MEASURING TECHNICAL, SCALE AND IRRIGATION EFFICIENCIES OF SUGARCANE SMALL-SCALE GROWERS IN THE NKOMAZI MUNICIPALITY OF MPUMALANGA PROVINCE

By

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ABSTRACT

The largest crop in the world in terms of production is sugarcane. It is produced in three provinces in South Africa. With approximately 50% of the gross farming income from field crops in Mpumalanga, KwaZulu-Natal, and the Eastern Cape coming from sugarcane, it is a critical crop for these regions. Small-scale sugarcane growers in South Africa are faced with numerous challenges such as technology acquisition, high input prices, reduced yield; lack of water for irrigation, persistent pests and land disputes.

The study aimed to analyse the technical, scale and irrigation efficiencies and socio-economic factors that affect the efficiencies of small-scale sugarcane growers in the Nkomazi Municipality. For the study, 90 small-scale sugarcane growers were selected using a simple random sampling method. The research area's small-scale sugarcane growers, according to the descriptive statistics of socioeconomic characteristics, are on average, 68 years old. The growers had an average of 8.81 years of farming experience. Their average off-farm income was R6 800, and their education levels ranged from 0 to 16 years. In one production year, growers received an average of 76.27 hours of extension assistance.

The Technical Efficiency (TE) scores of sugarcane growers had a mean of 90.8% with a minimum of 83% and a maximum of 100%, according to the Data Envelopment Analysis (DEA) data. This indicates that over 83% of the maximum practicable yield was produced by growers who were 90.8% technically efficient. The minimum of 83% indicates that to get the necessary score and be considered technically efficient, the least efficient grower would need to reduce input usage by 17%. Sugarcane growers' SE ratings ranged from a minimum of 26% to a maximum of 100%, with a mean of 69.04%. This indicates that 69% of the growers were effective at scaling up. The minimum scale efficiency level of 17.78 suggests that producers are not maximising output by leveraging land efficiency.

According to the DEA water slack data, sugarcane growers had an average irrigation efficiency of 90.8%, with a range of 87% to 100%. The minimal efficiency score of 87% indicates that the grower with the lowest efficiency at 87% needs to reduce on water use by 13% to meet the standard and be deemed efficient in their irrigation. Both the slack-based analysis' and the non-radial Slack-based Measure analysis' average irrigation efficiency ratings can be rounded to 91%: 90.8% and 90.55%, respectively. These average scores for irrigation efficiency show that 91% of the sugarcane growers in the survey use water effectively.

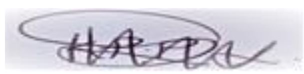
The truncated regression results indicated that all the socioeconomic variables expected to affect technical efficiency were significant. The coefficients of the included variables were -0.086, 0.098, 0.0463, -0.112, 0.144, 0.008, 0.063 and-0.111 corresponding to the age, gender, farming experience, level of education, off-farm income, extension access, extension hours and irrigation system, respectively. The study suggests that while some small-scale growers are interested in off-farm activities, they should have better access to extension services through various platforms, such as local radio stations. Therefore, extension officers should get a slot with the local radio station to access the small-scale sugarcane growers.

Keywords: Technical efficiency, Scale efficiency, Irrigation efficiency and Small-scale growers.

DECLARATION

I, Sithole Khabo Philile Pearl, confidently declare that the mini-dissertation hereby submitted to the University of Limpopo (UL), for the degree of Master of Science in Agriculture (Agricultural Economics), is the result of my work in design and execution and all the sources or materials contained herein have been duly acknowledged. I declare that this mini-dissertation has never been submitted previously by me for the award of any other degree, diploma or certificate at this or any other university.

Surname and initials **Signature**



Sithole KPP

DEDICATION

I dedicate this mini-dissertation to my entire family.

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First and foremost, let me praise and honour the Almighty God for the opportunity and capacity given to me to realise my aspiration in the form of this mini-dissertation.

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ABBREVIATIONS

TE	Technical efficiency
SE	Scale efficiency
IE	Irrigation efficiency
DMUs	Decision making units
VRS	Variable returns to scale
CRS	Constant returns to scale
DEA	Data envelopment analysis
SASRI	South African sugarcane research institution
DFA	Distribution free approach
SFA	Stochastic frontier approach
AP	Average product
TFA	Thick Frontier Approach
FDH	Free Disposal Hull

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND

The sugarcane sector in South Africa has significant social and economic implications because it contributes significantly to rural employment, sustainable development, and the country's Gross Domestic Product (GDP). According to the National Agricultural Marketing Council (NAMC) (2012), by 2012, the domestic industry's overall average annual income had reached about R12 billion. NAMC (2012) anticipated the overall average value of sugar cane production to be R5.1 billion, with total export revenues of R2.5 billion every year. The overall amount of support provided to the local value chain in the form of rebates to domestic manufacturers and value-added exports was estimated to be around R 300 million per year.

Farmers engage in farming with the intention to maximise profit, which can only be accomplished by optimising production with the fewest available inputs and natural resources. Sugarcane organisations are formed to assist farmers with technological adoption, sustainable land use, and water conservation in sugarcane production. The South African Research Institute under SASA aims to provide the most up-to-date farming technologies, undertake research on the best seed-cane types to employ, and support the adoption of technology and best management practices that promote responsible, sustainable, and profitable land use (Zhou, 2022). The South African cane grower and South African Farmers Development Association (SAFDA) is also aimed at assisting sugarcane farmers with farming technology, land and water. In common, all aforementioned organisations offer free extension services to small-scale growers.

In South Africa, the need of using contemporary technology in agriculture, especially in the face of climate change, cannot be overstated. Africa has twice the average number of agricultural machinery units as the next three sub-Saharan African countries Tanzania, Nigeria and Zimbabwe combined (Kirui and von Braun, 2018). In 2017, the agricultural sector spent 63.7 percent of total capital expenditure on new assets on machinery, tractors, and vehicles (Lombard, 2019).

Wireless communication, data management and analytics tools, remote sensing, robots, drones, satellite systems, and artificial intelligence (AL) are technologies used to produce services targeted at lowering costs, saving resources, optimising inputs, and increasing outputs (Aguera *et al*., 2020). In 2022, mechanisation accounts for about 50% of the total cost of sugarcane production (Tweddle, 2022). This is because sugarcane is a technology-intensive crop. Sugarcane farmers use technology for a variety of tasks and reasons, including soil preparation, plantation, irrigation, and harvesting, and sugarcane farmers use irrigation technology more than others. In a report by South African Sugar Research Institute (2017), the ways to encourage and promote stakeholder adoption of the innovations and technologies developed within the research programme are revised as most small-scale farmers are still constrained to adopt the technology.

According to Monteiro et al. (2010), the republic of South Africa is situated on Africa's southernmost tip, with a total land area of 122 million hectares, of which 18 million hectares are arable. Irrigated land accounts for around 1.3 million hectares or 9% of the overall agricultural land area of 14.6 million hectares. Groundwater and surface water sources are used to irrigate crops in South Africa. Groundwater irrigates only 24% of agricultural land compared to surface water, which irrigates 76%. Water scarcity affects agriculture both as a victim and as a contributor. Agriculture is the world's largest water consumer and a significant source of pollution. Agriculture is responsible for 70% of all freshwater withdrawals, with 60% of it going into irrigation. Unsustainable agricultural water usage practices such as flood irrigation and chemical run-offs undermine the sustainability of livelihoods that rely on water (Dankova, 2016). Sugarcane is a high-water-use crop. It is grown in three provinces in South Africa namely, KwaZulu-Natal, Eastern Cape, and Mpumalanga. In the South African sugarcane industry, the northern irrigated districts of KwaZulu-Natal and Mpumalanga produce around 30% of the entire yearly sugarcane harvest, accounting for 16% of the total area under sugar cane (Olivier and Singels, 2015). Because of competition with other crops, human water use, and periodic droughts, these locations have a high-water demand, putting strain on the sugar industry's limited resources.

Policymakers and environmentalists are increasingly criticising agriculture's use of water for irrigation, placing pressure on the industry to enhance irrigation efficiency and effectiveness. As a result, irrigation efficiency in irrigated sugarcane areas has been identified as a major source of concern. Even though the South African agriculture industry suffered significant losses as a result of the 2016 drought, sugarcane farmers were able to maintain crop output at 71 tonnes per hectare through the utilisation of bulk water upgrades provided by the Sustainable Water Fund (Solidaridad, 2019). The study further revealed that through project interventions, the yield output of small-scale farmers went up on average by about 34% between 2015 and 2018. The majority of small-scale farmers in Mpumalanga participating in the Sustainable Water Fund programme were discovered to be using undercapitalised infrastructure, leaving them without water for months. This indicates that the farmers have not used appropriate irrigation technology, which has a negative impact on their technical and irrigation efficiency.

Sugarcane production in South Africa is practised under sugar estate land, private commercial land and communal land. Small-scale farmers dominate the sector, which operates on tribal or communal land. Since the year 2000, the overall area under sugarcane cultivation in South Africa was reported to be 430 000 hectares (Boudreaux, 2010). This is due to land acquisition programmes created to encourage farming such as the Inkezo. Inkezo, a land reform corporation founded by sugar growers and millers in 2004, was established to aid the transfer of 80 000 hectares of land to black ownership (Van Rooyen, 2008). Inkezo facilitated the transfer of land in three sugarcane-producing provinces. According to Woodhouse and James (2017), in the Nkomazi Municipality of Mpumalanga Province, small-scale sugarcane production began in 1983 in the form of a scheme named the Nkomazi Irrigated Scheme covering several villages, namely, Buffelspruit, Schoemansdal, Driekoppies, Langloop, Tonga and Magogeni.

Production is organised in a form of projects of between 150 to 250 hectares, in which there are individually farmed plots of 2 to 10 hectares. Initially, in 1983, 2500 hectares were used for sugarcane production and in the mid-1990, the land was expanded to 7000 hectares. In 2005, there was a final expansion of 1300 hectares funded by the Land Bank. The land reform which occurred along with two methods in Nkomazi, restitution and market-led redistribution (James and Woodhouse, 2015). Growers were able to acquire additional plots of land. The sugar industry claims that the majority of land used for sugarcane in the Mpumalanga Province is owned by the beneficiaries of land reform.

Several programmes are put in place to support the sugarcane industry. There is a grower development funding facility in which the grower development account received a total investment of R206 million for the development of black growers in the industry. The sugar industry trust fund for education assists students from rural and urban communities with bursaries. To boost the income of small-scale growers who are delivering less than 5000 tons of cane per season, the supplementary payment fund issues financial support to them.

According to the South African Sugar Association (2020), the number of small-scale sugarcane growers has not increased as expected considering the acquisition of land for sugarcane farming since the early 2000s, as has the cane yield. This is owing to many challenges faced by the sugarcane business, including a lack of government financial support and expensive input and farming technology prices. Efficient use of inputs, technology, land and water remains an important subject in developing a sustainable and profitable agricultural sector.

1.2. PROBLEM STATEMENT

According to Woodhouse and James (2015), small-scale sugarcane production by black producers in the Nkomazi Municipality expanded from 2500 hectares to 8300 hectares of land for irrigated sugarcane production from 1983 to 2005. Despite the increase in land under sugarcane production, the output of sugarcane has been decreasing since the early 2000s and in 2019, it took a greater toll by decreasing by 6% (United States Department of Agriculture, 2020).

The Lomati and Komati rivers are the only sources of water for sugarcane growers in the Nkomazi area (Racionzer, 2011). Although the rivers are said to have good water quality, the Komati's downstream areas have several weirs and limited flow (Van der Laan *et al*., 2012). There is a greater challenge with sustainable utilisation of water for irrigation by small-scale sugarcane growers in Nkomazi and if growers do not realise better ways of irrigation, water will remain a problem (Annandale *et al.,* 2011).

However, small-scale sugarcane growers have not yet exploited the full potential of better farming technology even with the support they receive from the Nkomati mill and other sugarcane organisations (Murali and Prathap, 2016). Small-scale sugarcane growers tend to under-utilise or over-utilise production inputs, which harms their level of production efficiency (Ali *et al*., 2013). Small-scale sugarcane growers have the potential to improve production given the proper use of technology and inputs, efficient use of the available land and sustainable use of water. Hence, the study aimed to analyse the technical, scale and water-use efficiencies and socio-economic factors that influence the efficiencies of small-scale sugarcane growers in the Nkomazi Municipality.

1.3. AIM AND OBJECTIVES

1.3.1 Aim of the study

The study aimed to analyse the technical, scale and irrigation efficiencies and socio-economic factors that affect the efficiencies of small-scale sugarcane growers in the Nkomazi Municipality.

1.3.2. Objectives of the study

The objectives of the study were to:

i. Estimate technical efficiency levels of small-scale sugarcane growers in Nkomazi Municipality;
ii. Measure scale efficiency levels of small-scale sugarcane growers in Nkomazi Municipality;
iii. Estimate the irrigation efficiency of small-scale sugarcane growers in Nkomazi Municipality;
iv. Determine socio-economic factors affecting the technical efficiency of small-scale sugarcane growers in Nkomazi Municipality.

1.3.3. Research hypotheses

i. Small-scale sugarcane growers in the Nkomazi Municipality are not technically efficient;
ii. Small-scale sugarcane growers in the Nkomazi Municipality are not scale efficient;
iii. Small-scale sugarcane growers in the Nkomazi Municipality are not efficient in their water-use for irrigation;
iv. There are no known socio-economic factors that affect the technical efficiency of small-scale growers in Nkomazi Municipality.

1.4. RATIONALE OF THE STUDY

The importance of sugarcane production is not only the creation of employment, but also aids in mitigating poverty and improving rural livelihood. The study only focused on the themes such as technical, scale and irrigation efficiencies because they are important subjects in developing agriculture where resources are limited and conserving them is important. Improved efficiency can provide an opportunity for small-scale growers to improve their returns. The use of improved technologies in sugarcane farming increases the output by increasing both land and labour productivity. Instead of traditional methods which involve not only a lot of time, but also huge labour, through the use of technology, small-scale growers can access different types of machines for the cultivation of land and sustaining it (James, 2017). If the growers realise better farming practices by observing the grower with the highest efficiency score, their overall contribution to the total sugarcane production will increase and that will prevent growers from shifting to more profitable crops.

Sugarcane growers in the Nkomazi Municipality have been acquiring additional plots of land through inheritance and loan purchase (Woodhouse and James, 2015), which increases the scale of operation one is under, but it does not necessarily increase the output of sugarcane one can produce with that additional piece of land. Scale efficiency can be reached if a grower can operate as close to its most productive size as possible, so knowing whether the scale of operation is too big or too small can contribute significantly to production efficiency. The land size has an influence on the adoption of technology, the use of inputs and the production practice a grower uses.

Several studies conducted in Nkomazi Municipality (Haile, 2005; Jarmain *et al*., 2014; Singels, 2014; Olivier and Singels, 2015; Adetoro *et al*., 2020) stated that sugarcane production is under irrigated areas due to inconsistencies in rainfall. Full or supplementary irrigation is an attractive technological approach to increase the production efficiency of growers in the Nkomazi Municipality. In South Africa, irrigation water is scarce (Muleba, 2006); hence, its efficient and optimal application is of paramount importance. The availability and cost of obtaining water for irrigation are major contributors to the production efficiency and profitability of a farm.

1.5. ORGANISATIONAL STRUCTURE

This study consists of five chapters. The first chapter consists of the background introduction, the problem statement, objectives and the hypotheses of the study. Relevant previous studies in line with the current study are reviewed and discussed in Chapter two. A thoroughly detailed description of the study site, research methods and variables used for the study's objectives are outlined in Chapter three. Chapter four provides a detailed analysis of the socio-economic characteristics of small-scale growers that were used as the determinants of technical efficiency. Chapter five discusses the empirical findings of the study using a DEA approach, the Non-radial Slack-based Measure Model and a truncated regression of measuring all the efficiencies of focus and their determinants. The last chapter, which is chapter six, comprises the summary, conclusion and policy recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

This chapter provides definitions and a brief description of key terms. It gives a brief background of sugarcane and discusses sugarcane production in South Africa. The chapter further reviews the literature on technical, scale and water use efficiencies, particularly of sugarcane farming.

2.2. DEFINITION OF KEY CONCEPTS

2.2.1 Technical efficiency

According to Kumbhakar and Lovell (2000), as cited by Thabethe (2013), technical efficiency is a situation where a firm adopts an output-expanding or input-conserving approach. Kumbhakar and Lovell (2000) further elaborate on it in simple terms as the ratio of the observed to maximum feasible output, given the production technology and the observed input use.

2.2.2 Scale efficiency

Scale efficiency is the ability of a firm to choose the optimum size of resources (Tsekouras, 2007). For example, choosing the scale of production that will attain the expected production level.

2.2.3 Irrigation efficiency

Irrigation efficiency refers to the amount of water removed from the water source that is used by the crop. The ratio of the volume of water used to produce a crop to the volume of water extracted from a water resource is referred to as irrigation efficiency (Johnson and Cody, 2015).

2.2.4 Small-scale grower

Kirsten and Zyl (1998) define small-scale growers as those growers whose scale of operation is too small to attract the provision of the services needed to be able to increase production. Moreover, small-scale growers operate under the land size of one to ten hectares.

2.3. BACKGROUND OF SUGARCANE

Sugarcane (Saccharum officinarum L.) is one of the world's most important crops, primarily to refine into sugar and increasingly for biofuel. Sugarcane is cultivated for sucrose that accumulates in its stalk, although it was also traditionally grown for its edible inflorescences, for medicine, and as a raw material for weaving and a variety of other uses (Denham, 2014). Sugarcane is grown in most countries in Sub-Saharan Africa. The Food and Agriculture organisations of the United Nations (2015), as cited by Hess et al. (2016), revealed that five countries accounted for more than half the total production of sugarcane in Sub-Saharan Africa. South Africa contributed 23%, Sudan (including South Sudan) 9%, Kenya 7%, Swaziland 7% and Mauritius 7%. The United Nations on Food and Agriculture organisations (2019) revealed that the land that is under sugarcane production annually is around 26 million hectares worldwide and in 2018, the production of sugarcane globally stood at 1.91 billion tonnes and the average worldwide yield was 73 tonnes per hectare. The demand for sugarcane is increasing globally in response to the growing demand for bioethanol and increased sugar demand for human consumption (Hess *et al*., 2016).

2.4. SUGARCANE PRODUCTION IN SOUTH AFRICA

Sugar was introduced in South Africa in 1848, which led to the establishment of the first sugar mill in kwaDukuza in KwaZulu-Natal. Sugarcane has grown to be one of the most important crops in the country. Sugarcane is a key livelihood resource providing employment and income; it generates more income than any other single agricultural enterprise (Cockburn, 2014). South Africa has one of the world's leading cost-competitive sugar industries and is the main producer of sugarcane on the African continent (Muir *et al*., 2010). This is because sugarcane in South Africa is produced in both rainfed and irrigated land. The sugarcane industry has led to the establishment of many towns and cities such as Stanger and Malelane, value chain enterprises and the development and growth of other industries. The industry has great potential to successfully establish a biofuel industry through partnerships among the government, the private sector and foreign investors (Sishuba, 2021). This will positively contribute to solving many of the challenges the South African economy has been facing such as unemployment.

The sugarcane value-chain master plan to 2030 identified numerous constraints facing the industry and the decline of sugarcane output by 25%, the number of sugarcane farmers declined by 60% and employment estimated to reduce by 45% and R1 billion is set towards transforming the industry (Goossens, 2020). It is evident that sugarcane has been having economic contributions to the economy and now struggles to maintain it and has to do so by firstly transforming the farmers that the industry is depending on. According to Galal (2021), the total output of sugarcane produced in the country reduced to 19.3 million metric tons in 2020 as a result of farmers substituting their production of sugarcane for other more profitable and less capital-intensive crops. This further emphasises the fact that sugarcane farmers must adopt better methods, inputs and technologies of farming that will conserve environmental resources such as land and water and at the same time maximise output.

2.5. REVIEW OF PREVIOUS STUDIES

The concept of efficiency has been important since the early 2000s when the importance of minimising inputs for the maximum output was realised due to the increasing costs of inputs. Technical efficiency was the major focus in sugarcane farming, as several studies assessed the level of technical efficiency of sugarcane farmers while interest was also given to the factors that are expected to affect technical efficiency. Later on, more focus on scale efficiency and other farm efficiencies. Msuya and Ashimogo (2005) used a Cobb-Douglas production frontier assumed to have a truncated normal distribution to estimate the level of technical efficiency of outgrower and non-outgrower sugarcane farmers. The study randomly sampled 140 farmers in Turiani Division of Tanzania. The results of the study indicated a positive relationship between technical efficiency and age, education and experience.

A study by Dlamini *et al*. (2010) aimed at assessing the technical efficiency of sugarcane farmers in Vuvulane and Big bend used cross-sectional data collected from 40 sugarcane schemes and 35 individual sugarcane farmers. The results of the study indicated efficiency to range from 37.5 to 99.9% with a mean of 73.6% for the Vuvulane farmers, whilst for the big bend sugarcane farmers, it ranged from 71 to 94.4% with a mean value of about 86%. The study revealed farm size, age and education as having a negative relationship with technical efficiency and off-farm income having a positive relationship with technical efficiency. His results implied that farmers who are more involved in off-farm activities are more technically efficient than those who are not; furthermore when the farm size, age of a farmer and education level of a farmer increase, their technical efficiency also increases.

Ali *et al*. (2013) estimated technical efficiency using the stochastic production function. The study sampled 100 respondents of sugarcane growers during the year 2012. The results revealed that the elasticities of technical efficiency for tractor hours, seed rate, labour days, irrigation numbers, chemical fertilizer, FYM and herbicides were found at 0.185, 0.102, 0.145, 0.093, 0.084, 0.073 and 0.05, respectively. All these variables were positively significant, the mean value was 0.77 while the minimum and maximum efficiency values were 0.57 and 0.91, respectively. This implies that farmers can increase their output by 23%, if they allocate their resources efficiently. The results also indicated age, experience and education as having a positive relationship with technical efficiency, which is contrary to the finding of Dlamini *et al.* (2010), who found these variables to be having a negative relationship with technical efficiency.

Ambetsa *et al*. (2020) estimated the technical efficiency of smallholder sugarcane farmers using a stochastic frontier approach to measure the level of technical efficiency and a Tobit regression to analyse the determinants of technical efficiency. The results indicated a mean value of 0.7069, while the variables education, farming experience, family size, credit access and extension services were positively affecting the level of technical efficiency. A panel study was conducted in three different agro-climatic regions using primary data collected from 2011 to 2013 and the results of the mean technical efficiency scores for the Western Zone, Cauvery Delta Zone and North-Eastern Zone were 0.88, 0.92 and 0.765, respectively (Murali and Puthira Prathap, 2017). The authors found irrigation to have a significant contribution to technical efficiency in all three regions and identified education and experience in sugarcane farming to be the most influential determinants of technical efficiency.

Singh *et al.* (2019) adopted a stochastic production frontier to measure the technical efficiency of climatic and non-climatic factors in sugarcane farming using panel data from 1971-2014. The results indicated that all non-climatic factors have a statistically significant impact on sugarcane production and 91% variation in sugarcane production can be explained through the chosen climatic and non-climatic variables. A study by Ali (2020) used farm size, labour, seed rate, tractor hours, irrigation and urea as input variables to measure technical efficiency and all these variables were found to be statistically significant. 48.49% of the selected growers were below the mean technical efficiency level, indicating that most farmers were technically inefficient and should properly allocate their resources.

A study by Nuhfil and Djoko (2018) assessed the technical and scale efficiency of sugarcane farmers in Kediri District using a DEA approach and found technical efficiency and scale efficiency levels to be 0.917 and 0.856, respectively. The farmers were found to be more technically efficient as they use advanced farming inputs such as improved seed cane, herbicides, pesticides and fertilizer. The study further revealed that the farmers who had low technical efficiency scores were those who allocated their inputs excessively and only 13% of farmers in the district operated in an optimal scale of production.

Padilla-Fernandez and Nuthall (2001) measured the efficiencies of sugarcane farmers using a DEA approach under a specification of variable returns to scale (VRS). The mean pure technical, scale, overall technical, allocative and economic efficiency indices were 0.7580, 0.9884, 0.7298, 0.7941 and 0.6025. The result of the study indicated that the farmers were more scale efficient and the breakdown of scale efficiency of the 127 farmers was that 12 were operating at constant returns to scale, 51 were operating at increasing returns to scale, while 64 were operating at decreasing returns to scale. Furthermore, 12 farmers were found to be 100% technically efficient and at the same time were scale inefficient and 9 exhibited decreasing returns while 3 exhibited increasing returns to scale. This implies that 9 farmers were producing less output than the units of inputs used in the production while 3 were producing more output than the units of inputs used.

A study by Padilla-Fernandez and Nuthall (2012) assessed the allocative, technical and economic efficiencies of sugarcane farms using a non-parametric approach. Comparing small, medium, and large farms, small farms were found to have a mean technical score of 75.7% while medium and large farms were found to have scores of 82.3% and 83.4%, respectively. The allocative efficiency scores for small, medium and large farms were 80.4%, 84.5% and 85.9%, respectively. This implies that small farms are less efficient technically due to the slow adoption of farming technology, while they can allocate their resources or rather inputs more efficient.

A study by Thabethe (2013) analysed the technical, allocative and cost efficiency of small-scale sugarcane growers. From the study, technical efficiency was found to have a mean estimate of 68.5%, which is greater than the allocative and cost efficiency of

61.5% and 41.8%, respectively, thus small-scale sugarcane growers are more technically efficient.

The relationship between technology and irrigation in sugarcane farming is emphasised by a study that assessed the efficiency of irrigation water application in sugarcane cultivation, where the author measured the technical efficiency and irrigation water efficiency of tube well owners and buyers. The results revealed that tube well owners were more irrigation water-efficient than buyers, as the mean score was 0.86 for tube well owners and 0.72 for water buyers (Watto and Mugera, 2015). There is a slight difference of 6% in the number of farmers when comparing water use irrigation efficiency of tube well owners and water buyers, 30% of tube well owners and 30% of water buyers were fully efficient. Both groups of farmers were technical efficient as the mean technical efficiency score for tube well owners was 0.96 and 0.94 for water buyers, indicating the same level of proper technology use, input use and management practice.

Srivastava (2009) investigated the extent of Groundwater Extraction and Irrigation Efficiency focusing on farms under different water markets in India. The results of the study revealed that both buyers and owners of WEMs were technically inefficient in water–use, since most of the farmers owned land less than 2 hectares making them resource-poor and stagnated in adopting farming technology. Hence, the actual use of irrigation water has been found to be much higher than the optimum level, buyers irrigated on average 36.93 hours using about 15.40 litres while sellers irrigated 29.4 hours using about 24.91 litres.

A study by Watto and Mugera (2015) assessed the irrigation efficiency of sugarcane farmers in Pakistan between owners of tube wells and buyers. Owners of tube wells had a mean technological efficiency score of 0.96, while water buyers had a score of 0.94. Tube well owners had a 0.86 irrigation water efficiency score, while water buyers had a 0.72 score. The study discovered that 59% of tube well owners and 45% of water buyers were entirely technical productive across all farms, while only 36% of tube well owners and 30% of water buyers were fully efficient in irrigation water use. Nazir *et al*. (2013) undertook a study to identify factors affecting sugarcane farming in Pakistan and identified irrigation costs as one of the important factors affecting production.

To measure irrigation efficiency, Watto (2015) adopted a moment-based approach to analyse farmers' decisions to adopt tube-well technology when the groundwater table is declining. The results of the study indicated that the probability of tube-well adoption increases significantly with an increase in the expected mean and variance of profit. The study revealed that irrigation water distribution and irrigation application methods were the most neglected aspects in the region and this implied that irrigation efficiency was not prioritised.

2.6. MEASURING TECHNICAL AND SCALE EFFICIENCY IN SMALL-SCALE SUGARCANE PRODUCTION

According to Atici and Podinovski (2015), measuring efficiency is more accurate than measuring productivity in the agricultural sector. This measurement provides information on the performance between input and output in the most recent efficient frontier, which is essential for addressing objectives one through five. The problem of the specialisation of units in agriculture is always present and is exacerbated by the numerous possible farm outputs. Empirical studies on the efficiency of small-scale farmers in developing countries have utilised both DEA and SFA approaches, with only a few studies applying both (Serasinghe *et al.,* 2003; Alene, 2006; Lihn, 2012; Ayo and Mungatana, 2011). Existing studies that applied Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to measure technical efficiency have shown different results. Alene (2006) found that the mean technical efficiency showed contracting values, with the technical efficiency mean of DEA higher than that of SFA. Additionally, Lihn (2012) discovered that education and regional factors influenced technical efficiency when both DEA and SFA were used. The use of DEA and SFA to measure technical efficiency is an active area of research in agricultural economics, with numerous studies conducted to evaluate their efficacy.

One study that evaluated the use of DEA and SFA to measure technical efficiency in the agricultural sector is that of Hossain and Ahmed (2018). The study used both approaches to evaluate the technical efficiency of smallholder farmers in Bangladesh and found that the mean technical efficiency of the sample was higher when DEA was used than when SFA was used. The study also found that education, farm size, and access to credit were significant factors that influenced technical efficiency. Another study that evaluated the use of DEA and SFA in measuring technical efficiency in the agricultural sector is that of Zhang *et al.* (2019). The study applied both approaches to evaluate the technical efficiency of wheat production in China and found that the mean technical efficiency of the sample was higher when SFA was used than when DEA was used. The study also found that access to capital, farming experience, and education were significant factors that influenced technical efficiency.

As a result, there is a lot of ongoing study into the effectiveness of using DEA and SFA to quantify technical efficiency in the agriculture sector. The research's findings are not all in agreement with one another; some studies claim that using DEA results in higher technical efficiency while others claim that using SFA results in higher efficiency. Technical efficiency is also influenced by a variety of context-specific factors. To create more accurate methods for assessing technical efficiency and to better understand the variables that affect it in various agricultural situations, further study is required.

There have been numerous empirical studies that have applied scale efficiency to measure the productivity and efficiency of small-scale agriculture in developing countries. One such study is by Mugera and Langemeier (2011), who investigated the scale efficiency of smallholder dairy farmers in Kenya using data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Their findings showed that only 16% of the farmers were operating at a scale-efficient level, highlighting the need for policies and interventions to improve scale efficiency in the sector. A study by Mungatana and Ayo (2011) analysed the technical efficiency and scale efficiency of small-scale maize production in Nigeria using a stochastic frontier production function approach. Their results showed that scale efficiency was a significant factor in determining the overall efficiency of the farmers, with larger farms being more efficient than smaller ones. The study recommended that policies to promote economies of scale in small-scale agriculture could significantly improve the sector's productivity.

Similarly, a study by Paudel *et al.* (2013) examined the scale efficiency of smallholder vegetable farmers in Nepal using DEA. The results showed that the farmers had a low level of scale efficiency, with an average technical efficiency of 0.67 and a scale efficiency of 0.67. The study recommended that policies to promote access to credit, better market information, and improved extension services could help to improve scale efficiency in small-scale agriculture. At the absolute least, Hossain and Ahmed's (2018) study used DEA and SFA to examine the technical efficiency and scale efficiency of smallholder agriculture in Bangladesh. The findings demonstrated that scale inefficiency was a substantial contributor to the explanation of the farmers' overall inefficiency and that there was significant room for improvement in the sector through improved access to loans and market data.

Overall, the studies above highlight the importance of scale efficiency in small-scale agriculture in developing countries, and the need for policies and interventions to improve the productivity and efficiency of smallholder farmers. The findings suggest that promoting access to credit, market information, and extension services can help to improve scale efficiency and contribute to poverty reduction and sustainable development in rural areas.

2.7. STUDIES ON DETERMINANTS OF TE AND SE

An increasing quantity of research is being done on the factors that affect the technical and scale efficiency of small-scale sugarcane farmers in developing nations. One such study was conducted by Nhemachena *et al.* (2014), who used a stochastic frontier technique to examine the technical and scale efficiency of small-scale sugarcane growers in Zimbabwe. Their findings demonstrated the importance of access to loans and irrigation in determining both technical and scale efficiency, and the study recommended the need for improved access regulations for these resources. Another study by Assoumou Edjabou and Aka (2015) investigated the factors affecting the technical efficiency of small-scale sugarcane growers in Cote d'Ivoire using a Cobb-Douglas stochastic frontier model. Their findings revealed that education, experience, and access to credit significantly influenced technical efficiency, highlighting the importance of human capital development and access to finance in improving the productivity and efficiency of small-scale sugarcane growers.

Similarly, a study by Kiprop *et al.* (2019) analysed the determinants of technical efficiency of small-scale sugarcane growers in Kenya using DEA. Their results showed that access to credit, extension services, and use of improved inputs significantly influenced technical efficiency, with the study recommending the need for policies to improve access to these resources and promote technology adoption among small-scale sugarcane growers. Finally, a study by Ouma *et al.* (2019) examined the determinants of scale efficiency of small-scale sugarcane growers in Kenya using DEA. Their findings revealed that access to credit, farm size, and membership in a farmers' organisation were significant factors influencing scale efficiency, highlighting the importance of institutional support and access to finance in improving the productivity and efficiency of small-scale sugarcane growers.

The studies above emphasise the significance of institutional support, access to credit, and extension services in enhancing the technical and scale efficiency of small-scale sugarcane growers in developing nations. The results imply that initiatives to provide access to these resources and encourage technology adoption can aid in reducing poverty and fostering inclusive growth in rural areas. Economic variables were not included in this study as it only measured technical, scale and irrigation efficiencies, but not economic efficiency.

2.8. CONCEPTUAL FRAMEWORK

It is impossible to come up with a single, comprehensive definition or justification for the concept of efficiency. However, efficiency for a certain firm, is frequently broken down in economic circles using the output to input ratio during a given period. Therefore, computational productivity is used to gauge how effectively finite resources are used, with higher productivity translating to more output with the same or less input. Technical, scale, and input-use efficiency (in this case, irrigation efficiency using water utilisation) are the three different categories of efficiency that Farrell (1957) defined and characterised. The parametric or stochastic frontier production approach (SFA) and the non-parametric approach (DEA) are both used to evaluate relative efficiency indices (Coelli, 1995). The SFA assumes there is a functional relationship between inputs and outputs and uses statistical techniques to estimate parameters for the function and allows hypothesis testing.

According to Farrell (1957), the technical and scale components of any specific firm's efficiency make up its overall performance. DEA was described by Charnes *et al.* (1978) as the foundation for all subsequent advancements in the non-parametric approach. Two efficiency estimation techniques have been established, and they are categorised as parametric and non-parametric approaches by Lubis *et al*. (2014). DEA is distinguished by having a number of benefits, including the ability to handle multiple outputs and inputs, the capacity to handle distributional assumptions of the inefficiency term, and the ability to identify the best practice for every farm. Because the comparability of the inputs in this study was higher than that of the output, the input-oriented DEA was employed.

2.9. CONCEPTUALISATION STUDIES ON TE AND SE

Studies on technical and scale efficiency conceptualisation have been essential in identifying the variables influencing the success of firms and industries. These studies explore the manufacturing process using a variety of theoretical frameworks, such as data envelopment analysis, duality theory, and neoclassical economics. These studies are concerned with figuring out how effectively inputs are converted into outputs in a production process. Farrell (1957) conducted one of the first studies on technical efficiency and suggested a method for comparing the relative efficiency of firms in the same sector. By comparing a firm's actual production to the greatest output that might be made with the same inputs, a method known as the Farrell efficiency measure is used. Data envelopment analysis (DEA) is a non-parametric technique for assessing technical efficiency that does not necessitate explicit assumptions about the functional form of the production function. It was later extended through research by Charnes *et al*. (1978) and Banker *et al.* (1984).

On the other side, scale efficiency gauges how closely an entity adheres to the ideal size of production. This idea is crucial because businesses that are too big or too little might not be performing at their highest level of efficiency. Studies by Tyteca (1982) and Färe and Primont (1995) separately created methodologies for evaluating scale effectiveness based on the ideas of duality and residual income. These techniques emphasise the connection between output level, input pricing, and production of the firm.

2.10. THEORETICAL STUDIES ON TE AND SCALE EFFICIENCY

Theoretical studies have provided a framework for understanding technical and scale efficiency in the agricultural sector. These studies have defined technical efficiency as the ratio of the maximum attainable output to the actual output, given the same inputs, while scale efficiency is the ratio of the actual output to the minimum possible output, given the same inputs. One such study by Fare *et al.* (1994) introduced the concept of a production possibility set (PPS) as a way of measuring technical efficiency. The PPS represents the set of feasible combinations of inputs and outputs, and technical efficiency is measured by the distance from the observed production point to the PPS.

This study also introduced the concept of a cost-minimising input set (CMIS) to measure scale efficiency, which is the distance from the observed input point to the CMIS.

Another theoretical study by Coelli *et al*. (1998) introduced the concept of a meta frontier to account for differences in technology and production practices across regions or countries. The meta frontier represents the best technology available in each region, while the production frontier represents the best technology available in a particular region. This study also introduced the concept of a technical inefficiency index (TII) to measure technical inefficiency, which is the distance from the observed production point to the production frontier. Charnes *et al.* (1978) introduced DEA as a method for measuring technical efficiency. DEA is a non-parametric method that compares the observed output of a production unit with the output of other similar units, using the same inputs. DEA is based on the assumption that the most efficient unit will have a score of 1, while less efficient units will have scores less than 1. DEA has been widely used to measure technical efficiency in various industries, including agriculture.

2.11. SUMMARY OF LITERATURE REVIEW

The theoretical ideas of technical, scale, irrigation, and barriers to technical efficiency have been addressed in this chapter. To pinpoint the obstacles to efficiency, the qualitative approach was described. Few researches have demonstrated how both internal and external factors can hinder technical efficiency. The most commonly used method to measure technical efficiency is the DEA method and the common variables expected to affect technical efficiency are age, off-farm income and farming experience. Irrigation is the most important activity in farming yet little research has been done to evaluate its efficiency, although some researchers tried to include it as a variable.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter describes the study area and explains the methods and techniques that were used to collect and analyse data. In addition, the chapter gives details of the four techniques used to analyse data, namely, Descriptive Statistics, a DEA model and non-radial Slack-based Measure model and a truncated regression.

3.2. DESCRIPTION OF THE STUDY AREA

The study was conducted in the Nkomazi Local Municipality, which is located in the Mpumalanga Province. The Nkomazi region was selected for the study because it is the province's major sugarcane-producing area. The research area is in the Mpumalanga Province of South Africa, in the northeast. It has a population of 393 030 people and 92 202 houses covering a total area of 4 787 square kilometres (Census, 2011). The municipality is linked to Swaziland and Mozambique by a railway line and main national road (N4), respectively. This study assessed growers in two villages in the Nkomazi Municipality, namely, Buffelspruit and Driekoppies.

The resources of the Nkomazi Municipality include a unique combination of soil, climate and water. According to James and Woodhouse (2015), Nkomazi is located in the Lowveld, which has a tropical climate suitable for the production of sugarcane.

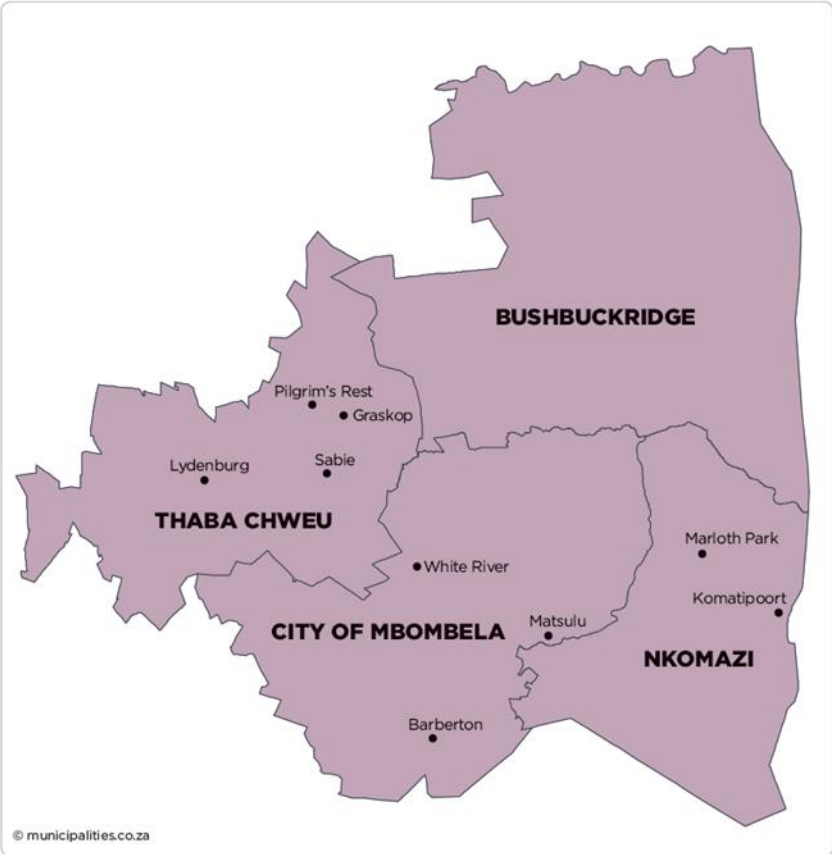

Figure 3. 1: The map showing local municipalities in the Enhlanzeni District of Mpumalanga Province.

Source: Municipalities of South Africa (2019)

3.3. DATA COLLECTION AND SAMPLING PROCEDURE

This research relied on primary data. A structured questionnaire was used to collect data on each grower's sugarcane yield, the number of inputs used in the production process, the amount of irrigation water used, and the growers' socio-economic characteristics. Three sections were included in the questionnaires. The socioeconomic characteristics were captured in Section A. Section B collected data on the amount of sugarcane produced, the amount of each input used, information on the determinants of inefficiency and the number of machines utilised by each grower during the production process. The amount of water used for irrigation was recorded in Section C. The surveys were written in English, with translations provided for those participants who did not have a strong understanding of the English language.

A representative sample of small-scale sugarcane growers in Nkomazi Local Municipality was chosen using a simple random selection approach. The simple random sampling approach was chosen because it assures that each individual is chosen completely at random and that every member of the population has an equal chance of being included in the sample (Owino and Obange, 2018). The study area has a total of 1243 small-scale sugarcane growers (Metiso and Tsvakirai, 2019). The sample size of 90 respondents was randomly selected for this study. The Raosoft scientific calculator was set to include a margin of error of 10% with a confidence interval of 99%.

3.4. ANALYTICAL TECHNIQUES

3.4.1. Descriptive statistics

Descriptive Statistics were used in profiling the socio-economic characteristics of small-scale sugarcane growers. The results were expressed in a form of tables and graph frequencies elaborated in percentages, sums and averages in Chapter four.

3.4.2. Data Envelop Analysis (DEA)

3.4.2.1. Background of the approach

Farrell (1957) invented DEA, which was further improved by Charnes *et al*. (1978) and updated by Banker *et al.* (1984). Data envelopment analysis (DEA) is a nonparametric method measuring relative efficiency and production frontiers within a group of homogeneous Decision Making Units (DMUs) with multiple inputs and multiple outputs (Haas and Murphy, 2003). It is an approach based on linear programming that empirically measures the relative efficiency of multiple similar entities (DMUs).

The DMU is the homogeneous group in process of converting inputs into outputs. In this study, the DMUs are sugarcane growers. In the study area, small-scale sugarcane production is organised in the form of projects named the Nkomazi Irrigation Scheme, where each grower owns a plot of between 2 to 10 hectares, each project has its management and receives extension services from the mill and local department of agriculture. All growers in the projects produce a homogeneous output, which is sugarcane using the same sets of inputs and sugarcane farming in the projects is under irrigated production.

3.4.2.2. Methods of measuring efficiency

A parametric and a non-parametric method are both used to assess efficiency. The stochastic frontier approach (SFA), the Thick Frontier Approach (TFA), and the Distribution Free Approach (DFA) are three independent approaches to the parametric technique (DFA). The efficiency frontier is built using econometric modelling, usually in the form of a Cobb-Douglas (log-linear) production function, according to parametric techniques. As a result, the production function is defined by a collection of explanatory variables (inputs, outputs, and other possible explanatory variables) as well as the two components of the composite error term and the inefficiency term in the regression (Iršová and Havránek, 2010).

According to Asmare and Begashaw (2011), concerning deviations from the production, function is treated as a combination of random error and inefficiency in the stochastic frontier approach. As a result, SFA commonly assumes a two-sided distribution, with the error component having a zero mean and the non-negative inefficiency factor being a one-sided distribution. With DFA, it is possible to relax the presumption that inefficiency is constant across time. Core inefficiency differs from random error in that it is permanent over time, whereas random errors tend to balance out over time. TFA also does not apply any distributional constraints to the composite error term, assuming that the inefficiency term differs between the greatest and lowest efficiency quartiles of the observed decision-making units and that random error exists within quartiles.

Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) are two nonparametric efficiency methodologies. Data envelopment analysis, on the other hand, is the most often used method in the field of research. It was created to assess the performance of various non-profit organisations, such as educational and medical institutions, that were resistant to traditional performance measurement techniques due to the complex and often unknown relationships between multiple inputs and outputs, as well as non-comparable factors that had to be considered (Porcelli, 2009). Non-parametric methods, in contrast to econometric approaches, are based on the notion that the efficiency frontier is derived from actual data of the most efficient decision-making unit (DMU) or the benchmark (Kuosmanen *et al*., 2015).

3.4.2.3. Justification of the approach selected

All the parametric approaches commonly suffer from potential specification errors, because the specified function is at best an approximation to the true but unknown counterpart, all of which require a particular functional form to be specified for the frontier. DEA approach assesses viable input and output combinations based on current data, as opposed to parametric methods that require the former formulation of a production or cost function. The experimentally observed, most efficient DMUs constitute the production frontier against which other DMUs are measured, and DEA has to encompass the property of the dataset's efficient DMUs. Despite its goal of calculating efficiency ratios, DEA has no restrictive assumptions, the flexibility to benchmark multi-dimensional inputs and outputs, and computational ease due to its express ability as a linear program.

3.4.2.4. DEA MODEL SPECIFICATION

Technical efficiency

The DEA model is used to simultaneously construct the production frontier and calculate technical efficiency measures. The model is provided for the case where each of the N farms has data on K inputs and M outputs. 4 Input and output data for the ith farm are expressed by the column vectors xi and Yi, respectively. The K×N input matrix, X, and the M×N output matrix, Y, represent the data for all N farms in the sample.

$\min_{Q,\lambda} Q$…………………….(1)

subjected to:

$$-y + y\lambda \quad\quad 0,$$

$$\theta x_1 - x\lambda \quad\quad 0,$$

$$N1'\lambda = 1$$

$$\lambda\ 0,$$

N1 is an N1 vector of ones, and I is an N×1 vector of constants, where θ is a scalar, N1 is an N×1 vector of ones, and I is an N×1 vector of constants. The technical efficiency score for the i-th farm is the value of θ received. It will meet the following criteria: 1, 1 denotes a frontier location and so a technically productive farm. according to the definition of Farrell (1957).

Scale efficiency

Ratio efficiency measures are:

TECRS = APC/AP

TEVRS = APV/AP

SE = APC/APV

TECRS, TEDRS, TEIRS denote a constant return to scale, decreasing return to scale and increasing return to scale, respectively. AP denotes average product, APC and APV denote average product under constant returns to scale and average products under variable returns to scale.

Where the indicators are all constrained by one and zero. Given this, it is clear that scale efficiency can easily be calculated scale as:

SE = TECRS/TEVRS………………………………..(2)

This scale efficiency measure has a drawback in that it does not reveal if the farm is working in an area with increasing or diminishing returns to scale. Running a second DEA issue based on it with non-increasing returns to scale (NIRS) can address this difficulty. This is accomplished by changing equation (1)'s DEA model by inserting the $N1'\lambda = 1$restriction with $N1' \leq 1$.

3.4.2.5. Non-radial Slack-based Measure Model

Background

The concept of efficiency is analysed in data envelopment analysis (DEA) using either radial or non-radial measures. The non-radial measure deals directly with the input-output slacks that must be minimised, therefore, inputs and outputs do not need to be optimised by the same proportion. The radial measure gives the proportion or a percentage by which all the inputs or outputs are to be reduced or increased simultaneously, whereas the non-radial measure deals directly with the input-output slacks that must be minimised. Radial measurements frequently produce a low-efficiency score, whereas Non-radial models do not (Muhammad and Farooq, 2018).

3.4.2.6. Model specification

To measure irrigation efficiency presumed as the efficiency of a particular input (which is water), the study used the non-radial Slack-based Measure Model that calculates efficiency together with slack values under the assumption of VRS introduced by Cooper *et al*. (2011) and formulated as follows:

Min $(\lambda, \theta, S^{-}, S^{+})[\theta - \varepsilon \sum_{t=1}^{n} S\bar{i} + \sum_{k=1}^{s} s_{k}^{+}]$……………..(3)

Subject to:

$$\sum_{J=1}^{N} \lambda_j x_{ij} - S\bar{i} = ox_{ig}$$

$$\sum_{J=1}^{N} \lambda_j y_{kj} - s_k^{+} = y_{kg}$$

$$\sum_{J=1}^{N} \lambda_j = 1$$

$$\lambda_j \geq 0$$

where $S^{-}, S^{+} \geq 0A_i$ and k*X is an $i \times n$ matrix of inputs, represents a $k \times n$ output row vector and $S\bar{i}$ and s_k^{+} represent the input and output slacks, respectively. The non-Archimedean infinitesimal order that is expected to be small or any real positive number is denoted by the symbol ε. The slack-based DEA model to estimate water input use efficiency (WUE) as proposed by Chemak *et al*. (2010) as follows:

$\mathrm{WUE} = \mathrm{TE} - \frac{V_{eP}}{V_0\rho}$…………………………(4)

Where TE is the technical efficiency estimated using equation 1, V_{eP} is the slack value of the input, and $V_0\rho$ is the observed quantity of the input.

3.4.2.7. TRUNCATED REGRESSION

Estimating determinants of inefficiency

The study used the second stage of the DEA analysis to determine socio-economic factors affecting the technical efficiency of small-scale sugarcane growers in Nkomazi Municipality, the study used the truncated regression proposed by Simar and Wilson (2007) that was bootstrapped to analyse the socio-economic background determinants of technical efficiency.

$$Y_j = \alpha_i + \sum_{j=1}^{\nu} B_j Z_j + \varepsilon_J \geq 0, j = 1, NB\varepsilon_J(0, \sigma^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(5)$$

Where Y_j is technical efficiency, Z_j is the set of explanatory variables for $j = 1, \ldots\ldots 12$, and ε_J is the error term.

Table 3. 1: Definition of variables

Variable	Description	Measurement
Dependent		
Efficiency	Technical, scale and irrigation	Tonnes
Independent Variables		
Age (x_1)	Age of farmer	1= 18-35years, 2=36-48years, 3=49-60years, 4=Above 60 years
Gender (x_2)		0=Male, 1=Female
Level of education(x_3)	The highest level of education a grower has	1=No formal education, 2=Primary education, 3=secondary education 4= Tertiary education

Farming experience (x_4)	The years of experience a grower has in sugarcane farming	1=0-5 years,2=6 – 10 years,3=11 – 20 years, 4=21 -29 years, 5= Above 30 years
Off-farm income (x_5)	The amount of money a grower generates from off-farm activities	1= No income, 2= R0-R5000, 3=5000-10000, 4= Above R10 000
Amount of seed-cane (x_6)	The amount of seed-cane	Tonnes
Amount of fertilizer (x_7)	Quantity of fertilizer in kilograms	Kilograms
Amount of chemicals (x_8)	Quantity of chemicals in litres	Litres
Number of machinery (x_9)	Number of machinery available on the farm	Number
Size of labour (x_{10})	Number of labourers	Number
Land size (x_{11})	Size of arable land	Hectares
Extension access (X_{12})	Whether a grower attends meetings by extension officers or not	1= yes and 0=no
Extension hours (x_{13})	The hours of extension service a grower receives	Hours
Irrigation system (x_{14})	The type of irrigation system a grower utilizes.	1= Flood irrigation, 2= Drip irrigation system, 3=Sprinkler and drip irrigation
Amount of water (x_{15})	Litres of water used for irrigation	Kilolitre

Table 3. 2: Description of the hypothesised effect of independent variables on technical, scale and irrigation efficiency of sugarcane production.

Variable	Description and measurement	Expected sign
Dependent		
Efficiency	Technical, scale and irrigation (number)	+/-
Independent Variables		
Age (x_1)	Age of farmer (Number of years)	+
Gender (x_2)	The gender of a grower (male or female)	+/-
Level of education(x_3)	The highest level of education a grower has (no formal, primary, secondary or tertiary education)	+
Farming experience (x_4)	The years of experience a grower has in sugarcane farming (0-5 years, 6 – 10 years, 11 – 20 years, 21 - 29 years or Above 30 years)	+
Off-farm income (x_5)	The amount of money a grower generates from off-farm activities (No income, R0-R5000, 5000-10000 or Above R10 000)	-

Amount of seed-cane (x_6)	The number of years the farmer spent in school (tonnes)	+
Amount of fertilizer (x_7)	Quantity of fertilizer in kilograms (Kilograms)	+
Amount of chemicals (x_8)	Quantity of chemicals in litres (Litres)	+
Number of machinery (x_9)	Number of machinery available on the farm(number)	+
Size of labour (x_{10})	Number of labourers (number)	+
Land size (x_{11})	Size of arable land (Hectares)	+/-
Extension access (x_{12})	Whether a grower attends meetings by extension officers or not	+
Extension hours (x_{13})	The hours of extension service a grower receives (Hours)	+
Irrigation system (x_{14})	The type of irrigation system a grower utilises (Flood irrigation, Drip irrigation system, Sprinklers, or Centre pivot)	+

Amount of water (x_{15})	Litres of water used for irrigation (Litre)	+

3.5. ETHICAL CONSIDERATIONS

3.5.1. Permission

Permission to carry out the study was obtained from the Turfloop Research Ethics Committee (TREC) before its commencement.

3.5.2. Inform Consent

The researcher notified the interviewees that participation in the study was voluntary and they were free to withdraw from participation at any time whenever they felt uncomfortable. The interviewees were asked to sign a consent form to show that they agreed to take part in the study.

3.5.3. Confidentiality

In this study, the confidentiality and anonymity of the participants were taken into consideration. The participants' real names were not disclosed in the study and the information they provided was used for research only.

3.5.4. Privacy

The researcher provided one-on-one sessions with the respondents so that other people would not hear the conversation.

3.5.5 Protection from harm

The researcher protected participants from harm by providing participants with the right to withdraw from the study whenever they did not feel comfortable in answering the questions, and by not disclosing their identities.

3.5.6. Respect

The researcher respected all participants regardless of gender, belief, race, etc.

3.6. CHAPTER SUMMARY

This chapter stated the study area where the data were collected, the data set and the analytical procedures that were used to analyse the data. The data were analysed using a DEA model, a Non-Radial Slack-Based Measure Model and a truncated regression. The study intended to measure technical, scale and water-use efficiency, and the factors affecting technical efficiency.

CHAPTER FOUR: SOCIO-ECONOMIC CHARACTERISTICS OF SMALL-SCALE SUGARCANE GROWERS IN THE NKOMAZI MUNICIPALITY

4.1. INTRODUCTION

This chapter provides insight into the socio-economic characteristics of smallholder and commercial farmers interviewed for the study in the Nkomazi Municipality of the Mpumalanga Province. The results presented below are drawn from the data garnered as detailed in Chapter 3. Descriptive statistics including frequencies cross-tabulation, standard deviation, mean, minimum and maximum values are used to describe the socio-economic characteristics of sugarcane small-scale growers in the Nkomazi Municipality.

4.2. DESCRIPTIVE STATISTICS

The study used a sample of 90 small-scale sugarcane growers from three villages under the Nkomazi irrigation schemes. The data were collected from Buffelspruit under the Khanyangwane Irrigation Scheme, Driekoppies under the Ngogolo Irrigation Scheme and Schoemansdal under Nhlangu-West Irrigation Scheme. 30 growers were randomly selected from each irrigation scheme. Sugarcane growers in the study area sell their produce to the Nkomati local mill in Malelane, the market is less competitive as the price is set by the mill.

4.2.1. Descriptive statistics of the socio-economic characteristics

Table 4. 1: Descriptive statistics of socioeconomic characteristics

Variable	Mean	Std Deviation	Minimum	Maximum
Age	68	12.744	38	87
Gender	0.53	0.502		
Level of education	8	2.042	0	16

Off-farm income	6.8	0.805		
Farming experience	8.81	1.121		
Extension access	0.43	0.498		
Extension hours	76.27	0.709	0	312

Source: Computed by author from study data (2022)

According to Table 4.1, the youngest grower in the Nkomazi Municipality is 38 years, with 87 being the oldest and an 68 years being an average age. These findings reveal that elderly people mostly practice sugarcane farming in the study area. The reasons may be that most of the beneficiaries under the Nkomazi Irrigation Scheme benefited from the land in 1983 when the project was initially introduced James and Woodhouse (2015) and most are still utilising it for sugarcane farming. The gender of growers in the study area has a mean average of 0.53 and a standard deviation of 0.502. On average, small-scale sugarcane growers in Nkomazi Municipality have 8 years of education with a minimum of zero years corresponding to no formal education and a maximum of 16 years corresponding to tertiary education. Growers in the study area earn an average of R6800 from off-farm activities and have an average of 8.81 years of farming experience. On average, sugarcane growers in the study area receive 76.27 hours of extension services, with the minimum of zero hours and a maximum of 312 hours in one production cycle.

Table 4. 2: Frequency and percentage results of socioeconomic characteristics

Variable	**Description**	**Frequency**	**Percentage**
Gender	Male	42	47
	Female	48	53
Age	18-35 years	0	0
	36-47 years	15	17

	48-60	32	36
	Above 60 years	43	47
Level of education	No formal education	25	28
	Primary education	27	30
	Secondary education	24	27
	Tertiary education	14	16
Farming experience	0-5 years	10	11
	6-10 years	8	9
	11-20 years	29	32
	21-30 years	15	17
	Above 30 years	28	31
Off-farm income	No income	19	21
	Below R5000	46	51
	R5000-R10000	20	22
	Above R10000	5	6
Extension access	Yes	51	57
	No	39	43
Extension hours	0	39	43
	104	39	43
	208	9	10
	312	3	4

Irrigation system	Drip	5	6
	Sprinkler	82	91
	Drip and sprinkler	3	3

Source: Computed by author from study data (2022)

Table 4.2 presents a summary of the frequency and percentage results of all the socioeconomic characteristics, which Figures 4.1 to 4.8 diagrammatically represents.

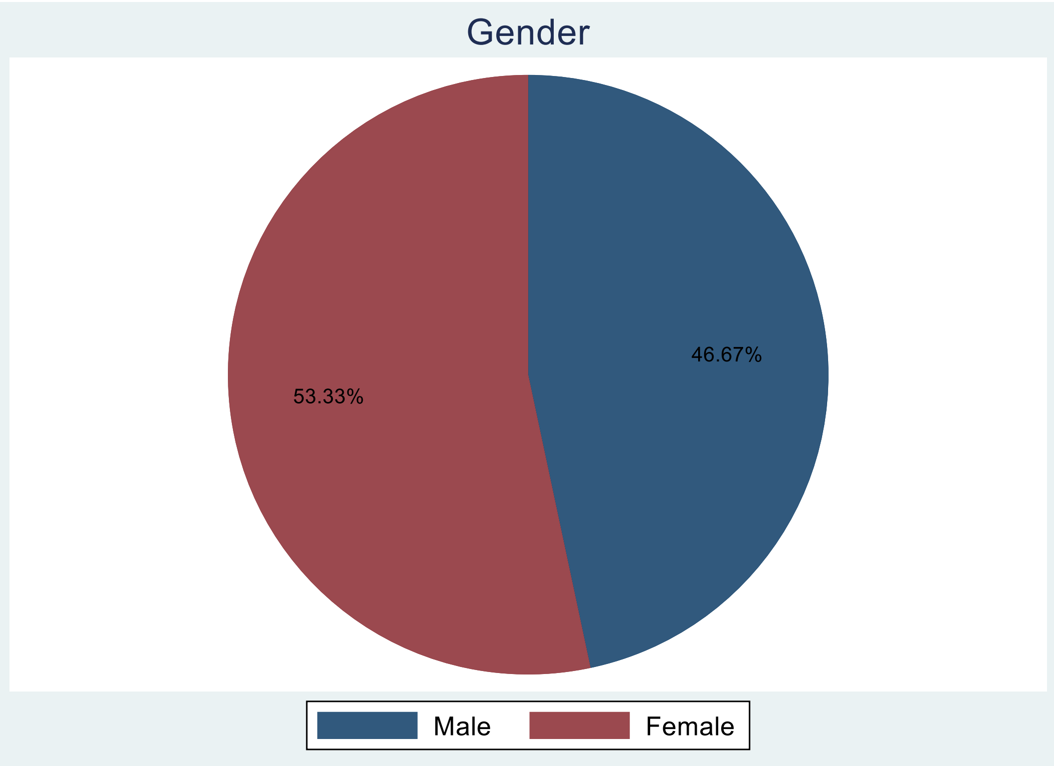

Figure 4. 1: Gender of a small-scale sugarcane grower

Source: Computed by author from study data (2022)

Figure 4.1 highlights the gender of growers in the Nkomazi Municipality. The above results indicate that sugarcane farming in the study area is dominated by female growers, as they are 53% compared to their male counterparts who comprise 47%. These results are in line with the findings of Gininda *et al*. (2014) and Agholor and Sithole (2020), whose studies sampled small-scale sugarcane growers in the Nkomazi Municipality and confirmed that women are dominating in sugarcane farming.

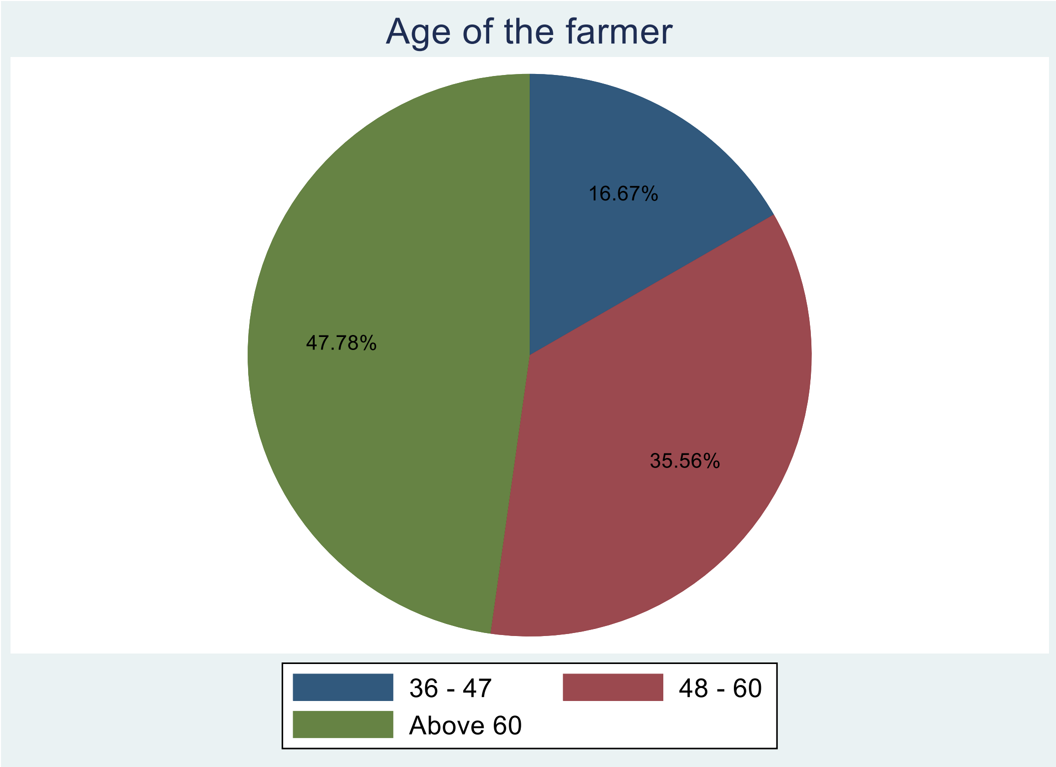

Figure 4. 2: Age of a small-scale sugarcane grower

Source: Computed by author from study data (2022)

The age of a grower was expressed as a categorical variable, where farmers can fall between the age of 18-35 years (youth), 36-48 years (adult), 49-60 years and above 60 years (elderly or pensioned). No growers were found to be between the age of 18-35 years. 17% of growers were between the ages of 36-47 years, 36% were between the ages of 48-60 years and most growers were above 60 years. These results imply that sugarcane farming in the area is dominated by elderly people who are above the age of 60 years (possibly pension beneficiaries). The youth does not participate in sugarcane farming at all. The findings of this study concur with the findings of a study by James and Woodhouse (2015), conducted in the Nkomazi Municipality with small-scale sugarcane growers. The study found sugarcane farming to be dominated by people above 50 years of age as they comprised 72%.

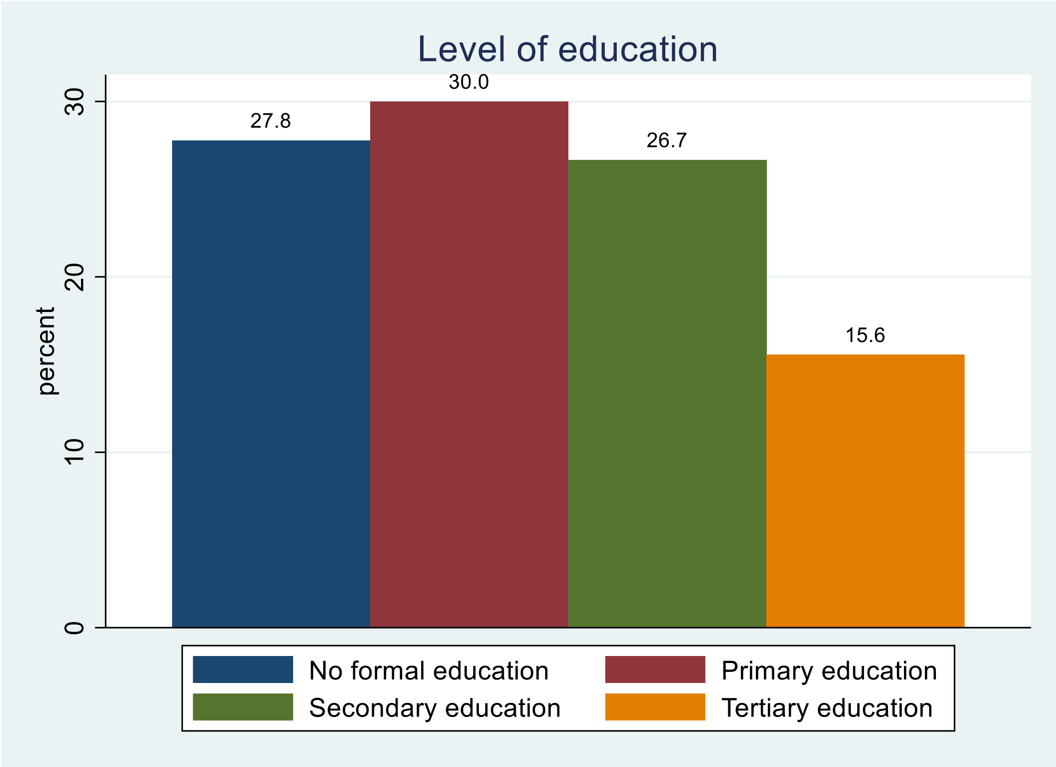

Figure 4. 3: Level of education of a small-scale sugarcane grower

Source: Computed by author from study data (2022)

The level of education of growers was expressed as a categorical variable, where it ranged from no formal education (a grower has never been to school), primary education (7 years of formal education), secondary education (12 years of education) and tertiary education (16 years). The results indicate that 28% of growers had no formal education, 30% had only primary education, 27 % had secondary education and the minority were growers with tertiary education at 16%. The results imply that a majority of growers in the study area had no formal education. This could be related to the majority of growers being above the age of 60 as most old people have no formal education. The results are in line with a study by Agholor and Sithole (2020), conducted in the Nkomazi Municipality, who found growers with no formal education to be 27% and the minority to be growers with tertiary education.

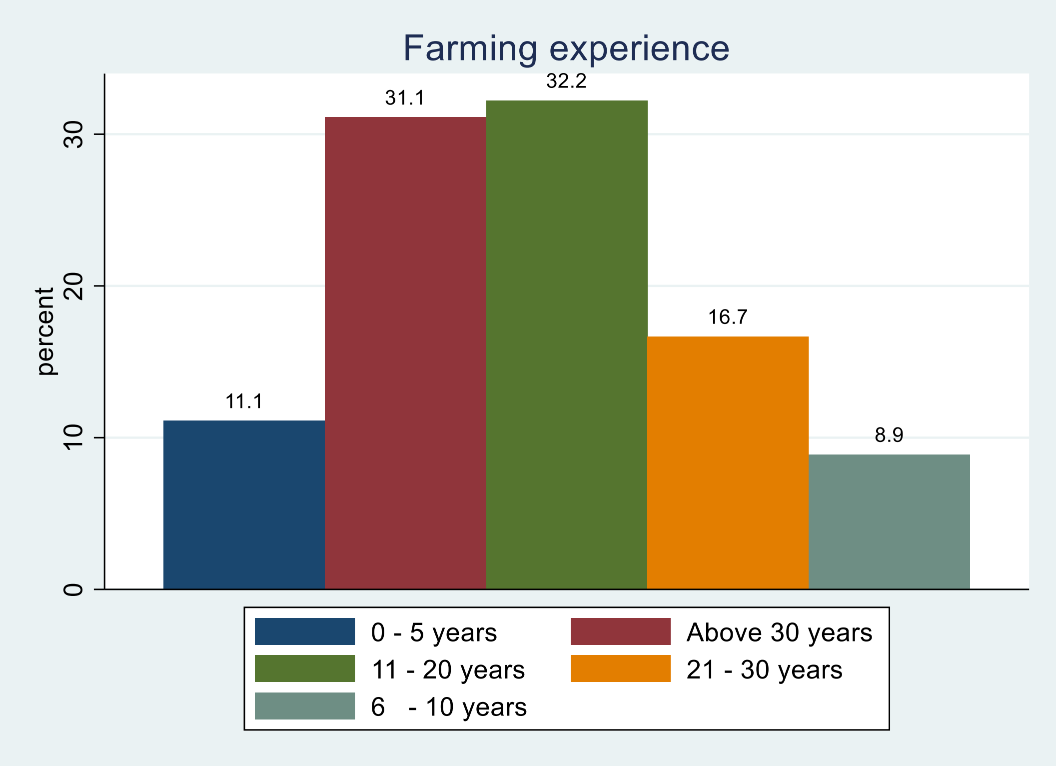

Figure 4. 4: Farming experience of a small-scale sugarcane grower

Source: Computed by author from study data (2022)

The farming experience of a grower was expressed as a categorical variable, which ranged from 0-5 years, 6-10 years, 11-20 years, 21-30 years and above 30 years. The above figure 4.4 indicates that growers with a farming experience between zero to 5 years were 11%, growers with a farming experience of between 6-10 were 9%, growers with farming experience of between 11-20 years were 32%, growers with between 21-30 years of farming experience were 17% and growers with above 30 years of experience were 31%. The results imply that sugarcane growers in the study area are experienced in sugarcane farming as most growers had a farming experience of above 6 years.

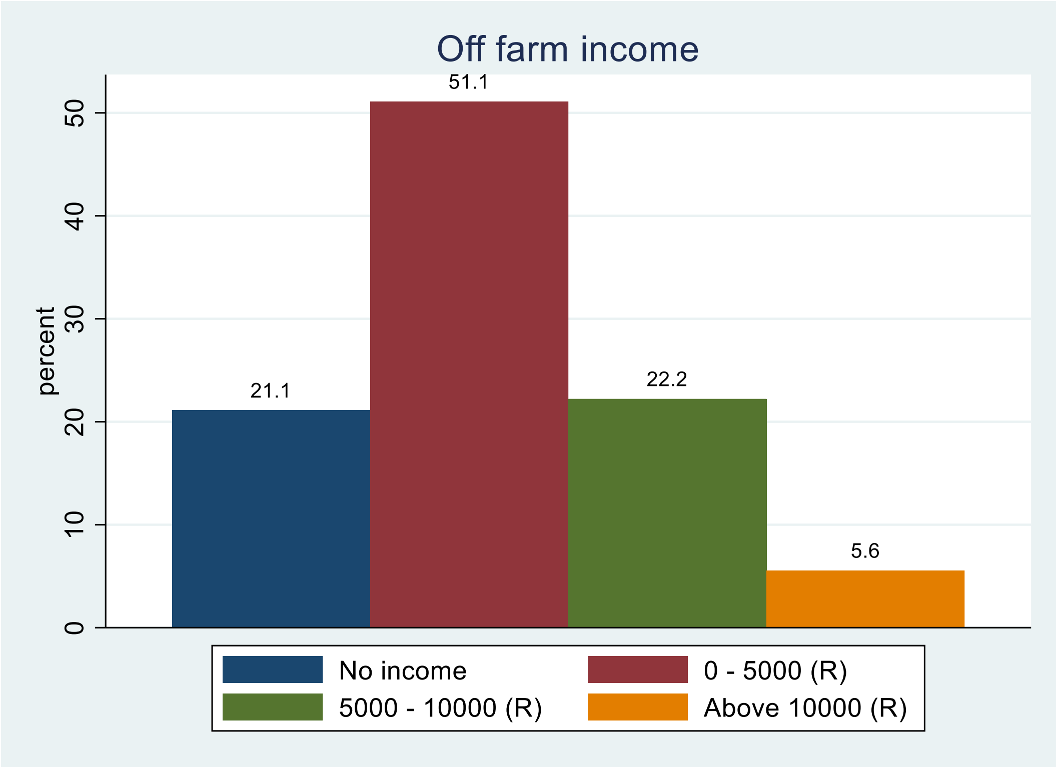

Figure 4. 5: off-farm income of a small-scale sugarcane grower

Source: Computed by author from study data (2022)

Off-farm income is simply the income a farmer generates from activities done outside of sugarcane farming. The off-farm income of a grower was expressed as a categorical variable, ranging from no income, below R5000, between R5000-R10000 to above R10000. 21% and 22% of growers had no income and an off-farm income of between R5000-R10000, respectively. The majority of growers had an income ranging from R0 to R5000 being 51% and the minority of growers having an off-farm income above R10000 are 6%. The results of this study indicate that most of the sugarcane growers in the study area had an income of below R5000. This could be inter-correlated with the results indicated in figure 4.2, which indicates that a majority of growers were above the age of 60. Growers above the age of 60 are eligible for a social pension grant of more than R2000 monthly.

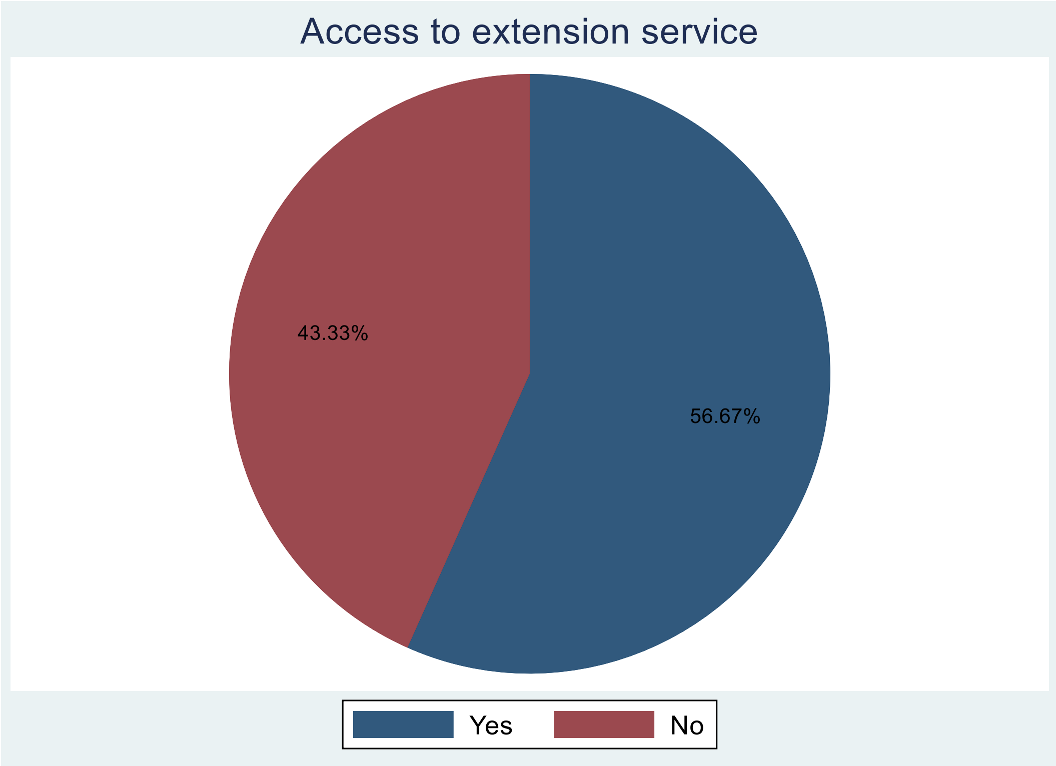

Figure 4. 6: Extension access

Source: Computed by author from study data (2022)

Extension services are rendered by the local agricultural government and the local Nkomati mill. Extension officers come to the farm three times a week, for two hours on each visit. Farmers who do not come to the farm when extension officers visit were 43% and a majority of farmers who utilise the extension service offered to them was 57%. These results imply that most sugarcane growers sampled utilise services offered by extension officers.

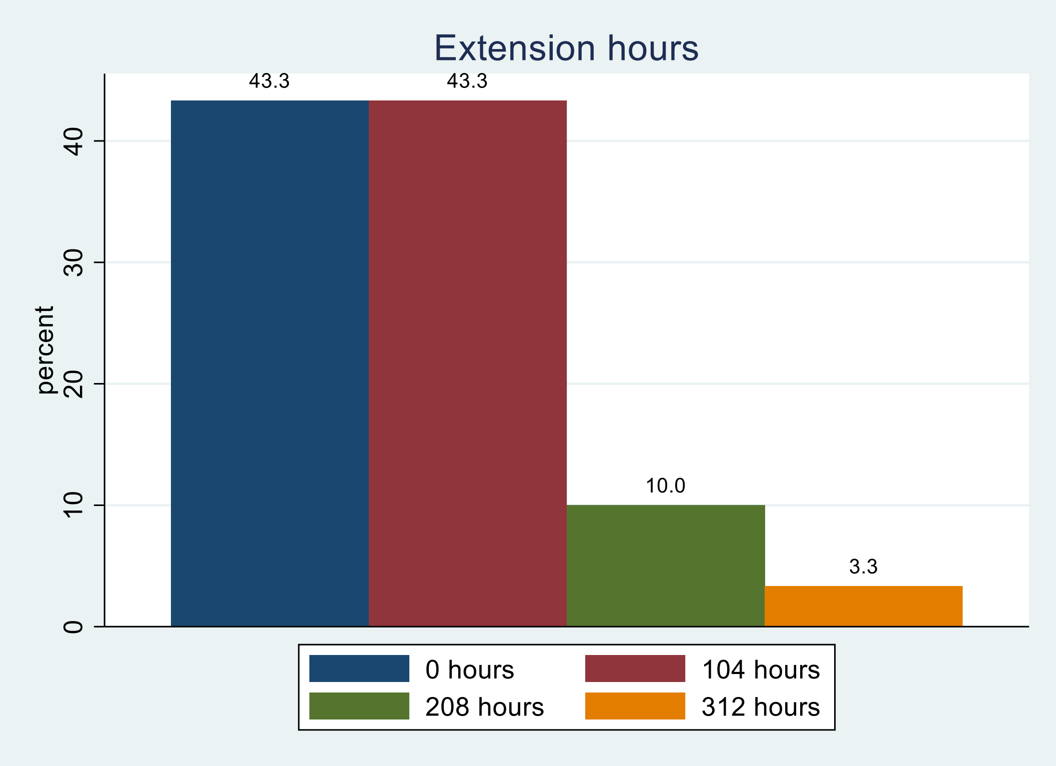

Figure 4. 7: Extension hours

Source: Computed by author from study data (2022)

The above Figure 4.7 indicates the hours a grower receives from extension services in the production cycle. This variable is derived from sixth variable (extension access), where 43% of the growers sampled had no access to extension service and on this variable are indicated by zero hours of extension services. From the remaining 57% of growers who have access to extension services, 43% attend extension meetings once. Growers attending the meetings twice a week are 10% and growers who attend all three meetings a week, being the minority, are 4%. These results imply that a majority of sugarcane growers do not attend the meetings by extension officers and amongst those who attend, most of them attend only once a week.

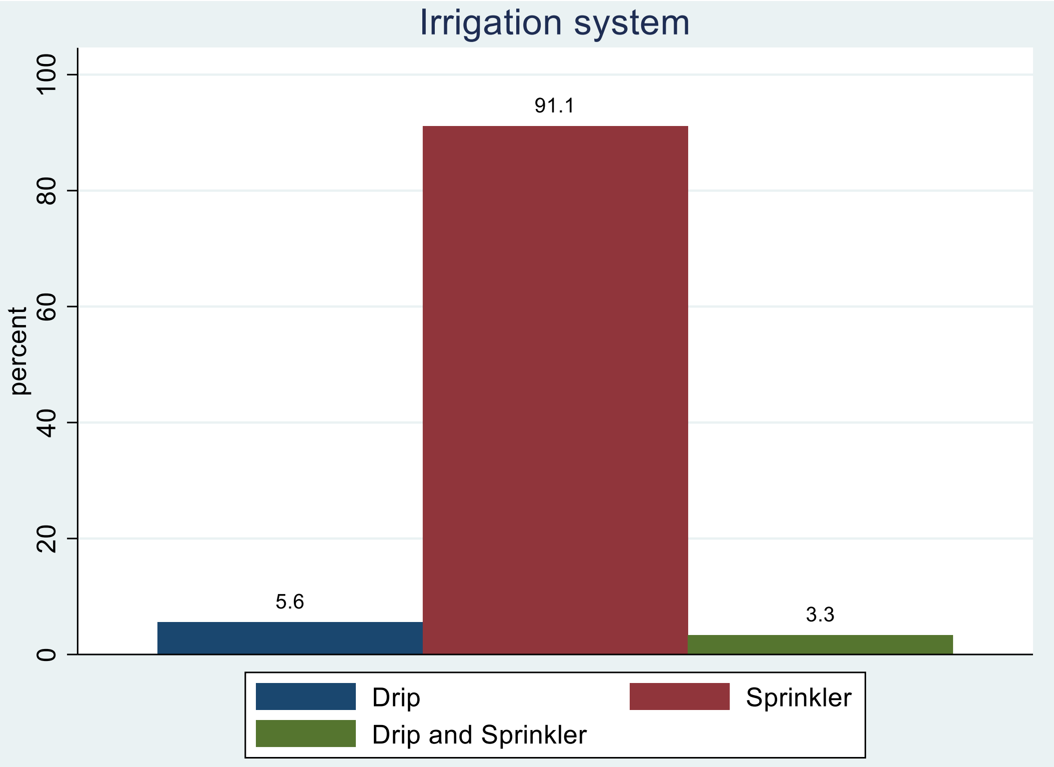

Figure 4. 8: Irrigation system

Source: Computed by author from study data (2022)

Growers in the study area are familiar with two irrigation systems: drip and sprinkler irrigation. 6% of growers used drip irrigation, 91% of growers, being the majority, used sprinkler irrigation and 3% used a combination of drip and sprinkler irrigation systems. These results imply that most growers in the area used sprinklers for irrigation and only a few used a drip or the combination of both drip and sprinkler. These results imply that growers in the study area adopted the use of a sprinkler irrigation and only a few adopted a drip irrigation system.

4.3. CHAPTER SUMMARY

This chapter presented the descriptive statistics results in detail. It provided diagrams demonstrating percentages for each variable to further unpack the socioeconomic status of small-scale sugarcane growers in the Nkomazi Municipality.

CHAPTER FIVE: DISCUSSION OF EMPIRICAL ANALYSIS RESULTS

5.1. INTRODUCTION

Chapter four laid a detailed foundation for empirical analysis by presenting an overview of basic growers' socio-economic characteristics and factors that were expected to affect the level of technical efficiency of small-scale sugarcane growers in the Nkomazi Municipality. The study aimed to analyse the technical, scale and irrigation efficiencies and socio-economic factors that affect the efficiencies of small-scale sugarcane growers in the Nkomazi Municipality. The study used descriptive statistics, the DEA approach, the Non-Radial Slack-based Measure Model and a Truncated regression. The specific objectives of the study were to estimate the technical efficiency levels of small-scale sugarcane growers, measure scale efficiency levels of small-scale sugarcane growers, estimate the irrigation efficiency of small-scale sugarcane growers and to determine socio-economic factors affecting the technical efficiency of small-scale sugarcane growers in the study area.

5.2. DESCRIPTIVE STATISTICS

This section dealt with technical, scale, irrigation efficiencies and the factors affecting technical efficiency. The study used Data envelopment analysis software R-studio to measure the level of all efficiencies researched and the factors that affect technical efficiency. In this study, the dependent variable was output, measured in tonnes.

Table 5. 1: Descriptive statistics of output and inputs variables

Variable	Mean	Std deviation	Median	Minimum	Maximum
Output (Sugarcane)	612.29	207.85	592.2	66.56	1476
Seed-cane	79.15	15.79	78.28	18.54	104.3
Labour	5	1.68	5	2	9
Fertilizer	7221.64	2128.0	7556.53	800.9	10643
Chemical	386.22	85.47	380	35	560

Land	7.68	1.64	7.6	2.1	10.1
Machinery	6	0.474	6.0	5	6
Water	974717	1158141	864000	95160	11635204

Source: Computed by author from study data (2022)

Table 5.1 above shows that sugarcane growers in the study area produced on average 612.29 tonnes of sugarcane in their previous production year (2021). A minimum of 66.56 tonnes were produced and a maximum of 1476. This implies that some farmers produce less than the expected average. This could be related to the minimum land size of 2.1, as growers produce according to their capacity and scale of production, which is measured by the land size. A typical grower uses on average 79.15 tonnes of seed cane in one production cycle, seed cane weighs more than a regular seed and growers use up to a maximum of 104.3 tonnes from a minimum of 18.54 tonnes. On average a grower hires 5 labourers to work in the preparation of land, plantation, daily irrigation, de-weeding, burning and harvesting of sugarcane. Sugarcane growers in the study area hire a maximum of 9 labours and a minimum of 2 labourers for the whole production year. The main activity done on the farm is irrigation, while the other activities are done seasonally.

Concerning fertilizer, sugarcane growers in the study area use MAP (planting fertilizer), Makhabeni [5:1:5(36)] and LAN [160:20:100(32)], and the required application of fertilizer per hectare is advised by extension officers. On average, growers uses 7221.64kgs of fertilizer, 800.9kgs being the minimum and 10643kgs the maximum. There are two different chemicals farmers enlisted to be using: Scat 360 SL used for de-weeding applied directly to the soil after or before it is prepared for plantation, and Piranh 510 SL applied months after the plant has started growing depending on the soil's needs. The amount of chemicals a grower applies depends on the soil's needs and extension officers advise growers on which, when and how many chemicals to use, but it is entirely up to the grower whether or not to take the advice. This leads to a minimum of 35 litres and a maximum of 560 litres of chemicals. This implies that a grower can decide to use one chemical to remove weeds and not apply any chemical again, while one may apply all suggested chemicals. Growers in the Nkomazi Municipality have an average of 7.68 hectares of land, a grower with 2.1

hectares of land has the minimum land size and the one with 10.1 has the maximum land size. Growers in the study area have an average of 6 amounts of machinery to use in the production process. The maximum of 6 types of machinery includes a tractor, disc, broom-sprayer; plough, ripper and irrigation system. A grower with a minimum of 5 did not utilise a ripper due to reasons related to the soil requirements on plantation time. A typical grower uses on average 974717 kilolitres of water for the whole production cycle, while the minimum amount of water used for irrigation is 95160 kilolitres and the maximum is 11635204 kilolitres.

The benchmarking performance management program R-studio and the accompanying packages were used to analyse the results in this chapter. The study's empirical findings were used to compare each producer to the optimum sugarcane-producing method. Under varied returns to scale, the DEA efficiency calculation in Table 5.2 was calculated. Given that a farm must have TE, SE and IE equal to 1, the frequency distribution of technical, scale and irrigation efficiency revealed variation.

Table 5. 2: Summary of technical and scale efficiency results

	TE		**SE**	
	Frequency	Percentage	Frequency	Percentage
0-24	0	0	0	0
26-49	0	0	16	17.78
50-74	0	0	37	41.11
75-99	87	96.7	30	33.33
100	3	3.3	7	7.78
Minimum		87		26
Maximum		100		100
Mean		90.8		69.04
Std Deviation	0.078		0.184	

Source: Computed by author from study data (2022)

The above table is a summary of technical and scale efficiency scores of the small-scale sugarcane growers in the Nkomazi Municipality. The mean technical efficiency of the growers was 90.8, while the mean scale efficiency of growers was 69.04. The technical efficiency of the farmers ranged from 0.83(83%) to 1(100). The least efficient farmers can reduce input usage or increase production by 17 percent [(1-0.83)/(1)] to achieve the required technical efficiency of the most efficient farmer. The scale efficiency of the growers ranged from 0.26(26%) to 1(100). The least efficient grower can reduce input usage or increase production by 74 percent [(1-0.26)/(1)] to achieve the required scale efficiency of the most efficient grower. Out of 90 growers interviewed, 87 growers had a technical efficiency score ranging from 75% to 99%, and only 3 growers were fully efficient at 100%. Growers who were fully scale efficient were 7, 16 growers had a scale efficiency score of between 26-49%, 37 growers had a scale efficiency score of between 50-74% and 30 growers were scale efficient at a level between 75-99%.

Table 5. 3: Returns to scale

RETURNS TO SCALE	**PERCENTAGE (N=90)**
TEC	14.3
TED	14.3
TEI	71.4

Source: Computed by author from study data (2022)

TEC, TED, TEI denotes constant return to scale, decreasing return to scale and increasing return to scale, respectively.

Table 5.3 showed that 14.3% of the sugarcane growers operated at the optimal scale of constant return to scale, while 14.3% of the growers exhibited a decreasing return to scale. These growers need to properly allocate inputs to increase technical efficiency. While the highest number (71.4%) of the growers exhibited an increasing return to scale, these growers were operating below the optimal scale.

The Slack-Based Measure Model was applied to estimate the irrigation efficiency of small-scale sugarcane growers. It is worth noting that all sugarcane growers under the Nkomazi Irrigation Scheme were irrigating and each grower was allowed to irrigate 8 hours every day. Furthermore, growers are advised to have 3 sprinklers per hectare, while with drip irrigation sugarcane is planted along counter lines.

Table 5. 4: Frequency distribution of slack-based irrigation efficiency

	Irrigation efficiency	
	Frequency	Percentage
0-24	0	0
26-49	0	0
50-74	0	0
75-99	87	96.7
100	3	3.3
Minimum		87
Maximum		100
Mean		90.8
Std Deviation	0.078	

Source: Computed by author from study data (2022)

As indicated in Table 5.4, no growers had an irrigation efficiency score below 74%. 96.7% of growers in the study area had an efficiency score of between 75 to 99 percent, while only 3.3% were fully efficient. The average efficiency score of growers was found to be 90.8%, implying that 90.8% of growers sampled are efficient in their water-use for irrigation.

The aggregated irrigation efficiency score was measured using the water-use formula explained in Chapter three.

Table 5. 5: Average percentage of aggregated irrigation efficiency measures

	Average percentage
Technical efficiency	90.8%
Water slack	239451.77 kilolitres
Water	974717 kilolitres

Source: Computed by author from study data (2022)

WUE= 90.8-(239451.11/974717)

WUE=90.55%

The average irrigation efficiency of sugarcane growers is 90.55%. These results imply that 90.55% of growers are efficient in the use of water for irrigation.

Table 5. 6: Bootstrap truncated estimates of determinants of technical efficiency

Variable	Estimate	Standard error	Pr(>ItI)	Confidence
Age^2 of a grower	-0.097	0.088	0.002**	0.1841
Age of a grower	-0.086	0.045	0.005**	0.2218
Gender of a grower	0.016	0.061	0.008**	0.2856
Level of education	-0.049	0.012	0.780	0.2923
Farming experience	0.046	0.064	0.030**	0.2675
Off-farm income	0.058	0.034	0.087*	0.1178

Extension access	0.034	0.028	0.094*	0.2761
Extension hours	0.090	0.048	0.682	0.1345
Irrigation system	-0.026	0.121	0.001***	0.0987

Note: *,** and *** denotes 10, 5 and 1 percent, respectively.

Source: Computed by author from study data (2022)

The results and presentation of the current study's findings complement those of more recent research that evaluated the factors influencing technical efficiency using a truncated regression including but not limited to those by Barasa *et al.* (2020), Long *et al*. (2020), Lépine *et al*. (2015), and Tetteh *et al*. (2020). Due to the DEA method's incapacity to take into account statistical errors, these authors encountered slightly higher standard errors than the coefficients in some variables and did not include test statistics values; instead, they presented the p or z values (Brown *et al*., 2018; Xue and Harker, 1999).

Age^2 was added to the model to reflect the impact of age, which may not have a linear relationship with technical efficiency. The shortened regression model was able to represent the impact of various ages without assuming that the effect is linear across all ages by using age^2 as a proxy for age. To model the impact of various ages, Tetteh *et al*. (2020) and Long *et al*. (2020) used the same methodology.

As illustrated in Table 5.6 above, there is a negative relationship between the age of a grower and technical efficiency, and it is significant at a 5% level. The negative effect of age on technical efficiency was also noted by (Ali *et al.,* 2013; Francis *et al.,* 2020; Dlamini *et al.,* 2010). This implies that as a grower moves from their youth to adulthood and further to their elderly ages, their level of technical efficiency decreases. A study conducted by Thabethe (2013) motivated by a positive coefficient argued that growers under the age of 40 are the ones that are more technically efficient.

The relationship between the gender of a grower and technical efficiency exhibited a positive impact and was significant at a 5% level. These results imply that both female and male growers are equally productive and that gender does not have any effect on productivity. These results are in line with the findings of Ambetsa (2020). The level of education is negatively related to technical efficiency, but it is not significant at any level. The adverse effect of education is evidence that it directly improves farmers' ability to allocate resources more effectively. Higher sugarcane output is anticipated as farmers become more educated. The results are consistent with the effect shown by Ali and Jan (2017) who found the level of education to be having a positive relationship with technical inefficiency, meaning the level of education had a negative relationship with technical efficiency. The finding contrasts that of Carrer *et al*. (2022) who concluded on a positive relationship between the level of education of growers and technical efficiency.

The years of farming experience a grower has concerning sugarcane growing had a positive relationship with technical efficiency at 5%. This implies that the more years of farming experience a grower has, the better they allocate resources to achieve an exceptional level of sugarcane output. These results concur with the findings of Matsvai *et al*. (2022) who reported a positive effect of experience with technical efficiency. The income a grower generates from off-farm activities has a positive relationship with technical efficiency at 10%, implying that when a grower is involved in off-farm activities to generate an income, they are more likely to be more technically efficient than does who have no off-farm income. The results are in line with the findings by Ali and Jan (2017) and Ali *et al*. (2020) who observed a negative relationship between off-farm income and technical inefficiency. On the contrary, Mbehoma (2013) observed a negative relationship between off-farm income and technical efficiency.

Extension access had a positive relationship with technical efficiency at 10%. Results imply that the more a grower has access to extension services, the more technically efficient they will be. The positive effect between technical efficiency and extension service was observed by Francis *et al.* (2020). Extension hours are positively related to technical efficiency, but it is not significant at any level. The more hours a grower invests in attending meetings conducted by extension officers or the more they avail themselves when an extension officer visits, the better they will allocate their resources for optimal output. Most small-scale growers have adopted sprinkler irrigation systems. There is a negative relationship between the irrigation system of growers and technical efficiency at a 1% level of significance. This implies that the significance of saving water while irrigating has not yet been realised by the growers in the study area, as the results in Chapter 4 indicated that only 5% of the growers adopted drip irrigation and only 3% adopted both the sprinkler and drip irrigation, the remaining 92% adopted sprinkler irrigation. This indicates that growers will be able to increase technical efficiency by adopting a more water-conserving irrigation system. The negative relationship between the irrigation systems and technical efficiency is accompanied by a higher percentage of growers using a sprinkler irrigation system only.

Table 5.7: Description of the hypothesised and actual effect of independent variables on technical efficiency of sugarcane production

Variable	Description and measurement	Expected sign	Actual sign
Dependent			
Efficiency	Technical efficiency	+/-	+/-
Independent Variables			
Age (x_1)	Age of farmer (Number of years)	+	–
Gender (x_2)	The gender of a grower (male or female)	+/-	+
Level of education(x_3)	The highest level of education a grower has (no formal, primary, secondary or tertiary education)	+	–
Farming experience (x_4)	The years of experience a grower has in sugarcane farming (0-5 years, 6	+	+

	– 10 years, 11 – 20 years, 21 -29 years or Above 30 years)		
Off-farm income (x_5)	The amount of money a grower generates from off-farm activities (No income, Below R5000, 5000-10000 or Above R10 000)	-	+
Extension access (x_6)	Werther a grower attends meetings by extension officers or not	+	+
Extension hours (x_7)	The hours of extension service a grower receives (Hours)	+	+
Irrigation system (x_8)	The type of irrigation system a grower utilises (Flood irrigation, Drip irrigation system, Sprinklers, or Centre pivot)	+	–

The table above originated from Table 3.2 in Chapter 3, which described the variables and their anticipated effects on efficiency. The expected sign and the actual sign obtained throughout the analysis are included in Table 5.7. The study solely focused on how socioeconomic factors influence technical efficiency, and the inputs were only utilised to calculate efficiency scores, thus they were omitted altogether. The output of sugarcane (technical efficiency), which was the dependent variable, can rise or fall depending on the independent variable. Technical efficiency was found to be negatively correlated with age, education level, and irrigation system. Technical efficiency was positively correlated with gender, farming experience, off-farm income, extension access, and extension hours.

5.3 CHAPTER SUMMARY

This chapter discussed the results obtained when addressing the objectives of the study in lieu of existing literature that either supported or contrasted the findings of the current study.

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1. INTRODUCTION

This chapter provides a summary of this study and the conclusions that were drawn from this study. The chapter also provides policy recommendations that may be employed to enhance the farm efficiency of small-scale sugarcane growing to ensure high yields, increased income and conservation of water for irrigation.

6.2. SUMMARY OF THE STUDY

The main aim of the study was to analyse the technical, scale and irrigation efficiencies and socio-economic factors that affect the technical efficiency of small-scale sugarcane growers in the Nkomazi Municipality. The study had four objectives: the first objective was to estimate the level of technical efficiency of growers; the second objective was to measure the scale efficiency level of growers; the third objective was to estimate the level of water-use efficiency of growers, and the fourth objective was to determine socio-economic factors affecting technical efficiency of small-scale sugarcane growers in Nkomazi Municipality. The study used various analytical techniques to fulfil the aforementioned set of objectives.

The study was conducted in the Nkomazi Local Municipality. For data collection purposes, 90 small-scale sugarcane growers were selected using a simple random sampling method. In organising and analysing data, DEA, a Non-Radial Slack-Based Measure Model and a Truncated regression were used to measure all the efficiencies and the factors affecting technical efficiency. Furthermore, descriptive statistics were utilised to analyse the socioeconomic characteristics that were used as the determinants of technical efficiency.

The DEA results of the study showed that the TE scores of sugarcane growers had a mean of 90.8% with a minimum of 83% and a maximum of 100%. This means that 90.8% of the growers were technically efficient and that the growers were able to produce over 83% of the maximum feasible output. The DEA results of the study showed that the SE scores of sugarcane growers had a mean of 69.04% with a minimum of 26% and a maximum of 100%. This means that 69% of the growers were scale efficient. The minimum scale efficiency level of 17.78 implies that growers were not utilising land efficiency to maximise output. The least efficient grower has to increase production by 74% to be at the same level as the most efficient grower. The

DEA results of water slacks indicated that on average irrigation efficiency of sugarcane growers was 90.8% with a minimum of 87% and a maximum of 100%. The minimum irrigation efficiency score of 87% implies that growers still have room to reduce the consumption of water for irrigation and still produce optimal output. The least efficient grower has to reduce the amount of water used for irrigation by 13% to be at the same level as the most efficient grower. The results of the Non-Radial Slack-Based Measure Model to measure the aggregated irrigation efficiency of all the growers combined is 90.55%, which is accurately at the same level as the slack-based average mean.

Finally, a Truncated regression was used to identify socioeconomic characteristics that influence technical efficiency. The study contributes to the literature by producing unbiased results by employing a bootstrapped DEA and regressing the socio-economic variables of technological efficiency using truncated regression. The empirical results of the truncated regression analysis found that age, gender, farming experience, level of education, off-farm income, extension access, extension hours and irrigation system were all significant in determining the technical efficiency of growers. However, age, level of education and irrigation system were found to be negatively related to technical efficiency. While gender, farming experience, off-farm income, extension access and extension hours were positively related to technical efficiency.

6.3. CONCLUSION

The study had four hypotheses: the first hypothesis was that small-scale sugarcane growers in the Nkomazi Municipality are not technical efficient; the second hypothesis was that small-scale sugarcane growers in the Nkomazi Municipality are not scale efficient; the third hypothesis was that small-scale sugarcane growers in the Nkomazi Municipality are not efficient in their irrigation, and the fourth hypothesis was that there are no known socio-economic factors that affect technical efficiency of small-scale growers in Nkomazi Municipality. The study used various analytical techniques to fulfil the aforementioned set of objectives.

Hypothesis one: Small-scale sugarcane growers in the Nkomazi Municipality are not technically efficient. This hypothesis was accepted because the DEA results revealed that the mean efficiency score was 90.8%, indicating that only 90.8% of the growers were technically efficient and 9.2% of the growers must allocate inputs properly to improve their efficiency. Therefore, the growers were over-utilising production inputs. The minimum of 83% also suggests that the least efficient grower has to decrease input usage by 17% to produce the required score to be technically efficient.

Hypothesis two: Small-scale sugarcane growers in the Nkomazi Municipality are not scale efficient. This hypothesis was accepted because results from the DEA analysis revealed that the mean scale efficiency score was 69.04%, indicating that 69.04% were scale efficient and 30.96% of the growers had room to improve their efficiency. The minimum of 26% suggests that the least efficient grower has to reduce input usage by 74% to achieve the required efficiency score to be technically efficient.

Hypothesis three: Small-scale sugarcane growers in the Nkomazi Municipality are not efficient in their irrigation. This hypothesis was accepted because the results indicated that the average irrigation efficiency scores from the slack-based analysis and the Non-Radial Slack-based Measure analysis were 90.8% and 90.55%, respectively and can both be rounded off to 91%. These average irrigation efficiency scores indicate that 91% are efficient in irrigation and 9% of the growers can still reduce the amount of water they use for irrigation to achieve the same level of sugarcane output. The minimum of 87% suggests that the least efficient grower at 87% has to reduce water usage by 13% to achieve the required efficiency score to be considered efficient in their irrigation.

Hypothesis four: There are no known socio-economic factors that affect the technical efficiency of small-scale growers in Nkomazi Municipality. This hypothesis was rejected because the results from the truncated regression revealed that all variables expected to affect technical efficiency were significant. Age, level of education and irrigation system had a negative relationship with technical efficiency. Gender, farming experience, off-farm income, extension access and extension hours had a positive relationship with technical efficiency.

6.4. RECOMMENDATION

Given the findings from the efficiencies of sugarcane growers in Nkomazi Municipality, several recommendations can be made. These recommendations will be an eye-opener to and relevant input in assisting several stakeholders (i.e. farmers, policymakers, workers' unions, government, etc.) to make consultative sustainable decisions.

a). The results from descriptive statistics revealed that 43% of growers in the study area did not attend meetings conducted by extension officers or rather did not have contact with extension officers at all. The results further revealed that amongst the 57% that have access to extension services, 43% only come once a week for extension meetings. Extension officers should find effective methods to communicate with sugarcane growers. The Nkomazi local radio station can be an effective platform to communicate with growers without them having to come to the farm. Extension officers can get a slot from the radio stations where they will be able to teach growers about new farming technology, improved recommended seed canes, input applications, loans and also price variations of inputs and other farming types of equipment. The platform can be opened for growers to also communicate back to the extension officers through a call during the radio programmes and ask questions related to the specific problem they might be facing on the farm.

b). Growers should adopt the use of a drip irrigation system, especially during the early growth stages of sugarcane to conserve water as that will direct water from the source straight to the root zone of the crop without wasting it. Boosting production or enabling themselves to add more hectares with the same amount of water, will enable producers to make better use of the water supply. Water needs to be conserved because the water supply used for irrigation is the same supply used by households, factories, and other businesses in the study area. Already, each grower is given 8 hours for irrigation each day, which amounts to approximately 38 400 litres of water per grower each day. This should stimulate interest to adopt efficient ways of irrigation.

c). The youth is not involved in sugarcane growing, as there were no growers between the ages of 18-35 years sampled. This could be constrained by the fact that obtaining land under the Nkomazi irrigation schemes is through land reform, inheritance, or internal purchases. This makes the sugarcane sector difficult to penetrate for young growers who want to join sugarcane farming. A new irrigation scheme should be established which will allow the youth to buy or lease land for sugarcane farming. Through the use of the National Youth Policy, the government can financially assist the youth to obtain land, machinery and inputs. This could boost economic growth and reduce youth unemployment. The unemployed agricultural graduates could be the ones to participate, as they already have knowledge in agricultural farming and different disciplines can be organised into one group (i.e. soil science, plant production, agricultural economists, etc.) to form cooperatives, which will ensure that a large number of unemployed agricultural graduates are absorbed.

d). An education programme that will allow growers to obtain enough education to read, write, and understand instructions should be established. The programme should not only allow growers, but also their children or beneficiaries without formal education to enrol in it. The programme should be done as a short course that sugarcane organisations, such as the cane growers, can establish through the local Mlumati TVET College. The short course can consist of modules related to sugarcane farming, farming technologies and economics. This will equip growers with the necessary knowledge they need to increase output and allocate resources efficiently. This can also make it easy for extension officers to disseminate information to an understanding audience, and it can solve the issue of lack of formal education and technology stagnation in sugarcane farming for the next generation as well.

6.5. AREAS FOR FURTHER STUDIES

The study was limited to one sugarcane-producing area in the Mpumalanga Province. Moreover, it only sampled 90 sugarcane growers and only used the DEA approach to measure the level of efficiencies. Therefore, the results of this study cannot be generalised to represent the entire population of small-scale sugarcane growers in the province. As such, future studies might consider using both the SFA and the DEA approaches to compare the results. These studies may also investigate input-slack efficiencies of all the inputs considered in sugarcane production.

The sugarcane industry consists of various participants along the value chain and sugarcane growers are among them, leaving out other interesting parties. Future studies might consider measuring the efficiencies of the mill in the production of sugar. The potential of sugarcane used for bioenergy and fuel ethanol has yet to be realised and more studies should be done taking into consideration the potential, constraints and other contributing factors in the sector.

6.6. CHAPTER SUMMARY

This chapter provided a summary of the findings and drew a conclusion based on the hypotheses tested in relation to the findings. It made recommendations while taking into account the impact that various factors had on the technical degree of efficiency and concurrently recognising the significance of scale and irrigation drivers.

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ANNEXURE A: QUESTIONNAIRE

Faculty of Science and Agriculture

SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

Department: Agricultural Economics and Animal Production

Household Questionnaire

Research Title: *Measuring Technical, Scale and Water-use efficiencies of Small-scale sugarcane growers in the Nkomazi municipality of Mpumalanga province*

Background Information:

Khabo Sithole is a MSc student from University of Limpopo, Faculty of Science and Agriculture, School of Agricultural and Environmental Sciences under the Department of Agricultural Economics and Animal Production conducting research on "*Measuring Technical, Scale and Water-use efficiencies of Small-scale sugarcane growers in the Nkomazi municipality of Mpumalanga province".* The responses given during this research will be treated as confidential information and the information obtained will be used for the purposes of this research only.

General Information:

Enumerator's name:
Name of the District Municipality:
Name of the Local Municipality:
Name of the village:
Contact number:
Date:

Section A: Socio-economic characteristics

1. Age

18 – 35 years	36 – 47 years	48 – 60 years	Above 60 years

2. Gender

Male	Female

3. Educational level

No Formal Education	Primary School Education	Secondary Education	University Education

4. Farming Experience

0-5 years	6 – 10 years	11 – 20 years	21 -29 years	Above 30 years

5. how much income do you receive from off-farm activities?

No income	Below R5000	5000-10000	Above R10 000

6. Do you receive extension service?

Yes	No

7. if yes, how many hours of extension services do you receive in one production cycle?

Section B: Amount of inputs and output

1. How much output of sugarcane did you produce last season (2020)?

2.How much seed-cane do you use for one production period?

3. How much fertilizer do you use in one production period?

4. How much chemicals do you use in one production period?

5. Do you use any machinery and implements to produce sugar cane?

Yes	
No	

6. If yes, circle all the machineries and implements you use?

1	2	3	4	5	6	7
Tractor	Irrigation pump	Plough	Disc	Truck	Ripper	Other

7. How many labourers do you have working in the farm?

8. How many hours did they work in the production of sugarcane?

9. What kind of land do you own?

Tribal ………………

Communal …………

Private ………………

Other ………………………. (Mention)

10. What size is your farm?

11. Do you use all the available land to grow sugar cane?

Yes		No	

12. If No, how much land was used for sugarcane in the last season?

13. How many times in a week do you go to the farm when the extension officer visits?

Section C: Amount of water and irrigation systems used

1. Pick all the irrigation systems you use in the whole production cycle?

Flood irrigation	
Drip irrigation system	
Sprinklers	
Centre pivot	

2. How much water did you use last season?

…………………….Thank you so much for your participation…………………………