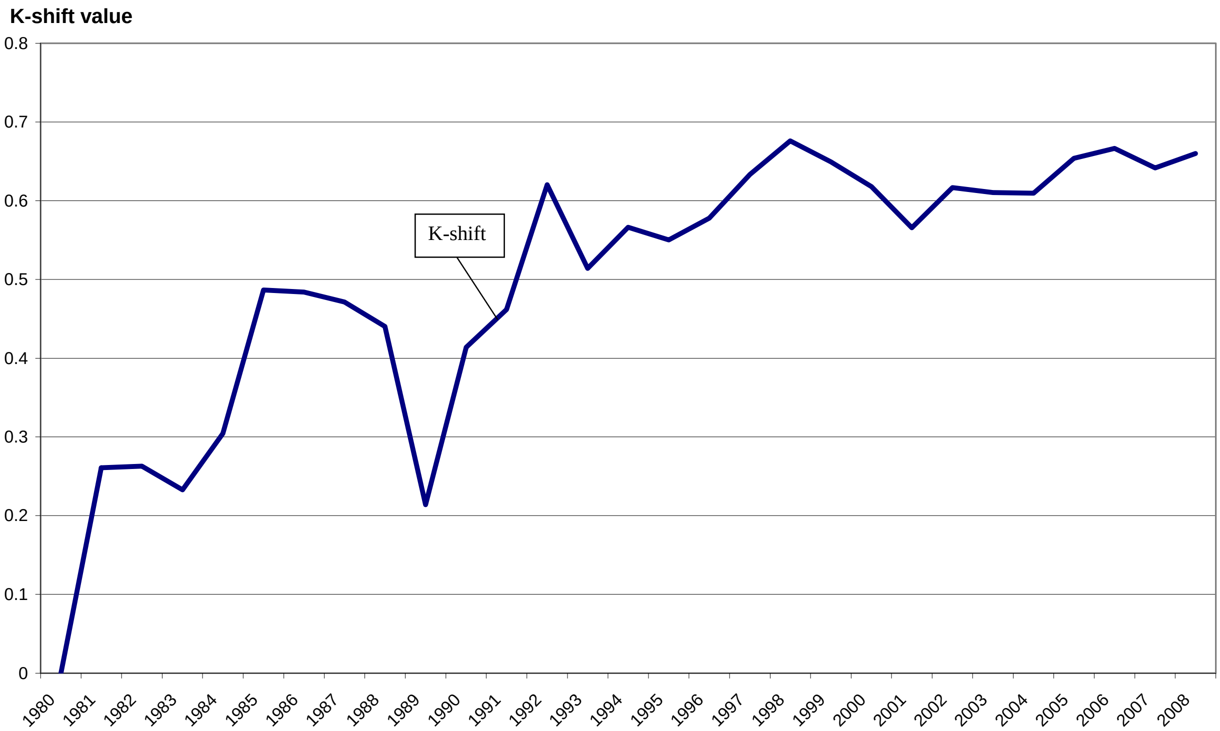


Figure 6.11: K-shift for the irrigation production areas

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Figure 6.12 shows the total k-shift for South Africa. This k-shift was calculated by weighting the three production areas' k-shifts against their share of total wheat production in South Africa. The weighted average experimental yield for South Africa, from Figure 6.8, was thus not used to estimate a separate k-shift value for South Africa but rather an aggregated k-shift value of the three production areas. This ensured that the growth in yield levels contributed by the three production areas was captured rather than general yield levels.

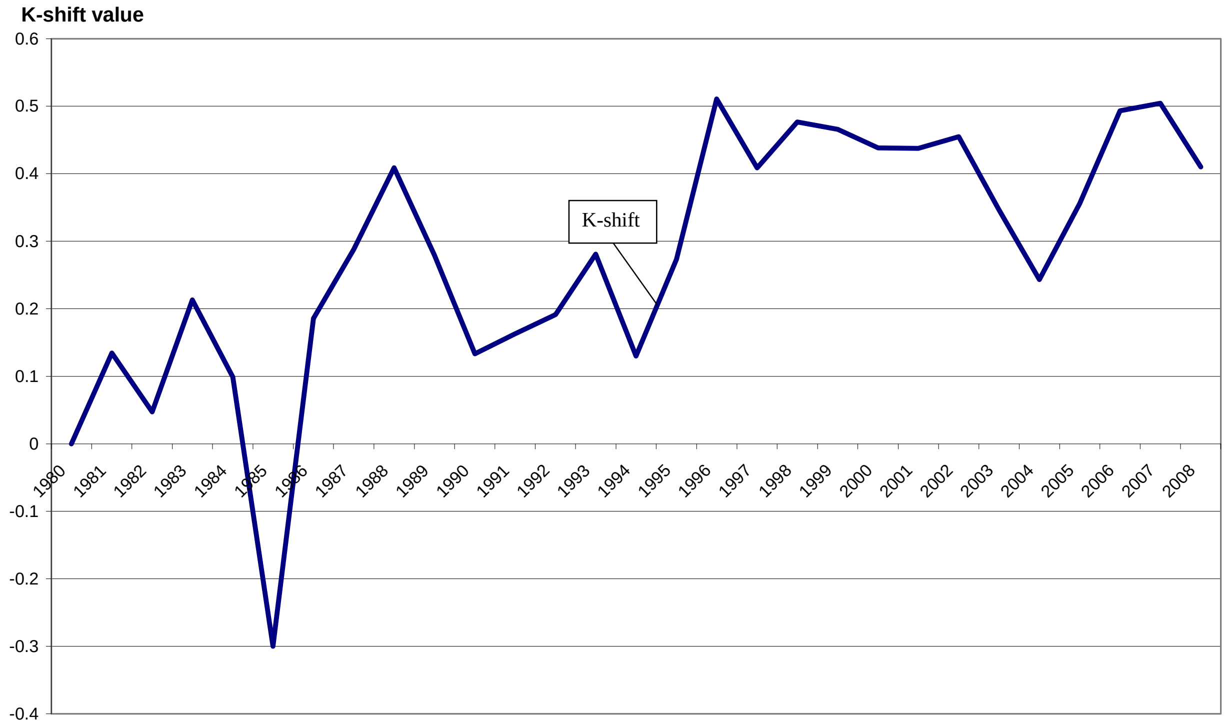


Figure 6.12: K-shift due to varietal improvement in South Africa

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Figure 6.9 to Figure 6.12 provide the k-shift values as calculated from the weighted average experimental wheat yields. Section 5.22 stated that if a full set of experimental yields by region for every new variety that was developed and adopted is not available, a regression model can be used to estimate the data, as in Pardey *et al.* (2004). The k-shift results obtained by Pardey *et al.* (2004) from a regression model are presented in Figure 6.13. The k-shift is for upland rice for various states in Brazil and it is noted that the k-shifts obtained from estimating data with a regression model are a lot smoother and with less variability than in the k-shifts obtained from using actual data. The magnitude of the k-shifts is also a lot smaller than in this dissertation due to the fact that a regression could be run and the weather variable could account for weather attributes. The two aforementioned differences can mainly be attributed to adverse weather conditions contributing towards the at times extreme variability, and a longer observation period resulting in larger k-shifts.

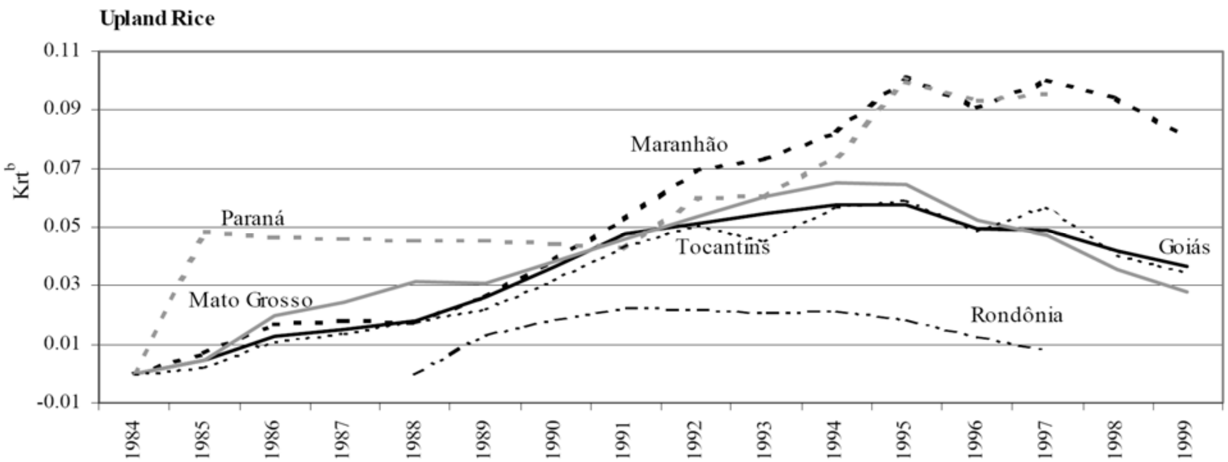


Figure 6.13: K-shift results obtained from a regression model

Source: Pardey et al. (2004)

6.4 ESTIMATE OF BENEFIT ATTRIBUTION

The figures presented in the previous section indicated the growth in experimental yields in the four major production areas. As mentioned earlier in the chapter, not all of the growth in both experimental and commercial yields can be attributed to varietal improvement alone and thus the impact that improved farming and irrigation practices has had on wheat yields in South Africa needs to be taken into consideration. Therefore, Section 6.4 provides a discussion of the attribution of benefits due to growth in wheat yields to the different factors identified.

6.4.1 Attribution of Yield Growth to Varietal Improvement

In the first part of this chapter, different questions were raised regarding the attribution of yield increases to varietal improvement research and other relevant sources. The issue of the counterfactual scenario ("with and without scenario"), as well as the difficulty of estimating these values, was also mentioned. Attributing these benefits to the various sources is at times a guessing game and no real method exists to assist with this.

The best option adopted for this dissertation was to rely on the opinions of experts in the wheat-breeding industry in terms of the attribution of the calculated benefits to the various sources. Three sources of yield increases were identified by the various experts:

- Varietal improvement due to research
- Better irrigation practices in irrigated areas
- Better farming practices in all of the production areas (cultivation, pest management, moisture conservation in dryland areas, etc.)

The opinions of various experts in different areas of the wheat sector were sought to assist with the attribution of the calculated benefits to these three factors. Experts agreed that not all the benefits can be attributed to varietal improvement despite the fact that only growth in experimental yields was used to calculate the benefits. In contrast to commercial yield growth, growth in experimental yields was to a lesser extent influenced by the abovementioned factors. The following conclusions were drawn with regard to the attribution of benefits to the various possible sources:

It was concluded that better irrigation and farming practices and varietal improvement in irrigated areas made an equal contribution to the increase in experimental yields. As a result, 50% of the growth in yields was attributed to both varietal improvement research and better irrigation and farming practices. A major contributor to increased yields was the movement away from flood irrigation and the utilisation of pivot irrigation systems. Note that these improved practices were also utilised in the experimental trials and were thus also reflected in experimental yield growth. Consensus was thus reached that only 50% of the gains in yields could be attributed to varietal improvement research in the irrigation production areas.

Better farming practices contributed to a lesser extent in the dryland production areas, and varietal improvement made the largest contribution to growth in experimental yield levels. It was agreed that 65% of the benefits were as a result of varietal improvement due to research and the remaining 35% due to improved farming practices and moisture conservation.

It is also important to note that due to the manner in which data was reported, the Northern and Eastern Cape production areas, mainly irrigation areas, were also included in the winter production area for 1980 – 1995 but accounted for in the benefit attribution. The share of area produced in the Western Cape was used to calculate the benefits for the winter production areas while the Eastern and Northern Cape production areas' benefits was added to the irrigation production area. Thus, a share of the benefits of the winter production area for these years was added to the benefits of the irrigation areas. This was done by calculating the hectare share of the three areas, and basis this attribute benefits to the irrigation production areas.

The results obtained from the expert opinions can be seen in Table 6.2 and it can be noted that for the winter production area, a weight of 60% of the benefits was attributed to varietal improvement and 40% to improved irrigation practices (especially in the Northern and Eastern Cape) and better farming practices in general (Western Cape). This indicates an amount of R1,575 billion attributable to varietal improvement and R1,050 billion attributable to these other factors mentioned above. For the dryland production area, 65% of the benefits could be attributed to varietal improvement with 35% attributed to other factors such as better utilisation of soils, better farming practices in general, and moisture conservation. This amounts to R8,268 billion attributed to varietal improvement and R4,452 billion attributed to other factors.

For the irrigation production area, 50% of the benefits could be attributed to varietal improvement and the other 50% to better irrigation practices and farming practices in general. Thus, benefits due to improved practices and varietal improvement amount to R3,972 billion respectively.

By adding up these totals, a total varietal improvement benefit amount for South Africa can be calculated. This figure adds up to be R13,815 billion, which is roughly five times the gross value of production in 2007. It is important to note that all of these figures are in real terms.

6.4.2 Attribution of Benefits to Different Role-Players

Following a similar approach to Pardey *et al*. (2004) and revisiting Equation 5.1.3 in Section 5.2.2.3, the benefits attributable to the relevant agencies in the wheat-breeding industry can be seen in Table 6.2.

Table 6.2: Benefit attribution to the leading wheat breeders in cultivar improvement research

Benefits from varietal improvement: 1980-2007				
Region	**ARC-SGI (‘000)**	**Sensako ('000)**	**Pannar ('000)**	**Total ('000)**
Winter production	R 965,231.81	R 606,844.53	R 2,681.93	R 1574,758.28
Dryland	R 6,116,152.56	R 1,572,895.14	R 578,861.67	R 8,267,909.37
Irrigation	R 1,382,477.42	R 2.542,276.67	R 30,530.90	R 3,955,284.99
Total	**R 8,463,861.80**	**R 4,722,016.34**	**R 612,074.50**	**R 13,797,952.64**
Benefit Share	61.34%	34.22%	4.44%	100.00%
Total Hectares Planted	21,776.88	14,586.28	905.20	37,268.36

Source: Author’s own calculations based on production and price data supplied by the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

From Table 6.2 above it can be noted that the ARC-SGI held the greatest share of benefits attributable to varietal improvement and had more hectares planted to their varieties between 1980 and 2007 than any other seed company. Sensako contributed more benefits in the irrigation areas with the ARC-SGI contributing the most in the dryland and winter production areas.

The ARC-SGI / public institutions were responsible for 61.34% of the benefits due to varietal improvement, with 58.43% of the total area planted in South Africa in the period 1980-2008 being planted with cultivars developed by the ARC-SGI / publicly. Sensako’s cultivars were responsible for 39.14% of the area planted between 1980 and 2007, accounting for 34.22% of the total benefits. Pannar, since their introduction into the market in the mid 1990s, was responsible for 2.43% of the total area planted and accounted for 4.44% of the total benefits due to varietal improvement during that time period.

6.4.3 Counterfactual Scenario

Revisiting the counterfactual scenario described in Chapter 5 and the criticism of the benefits of varietal improvement mentioned in Section 6.1, a counterfactual scenario can easily be described. In the first part of this chapter, mention is made of Morris and Heisey (2003), who stated that a common mistake made by impact assessment studies is to assume that yields would have remained that same as in the base year in the absence of research. From a South African perspective, spill-over effects from other sources to South Africa would have been limited, as South African trade was influenced by sanctions. As a result, South Africa would have had little opportunity to obtain better genetic material in the counterfactual scenario. Assuming no spill-over effects from other countries is irrational, and an estimate of the percentage by which yields would have grown in the absence of research has to be made. From Table 6.3 the counterfactual scenario can be estimated by attributing a percentage of the growth in yields or benefits to the spill-over effects. Estimating this percentage value is difficult, because there is no way of knowing how yields would have increased due to spill-over effects. If it is assumed that yields would have increase by 20% due to spill-over effects, which is a fair assumption considering that South African trade was negatively influenced by sanctions, the benefits attributed to varietal improvement must only be adjusted by this percentage value. Thus, using 20% as a good estimate, the benefits due to varietal improvement are as follows:

Table 6.3: Benefit attribution to varietal improvement assuming a 20% spill-over effect

Benefits from varietal improvement, improved practices and spill-over effect				
Region	**Varietal improvement (‘000)**	**Improved practices (‘000)**	**20% Spill-over effect (‘000)**	**Total ('000)**
Winter production	R 1,049,838.85	R 1,049,838.85	R 524,919.43	R 2,624,597.13
Dryland production	R 5,723,937.26	R 4,451,951.20	R 2,543,972.11	R 12,719,860.57
Irrigation	R 2,383,458.54	R 3,972,430.90	R 1,588,972.36	R 7,944,861.81
Total	R 9,157,234.65	R 9,474,220.96	R 4,657,863.90	R 23,289,319.51
Share	39.32%	40.68%	20.00%	100.00%

Source: Author’s own calculations based on production and price data supplied by the Directorate: Agricultural Statistics (2009) and the NCEC (2009), as well as expert opinions
Note: Values in the table are inflation adjusted, thus in real terms.

Table 6.3 shows that benefits from varietal improvement are still substantial and account for 39.32% of the total benefits of growth in experimental yield levels in South Africa. R9.2 billion of the benefits due to experimental yield increases can thus be attributed to varietal improvement, R9.5 billion to improved practices and R4.7 billion to spill-over effects from other countries.

6.5 CONCLUSION

Chapter 6 is a good example of the possible gains due to varietal improvement research in an industry and provides confirmation of the importance of new cultivar releases. The question of whether all of the benefits due to yield growth on both an experimental and a commercial level can be attributed to varietal improvement alone, is answered in the discussions above. The issue of a counterfactual or "without" research scenario was also accounted for and a separate benefit calculation was done for this scenario.

From Chapter 6 it can be noted that the ARC-SGI / public institutions have held the majority of the share of benefits in the wheat-breeding industry and accounted for the largest area planted to their cultivars. Sensako, although the current market leader in terms of market share, holds the second largest share of benefits and area planted, followed by Pannar. The ARC-SGI currently holds the largest market share in only one province, the Free State, with Sensako dominating the remaining eight provinces.

Chapter 6 concludes that the returns on investment in the South African wheat-breeding industry are exceptional, with benefits amounting to R13.8 billion in real terms assuming no genetic spill-over effects from other countries. Should these spill-over effects be taken into consideration, the benefits of varietal improvement would amount to R9.2 billion.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

On the basis of the results reflected in the analysis in Chapter 6, various conclusions can be drawn with regard to varietal improvement in general and the importance of varietal improvement research in an agricultural R&D setting. Despite the fact that similar studies have been criticised for their relevance and accuracy with regard to the estimation of research benefits, their significance cannot be overlooked. Impact assessment studies in many agricultural sectors will continue to be the foundation of priority setting in agricultural research and will forever assist in the promotion of investment in agricultural R&D.

To conclude, this chapter consists of a brief overview of the dissertation and the various conclusions drawn throughout the different chapters. Recommendations with regard to varietal improvement initiatives are made for both the private and public sectors, and possibilities for future studies are mentioned.

7.2 CONCLUSIONS: PRIVATE AND PUBLIC SECTOR BENEFITS

The following section reports the final results of the analysis. The market shares of the different role-players are reported for South Africa, and their current as well as future market situations are discussed.

7.2.1 Private Sector Benefits: Sensako

Two key role-players were identified in the analysis as being the most prominent private sector agencies: Sensako and Pannar. For many years Sensako has been contributing towards varietal improvement and this is evident in the cultivar production data obtained from the Wheat Board and the SAGL. The adoption of Sensako cultivars has followed an upward trend since the 1980s, with its market share gradually increasing. This is especially true in the

Swartland and Rûens production areas located in the Western Cape. No other institution is as prominent in these areas as Sensako.

The winter rainfall production area is not the only area where Sensako is currently a major force to be contended with. Sensako is currently dominant in all of the irrigation areas, with only the Free State, a dryland production area, being dominated by the ARC-SGI in terms of market share. Sensako's market share has, however, been increasing in the dryland production area since 2007.

Based on the empirical evidence from the analysis, it can be concluded that Sensako is currently the dominant force in varietal improvement in South Africa and will continue to play a very important role in terms of developing cultivars suited to the diverse South African conditions. Considering South Africa in total, Sensako's market share is currently estimated to be 64.19%.

7.2.2 Private Sector Benefits: Pannar

Pannar's first varietal release occurred only in the mid-1990s, with a number of cultivars having been released since. Pannar's largest market share is in the dryland production areas, especially the Free State. Pannar has, however, released cultivars in the irrigation areas, but does not feature as prominently as in the dryland areas.

From the market share results obtained for 2007, it is evident that Pannar's market share is gradually increasing in some provinces, but Pannar still faces numerous challenges in further increasing its market share.

For South Africa in total, Pannar's market share is estimated at 11.48% and has recorded a positive growth in market share from the previous production year. It is anticipated that Pannar will continue to increase its market share, both in the irrigated and dryland production areas.

7.2.3 Public Sector Benefits: ARC-SGI

From the 1980s until the mid-1990s, cultivars released by the ARC-SGI (public institutions) dominated the wheat production landscape in South Africa. The ARC-SGI has, however, lost its dominance as prime supplier of genetic material to the South African wheat sector in some of the key provinces.

For South Africa in total, the ARC-SGI's current market share is estimated at 24.33%, bearing in mind that the ARC-SGI (public institutions) is coming from a market share of 63.94% in 1980 (Author's own calculations based on data supplied by the Wheat Board, 1997).

Figure 7.1 concludes the findings for the South African wheat industry with the illustration of the market share of the respective role-players. From this illustration the major decrease in area planted to ARC-SGI cultivars can be seen, but at the same time, looking at the total shaded area of the ARC-SGI, it can be seen that the ARC-SGI accounts for the largest area planted to its cultivars as from 1980. The shift in market share from the ARC-SGI to the private sector can also be seen.

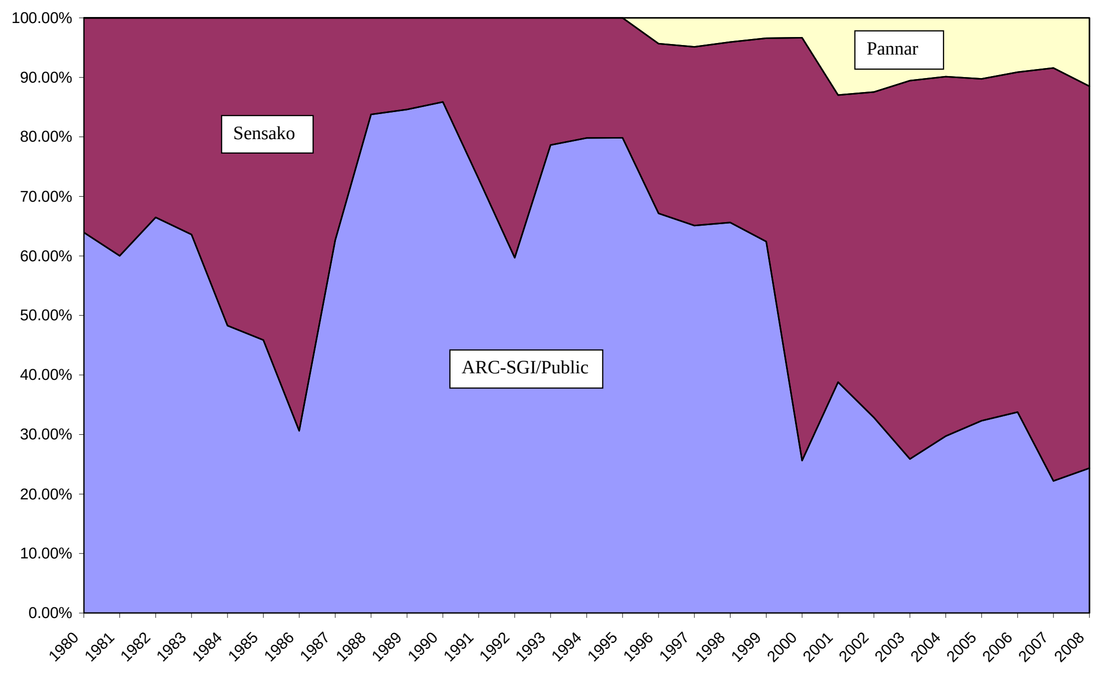


Figure 7.1: Market share of different role-players in the South African wheat industry: 1980-2008

Source: Author's own calculation based on cultivar production data supplied by the SAGL (2009) and the Wheat Board (1997)

7.3 RECOMMENDATIONS: PRIVATE AND PUBLIC SECTORS

7.3.1 Private Sector

The positive growth in the adoption of wheat cultivars released by private wheat breeders in the South African wheat industry provides the necessary evidence that private wheat breeders are allocating substantial resources to their research initiatives. This is particularly true for Sensako. Not only are the private wheat breeders spending considerable funds on research, but they are also implementing the correct marketing techniques to ensure that their new varieties are planted in the different production areas. Private sector wheat breeders will continue to be at the forefront of varietal improvement and will continue to ensure optimal adoption of their varieties in all of the production areas.

Sensako in particular will continue to be the dominant force in varietal improvement as long as they continue to attend to the following three factors.

- Using the best genetic material possibly obtainable
- Strictly following a detailed breeding and crossing policy/programme
- Ensuring the best possible marketing plan in all of the production areas

7.3.2 Public Sector

The ARC-SGI has a long and proud history of varietal improvement and has over the years made significant contributions to the genetic pool of wheat varieties in South Africa. Despite this, the ARC-SGI has lost a great deal of the market share since the 1980s, and recuperative measures must be instituted to ensure that the ARC-SGI is reinstated as the dominant force in varietal improvement in South Africa. From the results of the dissertation, a few recommendations can be formulated to assist in this process.

Effective marketing: The fact that the ARC-SGI does not market their own wheat cultivars contributes towards their diminishing market share in all of the production areas and especially the Western Cape. Thus, marketing initiatives similar to that instituted by All-gro, a division of the MGK Group, must be put in place in all of the production areas. All-gro has the right to market the majority of the ARC-SGI's irrigation cultivars in the Limpopo, North West, Mpumalanga, Gauteng and Northern Cape provinces, leading to an increase in the adoption of ARC-SGI cultivars in these areas (See Chapter 4). Similar initiatives need to be put in place in all of the production areas.

Special emphases on the Western Cape: The Western Cape production area was once dominated by the cultivars of the ARC-SGI / public institutions, but market share has shifted completely to the private wheat breeders. Although ARC research stations are located countrywide and in the Western Cape, this decrease in market share can mainly be attributed to poor marketing in this important wheat production area. The ARC-SGI has the potential to develop cultivars for these areas and has done so in recent years. These cultivars are, however, not planted in the Western Cape due to poor marketing.

Maintaining current market share: This is especially true for the dryland production area where the ARC-SGI still holds the largest market share. The continual release of new dryland cultivars for the Free State will ensure that the market share in this production area is maintained. This is possible due to geographical expertise, being situated in the Free State Province (Bethlehem).

Investment allocation: Research into varietal improvement needs to be demand driven to ensure that industry requirements are met. This can be done by shifting breeding goals to be more in line with what the wheat industry wants (better quality, for example). This must be done in correlation with current breeding goals to ensure that no varietal improvement in any area is lost.

Collaborative efforts: Collaborative efforts need to be put in place with both national and international wheat breeders to ensure not only the sharing of expertise in cultivar development and distribution, but also the use of potential genetic material in domestic breeding projects. Efforts must also be put in place for skills development in wheat breeding, thus ensuring that skilled wheat breeders remain at the ARC-SGI to assist with its research programmes.

7.4 CONCLUDING REMARKS

The recommendations above are formulated purely to promote the adoption of the ARC-SGI's cultivars and consequently increase the ARC-SGI's market share in the wheat industry. These recommendations can, however, only be achieved by increased investment in this form of R&D. All of the recommendations above rely heavily on the amount of funds allocated to research initiatives and projects and can only be realised if expenditure on research into varietal improvement and small grains is increased.

It can therefore be concluded that in order for the ARC-SGI to continue to be competitive in small grain research and more specifically in wheat varietal improvement, the promotion of investment is needed. An increase in funds allocated to small grain research will enable the ARC-SGI to sustain the current market share, improve current marketing strategies, regain a competitive market share in the Western Cape, and initiate collaborative efforts that will ultimately lead to improved wheat varieties and adoption.

From the results obtained in the dissertation, it can be concluded that the benefits of varietal improvement research in the South African wheat industry are significant, and in the case of the ARC-SGI / public wheat breeders, the benefits outweigh the costs dramatically. These findings indicate the possible returns on investment in various other areas of agricultural R&D. Despite the fact that impact assessment studies and the calculation of the benefits derived from varietal improvements have at times come under criticism, the results obtained in the dissertation confirm once again the benefits of varietal improvement, thus promoting the accountability of similar research initiatives.

REFERENCES

ALSTON, J.M., G.W. Norton and P.G. Pardey. 1998. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Cambridge: CAB International.

BARKLEY, A.P. 1997. *Kansas wheat breeding: An economic analysis, 1997 (Report of Progress 793)*. Manhattan, KS: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. [Online] Available from: http://www.ksre.ksu.edu/library/crpsl2/srp793.pdf [Downloaded: 2009-10-15].

BRENNAN, J.P. 1984. Measuring the contribution of new varieties to increasing wheat yields, 1984. *Review of Marketing and Agricultural Economics*, 52(3): 175-195. [Online] Available from: http://ageconsearch.umn.edu/bitstream/12281/1/52030175.pdf [Downloaded: 2009-10-15].

CeSTII (CENTRE FOR SCIENCE, TECHNOLOGY AND INNOVATION INDICATORS). 2009. *National Survey of Research and Experimental Development, 2007/08.* Pretoria: Department of Science and Technology. [Online] Available from: http://www.hsrc.ac.za/CCUP-RnD-7.phtml [Downloaded: 2010-01-26].

DIRECTORATE: AGRICULTURAL STATISTICS. 2009. *Abstract of Agricultural Statistics*. Pretoria: National Department of Agriculture.

DIXON, J.; NALLEY, L.; KOSINA, P.; LA ROVERE, R.; HELLIN, J. & AQUINO, P. 2006. Adoption and economic impact of improved wheat varieties in the developing world. *Journal of Agricultural Science*, 114: 489-502.

FAO (FOOD AND AGRICULTURAL ORGANISATION OF THE UNITED NATIONS). 2009. *FAOSTAT*. [Online]. Available from: http://faostat.fao.org/default.aspx [Accessed: 2010-01-26].

FPMC (FOOD PRICE MONITORING COMMITTEE). 2003. *Final Report of the Food Price Monitoring Committee*. Pretoria: National Department of Agriculture.

GCIS (GOVERNMENT COMMUNICATION AND INFORMATION SYSTEM). 2009. *Pocket Guide to South Africa 2009/2010*. Pretoria: Government Communication and Information System. [Online]. Available from: http://www.gcis.gov.za/resource_centre/sa_info/pocketguide/2009/013_agriculture_fish_and_forest.pdf.. [Downloaded: 2012-05-03].

LIEBENBERG, F. 2009. *South African agricultural production, productivity and research performance in the 20th century*. Unpublished PhD Thesis. University of Pretoria (in preparation).

MEYER, F. 2002. *Modelling the market outlook and policy alternatives for the wheat sector in South Africa*. Published Master's Dissertation. Pretoria: University of Pretoria [Online]. Available from:
http://upetd.up.ac.za/thesis/available/etd-09222005-122509/unrestricted/00dissertation.pdf [Accessed: 2010-01-26].

MORRIS, M.L. & HEISEY, P.W. 2003. Estimating the benefits of plant breeding research: Methodological issues and practical challenges. *Agricultural Economics*, 29: 241-252 [Online]. Available from: http://www.sciencedirect.com [Accessed: 2010-01-26].

NAMC (NATIONAL AGRICULTURAL MARKETING COUNCIL). 2003. *Summary Report, 2002*. Pretoria: Food Pricing Monitoring Committee [Online]. Available from: http://www.nda. gric.za/docs/fpmc/Vol4_Chap3.pdf [Downloaded: 2010-01-26].

NCEC (NATIONAL CROP ESTIMATES COMMITTEE). 2009. *Published Statistics, 2009*. Pretoria: National Department of Agriculture.

PARDEY, P.G.; ALSTON, J.M.; CHAN-KANG, C.; MAGALHÃES, E.C. & VOSTI, S.A. 2004. *Assessing and attributing the benefits from varietal improvement research in Brazil*. Washington, DC: International Food Policy Research Institute.

PRETORIUS, Z.A.; PAKENDORF, K.W.; MARAIS, G.F.; PRINS, R. & KOMEN, J.S. 2007. Challenges for sustainable cereal rust control in South Africa. *Australian Journal of*

Agricultural Research, 58: 593-601 [Online]. Available from: http://www.publish.csiro.au/?act=view_file&file_id=AR06144.pdf [Downloaded: 2008-04-14].

SAGL (SOUTH AFRICA GRAIN LABORATORY). 2009. *South African Wheat Crop Quality Season Reports, 1998-2008*. Pretoria: South Africa Grain Laboratory.

SARB (SOUTH AFRICAN RESERVE BANK). 2009. *Quarterly Bulletin - September 2009* (No. 253). Pretoria: South African Reserve Bank.

VAN DER MERWE, N. & HATTING, H. (2007). *LNR-Kleingraaninstituut en Saad*. Bethlehem: Agricultural Research Council-Small Grain Institute.

VINK, N. & KIRSTEN, J. 2000. *Deregulation of agricultural marketing in South Africa: Lessons learned (FMF Monograph No. 25)*. Sandton: Free Market Foundation [Online]. Available from: http://www.freemarketfoundation.com/htmupload/PUBDoc397.doc [Downloaded: 2010-01-26].

WHEAT BOARD. 1997. *Winter Grain Statistics, 1980 – 1997*. Pretoria: Wheat Board, Grading Inspection Services.

ANNEXURE A

Table A.1: Calculation of benefits with the calculated k-shift values: Dryland production area

Year	Real wheat price (Rand/ton)	Quantity produced dryland production area (ton)	K-shift value	Total Benefits (R)
1980	R 2,273.69	556,000	0.00	0.00
1981	R 2,320.17	1,108,000	0.23	R 595,020,575
1982	R 2,488.53	1,121,000	0.05	R 130,277,621
1983	R 1,990.08	692,165	0.36	R 490,282,899
1984	R 1,940.25	1,100,117	0.39	R 825,889,556
1985	R 1,805.61	446,266	-0.50	R -403,297,369
1986	R 1,788.29	1,155,621	0.40	R 834,935,303
1987	R 1,678.75	1,659,633	0.55	R 1,527,336,384
1988	R 1,273.03	2,126,432	0.51	R 1,386,422,555
1989	R 1,406.37	895,971	0.24	R 305,226,018
1990	R 1,385.25	713,403	0.13	R 130,379,039
1991	R 1,499.77	1,107,414	0.17	R 278,899,561
1992	R 1,499.22	249,946	0.28	R 106,120,107
1993	R 1,420.04	788,955	0.47	R 524,621,449
1994	R 1,245.64	451,371	0.09	R 49,555,837
1995	R 1,241.69	638,828	0.34	R 271,147,442
1996	R 1,310.52	1,217,000	0.54	R 861,760,898
1997	R 1,026.19	1,180,000	0.55	R 660,645,245
1998	R 941.59	590,500	0.55	R 306,204,886
1999	R 1,045.22	538,500	0.55	R 311,900,655
2000	R 1,165.35	908,000	0.56	R 589,930,204
2001	R 1,320.38	1,100,000	0.59	R 850,615,330
2002	R 1,321.08	820,000	0.49	R 528,551,873
2003	R 1,147.28	480,000	0.27	R 149,765,244
2004	R 830.70	510,000	0.33	R 140,407,244
2005	R 746.55	580,000	0.48	R 208,267,515
2006	R 1,025.38	780,000	0.63	R 500,544,308
2007	R 1,464.50	570,000	0.67	R 558,450,195
Total Benefits				R 12,719,860,574

Source: Author's own calculations based on data from the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

Table A.2: Calculation of benefits with the calculated k-shift values: Winter production area

Year	Real wheat price (Rand/ton)	Quantity produced in the winter production area (ton)	K-shift value	Total Benefits (R)
1980	R 2,273.69	622,664	0.00	R 0
1981	R 2,320.17	861,000	-0.01	R -16,107,815
1982	R 2,488.53	914,000	-0.02	R -37,692,775
1983	R 1,990.08	911,936	0.06	R 74,271,529
1984	R 1,940.25	919,392	-0.29	R -430,361,787
1985	R 1,805.61	963,073	-0.32	R -442,325,983
1986	R 1,788.29	928,991	-0.10	R -124,310,763
1987	R 1,678.75	1,102,076	-0.05	R -74,659,141
1988	R 1,273.03	1,026,956	0.25	R 277,437,259
1989	R 1,406.37	883,411	0.36	R 383,430,015
1990	R 1,385.25	734,083	0.05	R 40,244,783
1991	R 1,499.77	735,632	0.07	R 68,701,256
1992	R 1,499.22	921,509	0.07	R 80,118,095
1993	R 1,420.04	1,019,886	0.05	R 64,565,408
1994	R 1,245.64	1,140,693	0.12	R 149,920,757
1995	R 1,241.69	1,123,234	0.11	R 133,785,894
1996	R 1,310.52	806,000	0.43	R 451,417,475
1997	R 1,026.19	605,000	0.03	R 18,414,939
1998	R 941.59	590,000	0.32	R 177,033,457
1999	R 1,045.22	610,000	0.32	R 201,670,559
2000	R 1,165.35	691,000	0.21	R 169,159,619
2001	R 1,320.38	730,000	0.17	R 168,564,713
2002	R 1,321.08	891,800	0.35	R 417,185,315
2003	R 1,147.28	530,000	0.34	R 204,357,230
2004	R 830.70	520,000	0.03	R 12,147,217
2005	R 746.55	645,000	0.08	R 36,742,703
2006	R 1,025.38	730,000	0.26	R 197,078,745
2007	R 1,464.50	812,000	0.36	R 423,808,422
Total Benefits				R 2,624,597,129

Source: Author's own calculations based on data from the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

Table A.3 Calculation of benefits with the calculated k-shift values: Irrigation production area

Year	Real wheat price (Rand/ton)	Quantity produced in the winter production area (ton)	K-shift value	Total Benefits (R)
1980	R 2,273.69	291,000	0.00	R 0
1981	R 2,320.17	370,000	-0.01	R 223,797,634
1982	R 2,488.53	385,000	-0.02	R 251,939,627
1983	R 1,990.08	170,154	0.06	R 78,823,040
1984	R 1,940.25	313,304	-0.29	R 184,904,913
1985	R 1,805.61	270,553	-0.32	R 237,721,645
1986	R 1,788.29	236,198	-0.10	R 204,427,531
1987	R 1,678.75	373,392	-0.05	R 295,333,440
1988	R 1,273.03	445,012	0.25	R 249,332,914
1989	R 1,406.37	223,487	0.36	R 67,221,830
1990	R 1,385.25	254,885	0.05	R 146,144,441
1991	R 1,499.77	289,939	0.07	R 200,844,252
1992	R 1,499.22	144,618	0.07	R 134,478,383
1993	R 1,420.04	166,503	0.05	R 121,495,181
1994	R 1,245.64	240,177	0.12	R 169,424,210
1995	R 1,241.69	206,450	0.11	R 141,015,205
1996	R 1,310.52	677,000	0.43	R 512,540,594
1997	R 1,026.19	715,500	0.03	R 465,064,996
1998	R 941.59	507,500	0.32	R 323,088,502
1999	R 1,045.22	621,500	0.32	R 421,841,605
2000	R 1,165.35	749,550	0.21	R 539,670,217
2001	R 1,320.38	620,000	0.17	R 463,042,324
2002	R 1,321.08	715,200	0.35	R 582,569,486
2003	R 1,147.28	530,000	0.34	R 371,157,323
2004	R 830.70	650,000	0.03	R 329,138,973
2005	R 746.55	680,000	0.08	R 331,953,935
2006	R 1,025.38	595,000	0.26	R 406,514,218
2007	R 1,464.50	523,000	0.36	R 491,375,388
Total Benefits				R 7,944,861,805

Source: Author's own calculations based on data from the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

Table A.4: Calculation of benefits with the calculated k-shift values: South Africa

Year	Real wheat price (Rand/ton)	Quantity produced in the winter production area (ton)	K-shift value	Total Benefits (R)
1980	R 2,273.69	1,469,664	0.00	R 0
1981	R 2,320.17	2,339,000	-0.01	R 485,824,292
1982	R 2,488.53	2,420,000	-0.02	R 180,571,023
1983	R 1,990.08	1,774,255	0.06	R 415,949,017
1984	R 1,940.25	2,332,813	-0.29	R 323,616,877
1985	R 1,805.61	1,679,892	-0.32	R -462,907,092
1986	R 1,788.29	2,320,810	-0.10	R 552,692,898
1987	R 1,678.75	3,135,101	-0.05	R 1,091,001,968
1988	R 1,273.03	3,598,400	0.25	R 1,214,791,063
1989	R 1,406.37	2,002,869	0.36	R 495,786,833
1990	R 1,385.25	1,702,371	0.05	R 185,704,193
1991	R 1,499.77	2,132,985	0.07	R 329,180,986
1992	R 1,499.22	1,316,073	0.07	R 190,773,706
1993	R 1,420.04	1,975,344	0.05	R 446,283,396
1994	R 1,245.64	1,832,241	0.12	R 220,444,654
1995	R 1,241.69	1,968,512	0.11	R 339,133,467
1996	R 1,310.52	2,700,000	0.43	R 1,087,265,365
1997	R 1,026.19	2,500,500	0.03	R 673,000,870
1998	R 941.59	1,688,000	0.32	R 466,797,501
1999	R 1,045.22	1,770,000	0.32	R 534,658,563
2000	R 1,165.35	2,348,550	0.21	R 754,785,513
2001	R 1,320.38	2,450,000	0.17	R 885,559,954
2002	R 1,321.08	2,427,000	0.35	R 885,154,650
2003	R 1,147.28	1,540,000	0.34	R 405,540,408
2004	R 830.70	1,680,000	0.03	R 263,122,525
2005	R 746.55	1,905,000	0.08	R 323,396,474
2006	R 1,025.38	2,105,000	0.26	R 646,858,156
2007	R 1,464.50	1,905,000	0.36	R 862,965,375
Total Benefits				R 13,797,952,638

Source: Author's own calculations based on data from the Directorate: Agricultural Statistics (2009) and the NCEC (2009)

ANNEXURE B

Table B.1: Variables calculated for the winter production area: 1980-2007

Winter production area					
Year	Weighted average experimental yield	Weighted average commercial yield	Index of varietal improvement	Commercial index	K-shift*
1980	2.81	0.88	100.00	100.00	0.00
1981	2.78	1.24	98.89	140.67	-0.01
1982	2.74	1.28	97.74	145.64	-0.02
1983	2.97	1.32	105.88	150.04	0.06
1984	2.17	1.13	77.25	128.23	-0.29
1985	2.13	1.12	75.95	127.44	-0.32
1986	2.56	1.02	91.24	116.43	-0.10
1987	2.69	1.30	95.66	147.99	-0.05
1988	3.73	1.11	132.73	126.64	0.25
1989	4.41	1.22	156.96	138.21	0.36
1990	2.95	1.46	104.92	166.15	0.05
1991	3.03	1.52	107.95	172.18	0.07
1992	3.01	1.87	107.22	212.74	0.07
1993	2.96	1.78	105.55	201.87	0.05
1994	3.21	1.86	114.23	210.79	0.12
1995	3.17	2.03	112.78	231.04	0.11
1996	4.90	2.00	174.63	227.20	0.43
1997	2.89	1.51	103.06	171.82	0.03
1998	4.12	1.97	146.77	223.41	0.32
1999	4.11	1.97	146.26	223.53	0.32
2000	3.56	2.00	126.59	227.20	0.21
2001	3.40	2.12	121.19	240.37	0.17
2002	4.35	2.45	154.82	278.32	0.35
2003	4.23	1.63	150.62	185.25	0.34
2004	2.89	1.47	102.89	166.87	0.03
2005	3.04	2.14	108.26	242.62	0.08
2006	3.81	2.50	135.74	284.00	0.26
2007	4.36	2.50	155.37	283.82	0.36

Source: Author's own calculations based on data from the ARC-SGI (2009) and the NCEC (2009)

Note: *K-shift was calculated by using only the index of varietal improvement and Equation 5.11

Table B.2: Variables calculated for the dryland production area: 1980-2007

Dryland production area					
Year	**Weighted average experimental yield**	**Weighted average commercial yield**	**Index of varietal improvement**	**Commercial index**	**K-shift***
1980	1.42	0.79	100.00	100.00	0.00
1981	1.85	1.36	130.12	172.53	0.23
1982	1.49	1.18	104.90	149.51	0.05
1983	2.21	0.84	155.26	105.70	0.36
1984	2.32	1.20	163.11	151.36	0.39
1985	0.95	0.51	66.64	64.56	-0.50
1986	2.38	1.40	167.79	176.47	0.40
1987	3.15	1.93	221.34	243.44	0.55
1988	2.91	1.90	204.99	240.27	0.51
1989	1.88	0.81	131.97	101.78	0.24
1990	1.64	0.69	115.20	87.52	0.13
1991	1.71	1.17	120.18	147.94	0.17
1992	1.98	0.83	139.51	104.88	0.28
1993	2.67	1.49	188.06	188.46	0.47
1994	1.56	0.88	109.67	110.71	0.09
1995	2.16	0.78	151.94	98.62	0.34
1996	3.09	1.73	217.54	219.20	0.54
1997	3.13	1.49	220.06	188.86	0.55
1998	3.16	1.79	222.58	226.25	0.55
1999	3.19	1.80	224.29	226.96	0.55
2000	3.21	2.05	226.00	259.16	0.56
2001	3.43	2.20	241.34	278.17	0.59
2002	2.77	1.86	195.28	235.64	0.49
2003	1.95	1.50	137.35	189.66	0.27
2004	2.13	1.45	149.57	182.88	0.33
2005	2.74	1.53	192.67	192.99	0.48
2006	3.80	2.17	267.27	273.95	0.63
2007	4.29	2.65	302.11	335.21	0.67

Source: Author's own calculations based on data from the ARC-SGI (2009) and the NCEC (2009)

Note: *K-shift was calculated by using only the index of varietal improvement and Equation 5.11

Table B.3: Variables calculated for the irrigation production area: 1980-2007

Irrigation production area					
Year	**Weighted average experimental yield**	**Weighted average commercial yield**	**Index of varietal improvement**	**Commercial index**	**K-shift***
1980	2.32	1.16	100.00	100.00	0.00
1981	3.14	1.29	135.26	111.79	0.26
1982	3.15	1.25	135.68	107.94	0.26
1983	3.03	0.80	130.34	69.32	0.23
1984	3.34	1.41	143.71	121.62	0.30
1985	4.53	1.17	194.79	100.89	0.49
1986	4.50	1.10	193.79	94.77	0.48
1987	4.39	2.97	189.09	257.38	0.47
1988	4.15	3.49	178.61	302.27	0.44
1989	2.96	2.36	127.21	204.30	0.21
1990	3.96	2.69	170.62	233.16	0.41
1991	4.32	3.31	185.83	286.26	0.46
1992	6.12	3.95	263.33	342.00	0.62
1993	4.78	3.78	205.70	326.74	0.51
1994	5.36	5.09	230.58	440.66	0.57
1995	5.16	3.59	222.27	310.59	0.55
1996	5.50	3.59	236.79	310.30	0.58
1997	6.34	3.72	272.77	321.97	0.63
1998	7.17	4.41	308.76	381.88	0.68
1999	6.63	5.75	285.21	497.97	0.65
2000	6.08	5.15	261.67	445.79	0.62
2001	5.35	4.82	230.22	417.52	0.57
2002	6.06	5.22	260.81	451.42	0.62
2003	5.96	5.15	256.67	445.28	0.61
2004	5.95	5.27	256.13	455.81	0.61
2005	6.71	5.53	288.93	478.40	0.65
2006	6.96	5.27	299.68	456.45	0.67
2007	6.48	5.68	278.97	491.93	0.64

Source: Author's own calculations based on data from the ARC-SGI (2009) and the NCEC (2009)

Table B.4: Variables calculated for South Africa: 1980-2007

South Africa					
Year	Weighted average experimental yield	Weighted average commercial yield	Index of varietal improvement	Commercial index	K-shift*
1980	2.14	0.91	100.00	100.00	0.00
1981	2.40	1.31	117.80	144.55	0.13
1982	2.19	1.23	106.06	135.38	0.05
1983	2.63	0.98	131.28	108.31	0.21
1984	2.37	1.21	125.82	133.98	0.10
1985	1.90	0.86	86.40	94.76	-0.30
1986	2.71	1.20	135.95	132.38	0.19
1987	3.04	1.81	165.07	200.24	0.29
1988	3.30	1.81	176.47	200.19	0.41
1989	2.77	1.09	139.78	120.87	0.28
1990	2.16	1.10	117.12	121.24	0.13
1991	2.25	1.49	121.40	164.27	0.16
1992	2.80	1.76	130.70	194.48	0.19
1993	2.90	1.86	151.25	204.87	0.28
1994	2.50	1.76	118.11	194.65	0.13
1995	2.67	1.44	141.99	159.48	0.27
1996	4.01	2.09	206.99	230.46	0.51
1997	3.51	1.81	193.54	199.77	0.41
1998	4.17	2.27	205.35	250.22	0.48
1999	4.10	2.47	199.76	272.24	0.47
2000	3.79	2.51	194.78	277.69	0.44
2001	3.67	2.52	197.30	277.93	0.44
2002	3.86	2.58	189.18	284.80	0.45
2003	3.49	2.06	159.55	227.36	0.35
2004	3.02	2.02	145.50	223.53	0.24
2005	3.46	2.37	175.71	261.34	0.36
2006	4.27	2.75	221.83	303.95	0.49
2007	4.65	3.01	223.28	332.87	0.50

Source: Author's own calculations based on data from the ARC-SGI (2009) and the NCEC (2009)

Note: *The k-shift was calculated as a weighted average of the four production areas' k-shifts and not from the weighted average experimental yield in the table.

Table B.5: Adjustment factors obtained in the estimation of area planted

Adjustment factors obtained in the estimation of area planted				
Year	**Winter**	**Dryland**	**Irrigation**	**South Africa**
1980	0.31	0.56	0.33	0.42
1981	0.42	0.74	0.51	0.57
1982	0.43	0.79	0.48	0.61
1983	0.40	0.38	0.27	0.37
1984	0.54	0.52	0.43	0.52
1985	0.54	0.54	0.25	0.50
1986	0.41	0.59	0.23	0.46
1987	0.55	0.61	0.69	0.59
1988	0.37	0.65	0.83	0.56
1989	0.34	0.43	0.62	0.41
1990	0.63	0.42	0.51	0.48
1991	0.62	0.69	0.71	0.67
1992	0.77	0.42	0.47	0.61
1993	0.71	0.56	0.71	0.63
1994	0.76	0.56	0.82	0.66
1995	0.75	0.36	0.60	0.51
1996	0.41	0.56	0.64	0.52
1997	0.52	0.56	0.62	0.56
1998	0.48	0.57	0.61	0.54
1999	0.48	0.60	0.75	0.57
2000	0.56	0.63	0.88	0.65
2001	0.59	0.67	0.92	0.67
2002	0.54	0.70	0.88	0.66
2003	0.39	0.80	0.87	0.63
2004	0.51	0.69	0.89	0.64
2005	0.70	0.56	0.84	0.65
2006	0.66	0.57	0.77	0.63
2007	0.57	0.62	0.89	0.63
2008	0.65	0.73	0.87	0.72

Source: Author's own calculations based on data from the ARC-SGI (2009) and the NCEC (2009)

Table B.6: Estimated market share results for the winter production area: 1980-2008

Year	ARC-SGI	Sensako	Pannar
1980	29.77%	70.23%	0.00%
1981	23.89%	76.11%	0.00%
1982	28.36%	71.64%	0.00%
1983	27.19%	72.81%	0.00%
1984	0.00%	100.00%	0.00%
1985	0.00%	100.00%	0.00%
1986	0.00%	100.00%	0.00%
1987	36.32%	63.68%	0.00%
1988	66.74%	33.26%	0.00%
1989	68.19%	31.81%	0.00%
1990	76.69%	23.31%	0.00%
1991	78.47%	21.53%	0.00%
1992	83.49%	16.51%	0.00%
1993	87.57%	12.43%	0.00%
1994	86.96%	13.04%	0.00%
1995	87.01%	12.99%	0.00%
1996	84.67%	15.33%	0.00%
1997	84.61%	15.39%	0.00%
1998	84.57%	15.43%	0.00%
1999	84.28%	15.72%	0.00%
2000	2.11%	97.89%	0.00%
2001	4.46%	95.54%	0.00%
2002	0.00%	100.00%	0.00%
2003	0.00%	100.00%	0.00%
2004	0.00%	99.08%	0.92%
2005	0.00%	97.98%	2.02%
2006	0.00%	99.18%	0.82%
2007	0.00%	99.53%	0.47%
2008	0.00%	99.79%	0.21%

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Table B.7: Estimated market share results for the dryland production area: 1980-2008

Year	ARC-SGI	Sensako	Pannar
1980	88.70%	11.30%	0.00%
1981	87.01%	12.99%	0.00%
1982	93.52%	6.48%	0.00%
1983	93.04%	6.96%	0.00%
1984	88.86%	11.14%	0.00%
1985	90.42%	9.58%	0.00%
1986	62.76%	37.24%	0.00%
1987	85.62%	14.38%	0.00%
1988	95.92%	4.08%	0.00%
1989	93.85%	6.15%	0.00%
1990	91.90%	8.10%	0.00%
1991	71.57%	28.43%	0.00%
1992	29.03%	70.97%	0.00%
1993	71.93%	28.07%	0.00%
1994	74.61%	25.39%	0.00%
1995	76.57%	23.43%	0.00%
1996	62.83%	29.31%	7.87%
1997	61.81%	29.87%	8.32%
1998	60.80%	30.42%	8.78%
1999	53.70%	38.87%	7.43%
2000	46.61%	47.31%	6.07%
2001	70.12%	4.77%	25.11%
2002	69.05%	4.29%	26.66%
2003	56.61%	18.73%	24.66%
2004	66.59%	11.11%	22.30%
2005	65.68%	14.49%	19.83%
2006	66.29%	15.23%	18.48%
2007	60.45%	17.11%	22.44%
2008	52.89%	17.83%	29.28%

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

Table B.8: Estimated market share results for the irrigation production area: 1980-2008

Year	ARC-SGI	Sensako	Pannar
1980	95.31%	4.69%	0.00%
1981	81.35%	18.65%	0.00%
1982	81.27%	18.73%	0.00%
1983	81.98%	18.02%	0.00%
1984	51.45%	48.55%	0.00%
1985	44.77%	55.23%	0.00%
1986	32.49%	67.51%	0.00%
1987	59.96%	40.04%	0.00%
1988	75.60%	24.40%	0.00%
1989	80.26%	19.74%	0.00%
1990	65.24%	34.76%	0.00%
1991	64.42%	35.58%	0.00%
1992	55.92%	44.08%	0.00%
1993	62.78%	37.22%	0.00%
1994	67.53%	32.47%	0.00%
1995	69.90%	30.10%	0.00%
1996	45.81%	53.69%	0.50%
1997	37.91%	61.29%	0.80%
1998	30.02%	68.89%	1.09%
1999	23.75%	74.25%	1.99%
2000	17.49%	79.61%	2.90%
2001	9.00%	90.34%	0.65%
2002	3.86%	96.14%	0.00%
2003	11.92%	88.08%	0.00%
2004	9.56%	90.41%	0.03%
2005	8.60%	90.54%	0.86%
2006	17.37%	81.85%	0.78%
2007	11.01%	85.31%	3.68%
2008	28.70%	68.58%	2.72%

Source: Author's own calculations based on data from the ARC-SGI (2009), NCEC (2009), SAGL (2009) and Wheat Board (1997)

ANNEXURE C

Table C.1: Production data for Westernn and Northern Cape: 1980-2008

Year	Western Cape			Northern Cape		
	Ha	Tons	t/ha	Ha	Tons	t/ha
1980	543 000	478 000	0.88	52 000	125 000	2.40
1981	533 000	660 000	1.24	92 000	147 000	1.60
1982	553 000	709 000	1.28	96 000	156 000	1.63
1983	570 000	752 830	1.32	83 000	100 011	1.20
1984	644 000	726 961	1.13	46 000	142 405	3.10
1985	677 000	759 498	1.12	53 000	169 544	3.20
1986	687 000	704 116	1.02	51 000	197 017	3.86
1987	660 000	859 786	1.30	46 000	213 587	4.64
1988	653 000	727 956	1.11	47 000	262 898	5.59
1989	512 000	622 924	1.22	47 000	241 402	5.14
1990	334 576	489 354	1.46	53 011	227 342	4.29
1991	327 563	496 479	1.52	53 832	227 953	4.23
1992	334 932	627 251	1.87	55 031	276 393	5.02
1993	417 997	742 796	1.78	52 465	252 282	4.81
1994	397 795	738 144	1.86	55 268	364 796	6.60
1995	400 800	815 175	2.03	56 000	278 242	4.97
1996	403 000	806 000	2.00	68 000	345 000	5.07
1997	400 000	605 000	1.51	65 000	310 000	4.77
1998	300 000	590 000	1.97	35 000	225 500	6.44
1999	310 000	610 000	1.97	43 000	295 000	6.86
2000	345 500	691 000	2.00	56 000	324 800	5.80
2001	345 000	730 000	2.12	44 500	240 000	5.39
2002	364 000	891 800	2.45	54 000	320 000	5.93
2003	325 000	530 000	1.63	48 500	280 000	5.77
2004	354 000	520 000	1.47	51 100	300 000	5.87
2005	302 000	645 000	2.14	48 500	306 000	6.31
2006	292 000	730 000	2.50	40 000	250 000	6.25
2007	325 000	812 000	2.50	42 000	264 500	6.30
2008	350 000	840 000	2.40	50 000	325 000	6.50

Source: NCEC (2009)

Table C.2: Production data for Eastern Cape and Free State: 1980-2008

Year	Eastern Cape			Free State		
	Ha	Tons	t/ha	Ha	Tons	t/ha
1980	111 000	19 664	0.18	703 000	556 000	0.79
1981	118 000	54 000	0.46	812 000	1 108 000	1.36
1982	123 000	49 000	0.40	948 000	1 121 000	1.18
1983	121 000	59 095	0.49	828 000	692 165	0.84
1984	96 000	50 026	0.52	919 000	1 100 117	1.20
1985	113 000	34 031	0.30	874 000	446 266	0.51
1986	144 000	27 858	0.19	828 000	1 155 621	1.40
1987	36 000	28 703	0.80	862 000	1 659 633	1.93
1988	36 000	36 102	1.00	1 119 000	2 126 432	1.90
1989	36 000	19 085	0.53	1 113 000	895 971	0.81
1990	5 838	17 387	2.98	1 030 630	713 403	0.69
1991	7 029	11 200	1.59	946 464	1 107 414	1.17
1992	5 942	17 865	3.01	301 321	249 946	0.83
1993	15 209	24 808	1.63	529 319	788 955	1.49
1994	16 110	37 753	2.34	515 482	451 371	0.88
1995	16 550	29 817	1.80	819 000	638 828	0.78
1996	17 000	18 000	1.06	702 000	1 217 000	1.73
1997	13 000	24 000	1.85	790 000	1 180 000	1.49
1998	5 000	10 000	2.00	330 000	590 500	1.79
1999	4 000	10 500	2.63	300 000	538 500	1.80
2000	4 300	14 500	3.37	443 000	908 000	2.05
2001	2 900	9 000	3.10	500 000	1 100 000	2.20
2002	3 500	10 500	3.00	440 000	820 000	1.86
2003	2 500	8 500	3.40	320 000	480 000	1.50
2004	4 000	14 000	3.50	352 600	510 000	1.45
2005	4 000	14 500	3.63	380 000	580 000	1.53
2006	2 800	8 000	2.86	360 000	780 000	2.17
2007	3 800	15 200	4.00	215 000	570 000	2.65
2008	5 500	22 000	4.00	280 000	560 000	2.00

Source: NCEC (2009)

Table C.3: Production data for Kwazulu-Natal and Mpumalanga: 1980-2008

Year	Kwazulu Natal			Mpumalanga		
	Ha	Tons	t/ha	Ha	Tons	t/ha
1980	2 000	3 000	1.50	46 000	88 000	1.91
1981	2 000	4 000	2.00	49 000	92 000	1.88
1982	2 000	11 000	5.50	50 000	104 000	2.08
1983	2 000	9 300	4.65	40 000	48 370	1.21
1984	5 850	25 274	4.32	53 000	83 036	1.57
1985	8 675	30 537	3.52	36 000	76 171	2.12
1986	12 000	47 610	3.97	25 000	50 878	2.04
1987	13 000	50 706	3.90	29 000	90 678	3.13
1988	13 000	61 335	4.72	30 000	99 519	3.32
1989	13 000	24 078	1.85	25 000	46 607	1.86
1990	6 377	24 145	3.79	20 875	67 810	3.25
1991	5 378	20 391	3.79	17 097	67 430	3.94
1992	4 530	19 940	4.40	7 285	44 781	6.15
1993	4 304	15 021	3.49	7 824	37 788	4.83
1994	3 635	22 023	6.06	12 095	72 149	5.97
1995	3 500	12 412	3.55	10 500	40 708	3.88
1996	5 000	24 000	4.80	17 000	78 000	4.59
1997	5 800	23 000	3.97	22 000	96 500	4.39
1998	5 000	22 000	4.40	9 000	52 000	5.78
1999	6 000	37 000	6.17	11 000	70 000	6.36
2000	8 700	43 700	5.02	20 000	102 000	5.10
2001	11 000	50 000	4.55	25 000	115 000	4.60
2002	8 600	39 600	4.60	23 500	119 500	5.09
2003	7 000	31 900	4.56	9 000	36 000	4.00
2004	6 600	34 000	5.15	15 700	80 000	5.10
2005	9 000	41 500	4.61	18 000	92 000	5.11
2006	7 000	31 000	4.43	15 000	77 000	5.13
2007	6 000	28 800	4.80	5 000	25 000	5.00
2008	7 500	36 375	4.85	8 000	44 000	5.50

Source: NCEC (2009)

Table C.4: Production data for Limpopo and Gauteng: 1980-2008

Year	Limpopo			Gauteng		
	Ha	Tons	t/ha	Ha	Tons	t/ha
1980	84 000	89 000	1.06	2 000	3 000	1.50
1981	112 000	97 000	0.87	3 000	3 000	1.00
1982	112 000	76 000	0.68	3 000	4 000	1.33
1983	103 000	24 825	0.24	5 000	2 613	0.52
1984	113 000	101 813	0.90	7 000	30 962	4.42
1985	116 000	61 412	0.53	9 000	38 596	4.29
1986	99 000	35 557	0.36	9 000	31 983	3.55
1987	8 000	40 299	5.04	17 000	52 415	3.08
1988	12 000	36 384	3.03	17 000	63 286	3.72
1989	10 000	12 115	1.21	16 000	31 071	1.94
1990	3 620	12 276	3.39	2 992	8 217	2.75
1991	3 258	16 921	5.19	2 130	8 676	4.07
1992	2 003	8 577	4.28	2 324	9 138	3.93
1993	10 327	39 034	3.78	2 235	7 597	3.40
1994	10 827	46 700	4.31	2 861	9 057	3.17
1995	11 400	33 503	2.94	2 800	9 347	3.34
1996	20 000	65 000	3.25	1 800	8 000	4.44
1997	17 000	74 500	4.38	3 000	17 500	5.83
1998	9 000	38 500	4.28	2 000	13 500	6.75
1999	8 000	52 000	6.50	4 000	17 000	4.25
2000	15 000	75 000	5.00	5 000	18 000	3.60
2001	15 000	60 000	4.00	3 700	16 000	4.32
2002	17 000	68 000	4.00	2 500	12 000	4.80
2003	8 000	35 000	4.38	2 000	8 600	4.30
2004	15 500	63 000	4.06	2 500	14 000	5.60
2005	11 000	50 000	4.55	2 500	14 000	5.60
2006	18 000	81 000	4.50	2 000	10 000	5.00
2007	11 000	60 450	5.50	1 700	11 050	6.50
2008	20 000	110 000	5.50	2 000	12 400	6.20

Source: NCEC (2009)

Table C.5: Production data for North West and South Africa: 1980-2008

Year	North West			South Africa		
	Ha	Tons	t/ha	Ha	Tons	t/ha
1980	80 000	108 000	1.35	1 110 000	977 664	0.88
1981	66 000	174 000	2.64	1 231 000	1 709 000	1.39
1982	87 000	190 000	2.18	1 415 000	1 749 000	1.24
1983	57 000	85 046	1.49	1 218 000	1 009 073	0.83
1984	39 000	72 219	1.85	1 278 850	1 566 628	1.23
1985	71 000	63 837	0.90	1 307 675	853 283	0.65
1986	81 000	70 170	0.87	1 288 000	1 521 830	1.18
1987	58 000	139 294	2.40	1 098 000	2 253 437	2.05
1988	58 000	184 488	3.18	1 360 000	2 855 320	2.10
1989	58 000	109 616	1.89	1 345 000	1 279 230	0.95
1990	92 713	142 437	1.54	1 258 750	1 136 329	0.90
1991	71 215	176 521	2.48	1 125 916	1 593 750	1.42
1992	33 932	62 182	1.83	393 593	483 749	1.23
1993	25 118	67 063	2.67	621 689	1 054 926	1.70
1994	25 418	90 248	3.55	614 707	828 606	1.35
1995	42 600	110 480	2.59	951 750	994 922	1.05
1996	60 000	139 000	2.32	884 600	1 696 000	1.92
1997	66 500	170 000	2.56	986 800	1 773 000	1.80
1998	50 000	146 000	2.92	462 000	1 032 000	2.23
1999	32 000	140 000	4.38	401 000	1 022 000	2.55
2000	36 500	171 550	4.70	574 000	1 522 300	2.65
2001	26 400	130 000	4.92	614 100	1 626 000	2.65
2002	28 000	145 600	5.20	553 600	1 372 800	2.48
2003	26 000	130 000	5.00	402 500	868 600	2.16
2004	28 000	145 000	5.18	455 400	1 019 000	2.24
2005	30 000	162 000	5.40	487 000	1 130 000	2.32
2006	28 000	138 000	4.93	462 800	1 273 000	2.75
2007	22 500	118 000	5.24	289 200	957 550	3.31
2008	25 000	140 000	5.60	375 000	1 077 175	2.87

Source: NCEC (2009)