THESIS SUBMISSION

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Full name and surname: Ramigo Pfunzo

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Supervisor: Prof. Yonas T. Bahta

Co-supervisor: Prof. Henry Jordaan

Declaration

I declare that the work submitted for the Doctor of Philosophy in Agricultural Economics with the University of the Free State is my independent work and has not been submitted to any university or other tertiary institution.

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Ramigo Pfunzo   Date

Dedication

This Doctor of Philosophy (PhD) in Agricultural Economics is dedicated to my late mother and sister:

Hlengani Edith Mukhethiwa and Ramigo Halatedzi

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Authorship declaration

This is a publication-based thesis, and the details of the articles are as follows:

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- *Pfunzo, R., Bahta, Y.T. and Jordaan, H., 2024. Data on Economic Analysis (*on a small scale and commercial agricultural activities)*: 2021 Social Accounting Matrices (SAM): https://doi.org/10.38140/ufs.26008588.v1*
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Abstract

The development of irrigation systems is strategically used to improve food security and achieve the Sustainable Development Goals (SDGs 2) of ending hunger and poverty with the alignment of the South African National Development Plan (NDP). This study contributes to the construction of the 2017 and 2021 National Social Accounting Matrix (SAM) for South Africa. A 2017 and 2021 National SAM for South Africa incorporates regional accounts. Only in the Limpopo Province of South Africa are agricultural industries, labour, and households captured at the district level. In contrast, the agricultural sector, labour, and household accounts in other provinces remain unchanged.

However, the 2021 provincial SAM for Limpopo Province was successfully categorised according to irrigation systems and sources of water use. The irrigation systems were further disaggregated according to the maize industry, with the land account disaggregated according to the sources of water used for maize production. Most of the studies on the impact of electricity price increases found that it negatively impacted the economy in terms of a decline in GDP and an increase in unemployment. Different empirical studies reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. The study on the impact of electricity tariff increases on provincial and district agricultural sectors was successfully evaluated using the cost-push-price model. The modelling studies significantly contributed to evaluating various irrigation systems using SAM-based modelling and water sources for crop production, such as maize in the arid and semi-arid conditions of Limpopo Province. The Social Accounting Matrix (SAM) aimed to improve the database's quality for modelling, including, but not limited to, policy analysis, multiplier analysis, price analysis, and Computable General Equilibrium (CGE).

Most of the studies on the impact of electricity price increases had a negative impact on the economy in terms of a decline in GDP and an increase in unemployment. These studies further reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. Researchers rarely empirically assess the impact of electricity tariff increases on provincial and district agricultural sectors. Thus, another significant contribution was to evaluate the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and production.

The studies on irrigation techniques and water uses in the maize industry reported that the drip irrigation system was found to consume more groundwater and obtain yield and net profit with a reduced application. Most of the studies applied statistical analysis such as ANOVA (Analysis of Variance). However, no studies have directly computed in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling. The modelling studies would significantly contribute to evaluating various irrigation systems by using sources of water for crop production, such as maize in arid and semi-arid conditions of Limpopo Province, using SAM-based modelling.

The main objective of the study was to evaluate the effect of irrigation agriculture on the economy of Limpopo Province, South Africa. The first SAM multiplier analysis showed that output multiplier effects were more significant for rainfed agriculture than irrigation agriculture. However, irrigation agriculture had the highest institutional income, land return, and value-added multiplier compared to rainfed agriculture. The type of crop did not influence the findings, with irrigation consuming more input per unit of output. The results implied that innovative technology practices would improve water efficiency and increase the financial advantage of farmers while minimising environmental burdens.

The second analysis from the SAM price model showed that the cost of production for rainfed agriculture is much higher than that of irrigation agriculture in all regions of South Africa. Limpopo and Northern Cape provinces of South Africa had the highest costs of production increases for irrigation agriculture compared to other provinces. The policy implication of expanding the electricity sector will not only boost the agricultural sector in one region/province but will also increase output in other regions/provinces of the economy. The increase in electricity prices and the shortage of electricity provide an incentive for agricultural industries to invest in appropriate mitigation strategies, such as renewable energy sources. The third analysis from poverty indices concluded that irrigation is more advantageous in alleviating poverty than non-irrigation in Limpopo Province. The findings imply that investment in irrigation infrastructure is critical for enhancing irrigation access for many financially disadvantaged farmers. Therefore, increasing productivity is essential by investing in irrigation and ensuring farmers have full access to credit facilities.

The third analysis from the 2021 provincial SAM for Limpopo Province reported that micro and drip irrigation systems had the largest output multiplier effect. This implies that these irrigation systems play a significant role in increasing maize output, saving water, and improving food security, further allowing farmers to adopt these irrigation systems. However, pivot, sprinkler, drip, and micro-irrigation generate less value added and institutional incomes than other irrigation systems such as canal, flood, and coupling line irrigations. This implies that to enhance the value addition of pivot irrigation, farmers should significantly restrict water application to farms with reduced hectares to maximise profit.

Water schemes and groundwater had the highest farm return on maize in the province. The study concludes that the groundwater and water schemes play a significant role in growing and sustaining maize and other agricultural industries to reduce food insecurity. The government should consider introducing financial incentives to farmers currently experiencing challenges installing irrigation systems and borehole water on farms. Therefore, investment in irrigation infrastructure for these systems would improve affordability and accessibility for all farmers and further create better incomes.

The findings may not be applicable to other South African provinces due to regional variations in climate, resources, and agricultural practices. The environmental impact of irrigation, particularly water scarcity, is not explicitly addressed in terms of sustainability concerns. The study emphasises innovative technologies without acknowledging potential limitations in access or affordability for farmers lacking technology. The sole focus on profitability might overlook broader social or environmental considerations. Water scarcity was the most limiting factor due to climate change. However, improving water availability is required by implementing technologies to improve water management for sustainable agricultural production. Future research should consider disaggregating agriculture according to different crops to evaluate the economic impact of irrigation and rainfall at the regional level. The data should display racial and gender group classifications of households. The SAM did not include all districts in South Africa; therefore, researchers, academia, and stakeholders must consider focusing on other districts and possibly adding other accounts (sectors) from local municipalities. Further research is needed to compare the long-term economic, social, and environmental impacts of irrigation and rainfed agriculture in Limpopo by extending the SAM model to capture the environmental impact of irrigation on water resources and assessing the

social equity implications of irrigation, including access to water and land for small-scale farmers.

Keywords: Income, national accounts, land, output, agricultural industries, water use, multiplier analysis

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List of Abbreviations

CGE	Computable General Equilibrium
DBSA	Development Bank of Southern Africa
EC	Eastern Cape
FS	Free State
GHS	General Households Survey
GOS	Gross Operating Surplus
GP	Gauteng Province
HHD	Households
I/O	Input and Output
IFPRI	International Food Policy Research Institution
KZN	KwaZulu-Natal
LCS	Living Conditions Survey
LMD	Labour Market Dynamics
LP	Limpopo Province
MP	Mpumalanga Province
NAM	National Accounting Matrix
NC	Northern Cape
NDP	National Development Plan
NW	North West
PROVIDE	Provincial Decision-Making Enabling
QLFS	Quarterly Labour Force Surveys
RAS	Reticular Activating System
ROS	Rest of South Africa
ROW	Rest of the World
SAM	Social Accounting Matrices
SARB	South African Reserve Bank
SARS	South African Reserve Services
SDGs	Sustainable Development Goals
StatsSA	Statistics South Africa

SUT	Supply and Use Tables
WC	Western Cape
ZAR	R is the South African Rand, the national currency of South Africa

Chapter 1

1.1. Introduction and background

The agricultural sector supports approximately 60%-80% of the population in developing countries and is a major contributor to national income and economic growth (Hussain et al., 2007). In developing areas, approximately 183 million hectares of agricultural land are under some form of water management and storage infrastructure. Therefore, water storage infrastructure is essential for managing changes in rainfall (Peacock et al., 2007). In many regions, agricultural production is rainfed, which is often insufficient and unreliable (Baloi, 2022). As water is crucial in agricultural production, the sector is a major user of water resources. Improving irrigation efficiency is crucial to ensuring that food is produced with limited water (Phakhathi, 2016; Sinyolo et al., 2014).

In many countries, irrigation development is a primary strategy to achieve or improve food security and attain the Sustainable Development Goals (SDGs 2) of ending hunger and poverty, subsequently improving food security (Mupaso et al., 2023). Irrigation is vital for food production in areas of water scarcity, including sub-Saharan African countries, specifically South Africa (Darko et al., 2020). Extensive irrigation development has made it possible to improve agricultural production in regions far from water resources during the dry season. Irrigation provides ways of raising agricultural production by increasing agricultural output (yields) and cropping intensities (Abdullah, 2006). Rainfed agriculture is an important farming method that relies solely on rainfall for irrigation. It is practised extensively in regions with little access to supplemental irrigation. Rainfed agriculture is practised under a variety of soil types and agroclimatic and rainfall conditions. Rainfed agriculture leaves farmers exposed to ill-distributed and limited annual rainfall, as well as the occurrence of climatic hazards such as drought and floods. Undulating soil surfaces, practices of extensive agriculture, relatively large field sizes, and low crop yields compound the issue. On the other hand, irrigation is the artificial application of water to the soil for crop production. Controlled amounts of water are applied to land to grow crops, landscape plants, and lawns (Singh et al., 2017; Venkatesan et al., 2005). There are different types of irrigation agriculture. Farmers are more resilient when using irrigation than when relying on rainfed practices. Irrigation increases the availability and quality of water in agricultural production compared to rainfed agriculture. Thus, agricultural sustainability and livelihoods for many households are improved (Maru et al., 2023).

Clemmens (2006) emphasised that during the Green Revolution, Asia increased agricultural output because of irrigation. FAO (2007) stated that only 40% of global food production was in irrigated land. Schultz et al. (2005), Abdullah (2006), and Schultz et al. (2009) asserted that the world's food production will double by the period 2025-2030 to keep up with the food demand of a growing population of approximately 8 billion people. According to Schultz et al. (2009), approximately 80% of the increased demand for food is expected to grow from available cultivated areas, while 20% appears from newly established cultivated land. Schultz et al. (2009) and Abdullah (2006) reported that half of the needed production in the coming years is expected to come from the irrigated land due to its benefits of increasing output (yield). Irrigation comprises only 70% of water withdrawn from the world's river systems, whereas irrigation efficiency is less than 40% (Qureshi, 2018). Despite significant contributions to world crop production, there have been concerns and issues regarding the sustainability of irrigation agriculture, environmental impact, and performance.

Social Accounting Matrix (SAM) based models with Computable General Equilibrium (CGE) and SAM multipliers are applied to policy analyses and influence policy decisions within agricultural sector policy analyses and strategies. Most local and international studies use these applications. Pauw et al. (2007) explored agricultural efficiency and welfare in South Africa using a CGE model. The authors found that technological advances in agriculture should not be resisted because of their negative impact on agricultural employment.

Pauw et al. (2007) found that the welfare gains from declining prices were too significant, while employment gains in other (growing) sectors were likely to outweigh the loss of agricultural employment. Ferreira et al. (2022) used SAM multiplier analysis to examine the role of the agricultural sector in Ghana's development. The authors highlighted the sectors that should be promoted because they generated the highest increases in output, employment, and economic value added, as well as those with a significant impact on household income generation. Maré and Bahta (2022) used a partial equilibrium model to assess the export trade of live sheep in South Africa. They found that with a higher demand for live sheep exports, the prices and economic impact were also higher. Additionally, South Africa lost value-adding opportunities, such as output from abattoirs (hides and skin, offal, head, and consumable internal organs) and employment when live lambs were exported and slaughtered in destination markets. Bahta et al. (2014) used the CGE model to show the role of the agricultural sector in the dissemination of income and economic development in the Free State Province. The authors found that the agricultural sector played a significant role in reducing poverty and improving income distribution. However, considering poverty, the results suggested that the manufacturing sector increased income more than other sectors.

Taljaard (2007) applied CGE and SAM multiplier analysis to study the macroeconomy and irrigation agriculture in the Northern Cape Province of South Africa. The author found that the significant economy-wide impacts resulted from market risks or other exogenous factors influencing local irrigation agriculture, especially in a region where irrigation agriculture played such an important role. Kirsten and Van Zyl (1990) used an input-output (I/O) model to assess the economic impact of irrigation development and found that through forward and backward linkages, irrigation agriculture made an essential contribution to the regional economy in the Free State Province of South Africa. Doukkali and Lejar (2015) examined the energy costs of the irrigation policy in Morocco and highlighted that the policy, which targeted water-saving techniques, increased the use of subsidised energy. Subsequently, the indirect effects of energy subsidies exceeded the direct impact of agricultural subsidies. Brown (2017) used input-output models to evaluate the economic impact of irrigation development in Saskatchewan, Canada and found that irrigation provided an impetus for economic growth.

Although Brown (2017) and Kirsten and Van Zyl (1990) studied the impact of irrigation on agriculture, the authors did not include data on irrigated versus rainfed agriculture. Furthermore, the technique applied to the I/O model included a single production account and excluded information on household incomes at the district level. This meant that industries produced different commodities, and some industries produced multiple commodities. Doukkali and Lejar (2015) categorised agriculture according to irrigated and rainfed conditions but did not include detailed disaggregation information for factors and household incomes. Taljaard's (2007) study did not include agricultural activities and land accounts. The study's scope did not address whether the returns came from rainfed or irrigation agriculture, and the SAM did not consider the types of land and farms used for agricultural production/activities. Therefore, a new composition of the Northern Cape SAM is required to address the issues of agricultural activities. Additionally, a study at the district level is needed, which can be achieved by incorporating multiple production/industry accounts and incorporating land accounts (irrigated and rainfed).

Studies conducted by Tlhalefang and Galebotswe (2013), Hartono and Nugroho (2019), Lambert and Gong (2010), Van der Zee (2014), Akkemik (2011), He et al. (2010), Mbanda and Bonga-Bonga (2018), and Tarancon et al. (2010) focused on the electricity price increases on mining, manufacturing, and services sectors. However, researchers rarely empirically assess the impact of electricity tariff increases on provincial and district agricultural sectors. These authors pointed out that changes in electricity prices would affect producing sectors such as mining and manufacturing sectors, whereas producers' prices are affected more than consumers' prices and adversely affect GDP. They also found that the increase in the price of electricity would have negative and positive effects on the output of production and labour demand. These studies further reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. Silva et al. (2009) debated that change in electricity prices requires policy measures that favour poor households as they would be affected by an increase in price. Researchers rarely empirically assess the impact of electricity tariff increases on agricultural sectors at the provincial and district levels. This study contributes by quantifying the changes in electricity prices and their impact on prices in other sectors of the economy. Therefore, an explicit understanding of the effect of electricity price increases is required using the cost-push-price model.

Different studies have reported that drip, pivot, and flood irrigation systems are used for maize in the economy. Wang et al. (2018) found that drip irrigation was found to consume more groundwater than flood irrigation. Irfan et al. (2014) reported that maize crop yield and water use efficiency are higher for drip irrigation with good quality water. Zhang et al. (2021) found that drip and furrow irrigation obtained good yield and net profit with a reduced water application. Xu et al. (2021) modelled the effect of irrigation systems and water use efficiency on maize yield in China. The authors further stated that yield under drip irrigation increases compared to flood irrigation. The authors added that drip irrigation would be more suitable for adoption where groundwater quality would be used to achieve high crop production and increase water efficiency. Parvar et al. (2022) estimated the impact of water reduction on the production sectors of Iran's economy. They found that water resource constraints lead to decreased production and incomes and increased poverty across various economic sectors. In addition, water resources constraints have a more significant impact on gross operating surplus than on labour. Thus, optimising water consumption in crop production is more critical because the relative share of water use in the agricultural sector is higher than in other economic sectors. However, studies have yet to directly compute in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling. This research aimed to close this significant gap by evaluating irrigation systems and water uses on maize output, income, land returns, and value-added/GDP in Limpopo Province, South Africa.

1.2. Research problems

Chipfupa (2017), Mbusi (2013), and Fanadzo et al. (2010) reported that the South African government has tried in terms of restoring smallholder irrigation, stimulating productivity, and enhancing food security and incomes for households. Despite these efforts, the return on the amount invested in irrigation infrastructure is still low. The irrigation sector continues to rely on the government for maintenance and operational costs for restoring or improving some of the irrigation infrastructure, such as water pumps, canals, pipes, and other agricultural machinery and equipment required for irrigation infrastructure. In addition, the government is still helping some of the irrigation schemes with operational cost charges for using water (electricity and water) and administration for irrigation schemes. This support is due to limited implementation plans for cost recovery and maintenance and the lack of transfer of management and ownership.

There are no motives for farmers in irrigation in South Africa, and they have remained mostly inefficacious, with defective participation in markets and low productivity (Baloi, 2021). The irrigation scheme has not significantly contributed to food security and employment generation (Vink and Van Rooyen, 2009; Van Averbeke et al., 2011). The inland regions (Free State, North West, Limpopo, and Mpumalanga) are experiencing low and irregular rainfall due to continued increased drought incidents, and they could experience high evapotranspiration and evaporation rates. In South Africa, the inland regions (Free State, North West, Limpopo, and Mpumalanga) are climatically suitable to produce subtropical/tropical fruits and vegetables, and irrigated areas have been observed as the most important contributors towards GDP (Machethe et al., 2004). Thus, the predicated water deficit could increase the cost of production for most crops. This will result in most people in the marginalised areas of the Limpopo Province being affected and unable to afford most of the commodities. As the cost of irrigation water continues to increase, some farmers will reduce the labour force and land size used for producing agricultural commodities. Therefore, the water deficit in the production of agriculture would affect the expected target of the National Development Plan (NDP) of 2030 outcomes that focuses on the agricultural sector in terms of job creation, wealth creation, and food security (NDP, 2012).

Improvement in irrigation infrastructure is important and may improve water availability and enable the expansion of cropped areas. Sinyolo et al. (2014) stated that irrigation is important in raising agricultural productivity and enhancing performance. Denis and Manoma (2007) maintained that the capacity of irrigated agriculture to achieve food security and ease poverty caused the national government of South Africa to prioritise irrigation development. According to Cousin (2012), irrigation farming in South Africa is a priority as dry-land crop production is risky because of inadequate rainfall and regular droughts. Easing poverty and enhancing food security in marginalised areas are the main reasons for initiating irrigation in the country (Denis and Manoma, 2007). In furtherance, irrigation has the capacity to generate jobs in most of the regions that are considered marginalised, both directly and indirectly, through linkages (forward and backward linkages) (Van Averbeke et al., 2011). However, it is argued that despite its capability, irrigation has not met its requirements for improving rural development and easing poverty in South Africa. For Machethe et al. (2004), infrastructure deficiency and lack of institutional support have been noted as reasons for not meeting irrigation requirements in South Africa.

Answering fundamental questions with respect to regional components of irrigation in Limpopo Province is important. These questions incorporate the following:

- What is the economic impact of irrigation in Limpopo, and how are these impacts diffused on a district/regional basis?
- How will the future of irrigation development impact the districts/regions within the province?
- What is the economic impact of irrigation on the local districts/regions?
- What is the economic effect of irrigation systems/techniques on maize output and income in the Limpopo Province?
- What is the economic effect of water use on maize farm return?
- What is the economic impact of increased electricity prices on the agricultural sector?

1.3.Research objectives

The main objective of this research was to evaluate the effect of irrigation agriculture on the economy of Limpopo Province.

In order to achieve the main objective, specific objectives included the following:

- To discuss the macroeconomic methodological framework appropriate for modelling.

- To construct a 2017 national SAM with detailed information for irrigation and rainfed agricultural activities and land accounts.
- To compute the effect of exogenous shock (irrigation development) on output, income, land return, and value-added/GDP.
- To compute the cost-push SAM price models for electricity tariff increases on irrigation agriculture.
- To construct a 2021 provincial SAM database for Limpopo Province, with disaggregation information on irrigation systems and sources of water use in the maize industry in the economy of Limpopo Province, South Africa.

1.4. Contributions to the study

This study contributed by analysing the effect of irrigation agriculture on output, incomes (farm income and household income), and value-added/GDP using a 2017 National Social Accounting Matrix (SAM) reference to Limpopo Province.

Several SAMs have been reported over the years for policy analyses. Research generally uses multiplier analysis, input-output models, SAM-based input-output models, and CGE models to analyse the inter-sectoral linkages (multiplier effect) in any economic change in a specific sector, which will have a ripple effect in other sectors of the economy. However, empirical research in irrigated and rainfed agriculture is neglected, and models are limited to a single production account, which excludes detailed information on factors and household incomes at provincial and district levels. The South African SAMs developed by Phofoolo (2018), Van Deventer et al. (2019), and Davies and Thurlow (2021) do not contain detailed agricultural activities at the regional level. The SAMs developed by StatsSA (2005, 2012) are not ideal for policy analyses due to their limited redistribution of income, as they do not provide sufficient information for factors and household accounts and only record single industry and product accounts for agriculture, forestry, and fisheries. This study added to the agricultural industry accounts captured in a 2007 SAM adjusted by Punt (2013), where the researcher disaggregated agricultural activities according to South African provinces but never assessed agricultural activities from the district's perspective. The importance of the 2017 national SAM for South Africa would be through the disaggregation of agricultural activities by irrigation and rainfed accounts per South African provinces and per districts in Limpopo Province. In addition to this, the SAM comprises the return of land per agricultural activities, meaning the land account was split into irrigation and non-irrigation. Labour and households were categorised according to South African provinces and per district classifications.

Several studies on the impact of electricity price increases had a negative impact on the economy in terms of a decline in GDP and an increase in unemployment (Mbanda and Bonga-Bonga, 2018; Makgopa and Mpetsheni, 2022; Mutambo et al., 2023). These studies further reported that affordability was a big concern due to high production costs and increased market prices for commodities. Researchers rarely empirically assess the impact of electricity tariff increases on agricultural sectors at the provincial and district levels. Therefore, another significant contribution of this study was seen through evaluating the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and generation.

Furthermore, the study significantly contributed to the construction of the 2021 provincial SAM for Limpopo Province with disaggregated irrigation techniques and sources of water used by maize production. The maize industry was the only account disaggregated according to irrigation systems such as sprinkler, drip, pivot, micro, and other irrigation accounts. A 2021 provincial SAM database for Limpopo Province modelled the effect of irrigation systems and water uses on the maize industry on the economy of Limpopo Province, South Africa. The 2021 SAM is the most recent data available for Limpopo Province and was suitable for analysis of this research. Different studies on irrigation techniques and water use in the maize industry reported that drip irrigation systems were found to consume more groundwater and obtained yield and net profit with a reduced application (Wang et al., 2021; Irfan et al., 2014; Zhang et al., 2021; Jordan & Bahta, 2020). Most of these studies applied statistical analysis such as ANOVA (Analysis of Variance), economic benefits analysis, crop efficient estimation, CGE models, crop water demand software, and systematic apparatus analysis (conveyance efficiency and water surface elevation). However, no studies have directly computed in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based multiplier analysis. This study contributed by applying irrigation systems (such as drip irrigations, pivot irrigation, micro irrigation and coupling irrigation systems) and sources of water use (e.g., dams, rivers, surfaces, boreholes, and rain harvesters).

Limpopo was deemed a suitable province for determining the relationship between irrigation access and household incomes because the government invested significantly in irrigation infrastructure in the regions experiencing a water shortage. Most farmers in the province still cultivate under challenging conditions of water shortages or insufficient irrigation. Taljaard (2007) and Hassan (2007) found that many producers compete for limited water resources.

Thus, water is not used for basic human needs. It is also utilised to support productive economic activities that generate employment and income for the province's inhabitants. Given the significance of inter-sectoral linkages (multiplier effect) in any economy, changes in a specific sector will have a ripple effect in other sectors of the economy in Limpopo and the rest of South Africa. Therefore, it is imperative to have an explicit understanding of the effect of irrigation agriculture on output, land return, institutional income, and GDP to have a necessary strategy for prioritising irrigation policies that will contribute to economic development. This study played a role in examining the multiplier effect of irrigation agriculture within the districts of the Limpopo Province of South Africa. It addressed policies for irrigation that will alleviate risk, enhance the financial feasibility of farming, and establish a policy that is effective for water management in regions where irrigation plays a significant role in the economy.

1.5.Method and data use

In order to achieve the above-mentioned objectives, particular tasks were used:

- A macroeconomic database was needed to evaluate the economic impact of irrigated agriculture on the economy of Limpopo Province.
- A 2017 national SAM developed by a researcher/ author of this thesis as macroeconomic database for this research, which was completed using the 2017 Supply and Uses Tables (SUT), National Accounts 2021, South Africa Reserve Bank (SARB) 2021, South Africa Revenue Services (SARS), Commercial Agriculture Survey 2017, Labour Force Survey (LFS) 2017, General Household Survey (GHS) 2017, Global insight (2022) and Living Conditions Surveys (LCS) 2014/15. This database incorporated disaggregated accounts for agricultural activities, factors of production, and households in the SAM reference to Limpopo Province. Agricultural activities accounts were disaggregated by regional districts within the Limpopo Province. Thus, agricultural industries were defined according to the agricultural land they use to produce a combination of agricultural commodities. Agricultural activities were further divided into two categories in the regional districts: irrigation and non-irrigation agricultural activities. Factors of production consist of labour, capital, and land accounts. Labour and household accounts were disaggregated according to province and district classifications. Land accounts comprised rainfed (dry land) and irrigated land.

- Manual balancing with MS Excel was used to balance the unbalanced SAM. The unbalanced SAM was used as representative of a short summary of the South African economy, while a final balanced SAM was used for estimation and policy analysis.
- The SAM-based multiplier model was used to compute the effect of exogenous shock (irrigation development) on output, income, and value-added/GDP. Ramigo (2017), Miller and Blair (2009), and Kirsten and Van Zyl (1990) indicated that the significance of the multiplier concept can be referred to as a unit increase in investment that initially leads to an increase in income.
- The SAM price model was used to examine the changes in electricity price hikes on irrigation agriculture.
- A 2021 provincial SAM database developed by a researcher/ author of this thesis for Limpopo Province was used to disaggregate information on irrigation systems and sources of water use in the maize industry in the economy of Limpopo Province, South Africa.

1.6.Delineation of the research

This research consists of nine chapters. Chapter One, part of the introduction and background, presented the study's problem statement, objectives, and contribution. Chapter Two provides a review of the literature on the overview of the global and South African perspective of irrigation and further discusses the Theory of Social Accounting Matrices (SAM) and the empirical studies of the SAM-based models such as CGE and multipliers analysis. Chapter Three provides data on Economic Analysis: 2017 Social Accounting Matrices (SAMs) for South Africa. Chapter Four presents insights into the Impact of Irrigation Agriculture on the Economy of the Limpopo Province, South Africa: A Social Accounting Matrix Multiplier Analysis. Chapter Five discusses 2021 SAM data on small-scale and commercial agriculture in South Africa. Chapter Six provides the impact of electricity tariff increases on the agricultural industry in South Africa using the SAM price model. Chapter Seven presents a model of the effect of irrigation systems and water use on the maize industry in the economy of Limpopo Province in South Africa. Chapter Eight reports the summary, conclusion and policy recommendations. Chapter Nine presents proof of the published and submitted articles.

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Chapter 2: Literature Review

2.1. Introduction

This chapter presents the literature review on the global and domestic perspectives for irrigation. In addition, the chapter discusses the global and South African perspectives on irrigation and the role farmers play in irrigation. Other sections briefly discuss the Theory of Social Accounting Matrices (SAM) based models. Lastly, the author will present some of the selected empirical studies completed in South Africa and abroad.

2.2. Global perspective for irrigation

In the twentieth century, irrigation development has been used as the main instrument in different countries to enhance food production and achieve food security (Turral et al., 2010). The increase in agricultural production during this period was accompanied by the improvement of irrigated land (Clemmens, 2006). FAO (2020) and Ringler (2017) found that only 40% of crop production in the world was found in irrigated land, whereas approximately 20% comes from cultivated land. For Turral et al. (2010) and Hussain (2007), irrigation played a significant role during the period of the Green Revolution when Asia increased agricultural output in the mid-20th century. According to Ringler (2017), about 24% of the population in Asia was employed in irrigated farming, whereas more than 52% was used in Sub-Saharan Africa. About 68% of the potential irrigated areas in Asia are established, contrasted with about 39% in Africa (FA0, 2020). Turral et al. (2010), Molden et al. (2007), and Lipton (2007) reported that irrigation had been prioritised to increase household income and ease poverty. Molden et al. (2007) maintained that irrigation is essential as it creates employment opportunities and further enhances national income and economic development. In addition, Dedrick et al. (2000) reported that irrigation made it possible to generate foreign revenue for many countries by producing a surplus in food production.

Irrigation agriculture plays a massive role in uplifting agricultural production and achieving food security. According to FAOSTAT (2012), only 18% of the crop production worldwide is under irrigation. Sinyolo (2013) stated that irrigation agriculture in African countries plays a less important role than in other countries in the world. Lipton et al. (2003) debated that poor execution for African countries in terms of easing poverty can be attributed to less reliance on irrigation agriculture. Bacha et al. (2011) noticed that Asian countries experienced poverty reduction, whereas in Africa, poverty increased. In addition, in Africa, agricultural production is almost entirely rainfed and distributed unevenly in most parts of the regions (You et al., 2010). You et al. (2010) indicated that the rate of improving irrigation area over the past 30 years was approximately 2.3% in African countries. Countries such as Egypt, South Africa, Morocco, Sudan, and Nigeria account for nearly 75% of the overall irrigated land, of which there are about 12.2 million hectares on the African continent (FAOSTAT, 2012). South Africa comprises 1.3 million hectares of irrigated land, which is approximately 11% of the overall irrigated land in Africa. Despite some noteworthy improvements in irrigation, development in smallholder irrigation in Africa is limited and below expectations (Sinyolo, 2013).

There is an agreement that irrigation will significantly secure the world food supply in the coming decades (Kafle et al., 2022; Bryan et al.,2020). Thus, the significant role of irrigated areas in agricultural production will have to expand. This increase can be fulfilled by raising the regions with irrigation and drainage facilities and modernising existing irrigation and drainage systems (Turral et al., 2010). In addition, Malan and Hofwegen (2006) pointed out that irrigation accounts for approximately 70% of the water extractions from the world's river systems, of which less than 40% comes from canal irrigation systems. Despite the significant role that food production plays around the world, there are concerns and issues related to the sustainability of irrigated agriculture and its impact on the environment. Unreliable water supply, poor water management, poor system operations, and poor water distribution are some of the factors that cause poor performance (Baloyi, 2022).

World Bank (2020) reported that about 3% of crops produced in Africa experienced very low levels of irrigation. Baloyi (2021) stated that in some countries, such as India, a strong relationship was found between irrigation development and easing poverty. Irrigation development in this country contributed to the adoption of agricultural technology and further improved irrigation production. Baloyi (2021) mentioned that labour employment per hectare is more beneficial in irrigated than rainfed areas. The success of irrigation schemes in Zimbabwe led to increased irrigation investment and dam construction (Siwela, 2008). The main goal of increased investment in irrigation development was to reduce poverty and achieve food security (Mupaso et al., 2023).

2.3. Irrigation: A South African Perspective

Dzikiti et al. (2020) stated that the agricultural sector recorded only 60% of the country's freshwater resources for irrigation agriculture to support the insufficient rainfall. Therefore, irrigation agriculture is important for sustaining and growing the agricultural industry, achieving food security, and alleviating poverty and hunger (Mashabatu, 2022). Niekerk et al.

(2018) found that irrigation farming contributes approximately 25%-30% of the national agricultural production while recording about 90% of the high-value crop production, such as fruits and vegetables. In 2023, the agricultural sector contributed less than 3% of the GDP in the country (StatsSA, 2024). The South African irrigation agricultural sector comprises two significant sectors: large-scale and small-scale (Backeberg and Sanewe, 2010). The commercial sector (large-scale) operations have approximately 40 122 farmers (Zantsi, 2021), producing 95% of the national marketed output on the average farm size of about 2 113 ha (StatsSA, 2020; Liebernberg, 2013). These large-scale commercial farmers produce for local and foreign export markets. In general, the large-scale commercial sector in South Africa is more developed and advanced than the small-scale sector (Mathinya et al., 2022).

The small-scale irrigation farmers focused on household consumption comprise 2 ha and 20 ha of farm sizes (StatsSA, 2018). The small-scale sector is not sufficiently connected to local and export markets; these farmers largely produce for their own consumption, even though they often sell their surplus in the local markets (Mathinya et al., 2022; Zantsi et al., 2019; BFAP, 2020). This small-scale sector utilises approximately 4% of the irrigation water; commercial irrigation utilises about 94% of the irrigation water (Moyo, 2016). Fanadzo (2012) reported that the standard used to identify farmers as small-scale incorporates income level and land size. Machete et al. (2004) described small-scale farmers as those with insufficient resources and food paucity. Phakathi (2016) and StatsSA (2016) reported that small-scale irrigation can be classified as farmers using farms between 5 ha and 20 ha in size. Fanadzo and Ncube (2018) reported that small-scale and commercial agriculture have approximately 1.3 million ha of farms in South Africa under irrigation. Van Averbeke (2008) highlighted that many farmers are involved in these irrigations, and their many purposes are to help reduce poverty and achieve food security.

Phakhathi (2016) indicated that approximately 230,000 Black people in South Africa use small irrigation schemes to produce food in small plots for their livelihoods. Also, only 53% of the sprinkler irrigation systems are widely utilised in the country; flood irrigation accounts for 29%, whereas about 18.5% of the areas use drip and micro irrigation. Community gardeners utilise low-cost, effective technologies such as flood irrigation because maintenance costs are low. Irrigation is one of the sectors that consumes the most water in South Africa and generally relies on the composition and layout of the engineer to ensure the best economic and technical use of water pumped (Wale and Chipfupa, 2018). Muchara (2011) found that about 150,000 farmers engaged in community food gardening projects play a crucial role in producing vegetables on small irrigation farms. Sinyolo et al. (2014) stated that irrigation farming must raise agricultural production, generate employment, and achieve food security. Yokwe (2009) reported that in South Africa, Thabina irrigation schemes in Limpopo Province achieved the highest gross margin per hectare compared to dry land farming.

2.4. South African farmer's participation in irrigation

Muchara et al. (2014) reported that public participation, which involves public members or individuals in the process of decision-making, brings the possibility of harnessing the ways of managing natural resources. Participation is a process in which stakeholders could influence policy formulation and decision management affecting society and then find ways to establish a particular sense of ownership (Baloyi, 2021). Greyling (2015) mentioned that the South African agricultural sector consumes over 80% of the available land and approximately 60% of the available water. Muchara et al. (2014) added that irrigation farmers use most of the irrigation systems. Thus, there is a need to ensure that irrigation systems are sustainable. Also, through farmers' involvement, irrigation farmers can initiate institutions imperative in sustainable water management.

Mudhara and Senzanje (2020) asserted that farmers' involvement in irrigation can allow users to learn from one another and take responsibility for sustaining resources. Furthermore, the involvement of farmers in irrigation enhances compliance in the sense that it enables users to monitor each other's actions and be responsible through practising collaborative commitments such as meeting attendance (Muchara et al., 2014). Mudhara and Senzanje (2020), Muchara et al. (2014), and Van Averbeke (2012) reported that users' willingness to be involved in irrigation scheme management is imperative for the maintenance of the facilities. For most of the irrigation schemes being developed for communal use, it is imperative to know whether the users have provided consent for participation.

Irrigation management involvement is centred on the participation of the irrigation farmers and in the maintenance and operation of irrigation systems. Mudhara and Senzanje (2020) maintained that this turns irrigation farmers into water managers. The important aspect of having the farmers involved in the irrigation system management is to have a sense of ownership, encourage collective action, and enhance compliance.

2.5. The Theory of Social Accounting Matrices (SAM) based models.

Punt (2013), Round (2003) and PROVIDE (2003) define SAM as transactions that transpire in the economy for a period of one year. This particular transaction shows receipts and payments in the economy. The SAM is a representation of the System of National Accounts (SNA) in the matrix format as stated by the United Nations (2008), which further explains the interaction between Supply and Uses Tables (SUT) and institutional accounts (StatsSA, 2012). The SNA is the accounting framework used by the National Statistical Agencies (NSA) to incorporate data in a coherent, consistent way and integrate macroeconomic accounts. It plays a massive role in displaying the economic transactions that are taking place within the economy, as explained by Round (2003). The SAM is developed in the basic framework of the National Accounts Matrix (NAM). Each entry of the submatrix receipts (rows) and expenditure (columns) identifies groups of transactions in the economy. The total from the NAM is further used as a control viewed in the SAM. The database in a SAM could be used for government strategies and policies.

The primary data sources for constructing SAM are found from different sources such as the Supply and Use Table (SUT) and national accounts, including commercial agriculture surveys, labour force surveys, income and expenditure surveys, general households' surveys, and reserve banks. The significance of a SAM, as mentioned by Punt (2013), is that it displays a full circular flow of all details and other missing information in the SUT. Therefore, a SAM is an expansion of SUT. The total row and total column in a SAM must be equated for a SAM to be square. According to McDonald and Punt (2005), the critical property of a SAM is in the economic principles that state that for every expenditure, there is an income. This principle of economic prices is important for creating the macroeconomic accounts of any nation or region (PROVIDE, 2003). The advantage of using a SAM is that sectors within an economy can be disaggregated into sub-sectors. For example, this study disaggregated the agricultural sector according to irrigation and rainfed agriculture. A SAM is also important in gathering detailed information from different provenances (sources) of the economy and then highlighting the importance of the information on the data. It can also identify errors or missing information.

Thus, a SAM on its own is not a model but an instrument that can be utilised by academia, stakeholders, and policymakers for decision-making (Round, 2003). If it produces relevant detailed information, this tool can display an explicit picture of the production and dissemination of income within the economy (McDonald and Punt, 2005; Miller and Blair, 2009). Different models are developed from a SAM; these models incorporate the following: Computable General Equilibrium (CGE) models, price models, decomposition techniques, and multiplier models. Of the above-mentioned models, CGE and multiplier analysis are often used for income distribution, taxes, and government spending (fiscal policy) policy analysis. In this study, multiplier analysis was applied.

- CGE models are known as complete models that address policy issues for production activities, factors, and institutions such as households and companies (Punt, 2013; World Bank, 2003). These models consider all sectors within the economy and allow detailed policy analysis (McDonald and Punt, 2005). The benefits of using a CGE model in comparison with other models lie in the solid macroeconomic foundation that mostly includes economic theories. These theories focus on maximising consumption and reducing production costs. The CGE model is essential in capturing the allocation of resources to the production process and how this allocation may influence the incomes of other accounts, such as factors, households, and other institutions. The database used in the CGE models is in the form of a SAM.

- SAM multiplier models are an extension of the Leontief Input-Output (I/O) model (Miller and Blair, 2009). The Leontief I/O model captures only production linkages, whereas the SAM multiplier captures both production and consumption linkages. Consumption linkages arise when an increase in production generates extra incomes for institutions (firms, households, and government) and factors utilised to buy goods and services (Thurlow et al., 2009). When using the SAM multiplier, it is imperative to describe endogenous and exogenous accounts (Round, 2003 and PROVIDE, 2003). Endogenous accounts were described as those that can be influenced in the system, while exogenous accounts operate outside of the system and whose expenditures are independent of changes in income. One of the significant features of SAM-based multiplier analysis is that it can further display transactions in the form of a decomposition multiplier (Thorbecke, 2000), whereby it expands the level of addressing linkages within the economy (Mondlane et al., 2019) and changes in the income levels (Round, 2003).
- The SAM price model is referred to as the cost-push-price model, and within the model, quantities are fixed, and prices are flexible (changes). The values obtained in the cost-push-price model are used to estimate the effect on prices throughout the economy of new primary factor input costs in various sectors (Miller and Blair, 2009). Therefore, the prices are evaluated through costs of exogenous values of primary factors inputs.

Thus, the output prices are set to be equal to total production costs, which then leads to each price being equal to 1.

Table 1 indicates transaction accounts for the economy. The concepts and ideas of a SAM in the economic system are explained in detail below.

- Products account

Product accounts record the supply and demand of products within the economy. The final demand within a SAM comprises domestic and foreign demand. The domestic demand shows institutions (households, companies, and government), investments, and exports. The foreign final demand includes imports. The row accounts in a SAM show the consumption of products to the institutions and the rest of the world. The column accounts in a SAM records imports product and net product taxes (McDonald and Punt, 2005).

- Industries account

Industries accounts record transactions in the economy based on productive activities and further record details about the creation of added value (Punt, 2013). The SAM column reveals intermediate uses and factors of production used by the industry, as well as production taxes and subsidies. The industry accounts include the production cost in the columns and incomes from the products in the rows.

- Factors of production account

The factor accounts comprise labour and gross operating surplus (GOS)/mixed farming. Incomes to factor markets can come in the form of hiring labour, renting land or utilising capital for production (McDonald and Punt, 2005). The households owned factors (labour, capital, land) services. In short, the payments of the factors are distributed across various households, such as labour income, profits, and rental income. Other payments from factors are transferred to companies, the government and other countries. For example, if the farmers own the farm and use it for agricultural purposes, the cost of production taking place on that farm should be clearly considered through extra imputed income received and payment to factor. This payment will be distributed to the farms by the agricultural industry for the purpose of production factor, land, and the income will be received by the institution (household and enterprises) that owns the land (Punt, 2013). Apart from distinguishing between labour, gross operating surplus and land, the labour accounts are usually disaggregated according to education levels, gender, race, and occupations more than the gross operating surplus. The main purpose of doing that is to link different groups of households (Round, 2003).

- The Institutional accounts

The institution consists of enterprises, households, and governments. Most of the economic information recorded in the SAM is important through transactions between institutions. The decision of classification for households is very important in a SAM and should reflect the group classifications of households in the economy. Households generate income from a variety of sources, such as factor services (labour service, capital service, rental land), transfers from companies, government, and abroad (Round, 2003). Households also pay direct tax and then further distribute some of their income for savings.

The enterprise row accounts in a SAM display income received from factors and the government, while the column accounts record payment transactions to households, government (corporate taxes), savings, and abroad (Punt, 2003). The government accounts show incomes generated from other accounts (activities taxes, factors taxes, direct household taxes, corporate taxes, and distribution from abroad) in terms of tax payments. The column SAM records transfers made by the government to households, enterprises, savings, and abroad (Miller and Blair, 2009).

- Capital account

The capital accounts represent investments and their funding (Miller and Blair, 2009). The row capital account in a SAM receives income in the form of savings from institutions (households, companies, and government). The column capital in a SAM displays investment (Punt, 2013).

- Rest of the world account

The accounts for the rest of the world show export and import transactions. These accounts include current and capital accounts. In addition, trade may be visible or invisible (McDonald and Punt, 2005). The world CGE models would include more information on the rest of the world accounts to identify between various trading partners; on the other side, the single nation CGE models would include a single rest of the world account to capture more information in the household and factor accounts to trace the distribution of income in the country (Punt, 2013).

- Transaction account

The transaction account typically represents the income and payments from the commodity account within the accounting period, usually a year (Miller and Blair, 2009). Sometimes, these transaction accounts are used to link the distribution of the commodities to identify some of the discrepancies and enable the accounts to sum up all payments by a given account to equate the total sum of income for the corresponding account.

Table 1: Transaction accounts for the economy

Expenditure s/receipts	Products	Industries	Factors of production	Households	Enterprises	Government	Capital	ROW	Total
Products		Use matrix		Private consumption		Government consumption	Investment	Exports	Products demand
Industries	Make matrix								Industries income
Factors of production		Value added						Factors income from row	Factors income
Households			Factors income to households	Inter-household transfers	Transfer to household	Transfer to household		Transfer to household from row	Household income
Enterprises			Factors income to enterprises			Transfer to enterprise		Transfer to enterprise from row	Enterprise income
Government	Sales taxes, tariffs, export taxes	Indirect taxes, factor use taxes	Factors income to government, factors taxes	Transfer to government, direct household taxes	Transfer to government, direct enterprise			Transfer government from row	Government income
Capital				Household savings	Enterprise savings	Government savings		Balance of payment	Savings
Row	Imports		Factors income to row		Transfer to the row	Government transfer to row			Foreign exchange outflow

Total	Product Supply	Industry inputs	Factor expenditure	Household expenditure	Enterprise expenditure	Government expenditure	Investment	Foreign exchange inflow

Source: Adapted from Lofgren et al. (2002, cited by Taljaard et al., 2008).

2.6 Similar empirical studies of the SAM-based models (multipliers and CGE analysis)

2.6.1 Construction of 2017 and 2021

Several SAMs worldwide and in South Africa have been developed over the past decades. Ramigo (2024) and Phoofolo (2018) developed 2020 and 2014 national Social Accounting Matrices (SAMs) for South Africa with detailed disaggregated agricultural subsectors. Punt (2013) updated a 2007 SAM for South Africa constructed by PROVIDE with detailed information for agricultural industries per province in South Africa.

Taljaard (2007) used a 2000 SAM for South Africa built by PROVIDE with detailed information for agricultural activities per province in South Africa and per district in the Northern Cape Province. Van Deventer et al. (2019; 2015) and Van Deventer and Davies (2023) constructed 2019, 2016, 2015, and 2012 SAM for South Africa with a single aggregated agricultural sector and detailed accounts for labour, capital stocks, and households. IFPRI (2024a; 2024b; 2024c; 2024d; and 2024e) constructed 2021, 2022, and 2022/2023 Social Accounting Matrices for Columbia, Ghana, Guatemala, India and Malawi with disaggregated agricultural activities. All the SAMs mentioned above were designed for income distribution and policy analysis.

However, the construct could have been more detailed in terms of the disaggregation of agricultural activities according to irrigation and rainfed per provinces and districts in South Africa. The above-mentioned SAMs could, however, not address various irrigation systems based on the sources of water used for crop production. This study significantly contributes to constructing the 2017 national and 2021 provincial SAMs for South Africa. The importance of 2017 would be through the disaggregation of agricultural activities by irrigation and rainfed accounts per South African provinces and per districts in Limpopo Province. In addition to this, the SAM comprises the return of land per agricultural activities, meaning the land account was split into irrigation and non-irrigation. Labour and households were categorised according to South African provinces and per district classifications. On the other hand, the significance of 2021 Limpopo SAM was seen through disaggregating agricultural activities according to crop production in the provinces. This crop production was further linked to the sources of water use. Only the maize industry was further disaggregated according to various irrigation techniques such as drip, sprinkler, canal, and pivot irrigations. Table 2 summarises similar studies of the construction of SAM.

Table 2: Similar studies of the construction of SAM

Author/s	Objectives	Data and Methods	Remarks
Ramigo (2024)	The study's main objective was to develop a 2020 SAM for South Africa with disaggregated agricultural activities, commodities, labour, households, and government taxes.	The main data sources for the construction of a SAM were obtained from various sources such as the Supply and Use Tables (SUT), national accounts, Census of Commercial Agriculture, agricultural abstracts, Quarterly Labour Force Survey (QLFS), South African Revenue Service (SARS), trade map and South African Reserve Bank (SARB).	The final 2020 SAM comprised 265 accounts: 117 activities/industries (of which agricultural industries were disaggregated into 24 agricultural subsectors, one forestry and fishing), 129 products/commodities (of which agricultural commodities were disaggregated into 24 agricultural subsectors), one margin account, one account for capital, one account for land, four accounts for labour, four accounts for households, one enterprise, three taxes accounts, one account for government, one account for investment/savings, change inventories and one international trade (export/import) account.

Phoofolo (2017)	The main objective of the study was to develop a 2014 SAM for SA with disaggregated agricultural activities.	National Accounts, Supply and Uses Tables, Quarterly Labour Force Surveys (QLFS), General Households Surveys (GHS), Living Conditions Surveys, Census of Commercial Agricultural and Trade maps.	The 2014 SAM for SA had detailed information on the agricultural and non-agricultural sectors. This SAM had a total of 268 accounts, of which 104 accounts were activities and 133 products, six factors and 14 households for government taxes account, one account for transaction costs, government, savings-investment, stock changes, enterprises, and the rest of the world.
Punt (2013)	The study's main purpose was to update a national SAM for SA with detailed agricultural industries and commodities that can be used for the calibrated CGE model.	The main data source used were 2002/2007 SASUT, 2002/2007 Census of Commercial Agriculture from Statistics South Africa, 2008 forestry information from Godsmark, 2000 Income and Expenditure surveys (IES), 2000 labour force surveys, SARS quarterly bulletin for national accounts and	The macro-SAM is 2007. The complete 2007 SAM for South Africa included 543 accounts, of which 115 accounts were commodities and 143 industries, 142 labour, one land, one capital, eight taxes accounts, one general government and 126 households accounts, an investment/savings account, an account for stock changes and an

		2007 imports and exports data.	international trade and transfers account. About 48 agricultural industries were identified according to regions in South Africa. This SAM displayed all the descriptions to enlighten the reader about the construction of SAM and sources of data that were collected towards the contribution of nation SAMs for South Africa.
Taljarrd (2007)	The main purpose was to modify national SAM with disaggregated detailed information for agricultural industries, households, and factors in the Northern Cape Province, built by PROVIDE (2005).	Different sources of data were extracted from the SUT, and households and labour were obtained from Statistics South Africa.	The base year for national SAM for SA was 2000. The national SAM for South Africa comprises detailed agricultural activities in the Northern Cape Province, which was used for CGE and multiplier models. The developed SAM for SA incorporated commodity and activity accounts, transaction accounts, factor, institutional accounts, capital accounts and the rest of the world.
Van Deventer et al. (2019)	The main objective was to build a 2015	The data used for the development of SAM	The macro-SAM had 14 accounts, such as

	SAM for South Africa.	were 2015 national accounts obtained from the South Africa Quarterly Bulletin, 2015 SUT obtained from Statistics South Africa, Living Conditions Survey for 2014/15, 2015 Quarterly Labour Force Survey and 2015 General Households surveys.	activities, products, labour, capital, enterprise, households, government, net activities, taxes, product taxes, import duties, income taxes, inventory change, investment/savings, and trade (export/imports). The final 2015 micro-SAM for South Africa had 195 accounts, of which 62 accounts were industries and 104 products. Factor input was classified into labour, and capital labour was further disaggregated into four categories, such as primary, middle, secondary and tertiary education, and households had 14 accounts (deciles 1 to 14). Government taxes had four accounts in the SAM.
Van Deventer et al. (2015)	The main objective of the study was to construct a 2012 SAM for SA.	The data used for the development of SAM were 2012 national accounts obtained from the South Africa Quarterly Bulletin, 2012 SUT obtained	The SAM is used for the purposes of policy analysis and distributional incomes and could be used to identify government, investment, and foreign

		from Statistics South Africa, 2012 Labour Market Dynamics (LMD) Surveys for the Quarterly Labour Force Survey (QLFS).	accounts. In addition, the final SAM had fully disaggregated micro-SAM with detailed information on labour and household classification, which remains consistent with the National Accounts and 2012 SUT.
Van Deventer and Davies (2023)	The main objective was to develop a 2019 SAM for SA with disaggregated occupational and capital stock details.	The data used for the development of SAM were 2019 national accounts obtained from the South Africa Quarterly Bulletin, 2019 SUT obtained from Statistics South Africa, Living Conditions Survey for 2014/15 and 2019 Quarterly Labour Force Survey, the annual financial statistics survey for the year 2019 and 2019 General Households surveys.	The SUT were consistent with the SARB Quarterly Bulletin National Account. The SUT had single labour, households, and gross operating surplus. The SUT was then further disaggregated across labour, gross operating surplus and household groups using the 2018 and 2019 LMD data and 2014/15 Living Condition Surveys.

IFPRI (2024d)	The main objective was to develop a 2022 SAM for Columbia with disaggregated agricultural production.	The sources that were used are 2022 integrated national accounts, 2018 SUT, 2022 government public services compilations, 2022 world development indicators, 2022 GDP series, FAOSTAT online database, municipal agricultural evaluation 2018, 2018 Annual Trade Survey, 2018 Annual Industry Survey and 2016/17 National Household Budget Survey.	The nation SAMs for Columbia displayed a consistent and accurate dataset. This SAM showed 42 domestic production and three factors (labour, land, and capital) accounts. Labour was split according to educational classification, and single agricultural land and households were disaggregated according to urban and rural per-consumption quintiles. This SAM helped improve model-based research and policy analysis in developing nations.
IFPRI (2024c)	The main objective was to construct a 2022 SAM for Malawi with disaggregated agricultural industries.	The study used 2017 rebased GDP series, 2019 government finance statistics online database, 2016/2017 SUT, 2022 balance of payments compilations, Census of Economic Activities, Annual Economic Survey, and the fifth integrated	The 2022 SAM for Malawi provided a consistent, comparability and transparency dataset that could be used to improve research and policy development in developing countries. This SAM had 42 production accounts and three factor accounts such as

		households survey 2019/2020.	labour, land, and capital. Labour was categorised into three education classifications, single agricultural land and capital account. Households were disaggregated according to per-consumption quintiles.
IFPRI (2024e)	The main objective was to develop a 2021 SAM for Guatemala with disaggregated agricultural activities.	The sources used were 2021 National Accounts series, 2021 SUT, government Finance Statistics online database, 2021 world development indicators, 2021 balance of payment compilations, 2022 GDP series, FAOSTAT online database, 2014 National Household Budget Survey, 2021 TRAINS online database, and 2018 SUT.	The study concluded that the purpose of SAM was to enhance the quality of data used for policy analysis in the CGE and multipliers models. The 2021 macro-SAM for the Guatemala had nine accounts. The national accounts showed detailed information for service sector GDP, and the domestic production comprised 42 activities.
IFPRI (2024b)	The main objective was to develop a 2022 SAM for Ghana with disaggregated agricultural activities,	The sources used were the 2013 rebased GDP, 2013 Supply and Use Tables (SUT), Ghana 2022 consolidated public	The 2022 SAM for Ghana displayed 42 accounts, three labour education classifications, and ten rural and urban

	taxes, labour, and households.	finances, 2016-2017 Ghana Living Standard Surveys, 2022 Balance of Payment Compilation, 2022 World Development Indicators, FAOStats online database, TRAINS online database.	households per-consumption quintiles. In addition to this account, SAM showed a single account for agricultural land and capital.
IFPRI (2024a)	The main objective was to construct a 2022/23 SAM for India with disaggregated agricultural activities, taxes, labour, and households.	Data sources used were 2022/2023 national accounts statistics, 2019/20 SUT, 2022 government finance statistics online database, 2022 world development indicators, 2021 TRAINS online database, Annual Report-Periodic Labor Force Survey (PLFS) 2022-23, Survey on Household Consumption Expenditure: 2022-2023.	The 2022/2023 SAM for India displayed 42 domestic production activities, single agricultural land, capital and three labour classifications and ten households per rural and urban classification categories.
However, the construct could have been more detailed in terms of the disaggregation of agricultural activities according to irrigation and rainfed per provinces and districts in South Africa. Also, the above-mentioned SAMs could not address various irrigation systems by sources of water used for crop production. This study significantly contributes to the construction of the 2017 national and 2021 provincial SAMs for South Africa. The importance of 2017 would be through the			

disaggregation of agricultural activities by irrigation and rainfed accounts per South African provinces and per districts in Limpopo Province. In addition to this, the SAM comprises the return of land per agricultural activities, meaning the land account was split into irrigation and non-irrigation. Labour and households were categorised according to South African provinces and per district classifications. On the other hand, the significance of 2021 Limpopo SAM was seen through disaggregating agricultural activities according to crop production in the provinces. This crop production was further linked to the sources of water use. Only the maize industry was further disaggregated according to various irrigation techniques such as drip, sprinkler, canal, and pivot irrigations.

2.6.2 Empirical studies on SAM base model such as Multiplier Analysis, Input-Output and CGE models (Insights into the Impact of Irrigation Agriculture on the Economy)

Most local and international studies use these applications. Ramigo (2017) used a SAM multiplier model to assess the contribution of agriculture to Limpopo's economic growth and development. The findings showed that the agricultural sector contributes less towards the economy compared to the non-agricultural sector in terms of output, income, and value added. In the case of the agricultural sub-sectors, subtropical fruit and forestry contributed relatively well to the output. The electricity, water, financial, and community services were found to have a significant impact on the development of Limpopo and should become an important priority due to having large multipliers compared to other sectors of the economy.

Mukarati and Makombe (2017) used SAM decomposition and structural path analysis to study the effect of the agricultural sector on household income in South Africa. The findings revealed that the agricultural sector contributes 4% to the overall economy and adds value to household income. The impact of the agricultural sector on increasing household income is clearly shown through linkages (forward and backwards). In addition, the study found an increase in the return for land for poor households.

Mulanda (2020) used SAM-based modelling (multipliers and CGE analysis) to study the composition of the Zambia economy's agricultural sector and the sector's significant role in policy decisions. The study found that primary agriculture has the highest output compared to other sectors of the economy, such as the service sector. Within the livestock subsector, it was found to have the highest output. In the case of the CGE model, the findings revealed that transaction costs played an important role in minimising production costs for agriculture by approximately 30% and expanding its value addition for all the processing activities in the economy.

Pauw et al. (2007) studied agricultural efficiency and welfare in South Africa using a CGE model. The authors found that technological advances in agriculture should not be resisted because of their negative impact on agricultural employment. They showed that the welfare gains from declining prices were too significant, while employment gains in other (growing) sectors were likely to outweigh the loss of agricultural employment.

Ferreira et al. (2022) used SAM multiplier analysis to examine the role of the agricultural sector in Ghana's development. The authors highlighted the sectors that should be promoted because they generated the highest increases in output, employment, and economic value added, as well as those with a significant impact on household income generation. Maré and Bahta (2022) used a partial equilibrium model to assess the export trade of live sheep in South Africa. They found that with a higher demand for live sheep exports, the prices and economic impact were also higher. Additionally, South Africa lost value-adding opportunities, such as output from abattoirs (hides and skin, offal, head, and consumable internal organs) and employment when live lambs were exported and slaughtered in destination markets.

Van Deventer and Tarp (2020) studied Myanmar's agro-industry, exports, and income distribution using the decomposition multiplier technique. The study found that rural low-income households benefit from increased agro-processing and crop production. In addition, the authors further mentioned that rural-income households are strongly linked to agro-processing through the process of feedback and spillover. Despite the increase in rural household income from agro-processing, the sector has yet to reach its level of development in the country. Promoting trade through the improvement of exports would benefit rural low-income households more compared to other households.

Mondlane and Van Deventer (2019) used the SAM multiplier decomposition approach to study Mozambique's agricultural development, trade, and distribution income levels. The results reported a strong link between food processing and low rural household incomes due to inputs used in crop production. However, the authors further found that food processing has a small impact on the economy due to the relatively low multiplier caused by imports. Most of the processed foods are imported from other countries, such as South Africa. For the country to continue stimulating economic growth, the government has invested in infrastructure to unfasten the capability of crop production and food processing.

Bahta et al. (2014) used the CGE model to show the role of the agricultural sector in the dissemination of income and economic development in the Free State Province. The authors found that the agricultural sector played a significant role in reducing poverty and improving income distribution. However, considering poverty, the results suggested that the manufacturing sector increased income more than other sectors.

Cloete (2013) applied SAM multiplier analysis to study the contribution of agricultural development in the North West Province. The simulation results proved that development policies show clear positive contributions within the various agricultural sub-sectors in the economy. The study further mentioned that insufficient or poor planning for functional institutions in the province is one of the constraints for agricultural development.

Taljaard (2007) applied CGE and SAM multiplier analysis to study the macroeconomy and irrigation agriculture in the Northern Cape Province of South Africa. The author found that the significant economy-wide impacts resulted from market risks or other exogenous factors influencing local irrigation agriculture, especially in a region where irrigation agriculture played such an important role. Taljaard's (2007) study did not include agricultural activities and land accounts. The study's scope did not address whether the returns came from rainfed or irrigation agriculture, and the SAM did not consider the types of land and farms used for agricultural production/activities. Therefore, a new composition of the Northern Cape SAM is required to address the issues of agricultural activities. Additionally, a study at the district level is needed, which can be achieved by incorporating multiple production/industry accounts and incorporating land accounts (irrigated and rainfed).

Doukkali and Lejar (2015) studied the energy costs of the irrigation policy in Morocco and highlighted that the policy, which targeted water-saving techniques, increased the use of subsidised energy. Subsequently, the indirect effects of energy subsidies exceeded the direct impact of agricultural subsidies. These authors categorised agriculture according to irrigated and rainfed conditions but did not include detailed disaggregation information for factors and household incomes. However, they did not include detailed disaggregation information for factors and household incomes.

Kirsten and Van Zyl (1990) used an input-output (I/O) model to assess the economic impact of irrigation development and found that through forward and backward linkages, irrigation agriculture made an essential contribution to the regional economy in the Free State Province of South Africa. The study's scope did not address whether the returns came from rainfed or irrigation agriculture, and the SAM did not consider the types of land and farms used for agricultural production/activities. Therefore, a new composition of the Northern Cape SAM is required to address the issues of agricultural activities. Additionally, a study at the district level is needed, which can be achieved by incorporating multiple production/industry accounts and incorporating land accounts (irrigated and rainfed).

Brown (2017) used input-output models to evaluate the economic impact of irrigation development in Saskatchewan, Canada and found that irrigation provided an impetus for economic growth. Although Brown (2017) and Kirsten and Van Zyl (1990) studied the impact of irrigation on agriculture, the authors did not include data on irrigated versus rainfed agriculture. Furthermore, the technique applied to the I/O model included a single production account and excluded information on household incomes at the district level. This meant that industries produced different commodities, and some industries produced multiple commodities. Table 3 summarises similar studies on models.

Table 3: Summary of literature to identify a gap in knowledge or literature for SAM-based models (multiplier and CGE models)

Author/s	**Objective**	**Data and Methods**	**Findings**	**Remarks**
Ferreira et al. (2022)	The main objective of this study was to determine the significant role of the agricultural sector in the development of Ghana.	The study used SAM multiplier analysis for the 2015 Ghana SAM.	The findings showed that the primary sector will play a massive role in the employment generation and further stimulate economic growth in the country. The study further selected important crops such as sorghum,	Changing policies that promote commercial agriculture will help to promote the development of exportable agricultural products and encourage agricultural marketing.

			millet, pulse, tobacco, cotton, and fibres to be considered for economic development. In addition, the authors suggested policies should mostly focus on promoting the primary sector due to its ability to generate jobs, enhance output, and increase household income.	
Mondlane and Van Deventer (2019)	The main objective of the study was to evaluate agricultural development, trade, and distribution income levels in Mozambique.	The study used a 2015 SAM for Mozambique to compute the multiplier decomposition approach.	The results reported that there is a strong link between food processing and low rural household income due to inputs used in crop production. However, the authors further found that food processing has a small impact	This study concluded that international trade with high rates of imports regarding food processing is mainly sourced from South Africa.

			on the economy due to the relatively low multiplier caused by imports.	
Mukarati and Makombe (2017)	The main objective of the study was to determine the effect of the agricultural sector on household income in South Africa.	The study used SAM decomposition and structural path analysis.	The findings revealed that the agricultural sector contributes 4% to the overall economy and adds value to household income. The impact of the agricultural sector on increasing household income is clearly shown through linkages (forward and backwards).	The study concluded that there is an increase in the return for land for poor households.
Kistern and Van Zyl (1990)	This study aimed to assess the economic contribution of irrigation agriculture in the Free State.	The study used the Input-Output models for the western Free State.	The output multiplier for irrigation agriculture was among the highest of all the sectors in the southwestern	Irrigation agriculture made an important contribution towards the regional economy of the southwestern Orange Free State

			Orange Free State.	through its forward and backwards linkages.
Mulanda (2020)	The main objective of the study was to determine the composition of the agricultural sector in the Zambia economy and the significant role that sector plays in policy decisions.	The study applied a 2007 SAM for Zambia to calculate the multipliers and CGE analysis.	The study found that primary agriculture has the highest output compared to other sectors of the economy, such as the service sector. Within the livestock subsector, it was found to have the highest output. In the case of the CGE model, the findings revealed that transaction costs played an important role in minimising production costs for agriculture by approximately 30% and expanding its value addition	Most processed foods are imported from other countries, such as South Africa. For the country to continue stimulating economic growth, the government has invested in infrastructure to unfasten the capability of crop production and food processing.

			for all the processing activities in the economy.	
Van Deventer and Tarp (2020)	The main objective of the study was to assess the agro-industry, exports, and income distribution in Myanmar.	The study used a 2017 SAM for Myanmar to calculate the decomposition multiplier technique.	The study found that rural low-income households benefit from increased agro-processing and crop production. In addition, the authors further mentioned that rural-income households are strongly linked to agro-processing through the process of feedback and spillover. Despite the increase in rural household income from agro-processing, the sector has yet to reach its level of development in the country.	Promoting trade through the improvement of exports would benefit rural low-income households more compared to other households.

Taljaard (2007)	The overall objective of this study was to develop a model capable of quantifying the economy-wide impacts of market risk and other exogenous factors, with specific reference to efficient irrigation water use.	The study applied a 2000 SAM for South Africa with detailed information on agro-ecological regions in the Northern Cape Province to calculate the CGE and SAM multiplier models.	Significant economy-wide impacts can result from market risks or other exogenous factors influencing local irrigation agriculture, especially in a region where irrigation agriculture plays such an important role as in the NCP.	South Africa is relatively underdeveloped in the management of water supply and demand. In this regard, innovative technological development, combined with cutting-edge research in this field, is the only way in which effective water use will ultimately advance and thereby optimise the net benefit of society as a whole.
Ramigo (2017)	The main research objective of this study was to assess the role of agriculture in economic growth and development in rural Limpopo.	The study used the Limpopo (SAM) for 2006, which was developed by Conningarth Economists, as a database to develop a multiplier model.	The results from the SAM multiplier analysis indicated that R1 million injected into the agricultural sector will lead to a notable change in output (R1.67 million) and	It was concluded that although most of the people in the province live in rural areas and are assumed to engage in the agricultural sector as a source of livelihood, the agricultural sectors contribute

			value added (R764 000). Some of the agricultural sub-sectors generated a large increment in output – the largest being subtropical fruit and forestry. The water and electricity industry was ranked first for output (R2.02 million) and third for value added (R900 000). The financial industry was ranked first for value added (R962 000) and sixth for output (R1.77 million). The results showed that tertiary sector industries are gaining more position on the list of leading industries in Limpopo.	less to economic growth than non-agricultural sectors in Limpopo. To achieve significant development in Limpopo, more focus should be placed on the water and electricity (output), financial insurance (value added) and community and personal services (income) sectors for their contribution to economic growth due to large multipliers when compared to other sectors.

			Moreover, investment in the tertiary sector seems important for economic development because of its linkage to other sectors.	
Pauw et al. (2007)	To evaluate the agricultural efficiency and welfare in South Africa.	The study applied CGE models.	The results suggest that technological advances in agriculture should not be resisted because of their negative impact on agricultural employment.	The important lesson is that the achievement of greater efficiency in agricultural production almost invariably implies that employment in agriculture will decline unless the growth in total demand is sufficiently large to offset the (direct) decline in employment due to efficiency gains.
Mare and Bahta (2022)	The main objective of this study was to evaluate the export trade for live sheep in the economy of South Africa.	The study used a 2015 SAM for South Africa with detailed information on the agricultural sector to determine a	The study recorded that there is a high demand for exporting live sheep. However, the country lost	The study was important for assisting policymakers in developing necessary strategies to continue to

		partial equilibrium model.	opportunities for value-adding from output such as abattoirs, hides and skins, and consumable internal organs.	enhance live sheep exports.
Cloete (2010)	To improve the success of rural agricultural development in the North West Province (NWP).	The study applied a 2006 provincial SAM for North West developed by Conningarth Economists as a base year to calculate the Leontief inverse matrix in the multiplier analysis.	The simulated results proved that development policies (i.e., land redistribution) yield different economy-wide impacts within the various agricultural sub-sectors of the province.	The lack of proper and functional institutions could be the main reason for the high failure rate of rural agricultural development in the NWP.
Bahta et al. (2014)	To analyse the impact of the agriculture sector on welfare and income distribution in Free State.	Applied CGE models.	The results suggest that the agricultural sector significantly reduces poverty and improves income distribution, but considering poverty, the results suggest that the manufacturing	Agriculture has a greater impact on poor-income households than industrial-based growth. The assumption is that more poor households rely on agriculture than other sectors.

			sector increases income more than other sectors.	
Brown (2017)	To estimate the economic impacts of existing levels of irrigation in Saskatchewan and the local region. To estimate the economic impacts of expanded levels of irrigation in Saskatchewan and the local region. To estimate the net regional (community level) impacts of conversion from dryland farming to irrigation at the regional level (for the LDDA).	The study applied the Input and Output (I/O) model for the irrigation sector.	The study found that the total economic impacts of irrigation development from 2011-2016, enabling an additional 8,472 acres of irrigated production, amounted to $200.83 million in output (sales), generating $86.60 million in GDP contributions at market prices.	The study found the economic impacts of irrigation, currently and potentially, to be extensive in each scenario, offering considerable regional impacts over and above the dryland production alternatives.
Doukkali and Lejar (2015)	This study aimed to assess the consumption and the multiplier effect of the use of energy and irrigation water for rainfed and irrigated agriculture at the national level in Morocco.	The study used Social Accounting Matrix multiplier analysis to compute the direct and indirect effects of subsidising	The results found that the water-saving techniques increased the use of subsidised energy. Subsequently, the indirect effects of	A Social Accounting Matrix can help decision-makers make the necessary trade-offs between irrigated and rainfed agriculture.

<table>
<tr><td></td><td></td><td>energy used by agriculture.</td><td>energy subsidies exceeded the direct impact of agricultural subsidies.</td><td></td></tr>
<tr><td colspan="5">Gap: Even though the study done by Brown (2017) and Kirsten and Van Zyl (1990) seemed relevant to this study, the technique applied to the I/O model was limited to including a single production account and excluded multiple commodities industries. This means industries can produce multiple commodities, and different industries can produce multiple commodities. The study completed by Taljaard (2007) seemed to have a better approach for this study. However, the author could not address certain issues in the agricultural activities and land accounts.

Firstly, the returns to land from agricultural activities were not clearly addressed in the study in terms of whether the returns came from rainfed or irrigation agriculture. Secondly, even though a SAM clearly displayed regions engaged in agricultural activities within the Northern Cape, the author did not reveal types of land utilised for agricultural production/ activities in those regions. Lastly, Taljaard (2007) used a national SAM for 2000 prices, which is outdated. Therefore, a new composition of the Northern Cape SAM is required to address the current issues of agricultural activities. This study contributed by analysing the effect of irrigation agriculture on output, incomes (farm income and household income) and value added/GDP using a 2017 national Social Accounting Matrix (SAM) reference to Limpopo Province.

Several SAM had been reported over the years for policy analyses. Research generally uses multiplier analysis, input-output models, SAM-based input-output models, and CGE models to analyse the inter-sectoral linkages (multiplier effect) in any economic change in a specific sector, which will have a ripple effect in other sectors of the economy. However, empirical research in irrigated and rainfed agriculture is neglected, and models are limited to a single production account, which excludes detailed information on factors and household incomes at provincial and district levels. Therefore, an explicit understanding of the effect of irrigation agriculture on output, land return, institutional and household incomes, and value added is needed to develop a strategy for irrigation policies that contribute to economic development.</td></tr>
</table>

2.6.3 Empirical studies on the impact of electricity tariff increases on the agricultural industry (Cost-push-price models)

Most studies have been conducted in South Africa and abroad using electricity. Tlhalefang and Galebotswe (2013) used a SAM price multiplier analysis to study the welfare effects of higher energy and food prices. The results showed that agriculture, electricity, water, government, and non-diamond mining were affected after the introduced shocks in the production sectors. The study concluded that there is a need for government intervention to invest in agricultural production to raise yield and energy production and to ensure efficiency gains in food and energy are achieved.

Hartono and Nugroho (2019) applied a SAM price model to determine the impact of increasing prices on Indonesia's economy. The study found that households were the most negatively affected by the rising food prices. The study concluded that increases in the prices of rice will reduce the poverty rate in Indonesia. In addition, a change in the price of rice would undoubtedly affect the producers' and consumers' cost of inputs and standard of living, especially for low-income household earners.

Hassen and Degu (2019) studied the effect of power outages on the productivity of micro and small enterprises in Ethiopia and applied a cross-sectional survey. The study found that the power outages had a negative impact on the productivity and profitability of small businesses due to a decrease in the production process. It was then concluded that focusing on sustainable and dependable power is critical for improving the overall efficiency of micro, small, and medium firms.

Makgopa and Mpetsheni (2022) studied the effect of load shedding on small and medium enterprises in South Africa. The study found that load shedding negatively affects the performance of small and medium enterprises by reducing operating profits and competitiveness. Small and medium-sized food companies should embrace alternative energy power sources such as backup generators and adjust operations to mitigate the effects of power outages.

Cissokho (2019) evaluated the effect of power outages on the productivity of small-scale enterprises in the manufacturing sector in Senegal using the panel data for small-scale enterprises. The study found that power disruptions had severely affected the productivity of small and medium firms in Senegal. It was concluded that the small and medium enterprises equipped with a generator had proven to be effective in mitigating the power outages on productivity.

Mbanda and Bonga-Bonga (2018) conducted a study using a CGE model to analyse the increase in electricity tariffs in South Africa. The study found that an increase in the price of electricity would cause an increase in production output and labour demand in some of the sectors of the economy through supply side effects. The study concluded that the effect of electricity tariff increases is not entirely negative on the economy if it produces an increase in output in some of the sectors of the economy.

Tarancon et al. (2010) reported a study evaluating the influence of manufacturing sectors on the demand for electricity. The findings recorded a small proportion of an increase in electricity, which would have a strong enough motive to adopt technologies and practices that reduce electricity consumption. Thus, the manufacturing sectors greatly impact electricity demand and the sectors whose production costs would be severely affected by increased electricity prices.

Mutambo et al. (2023) studied the impact of electricity load shedding on the operations of small-scale enterprises in selected developing countries. The study found that the effects of electricity load shedding on small and medium enterprises had negatively affected business operations and economic growth and impeded the development of the small and medium enterprises.

Abubakar et al. (2022) conducted a study on post-COVID-19 electrical load shedding on Cameroon's northern interconnected grid. The authors found that temperature and precipitation had a low influence on the energy crisis. The study discovered that the most significant factor that led to the shortage of power was the outcome of electricity production cost, which is more significant compared to market price. In addition, it was revealed that patient care was affected mainly by load-shedding. The recommendation was given to energy practitioners and grid managers.

Nguyen (2008) studied the impact of a rise in electricity tariffs on prices of other commodities in Vietnam. The study concluded that the price of electricity would cause the prices of all other products to increase. Thus, policymakers should look at the policy in terms of the government's support of socio-economic development to improve the security of the energy system.

Zhao and You (2008) assessed the effect of electricity price reform on the economy of China. The results showed that the effect of the multiplier on capital account was significantly greater in all endogenous accounts multiplier effect. In the case of the industries, it was revealed that the effect of price adjustment on electric machinery and petroleum and chemical processing commodities was significant. The coal industry was correlated with the electric power sector and highlighted coal as a significant combust adopted in power producers.

Akkemik (2011) studied the impact of electricity price changes on price formation in Turkey's economy. The study showed that different sectors in the economy, such as energy-producing sectors (electricity, gas, water, coal, and petroleum), mining, and iron and steel sectors, would be more severely affected than other sectors in the economy. The remarks reported that consumer prices would be more severely experienced than producer prices.

Most of the studies mentioned above have found that the impact of electricity price increases had a negative effect on the economy in terms of a decline in GDP and an increase in unemployment. These studies further reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. Researchers rarely empirically assess the impact of electricity tariff increases on agricultural sectors at the provincial and district levels. This study contributed by evaluating the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and generation. Table 4 summarises similar studies on electricity tariff increases.

Table 4: Empirical studies on the impact of electricity tariff increases on the agricultural industry

Author/s	**Objective**	**Data and Methods**	**Findings**	**Remarks**
Mbanda and Bonga-Bonga (2018)	The objective was to analyse the electricity tariff increase in South Africa.	The study applied CGE models.	The study found that an increase in the price of electricity would	The study concluded that the effect of electricity tariff

			cause an increase in production output and labour demand in some of the sectors of the economy through supply side effects.	increases is not entirely negative on the economy if it produces an increase in output in some of the sectors of the economy.
Tlhalefang and Galebotswe (2013)	The main aim of this study was to determine the effects of increased prices of internationally traded energy and food products on the sectors of the economy in Botswana.	The study applied SAM price models.	The results showed that agriculture, electricity, water, government, and non-diamond mining were affected after the introduced shocks on production sectors.	The study concluded that there is a need for government intervention to invest in agricultural production to raise yield and energy production and to ensure efficiency gain in food and energy.
Akkemik (2011)	This study determined the potential impacts of changes in the prices of electricity in Turkey.	The study used a 2002 SAM for Turkey and cost-push-price models.	The study showed that different sectors in the economy, such as energy-producing sectors (electricity, gas, water, coal, and petroleum), mining, and iron and steel sectors, would be more severely affected than other sectors in the economy.	The remarks reported that consumer prices would be more severely experienced than producer prices.

Nguyen (2008)	This article assessed the impact of electricity tariff increases on products.	The study applied the Input and Output technique.	The study concluded that the price increase in electricity would cause the prices of all other products to increase.	The remarks indicated that the policymakers should consider the policy in terms of government support and socio-economic development to improve the security of the energy system.
Tarancon et al. (2010)	This study aimed to evaluate the influence of manufacturing sectors on the demand for electricity.	This study applied the Input and Output approach technique.	The findings recorded a small proportion of increases in electricity would have a strong enough motive to adopt technologies and practices that reduce electricity consumption.	The manufacturing sectors have a significant impact on electricity demand and the sectors whose costs of production would be severely affected by an increase in electricity prices.
Zhao and You (2008)	The study objective was to assess the effect of electricity price reform on China's economy.	The study used SAM price model.	The results showed that the effect of multiplier on capital account was significant in all endogenous accounts multiplier effect. In the case of the	The coal industry was correlated with the electric power sector and highlighted coal as a major combustible adopted in power producers.

			industries, it was revealed that the effect of price adjustments on electric machinery and petroleum and chemical processing commodities is significant.	
Mutambo et al. (2023)	The study’s main aim was to evaluate the impact of electricity load shedding on the operations of small-scale enterprises in selected developing countries.	The study used a traditional literature review as the methodology.	The study found that the effects of electricity load shedding on small and medium enterprises had negatively affected business operations and economic growth and impeded the development of the small and medium enterprises.	The study concluded that investing in infrastructure and promoting energy efficiency would decrease the harmful effects of power loss and generate an enabling environment for the growth of small and medium enterprises.
Aboubakar et al. (2022)	This study explored electrical load shedding on Cameroon's northern interconnected grid post COVID-19.	The study used time series data by applying multiple linear regression analysis.	The authors found that temperature and precipitation had a low influence on the energy crisis. The study discovered that the most	It was revealed that patient care was mostly affected by loadshedding. The recommendation was given to energy

			significant factor that led to power shortage was the outcome of electricity production cost, which is greater than the market price.	practitioners and grid managers.
Cissokho (2019)	This study evaluated the effect of power outages on the productivity of small-scale enterprises in the manufacturing sector in Senegal using the panel data for small-scale enterprises.	The study used quantitative research. Regression analysis.	The study found that power disruptions had severely affected the productivity of small and medium firms in Senegal.	It was concluded that the small and medium enterprises equipped with a generator had proven to be effective in mitigating the power outages on productivity.
Hassen and Degu (2019)	This study examined the effect of power outages on micro and small enterprises' productivity in Ethiopia by applying a cross-sectional survey.	This study used Ordinary Least Square (OLS) regression and Multinomial Switching regression.	The study found that the power outages negatively impacted the productivity and profitability of small business due to a decreased production process.	It was then concluded that focusing on sustainable and dependable power is key to improving the overall efficiency of micro, small and medium firms.
Makgopa and Mpetsheni (2022)	This paper studied the effect of load shedding on small and medium	This study applied a qualitative approach to	The study found that load shedding negatively affects	It was suggested that to mitigate the effects of power outages,

	enterprises in South Africa.	gain an in-depth understanding of the effect of load shedding on small and medium enterprises.	the performance of small and medium enterprises by reducing operating profits and competitiveness.	the food industry in small and medium enterprises should embrace alternative energy power sources such as backup generators and adjust operations.
Hartono and Nugroho (2019)	The study's main aim was to evaluate the impact of increasing prices on Indonesia's economy.	The study used the SAM prices model.	The study found that households were the most negatively affected by raising food prices.	The study concluded that increasing rice prices will reduce Indonesia's poverty rate. In addition, a change in the price of rice would certainly affect the producers' and consumers' cost of inputs and standard of living, especially for low-income household earners.
Most of the studies mentioned above have found that the impact of electricity price increases had a negative impact on the economy in terms of a decline in GDP and an increase in unemployment. These studies further reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. Researchers rarely empirically assess the impact of electricity tariff increases on agricultural sectors at the provincial and district levels. This study contributed by evaluating the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and production.				

2.6.4 Empirical studies on the effect of irrigation systems and water uses on the maize industry

Past studies revealed that the maize performs better under the drip and furrow irrigation systems, and the water used requirement was estimated to be between 351 mm and 685 mm using the crop coefficient estimation (Ray et al., 2024). In addition, the study reported that the drip-irrigated maize had a higher yield and profit compared to the furrow-irrigated crops. It was suggested that to achieve SDGs (Sustainable Development Goals), agricultural production must increase with optimum irrigation water application.

Zhang et al. (2017) used the economic benefit analysis to study and differentiate the irrigation systems to enhance maize yield and water productivity. The authors reported different results for drip irrigation, flood irrigation, and border irrigation for maize; drip irrigation was found to consume more groundwater than flood irrigation. The authors further stated that yield under drip irrigation increases compared to flood and border irrigations. These types of irrigation systems could substantially reduce irrigation water applications and increase water productivity.

Irfan et al. (2014) reported that maize crop yield and water use efficiency are higher for drip irrigation with good quality water. The data was taken from the Agricultural Meteorology Cell, Crop Physiology Department, and the University of Agriculture, Faisalabad. This study used the Crop Water (CROPWAT) Model to determine the irrigation scheduling. The authors further highlighted that drip irrigation would be more suitable for adoption where groundwater quality would be used to achieve high crop production and increase water efficiency. The study concluded that drip irrigation could be used to produce high yields and use water efficiently.

Zhang et al. (2021) found that drip and furrow irrigation obtained good yield and net profit with a reduced water application. The author used statistical analysis such as ANOVA (Analysis of Variance) and the least significant difference (LSD). This is because drip irrigation has a higher water consumption coefficient in maize than furrow and border irrigations. Thus, furrow and drip irrigations have been preferred to produce highly efficient irrigation and increase water use efficiency worldwide compared to flood irrigation, which reduced water use efficiency.

Parvar et al. (2022) estimated the impact of water reduction on production sectors of Iran's economy using the SAM-based models. They found that water resource constraints lead to decreased production and incomes and increased poverty across various economic sectors. In addition, water resource constraints have a more significant impact on gross operating surplus than on labour. Therefore, the optimisation of water consumption in crop production is more significant because the relative share of water use in the agricultural sector is higher than in other economic sectors.

Xu et al. (2021) explored the effect of irrigation systems and water use efficiency on maize yield in China using the WHCNS (Soil-Water-Heat-Carbon-Nitrogen-Simulator) model to simulate grain yield, water, and nitrogen fertiliser use efficiencies under different irrigation systems and rainfed conditions. They found that the significance of drip irrigation over border irrigation reduced evaporation without affecting the transpiration rate for cereals crops. They further highlighted that drip irrigation improves grain quality and water use efficacies and reduces water loss through runoff and drainage.

Suryavanshi and Buttar (2020) studied the impact of different irrigation techniques on the water productivity of wheat and found higher water productivity for drip-irrigated wheat compared to sprinkler-irrigated wheat. Drip irrigation is a better technique in terms of saving irrigation water and increasing yield using the economic benefits analysis for drip irrigation and border irrigation (Liu et al., 2023). It was suggested that drip irrigation is more effective for sustainable agricultural development.

Kotze et al. (2024) studied the factors affecting water use behaviour and efficiency for food production in South Africa. These authors used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework and guidelines to identify the articles included in the review. The study found that improving water allocation with better use of groundwater savings would lead to better water management and further enhance irrigation efficiency.

Ketsela et al. (2024) conducted a study to assess small-scale irrigation schemes' performance using the crop water demand software and systematic apparatus analysis (conveyance efficiency and water surface elevation). This method was proposed due to the net volume of water harvested during night storage, and it significantly helps to enhance water management and sustainability. It was recommended that a water harvesting method be adopted to reduce water scarcity problems.

Jordaan and Bahta (2020) studied the mitigation of water use irrigation agriculture in South Africa using the SAM-based CGE model and reported that the pivot irrigated maize and wheat yield decreased because of increased input costs such as fertiliser and oils. They further highlighted that to increase the maize and wheat yield for pivot irrigation, it is significant to restrict water applications using a limited number of hectares to maximise profit. However, no studies have directly computed in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling. This study contributed by applying various irrigation systems (e.g., drip irrigations, pivot irrigation, micro irrigation and coupling irrigation systems) and sources of water use (e.g., dams, rivers, surfaces, boreholes, and rain harvesters). Table 5 summarises similar studies on the effect of irrigation.

Table 5: Empirical studies on the effect of irrigation systems and water uses on the maize industry

Author/s	**Objective**	**Data and Methods**	**Findings**	**Remarks**
Jordaan and Bahta (2020)	This study aimed to determine the effect of policy-driven water cost changes and water restrictions on output, yield, and other macroeconomic variables in irrigation agriculture.	A 2009 SAM for South Africa was utilised to develop an IFPRI CGE model.	The findings reported that the pivot irrigated maize and wheat yield decreased because of increased input costs such as fertiliser and oils. They further highlighted the increase in the maize and	It is significant to restrict water applications using a limited number of hectares to maximise profit. However, no studies have directly computed in detail various irrigation systems by the source of water

			wheat yield for pivot irrigation.	used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling.
Irfan et al. (2014)	The main purpose of this study was to evaluate the irrigation management techniques and water on maize production and water use efficiency.	The collected data focused on germination rate, plant and crop yield, and efficiency of water use.	The study concluded that the maize crop yield and water use efficiency are higher for drip irrigation with good quality water.	The authors further highlighted that drip irrigation would be more suitable for adoption where groundwater quality would be used to achieve high crop production and increase water efficiency.
Zhang et al. (2021)	The main objective of this research was to compare different irrigation systems to synergistically improve maize's yield, water productivity and	A statistical analysis (ANOVA) was used.	The research found that drip and furrow irrigation obtained good yield and net profit with a reduced water	The remark of the study shows that highly efficient irrigation technologies also provide a theoretical basis

	economic benefits in an arid irrigation area.		application. This is because drip irrigation has a higher water consumption coefficient in maize than furrow and border irrigations.	for the decision-making of agricultural water management and allocation in arid irrigation areas.
Parvar et al. (2022)	The study's main aim was to estimate the effect of water reduction on economic sector production in Iran's economy.	The study used SAM multiplier analysis.	They found that water resource constraints lead to decreased production and incomes and increased poverty across various economic sectors. In addition, water resources constraints have a greater impact on gross operating surplus than on labour.	It was found that the optimisation of water consumption in crop production is more significant due to the relative share of water use in the agricultural sector being higher than in other economic sectors.
Xu et al. (2021)	The study's main purpose was to evaluate the modelling effect of irrigation systems and water use	Input data of model (water, heat, carbon, Nitrogen, soil simulator models).	The research found that the significance of drip irrigation over border irrigation	The research reported that drip irrigation improves grain quality and water use

	efficiency on maize yield in China.		reduced evaporation without affecting the transpiration rate for cereal crops.	efficacies and reduces water loss through runoff and drainage.
Ray et al. (2024)	The main objective of this study was to develop strategies for improving water productivity in maize.	The study used crop efficient estimation to determine the quantity of water crops needed at different stages for field water management.	The study reported that the drip-irrigated maize had a higher yield and profit compared to the furrow-irrigated crops.	It was suggested that to achieve SDGs (Sustainable Development Goals), agricultural production must increase with optimum irrigation water application.
Liu et al. (2023)	The main objective of this study was to improve growth, water use efficiency, and economic benefits for maize production in China.	The economic benefits analysis was computed using the ration of benefits to costs for drip and border irrigations. In addition, the statistical analysis was applied for ANOVA (Analysis of Variances).	Drip irrigation is a better technique in terms of saving irrigation water and increasing yield using the economic benefits analysis for drip irrigation and border irrigation.	It was suggested that drip irrigation is more effective for sustainable agricultural development.

Kotze et al. (2024)	The authors studied the factors affecting water use behaviour and efficiency for food production in South Africa.	These authors used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework and guidelines to identify the articles included in the review.	The study found that improving water allocation with better use of groundwater savings would lead to better water management and further enhance irrigation efficiency.	It was suggested that implementing strategies and policies would assist stakeholders in directing and supporting farmers in anticipating the challenges experienced in the farms' achievement. The authors also recommend that the findings could be used to design and develop different techniques to explore similar and relevant topics in the agricultural field.
Ketsela et al. (2024)	This study assessed the performance of small-scale irrigation schemes.	The crop water demand software and systematic apparatus analysis (conveyance	The study found that improving water allocation with better use of groundwater savings would	It was concluded that adopting water harvesting technology and developing strong water

		efficiency and water surface elevation) were used for this study.	lead to better water management and further enhance irrigation efficiency.	users' associations are some suggestions to decrease water scarcity challenges and enhance water management and sustainability.
Zhang et al. (2017)	The main aim of the study was to determine economic benefit analysis to differentiate the irrigation systems to enhance maize yield and water productivity.	The study used statistical analysis such as ANOVA (Analysis of Variance).	The study reported different results for drip irrigation and flood irrigation for maize; drip irrigation was found to consume more groundwater than flood irrigation.	The study concluded that yield under drip irrigation increases compared to flood irrigation. It was suggested that the producers select the appropriate, more efficient irrigation, such as drip irrigation over border and furrow irrigations.
Suryavanshi and Buttar (2020)	The authors studied the impact of different irrigation techniques and water productivity of wheat and found higher water	The study used statistical analysis such as ANOVA (Analysis of Variance).	Drip irrigation is a better technique for saving irrigation water and increasing	It was suggested that drip irrigation is more effective for sustainable

	productivity for drip-irrigated wheat compared to sprinkler-irrigated wheat.		yield using the economic benefits analysis for drip irrigation and border irrigation.	agricultural development.
Ntshidi et al. (2023)	The main objective of this study was to determine different irrigation systems for water use partitioning and plant water relations of apple trees growing on deep sandy soils in the Mediterranean climatic conditions of South Africa.	The study used statistical analysis such as ANOVA (Analysis of Variance).	This study found drip irrigation beneficial for water savings compared to surface irrigation systems.	This study recommended that maintaining the right balance between obtaining optimal yields and saving water needs a detailed understanding of tree response to the specific irrigation system. This is of significant benefit as water resources become scarce because of climate change and escalating competition among various water users.
Different studies on irrigation techniques and water uses in the maize industry reported that drip irrigation systems consumed more groundwater and obtained yield and net profit with a reduced application. Most of these studies applied statistical analysis such as ANOVA (Analysis of				

Variance), economic benefit analysis, crop efficient estimation, and the crop water demand software and systematic apparatus analysis (conveyance efficiency and water surface elevation). However, no studies have directly computed in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling.

2.6.5 General contribution

In brief, the current study contributed to the construction of the 2017 National for South Africa and 2021 provincial SAM for Limpopo Province. The 2017 SAM for South Africa significantly contributed to the disaggregation of agricultural activities, labour, land, and household accounts according to regions (provinces and districts). The agricultural activities and land accounts were disaggregated according to irrigation and rainfed accounts, whereas labour and household accounts were split according to provinces and districts for South Africa. Most of the studies mentioned above have found that the impact of electricity price increases had a negative impact on the economy in terms of a decline in GDP and an increase in unemployment. These studies further reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. Researchers rarely empirically assess the impact of electricity tariff increases on agricultural sectors at the provincial and district levels. This study contributed by evaluating the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and production.

On the other hand, the 2021 provincial SAM for Limpopo Province was categorised according to irrigation systems and sources of water use. The irrigation systems were further disaggregated according to the maize industry. The land account was disaggregated according to the sources of water used for maize production. The empirical research in irrigated and rainfed agriculture needs to be addressed, and models are limited to a single production account, which excludes detailed information on factors and household incomes at provincial and district levels. Different studies on irrigation techniques and water uses in the maize industry reported that drip irrigation systems consumed more groundwater and obtained yield and net profit with a reduced application. Most of these studies applied statistical analysis such as ANOVA (Analysis of Variance). However, no studies have directly computed in detail various irrigation systems by source of water uses on crop production, such as maize in the arid and semi-arid conditions of Limpopo Province, using Social Accounting Matrix (SAM) based modelling. The modelling studies would significantly contribute to evaluating various irrigation systems by using sources of water for crop production, such as maize in arid and semi-arid conditions of Limpopo Province, using SAM-based modelling.

2.7. Summary

This section thoroughly summarised the reviewed literature on the global and South African perspectives for irrigation. The empirical literature revealed that irrigation is important as it creates employment opportunities and further enhances national income and economic development. In addition, irrigation enabled the generation of foreign revenue for many countries by producing a surplus in food production. Irrigation agriculture plays a massive role in uplifting agricultural production and achieving food security. Irrigation is one of the sectors that consumes the most water in South Africa. Generally, it relies on the composition and layout of the engineered systems to ensure the best economic and technical use of water pumped.

The 2017 SAM for South Africa significantly contributed to the disaggregation of agricultural activities, labour, land, and household accounts according to regions (provinces and districts). The 2021 provincial SAM for Limpopo Province was categorised according to irrigation systems and sources of water use. The irrigation systems were further disaggregated according to the maize industry. The land account was disaggregated according to the sources of water used for maize production. The empirical research in irrigated and rainfed agriculture is neglected, and models are limited to a single production account, which excludes detailed information on factors and household incomes at provincial and district levels. The modelling studies would significantly contribute to evaluating various irrigation systems by determining the sources of water used for crop production, such as maize in arid and semi-arid conditions of Limpopo Province, using SAM-based modelling.

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Chapter 3: Data on Economic Analysis: 2017 Social Accounting Matrices (SAMs) for South Africa

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Abstract

The purpose of the Social Accounting Matrix (SAM) is to improve the quality of the database for modelling, including, but not limited to, policy analysis, multiplier analysis, price analysis, and Computable General Equilibrium. This article contributes to constructing the 2017 national SAM for South Africa, incorporating regional accounts. Only in Limpopo Province of South Africa are agricultural industries, labour, and households captured at the district level, while agricultural industry, labour, and household accounts in other provinces remain unchanged. The main data sources for constructing a SAM are found from different sources, such as Supply and Use Tables, National Accounts, Census of Commercial Agriculture, Quarterly Labour Force Survey, South Africa Revenue Service, Global Insight (regional explorer), and South Africa Reserve Bank. The dataset recorded that land returns for irrigation agriculture were highest (18.2%) in the Northern Cape Province of South Africa compared to other provinces, whereas the Free State Province of South Africa rainfed agriculture had the largest shares (22%) for payment to land. Regarding intermediate inputs, rainfed agriculture in the Western Cape, Free State, and Kwazulu-Natal Provinces paid approximately 0.4% for using intermediate inputs. In terms of the districts, land returns for irrigation were highest in the Vhembe district of Limpopo Province of South Africa with 0.3%. Despite Mopani district of Limpopo Province of South Africa having the lowest land returns for irrigation agriculture, it has the highest share (1.6%) of payment to land from rainfed agriculture. The manufacturing and community service sectors had a trade deficit, whereas other sectors experienced a trade surplus. The main challenges found in developing a SAM are scarcity of data to attain the information needed for disaggregation for the sub-matrices and insufficient information from different data sources for estimating missing information to ensure the row and column totals of the SAM are consistent and complete.

Keywords: agricultural industries; national accounts; supply and use tables

3.1. Introduction

This paper contributes to constructing the national SAM for South Africa using 2017 prices. Punt [1], Round [2], and PROVIDE [3] define SAMs as transactions that transpire in the economy for a period of one year. This particular transaction shows receipts and payments in the economy. The primary data sources for constructing the SAM are found from different sources, such as Supply and Use Tables (SUT), National Accounts, Census of Commercial Agriculture, Quarterly Labour Force Survey (QLFS), Living Condition Survey (LCS), General Households Survey (GHS), South Africa Revenue Services (SARS), Global Insight (regional explorer), and South Africa Reserve Bank (SARB). The significance of a SAM, as mentioned by Punt [1], is that it displays a full circular flow of all details in the SUT and other missing information in the SUT. Therefore, a SAM is an expansion of the SUT. The row and column totals in a SAM must equate and square. Different models are developed from a SAM; these models incorporate Computable General Equilibrium (CGE) models and multiplier models. Of the above-mentioned models, CGE is known for its dominance due to the inclusion of a set of simultaneous equations.

Several SAMs had been reported in previous years for policy analyses in South Africa and internationally:

- Taljaard [4] used a 2000 SAM developed by PROVIDE [5], which included district accounts for agricultural industries in the Northern Cape. Punt [1] further reconstructed this SAM to 2007 prices, which included provincial agricultural industries in South Africa.
- Davies and Thurlow [6] developed a 2009 SAM for South Africa with a single agricultural sector. Van Seventer et al. [7–9] updated a SAM to 2012, 2015, and 2016, respectively.
- Phoofolo [10] provided a 2014 SAM with a disaggregated agricultural sector and a single account for agricultural land in South Africa. StsaSA [11–14] constructed SAMs for 1998, 2002, 2005, and 2011.
- Conningarth Economist[1] developed different SAMs that are utilized for consultancy work. Conningarth Economist [15,16] recorded a 2006 and 2018 SAM for provincial (Limpopo and Kwazulu-Natal) commissioned by the Development Bank of Southern Africa (DBSA).
- Aragie and Thurlow [17] constructed a 2018 SAM for Ethiopia, which included disaggregated agricultural activities and land accounts for single cultivated crops. IFPRI uses this SAM for policy analysis. Additionally, a

2018 Nigerian SAM was developed by Thurlow [18]. Aragie and Thurlow [19] developed a 2015 SAM for Ghana with the purpose of estimating home production for home consumption and including large shares of subsistence agriculture. Household accounts were defined according to regions, and each region had a specific agricultural industry producing subsistence commodities. Pradesha [20] produced a 2018 SAM for the Philippines with disaggregated agricultural activities and further split capital accounts according to crop and livestock. The SAM also includes land accounts based on cultivated cropland.

Most of the SAMs mentioned above were designed for policy analysis, as they provide detailed information for factors and household accounts. However, the South African SAMs developed by Phofoolo [10], Van seventer et al. [7–9], and Davies and Thurlow [6] do not contain detailed agricultural activities at the regional level. The SAMs developed by StatsSA [11–14] are not ideal for policy analyses due to their limitation of redistribution of income, as they do not provide sufficient information for factors and household accounts and only record single industry and product accounts for agriculture, forestry, and fisheries. This study adds to the agricultural industry accounts captured in a 2007 SAM adjusted by Punt [1], where the researcher disaggregated agricultural activities according to South African provinces but never assessed agricultural activities from the district's perspective. On the other hand, Taljaard [4] evaluated irrigation agriculture from the Northern Cape district perspective by disaggregating agricultural activities according to regions using a 2000 SAM developed by PROVIDE [3].

This study followed a similar composition to that conducted by Taljaard [4], incorporating provincial and district accounts for agricultural industries in the national SAM for South Africa. Regional districts within the Limpopo Province will disaggregate agricultural activity accounts. This means that agricultural industries are defined according to the agricultural land they use to produce a combination of agricultural commodities. Agricultural activities will further be divided into two categories in the regional districts: irrigation and non-irrigation agricultural activities. Factors of production consist of labour, capital, and land accounts. Labour and household accounts will be disaggregated according to province and district classifications. Land accounts comprise rainfed (dry land) and irrigated land. According to the knowledge of the researcher/authors, no study has been conducted in Limpopo Province using a national SAM with a disaggregated agricultural industry account according to district level.

This dataset plays a vital role in evaluating the economic impact of irrigation and non-irrigation sectors in various regions/districts of the Limpopo Province and other regional sectors in other provinces of South Africa. In addition, a SAM is designed to address the issues of distribution of institutional incomes and labour remunerations by regions in the Limpopo Province and the farming return by each production activity in the provinces. Hence, it is significant to develop this type of dataset to assess the significance of irrigation agriculture in the Limpopo Province.

3.2. Data Description

A 2017 national SAM for South Africa, which incorporates details about regional accounts for agricultural activities, labour, and households, comprises two hundred thirty accounts: one hundred six commodities (of which six are agrarian commodities), eighty-seven industries (of which agricultural sectors are divided into irrigation and non-irrigation), one transaction account, one account for capital, two accounts for land, thirteen accounts for labour, thirteen accounts for households, one enterprise, four tax accounts, one account for government, one account for investment/savings, change inventories, and one international trade (rest of the world) account.

Table 5 reported the South Africa macro-SAM for 2017 derived from the aggregated balanced SAM (million ZAR[2] (Rand), national currency of South Africa, USD 1 = ZAR 13.3055). As part of the intermediate input, the commodity demand recorded 45% (ZAR 4,791,222) of the total demand for commodities (ZAR 10,763,912). The domestic final demand was reported at 43% (ZAR 4,593,943), and exports accounted for 13% (ZAR 1,378,747). Imported commodities recorded 12% (ZAR 1,319,114) of the total ZAR 10,763,912 supply. At the basic prices, the total domestic production was ZAR 4,791,222, which includes payment to primary inputs of 46% (ZAR 4,090,904) and producer taxes of 1% (ZAR 82,421). South Africa was reported to be a net exporter of goods and services to the rest of the world in 2017 (ZAR 59,633), causing the country to have a net surplus on the current account.

In the case of household income (ZAR 3,697,568), as captured from the developed SAM, most of the income came from labour services, with a reported 60% (ZAR 2,223,661). Other incomes came as payment from enterprise at 15% (ZAR 546,186), from returns to capital at 14% (ZAR 533,956), and distribution from the government at 10% (ZAR 372,053). Most of the expenditure was reported as consumption of commodities at 75% (ZAR 2,756,540). Other expenditures came from payment to direct taxes at 13% (ZAR 465,800), payment to enterprises at 11% (ZAR 403,395), and savings at 2% (ZAR 62,222).

As recorded in the row account in the SAM, the government income received 63.1% (ZAR 1,241,379) of the income from producers, products, and income taxes. Other income came as payment from institutions at 26.7% (ZAR 526,255), payment from capital at 10.1% (ZAR 199,534), and transfer from the rest of the world at 0.1% (ZAR 1285). The total government expenditure was reported as ZAR 1,968,453. Of this total expenditure, 42.9% were consumptions of commodities, followed by transfers to institutions at 48.1%, transfers to savings at 0.1% (ZAR 2019), and transfers to the rest of the world at 2.6% (ZAR 51,690). The total investment, as recorded in the column account of a SAM, was ZAR 869,505. Of this total value, the domestic investment was reported to be at ZAR 873,223, with decreased inventory (ZAR 3717). Most of the domestic savings were reported as transfers from enterprises at 76.1% (ZAR 661,505), savings from households' income at 0.7% (ZAR 62,222), and savings from the government at 0.2% (ZAR 2019).

Table 2: A 2017 macro-SAM for South Africa (ZAR million).

	Activities	Commodities	Labour	Capita	Land	Enterprise	Households	Governments	Activities Tax	Prod Tax	Individual Tax	Corporate Tax	Change in Inventory	Investment	ROW	Total
Activities	0	8965	0	0	0	0	0	0	0	0	0	0	0	0	0	8965
Commodities	4792	0	0	0	0	0	2756	967	0	0	0	0	−3	873	1374	10,760
Labour	2225	0	0	0	0	0	0	0	0	0	0	0	0	0	11	2237
Capital	1863	0	0	0	0	0	0	0	0	0	0	0	0	0	69	1933
Land	1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1969
Enterprise	0	0	0	994	0	201	403	398	0	0	0	0	0	0	0	1997
Households	0	0	2223	531	1	546	0	173	0	0	0	0	0	0	21	3498
Government	0	0	0	199	0	350	0	176	82	480	266	212	0	0	1	1769
Activity tax	8242	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82
Product taxes	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	480
Individual tax	0	0	0	0	0	0	266	0	0	0	0	0	0	0	0	266
Corporate tax	0	0	0	0	0	212	0	0	0	0	0	0	0	0	0	212
Change in inventory	0	0	0	0	0	0	0	0	0	0	0	0	0	−3	0	−3
Savings	0	0	0	0	0	661	62	2	0	0	0	0	0	0	143	8695
ROW		1314	13	207	0	25	9	51	0	0	0	0	0	0	0	1622
Total	8965	10,760	2237	1933	1	1997	3498	1769	82	480	266	212	−3	8695	1622	

Source: SARB National Account [21] and authors' estimations.

Table 6 reveals the share of the total value output of payments for intermediate inputs, labour, gross operating surplus (GOS), land, and net activity taxes. The land returns for irrigation agriculture were highest in the Northern Cape Province of South Africa with about 18.2% compared to other provinces of South Africa, followed by the Eastern Cape Province of South Africa with 5.5%, Western Cape Province of South Africa with 4%, and the North West and Free State Provinces of South Africa with 2.2%. The payment to capital (GOS) for rainfed agriculture in the Northern Cape was 0.8%. Free State rainfed agriculture had the largest shares for payment to land (22%), followed by North West with 13.2% and Northern Cape (7.6%). Regarding intermediate inputs, rainfed agriculture in the Western Cape, Free State, and Kwazulu-Natal paid approximately 0.4% for using intermediate inputs. These industries paid around 0.1% each for labour remuneration and 0.3%, 0.4%, and 0.2% for utilizing capital (gross operating surplus).

In terms of the districts, land returns for irrigation agriculture were highest in the Vhembe district of Limpopo Province of South Africa with only 0.3%, followed by Capricorn of Limpopo Province of South Africa (0.2%), Waterberg of Limpopo Province of South Africa (0.2%), Sekhukhune of Limpopo Province of South Africa (0.2%), and Mopani of Limpopo Province of South Africa with 0.1%. Despite Mopani having the lowest land returns for irrigation agriculture, it has a high share (1.6%) of payment to land from rainfed agriculture, followed by Waterberg (0.7%), Vhembe (0.6%), Capricorn (0.5%), and Sekhukhune (0.1%).

Table 3. Components of total output by industries.

Industries	Intermediate Use	Labo ur	GO S	Land	Net Taxes	Total
	%					ZAR Million
Irrigation agriculture Western Cape (WC)	0.0	0.1	0.3	4.0	0.0	7065
Rainfed agriculture WC	0.4	0.1	0.2	2.8	0.0	24,935
Irrigation agriculture Eastern Cape (EC)	0.0	0.0	0.1	5.5	0.0	1900
Rainfed agriculture EC	0.3	0.1	0.2	4.0	0.0	19,112
Irrigation agriculture Northern Cape (NC)	0.0	0.0	0.1	18.2	0.0	3257
Rainfed agriculture NC	0.2	0.2	0.8	7.6	0.0	27,291
Irrigation agriculture Free State (FS)	0.0	0.1	0.3	2.2	0.0	6704
Rainfed agriculture FS	0.4	0.1	0.4	22.0	0.0	29,553
Irrigation agriculture KwaZulu-Natal (KZN)	0.0	0.1	0.3	0.8	0.0	6623

Rainfed agriculture KZN	0.4	0.0	0.2	4.3	0.0	25,658
Irrigation agriculture North West (NW)	0.0	0.0	0.3	2.2	0.0	7086
Rainfed agriculture NW	0.2	0.0	0.1	13.2	0.0	9778
Irrigation agriculture Gauteng (GP)	0.0	0.0	0.1	0.3	0.0	1339
Rainfed agriculture GP	0.4	0.0	0.0	0.6	0.0	21,133
Irrigation agriculture Mpumalanga (MP)	0.0	0.2	0.2	0.8	0.0	6892
Rainfed agriculture MP	0.4	0.0	0.0	6.9	0.0	18,798
Irrigation agriculture Mopani district of Limpopo Province	0.0	0.0	0.0	0.1	0.0	380
Rainfed agriculture Mopani	0.0	0.0	0.1	1.6	0.0	2943
Irrigation agriculture Vhembe district of Limpopo Province	0.0	0.0	0.0	0.3	0.0	1130
Rainfed agriculture Vhembe	0.0	0.0	0.0	0.6	0.0	2211
Irrigation agriculture Capricorn district of Limpopo Province	0.0	0.0	0.0	0.2	0.0	520
Rainfed agriculture Capricorn	0.0	0.0	0.0	0.5	0.0	2073
Irrigation agriculture Waterberg district of Limpopo Province	0.0	0.0	0.0	0.2	0.0	945
Rainfed agriculture Waterberg	0.0	0.0	0.0	0.7	0.0	2016
Irrigation agriculture Sekhukhune district of Limpopo Province	0.0	0.0	0.0	0.2	0.0	1411
Rainfed agriculture Sekhukhune	0.0	0.0	0.0	0.1	0.0	1248
Forestry	0.2	0.2	0.2	0.0	0.3	20,631
Fishing	0.1	0.1	0.3	0.0	0.0	9793
Mining of coal and lignite	0.9	1.2	3.3	0.0	1.3	132,456
Mining of gold and uranium ore	0.9	1.6	0.6	0.0	1.7	89,982
Mining of metal ores	2.3	4.5	4.6	0.0	1.3	297,675
Other mining and quarrying	1.0	1.1	1.5	0.0	0.6	99,576
Food	4.9	2.4	3.1	0.0	0.6	346,765
Beverages and tobacco	1.5	0.9	0.9	0.0	1.0	107,199
Spinning, weaving, and finishing of textiles	0.6	0.2	0.0	0.0	0.1	34,320
Knitted, crouched fabrics, wearing apparel, fur articles	0.5	0.3	0.0	0.0	0.2	28,227
Tanning and dressing of leather	0.1	0.0	0.1	0.0	0.0	8625
Footwear	0.2	0.1	0.0	0.0	0.1	10,087
Sawmilling, planning of wood, cork, straw	0.7	0.5	0.6	0.0	0.3	57,037
Paper	1.4	0.6	0.5	0.0	0.1	90,797
Publishing, printing, recorded media	0.8	0.7	0.0	0.0	0.5	54,291
Coke ovens, petroleum refineries	2.7	0.4	1.8	0.0	1.1	169,762
Nuclear fuel, basic chemicals	2.1	0.8	0.3	0.0	−1.3	121,006
Other chemical products, man-made fibres	2.3	1.3	0.1	0.0	0.9	142,443
Rubber	0.3	0.2	0.1	0.0	0.0	20,813
Plastic	0.5	0.6	0.1	0.0	0.0	39,425
Glass	0.2	0.1	0.0	0.0	0.1	10,724
Non-metallic minerals	0.8	0.3	0.3	0.0	0.2	51,617

Basic iron and steel, casting of metals	3.3	0.6	0.2	0.0	0.7	179,502
Basic precious and non-ferrous metals	0.8	0.3	0.2	0.0	0.1	51,733
Fabricated metal products	1.6	1.1	0.1	0.0	0.1	102,199
Machinery and equipment	1.5	1.2	0.4	0.0	0.1	106,041
Electrical machinery and apparatus	0.9	0.4	0.0	0.0	0.3	52,430
Radio, television, communication equipment, and apparatus	0.2	0.2	0.1	0.0	0.0	16,272
Medical, precision, optical instruments, watches and clocks	0.1	0.1	0.1	0.0	0.1	9901
Motor vehicles, trailers, parts	3.6	1.3	0.3	0.0	0.1	208,316
Other transport equipment	0.3	0.3	0.0	0.0	0.1	19,661
Furniture	0.4	0.2	0.1	0.0	0.1	24,396
Manufacturing n.e.c, recycling	0.7	0.3	0.9	0.0	0.2	57,164
Electricity, gas, steam, and hot water supply	1.7	1.7	4.7	0.0	0.3	208,591
Collection, purification, and distribution of water	0.7	0.5	1.2	0.0	−0.3	70,669
Construction	6.5	3.2	3.5	0.0	2.1	450,850
Wholesale trade, commission trade	3.9	4.7	5.0	0.0	5.8	386,908
Retail trade	3.1	3.8	4.5	0.0	4.8	319,280
Sale, maintenance, repair of motor vehicles	1.4	2.2	1.8	0.0	1.9	151,506
Hotels and restaurants	1.1	0.7	1.0	0.0	1.4	91,570
Land transport, transport via pipelines	3.8	3.3	8.1	0.0	4.6	407,224
Water transport	0.1	0.0	0.1	0.0	0.1	5699
Air transport	0.7	0.2	0.7	0.0	0.3	49,518
Auxiliary transport	1.1	0.9	1.2	0.0	0.8	95,597
Post and telecommunication	3.0	1.4	2.4	0.0	1.6	221,701
Financial intermediation	2.4	4.0	4.0	0.0	3.8	282,385
Insurance and pension funding	2.1	1.7	2.6	0.0	2.5	190,402
Activities in financial intermediation	2.5	2.8	1.8	0.0	1.5	214,551
Real estate activities	3.8	0.8	10.2	0.0	38.8	418,269
Renting of machinery and equipment	0.4	0.2	0.2	0.0	0.2	28,965
Computer and related activities	0.6	0.4	0.0	0.0	0.2	37,900
Research and experimental development	0.1	0.2	0.4	0.0	0.0	18,491
Other business activities	4.7	4.1	1.9	0.0	1.4	354,429
Government	6.7	29.5	4.7	0.0	10.5	1,075,263
Education	1.0	1.0	1.3	0.0	2.2	95,396
Health and social work	2.4	1.9	2.1	0.0	2.7	199,690
Sewerage and refuse disposal	0.0	0.0	0.0	0.0	−0.3	2476
Activities of membership organisations	0.1	0.0	0.1	0.0	0.2	5115
Recreational, cultural, and sporting activities	0.7	0.3	0.2	0.0	1.3	47,694
Other activities	0.1	0.0	0.0	0.0	0.2	6069
Non-observed, informal, non-profit households	4.0	5.1	11.9	0.0	0.0	526,670

%s (%)	100.0	100.0	100.0	100.0	100.0

Source: Authors' estimation from 2017 SAM.

Table 7 records the shares of the total value of demand of intermediate use, household consumption, government consumption, investment, and exports for the commodities incorporated in the SAM. Agriculture, live animals, forestry, and fishing are primarily utilized as intermediate demand (about 3.1%). Whereas only 4.5% of these commodities are consumed by households, approximately 2.8% of the same commodities are exported to the rest of the world. The total demand for agricultural commodities is estimated at ZAR 232 million, whereas live animal consumption is about ZAR 70 million, forestry ZAR 23 million, and fishing ZAR 11 million. Food processing accounted for about 2.5% of exported commodities, with about 20% of the processed food consumed by households. The overall demand consumption for food processing commodities is approximately ZAR 831 million.

In the case of mining commodities, about 18.8% of the demand for mining was exported, of which 12.9% came from metal ores, with a demand of 1.2% for intermediate inputs. Coal and lignite recorded only 1.8% of the export demand, with household consumption of 0.1%. The total demand for mining commodities is reported at ZAR 814 million.

Table 4. Components of total demand by commodities.

Commodities	Consumptions					
	Intermediate	Household	Gov	Investment	Export	Total
	%					ZAR Million
Agriculture	1.6	3.4	0.0	−0.1	2.6	232,646
Live animal	1.0	0.7	0.0	0.0	0.2	70,357
Forestry	0.4	0.2	0.0	0.0	0.0	23,922
Fishing	0.1	0.1	0.0	0.0	0.1	11,426
Coal and lignite	1.3	0.1	0.0	0.0	1.8	103,478
Metal ores	1.2	0.0	0.0	0.2	12.9	356,979
Other minerals	4.1	0.0	0.0	0.2	3.9	287,546
Electricity and gas	0.9	0.2	0.0	0.0	0.1	52,583
Natural water	0.3	0.0	0.0	0.0	0.0	14,321
Meat	0.2	2.8	0.0	0.0	0.1	91,274
Fish	0.3	0.4	0.0	0.0	0.1	26,098
Vegetables	0.0	0.5	0.0	0.0	0.1	15,170
Fruit and nuts	0.3	0.5	0.0	0.1	0.1	31,658
Oils and fats	0.2	0.7	0.0	0.0	0.2	35,032
Dairy products	0.2	1.6	0.0	0.3	0.2	63,309
Grain mill products	0.2	1.7	0.0	0.0	0.1	57,831

Starch products	0.0	0.8	0.0	0.0	0.1	23,935
Animal feeding	0.3	0.6	0.0	0.0	0.1	31,240
Bakery products	0.4	3.2	0.0	0.2	0.0	108,506
Sugar	0.2	0.8	0.0	0.0	0.1	33,553
Confectionary products	0.1	0.4	0.0	0.0	0.0	16,820
Pasta products	0.0	0.1	0.0	0.0	0.0	2512
Food n.e.c.	0.4	1.1	0.0	0.0	0.3	55,537
Alcohol, beverages	0.5	2.6	0.0	0.0	0.2	99,229
Soft drinks	0.6	0.9	0.0	0.0	0.3	60,645
Tobacco products	0.6	1.6	0.0	0.0	0.3	79,183
Textile fabrics	0.6	0.1	0.0	0.0	0.1	35,206
Made-up textile articles	0.1	0.5	0.0	0.0	0.1	22,314
Carpets	0.0	0.1	0.0	0.0	0.0	4202
Textile n.e.c.	0.2	0.1	0.0	0.0	0.0	12,558
Knitting fabrics	0.0	0.0	0.0	0.0	0.1	5109
Wearing apparel	0.2	1.6	0.0	0.0	0.6	67,275
Leather products	0.2	0.2	0.0	0.0	0.2	21,085
Footwear	0.2	0.8	0.0	0.0	0.1	33,197
Wood products	1.3	0.1	0.0	0.0	0.5	76,657
Paper products	2.3	0.4	0.0	−0.1	0.8	139,616
Printing	1.6	0.3	0.0	0.0	0.1	88,309
Petroleum products	5.9	3.9	0.0	0.1	2.0	438,704
Basic chemicals	3.1	0.0	0.0	−0.1	2.4	204,468
Fertilizers, pesticides	0.7	0.2	0.0	0.0	0.3	45,020
Paint, related products	0.9	0.1	0.0	0.0	0.1	46,591
Pharmaceutical products	0.7	1.6	0.0	−0.1	0.3	83,918
Soap, cleaning, perfume	0.1	2.2	0.0	0.0	0.3	73,329
Chemical products, n.e.c.	0.7	0.0	0.0	0.0	0.2	37,464
Rubber tyres	0.4	0.3	0.0	0.0	0.2	31,223
Other rubber products	0.2	0.0	0.0	0.0	0.0	11,610
Plastic products	1.7	0.2	0.0	0.0	0.2	93,663
Glass products	0.3	0.2	0.0	0.0	0.1	24,584
Non-structural ceramic	0.1	0.1	0.0	0.0	0.0	8182
Structure non-refractory clay	0.5	0.0	0.0	0.0	0.8	41,443
Plaster, cement	0.4	0.0	0.0	0.0	0.5	30,365
Articles of concrete	0.7	0.0	0.0	0.0	1.1	55,484
Non-metallic products n.e.c.	0.3	0.0	0.0	0.0	0.5	25,334
Furniture	0.2	0.3	0.0	2.5	1.5	73,258
Jewellery	0.1	0.2	0.0	0.0	0.1	15,490
Manufactured products	0.1	0.5	0.0	0.0	0.1	22,459
Wastes, scraps	0.5	0.0	0.0	0.0	0.1	26,266
Iron, steel products	2.9	0.0	0.0	−0.1	1.9	181,080
Non-ferrous metals	1.7	0.0	0.0	0.1	0.3	87,131
Structural metal products	0.9	0.0	0.0	0.3	0.3	53,974
Tanks, reservoirs	0.2	0.0	0.0	0.0	0.0	9509
Other fabricated metal	1.5	0.2	0.0	0.0	0.4	87,189
Engines, turbines	0.0	0.0	0.0	2.0	0.0	18,983
Pumps, compressors	0.2	0.0	0.0	1.5	0.1	24,819
Bearings, gears	0.2	0.0	0.0	0.2	0.2	13,509
Lifting equipment	0.2	0.0	0.0	0.4	0.1	16,536

General machinery	0.2	0.0	0.0	1.6	0.6	37,438
Special machinery	0.8	0.0	0.0	9.5	0.9	139,810
Domestic appliances	0.1	0.4	0.0	0.4	0.4	29,592
Office machinery	0.2	0.1	0.0	3.0	0.0	40,788
Electrical machinery	1.3	0.1	0.0	5.5	0.1	115,460
Radio, television	2.3	0.2	0.0	0.4	0.2	121,664
Medical appliances	0.2	0.2	0.0	3.3	0.1	46,240
Motor vehicles, parts	3.9	4.5	0.0	14.2	0.1	438,867
Ships and boats	0.0	0.0	0.0	1.8	0.1	21,699
Railway and trams	0.0	0.0	0.0	0.4	0.0	5952
Aircrafts	0.0	0.0	0.0	0.7	0.5	20,456
Other transport equipment	0.1	0.1	0.0	0.0	0.0	5419
Construction	0.1	0.0	0.0	23.1	0.4	214,400
Construction services	0.1	0.2	0.0	21.0	0.1	191,826
Trade services	0.3	0.0	0.0	0.0	40.8	949,566
Accommodation	0.4	1.1	0.0	0.0	0.5	58,644
Catering services	0.2	2.2	0.0	0.0	0.1	72,057
Passenger transport	1.6	5.0	0.0	−0.1	0.8	232,655
Freight transport	1.5	3.4	0.0	−0.1	7.9	345,330
Supporting transport services	1.3	0.6	0.0	0.0	0.4	91,815
Postal, courier services	0.3	0.1	0.0	0.0	0.1	17,478
Electricity distribution	1.7	3.6	0.0	−0.1	0.0	177,495
Water distribution	0.7	1.0	0.0	0.0	0.0	62,849
Financial services	6.0	2.3	0.0	−0.1	0.2	354,927
Insurance, pension	0.9	4.2	0.0	−0.1	1.6	197,807
Other financial services	4.7	0.0	0.0	−0.1	0.5	237,944
Real estate services	3.4	10.7	0.0	3.2	0.1	488,095
Leasing, rental services	2.7	0.3	0.0	0.0	0.0	139,528
Research, development	0.0	0.0	0.0	4.8	0.0	41,716
Legal, accounting	0.8	0.5	0.0	0.9	0.1	62,390
Other business services	5.6	0.4	0.0	−0.1	0.5	289,486
Telecommunications	3.1	2.9	0.0	−0.1	0.6	239,037
Support services	2.0	2.6	0.0	−0.1	0.2	170,596
Manufactured services n.	0.1	0.0	0.0	0.0	0.0	7168
Public administration	1.9	1.2	100.0	−0.1	0.0	1,093,002
Education services	0.5	2.4	0.0	0.0	0.0	88,087
Health, social services	1.4	5.3	0.0	−0.1	0.2	216,261
Other services n.e.c.	1.8	5.0	0.0	−0.1	1.0	245,799
%s (%)	100.0	100.0	100.0	100.0	100.0	

Source: Authors' estimation from 2017 SAM.

Figure 1 presents the share of the commodities exported or imported. The trade service sector had the largest share (42%) of commodities exported to the rest of the world, followed by the manufacturing sector with about 20%, mining (19%), transport services (9%), and food processing (3%). Agriculture exported only 2% of their commodities to other countries. In the case of imported commodities, about 68% of commodities were imported by manufacturing sectors, followed by mining with approximately 11%, financial and community services (11%), food processing (3%), and agriculture (1%).

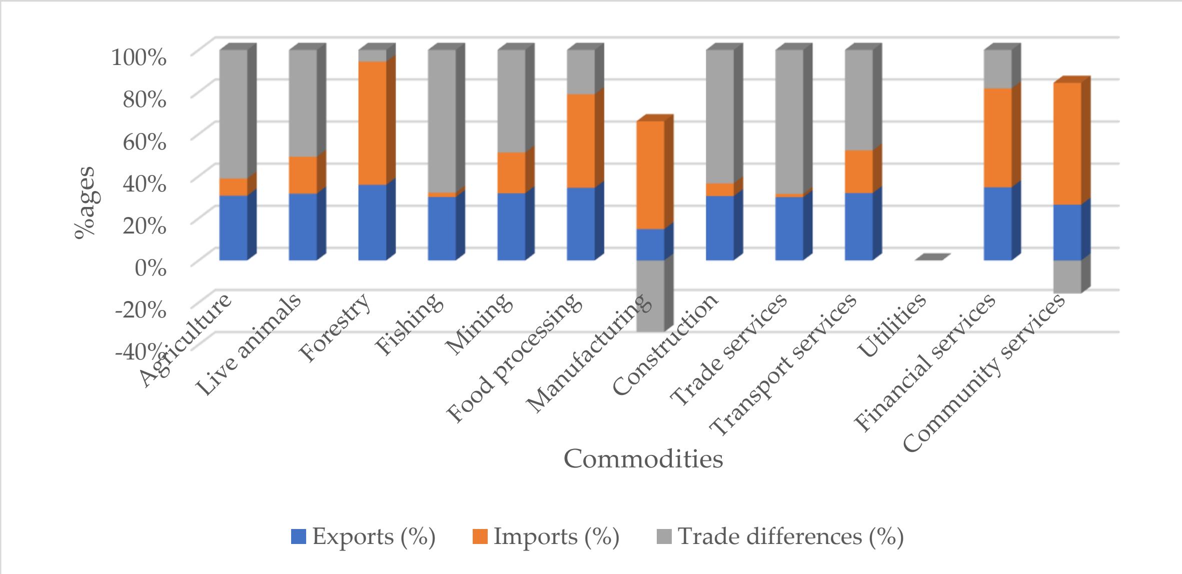

Figure 1. Share of commodities exported/imported. Source: Authors' estimation from SAM of 2017.

The manufacturing and community service sectors had a trade deficit of ZAR 440 million and ZAR 11 million, respectively (Figure 2). In contrast, other sectors (such as agriculture, mining, food processing, construction, trade services, transport services, and financial services) within the economy experienced a trade surplus.

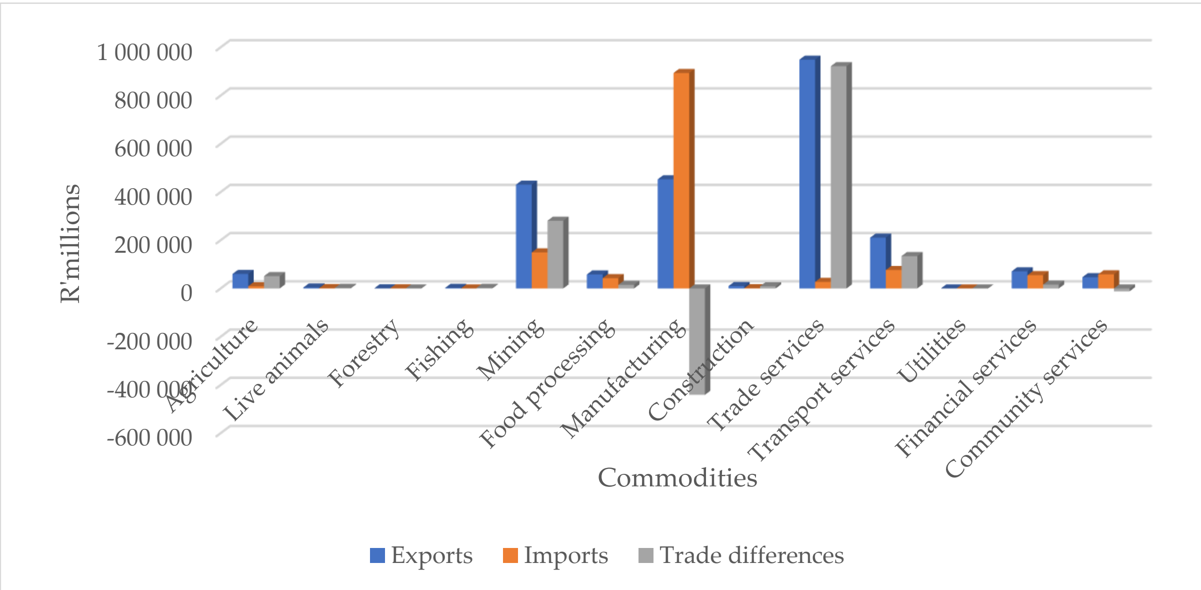

Figure 2. Values of Commodities exported/imported. Source: Authors' estimation from SAM of 2017.

Table 8 indicates different sources of income based on province and district classification groups. Over 50% of the households in Gauteng Province received their incomes through labour remuneration (26.1%) and gross operating surplus (27.1%), followed by Kwazulu-Natal with about 18.9% and 17.4%, respectively. About 37% of the households in the Northern Cape generate their income from using land, compared to only 16% of Free State households. More than 17% of households in the Eastern Cape received shares of income from the government through grants or subsidies, whereas only 18% of income comes from abroad.

In the districts, approximately 4.8% of the household income in the Capricorn district of Limpopo Province of South Africa comes from abroad, while only 4.3% is from the government. About 2.3% of the labour remuneration is distributed to the households of Vhembe district of Limpopo Province of South Africa, followed by Capricorn of Limpopo Province of South Africa with 2.2%, Sekhukhune of Limpopo Province of South Africa (1.9%), Mopani of Limpopo Province of South Africa (1.8%), and Waterberg of Limpopo Province of South Africa with 1.3%. Only 3% of incomes from enterprises are shared with Mopani of Limpopo Province of South Africa households, while 3.4% goes to the Capricorn district. About 1% of the household incomes in the Capricorn and Mopani districts are generated using land, whereas land returns for Vhembe and Waterberg households are estimated at 0.7% each.

Table 5. Shares of household incomes.

Categories	Household Incomes						
	Labour	GOS	Land	Enterprise	Gov	ROW	Total
	%						ZAR Million
WC_HHD	12.1	13.6	8.8	9.5	5.9	3.2	404,297
EC_HHD	11.9	7.5	12.3	10.3	17.7	18.4	395,067
NC_HHD	2.3	2.3	37.1	3.8	4.1	3.4	92,837
Free State_HHD	4.8	5.4	16.4	4.6	6.0	4.8	172,824
KZN_HHD	18.9	17.4	4.0	20.2	20.1	20.1	663,463
North West_HHD	6.9	6.4	11.5	6.0	6.2	6.9	233,323
Gauteng_HHD	26.1	27.4	0.8	23.1	14.5	14.2	880,869
Mpumalanga_HHD	7.4	10.4	5.3	10.8	10.2	12.4	300,078
Mopani_HHD	1.8	2.5	1.0	3.1	3.9	4.3	78,725
Vhembe_HHD	2.3	1.6	0.7	2.0	2.6	2.9	75,341
Capricorn_HHD	2.2	2.7	1.1	3.4	4.3	4.8	90,594
Waterberg_HHD	1.3	1.7	0.7	2.1	2.7	3.0	53,932
Sekhukhune_HHD	1.9	1.0	0.4	1.2	1.6	1.8	57,315
%s	100.0	100.0	100.0	100.0	100.0	100.0	

Note: WC—Western Cape Province, EC—Eastern Cape Province, NC—Northern Cape Province, and HHD—households. Source: Authors from SAM of 2017.

Table 9 shows expenditure shares by households of South African Provinces and districts of Limpopo Province. Regarding provinces, Gauteng households spent a large proportion of their disposable income on commodities (27.4%), whereas about 23% of their income is saved domestically or abroad. Free State households spent a large proportion (24.7%) of their incomes on paying taxes. Approximately 22.9% of the households in the Western Cape distributed their incomes in savings either domestically or abroad. In comparison, about 11% of the households used some of their income to purchase commodities and pay taxes. In terms of districts, most of the households in the districts of Limpopo spent their disposable income on paying taxes. Households in Mopani spent about 2.1% of their expenditure on commodities, followed by Vhembe and Capricorn with 1.7%, Sekhukhune (1.6%), and Waterberg (1.4%). Only 1.3% of the households in Capricorn saved their incomes either domestically or abroad, followed by Vhembe (0.9%), Mopani (0.7%), Waterberg (0.6%), and Sekhukhune (0.5%).

Table 6**.** Shares of the household expenditures.

Categories	Commodities	Enterprises	Individual Taxes	Savings	ROW	Total
			%			
WC_HHD	11.5	9.5	11.7	22.9	22.9	404,297
EC_HHD	11.9	10.3	6.4	13.0	13.0	395,067
NC_HHD	2.3	3.8	4.5	4.3	4.3	92,837
Free State_HHD	3.0	4.6	24.7	7.7	7.7	172,824
KZN_HHD	20.0	20.2	7.5	13.4	13.4	663,463
North West_HHD	6.5	6.0	9.6	4.9	4.9	233,323
Gauteng_HHD	27.4	23.1	6.4	23.3	23.3	880,869
Mpumalanga_HHD	8.9	10.8	2.6	6.6	6.6	300,078
Mopani_HHD	2.1	2.2	4.4	0.7	0.7	78,725
Vhembe_HHD	1.7	2.6	5.9	0.9	0.9	75,341
Capricorn_HHD	1.7	4.8	8.5	1.3	1.3	90,594
Waterberg_HHD	1.4	1.0	4.1	0.6	0.6	53,932
Sekhukhune_HHD	1.6	1.1	3.6	0.5	0.5	57,315
%s	100.0	100.0	100.0	100.0	100.0	

Source: Authors' estimation from SAM of 2017.

Figure 3 presents the shares of household consumption by region. Over 70% of the agricultural commodities are consumed by five provinces (Western Cape (88%), Eastern Cape (82%), Northern Cape (77%), Gauteng (73%), and Mpumalanga (72%)). Regarding household consumption by live animals, North West and Free State households consumed about 71% and 70%, respectively. The least of the household consumption comes from forestry and fishing. Looking at the district level, Mopani and Sekhukhune consumed over 80% of the agriculture commodities, whereas Vhembe and Waterberg consumed about 70%. Capricorn households consumed approximately 83% of forestry, while the remainder comes from agriculture with 14% and live animals with about 3%.

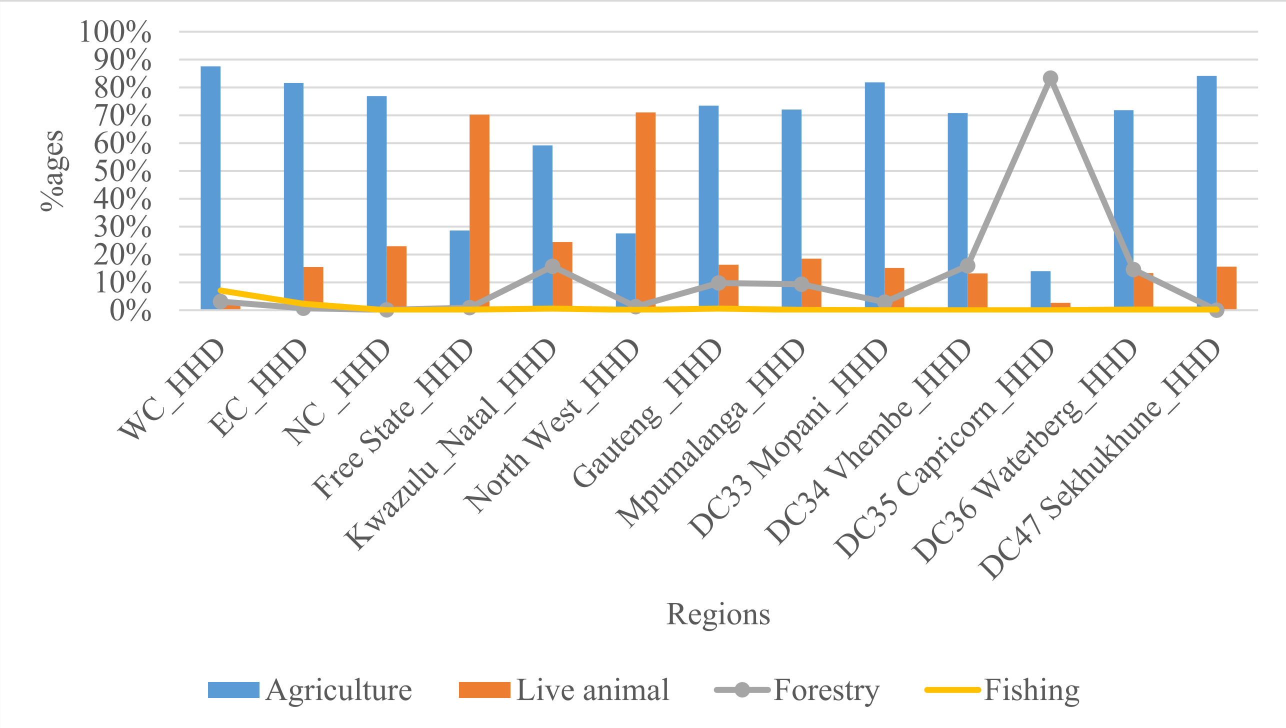

Figure 3. Shares of the household consumption by region. Source: Authors' estimation from SAM of 2017.

Table 10 indicates the income and expenditure of the South African government in 2017. The table below indicates that most government income is accumulated through tax receipts. Net product, direct income, and corporate taxes are 27.1%, 15.1%, and 12%, respectively. Consumption spending dominated South African government expenditure, with a high proportion of about 54.7%, followed by transfers to enterprises with a share of 22.5% and transfers to households with only 9.8%. Transfers to the rest of the world and savings form the smallest components, with shares of 2.9% and 0.1%, respectively.

Table 7. Income and expenditure for the South African government.

Income	Value (ZAR Million)	Share (%)	Expenditure	Value (ZAR Million)	Shares (%)
Capital	199,534	11.3	Consumptions	967,897.9	54.7
Enterprises	350,156	19.8	Transfer to enterprises	398,694.1	22.5
Government	176,099	10.0	Transfer to households	173,148.9	9.8
Net activity tax	82,421	4.7	Inter-transfer to gov	176,099	10.0
Net dom prod tax	480,251	27.1	Transfer to savings	2019	0.1
Direct income tax	266,895.9	15.1	Transfer to ROW	51,690	2.9
Corporate tax	212,907	12.0			
ROW	1285	0.1			
Total	1,769,549	100.0	Total	1,769,549	100.0

Source: Authors' estimation from SAM of 2017.

3.3. Methods and Materials

The primary data sources for each type of account used to develop a 2017 SAM are presented in Table 11. The range of data sources used to build the SAM showed that it may be possible for the SAM not to balance (column totals and row totals are unequal). Therefore, different steps will be discussed in detail regarding the unbalanced SAM, and the evaluation of missing information will be provided to have a full and steady SAM for South Africa.

- ❖ First step: Adjusting the information in the SUT.

  The 13 accounts in the National Accounts [21] were used as a base to derive more information from [22], with 62 industries and 104 commodities (contains a single account for the agricultural industry and commodity). The SUT does not provide sufficient and complete information for a SAM. Therefore, more detailed information was further included in single agriculture, labour, household, and government accounts through disaggregation of these accounts, as discussed in the following sections.

- ❖ Second step: Disaggregating accounts in the final demand.

  The SUT for 2017 comprises only a single household account [22]. To divide the account into a complete matrix recording expenditures by various household racial classification categories, the Living Condition Survey [23] and Global Insight (regional explorer) [24], which incorporate consumption expenditure data, were used. The share of expenditure for various household groups was estimated according to each commodity in the 2017 SUT so that the matrix can provide rich information for final consumptions on households [21]. The remaining categories for final demand, such as government expenditure, investment, change in inventory, and exports, are attained from the Use Table [21].

- ❖ Third step: Disaggregating accounts for compensation of employees.

  The 2017 Use Table recorded wages and salaries for each industry [21]. The single account of labour is reported for employees' compensation. These salaries and wages are disseminated from each industry to various 13 labour group classifications using the information attained in [22].

- ❖ Fourth step: Labour income payments to households and abroad.

  The wage and salary payments to households are estimated from the information in [23,24]. The labour income received from abroad was disseminated to various identified labour group classifications based on the estimated shares in the total domestic employment income.

- ❖ Fifth step: Source of household income.

  In addition, from labour income, the household accounts received various incomes from the gross operating surplus and land. Other incomes to households are distributed from enterprises, the government, and abroad. The shares for household income were estimated from [23,25], because these contained data on labour, capital, enterprise, and government.

- ❖ Sixth step: Disaggregating the account in the agricultural industries.

  Detailed information on the output value for agricultural industries was found from [26]. The output shares were estimated for all agricultural industries included in the South African SAM. The payments from agricultural industries to labour were estimated from the data attained in [26,27]. Few adjustments were made manually due to the disaggregation of labour incomes and agricultural industries. The payments of farm industries were distributed to gross operating surplus as part of the income received. The estimation was conducted using the data found in [26]. In addition, the gross operating surplus control total was split into land and capital using the land and capital value ratios derived from [26]. Land rental values were added as a production factor to the agricultural industry, forestry, and fishery accounts. The control total for land was further split into irrigated land and dry land using share estimation from [26]. The categories of these land values were disseminated to the agricultural, forestry, and fishery industries according to their production hectares.

The information on the Producer (production) taxes was derived from the data attained in [28]. The agricultural production taxes are disseminated across all agricultural activities according to output shares. The detailed information on the net domestic commodity taxes was also derived from [28]. The control total for net domestic commodities is disseminated across all agricultural commodities, paying for taxes based on the commodities' output values shares.

The exports and imports for agricultural commodities were estimated according to the information attained from [26,29].

- Seventh step: Deriving the intermediate consumption.

The disaggregation was conducted following the 2017 Use Table for South Africa [22] in order to explicitly give information on the products (single agricultural commodities) that were utilized as inputs by the agricultural industry. The expenditure for agricultural industries is used according to individual commodities. The information on the expenditure by industries is found in [26].

Table 8. Data sources for each type of account in SAM.

Type of Accounts	Data Sources
Commodities and industries/activities	2017 Supply and Use Tables [22]. South Africa Reserve Bank Quarterly Bulletin [21]. Census Commercial Agriculture for 2017 [26]. Regional Global Insight [24].
Factors of production	2017 Supply and Use Tables [22]. Living Condition Surveys 2014/15 [23]. Regional Global Insight [24]. Quarterly Labour Force Surveys (QLFS) 2017 [27]. South Africa Reserve Bank Quarterly Bulletin [21].
Households	Living Condition Surveys 2014/2015 [23]. General Household Survey (2017) [25]. Quarterly Labour Force Surveys (QLFS) 2017 [27]. Regional Global Insight [24]. South Africa Reserve Bank Quarterly Bulletin [21] Supply and Uses Tables for 2017 [22].
Enterprises	Living Condition Surveys 2014/15 [23]. General Households Surveys 2017 [25]. South Africa Reserve Bank Quarterly Bulletin [21].
Government	South Africa Reserve Bank Quarterly Bulletin [21].

	General Household Survey (2017) [25]. Supply and Use Tables for 2017 [22]. Data for product and income taxes for 2017 [28].
Capital	Supply and Use Tables for 2017 [22]. South Africa Reserve Bank Quarterly Bulletin [21].
International trade	Supply and Use Tables (SUT) for 2017 [22]. Data for exports and imports for 2017 [29]. South Africa Reserve Bank Quarterly Bulletin [21].

Source: Authors' compilation.

3.4. User Notes

This dataset is of paramount importance to policymakers, stakeholders, and academia. In addition, the data can be modified through disaggregation of the sectors to suit the purpose of the research. The dataset could be transformed into models such as Computable General Equilibrium (CGE) and multiplier models.

The SAM plays a vital role in terms of the potential impact of water prices/taxes and electricity tariffs on agricultural sectors in the economy of Limpopo Province. Limpopo Province is an exciting province for evaluating the relationship between irrigation and non-irrigation in various districts and the distribution of incomes because the South African government has designated their role to inject money into irrigation infrastructure in various districts that are facing challenges of water.

3.5. Conclusions

The purpose of the SAM is to improve the quality of the database for modelling, including, but not limited to, policy analysis, multiplier analysis, price analysis, and Computable General Equilibrium (CGE). This article contributes to constructing the 2017 national SAM for South Africa, incorporating regional accounts. Only in Limpopo Province are agricultural industries, labour, and households captured at the district level, while agricultural industry, labour, and household accounts in other provinces remain unchanged. The primary data sources for constructing a SAM are found in different sources such as the Supply and Use Tables (SUT), National Accounts, Census of Commercial Agriculture, Quarterly Labour Force Survey (QLFS), South Africa Revenue Service (SARS), Global Insight (regional explorer), and South Africa Reserve Bank (SARB). The significance of a SAM is that it displays a full circular flow of all details and other missing information in the SUT.

The dataset recorded that land returns for irrigation agriculture were highest in the Northern Cape, with about 18.2%, compared to other provinces. In contrast, the Free State rainfed agriculture had the largest shares (22%) for payment to land. Regarding intermediate inputs, rainfed agriculture in the Western Cape, Free State, and KwaZulu-Natal paid approximately 0.4% for using intermediate inputs. In terms of the districts, land returns for irrigation were highest in the Vhembe district at 0.3%. Despite Mopani having the lowest land returns for irrigation agriculture, it has the highest share (1.6%) of payment to land from rainfed agriculture.

The trade sector had the highest share (42%) of commodities exported to the rest of the world, whereas agriculture exported only 20% of its commodities to other countries. The manufacturing and community service sectors had a trade deficit of ZAR 440 million and ZAR 11 million, respectively. In contrast, other sectors (such as agriculture, mining, food processing, construction, trade services, transport services, and financial services) within the economy experienced a trade surplus.

The main challenges found in developing a SAM are scarcity of data to attain the information needed for disaggregation for the sub-matrices and insufficient information from different data sources for estimating missing information to ensure the row and column totals of the SAM are consistent and complete. Specific challenges are as follows:

- ❖ The 2017 QLFS does not provide detailed information for disaggregated sectors; it only records information in the aggregated format. In addition, the QLFS does not incorporate information for labour remuneration from the district level.
- ❖ Detailed data on the agricultural sector at a regional level in South Africa are difficult to find and often released based on the period of agricultural surveys and the detailed information mentioned in the surveys. It is challenging to obtain all the required information to construct a SAM.

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Abbreviations

The following abbreviations are used in this manuscript:

CGE	Computable General Equilibrium
DBSA	Development Bank of Southern Africa
EC	Eastern Cape
FS	Free State
GHS	General Households Survey
GOS	Gross Operating Surplus
GP	Gauteng
HHD	Household
IFPRI	International Food Policy International Research
KZN	KwaZulu-Natal
LCS	Living Condition Survey
MP	Mpumalanga
NC	Northern Cape
PROVIDE	Provincial Decision-Making Enabling
QLFS	Quarterly Labour Force Survey
SAM	Social Accounting Matrix

SARB	South Africa Reserve Bank
SARS	South Africa Revenue Service
StsaSA	Statistics South Africa
SUT	Supply and Use Tables
WC	Western Cape
ZAR	R is the South African Rand, the national currency of South Africa

Notes

1 Conningarth Economists is a consulting firm that specializes in quantitative economic analysis in several fields, including, but not limited to, models based on standard input and output analysis, Social Accounting Matrix (SAM), macro-economic impact analysis, Computable General Equilibrium, and cost–benefit analysis.

2 R is the national currency of South Africa—Rand (ZAR).

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Chapter 4: Insights into the Impact of Irrigation Agriculture on the Economy of the Limpopo Province, South Africa: A Social Accounting Matrix Multiplier Analysis

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Abstract

The development of irrigation systems is strategically used to improve food security and achieve the Sustainable Development Goals (SDGs 2) of ending hunger and poverty. The objective of this research was to evaluate the effect of irrigation agriculture on the economy of the Limpopo Province, South Africa. This study used the 2017 national social accounting matrix (SAM) as a database with detailed information on irrigation and rainfed agricultural activities and land accounts to compute the effect of exogenous shock on output, income, land, and value-added using SAM multiplier analysis. The findings showed that output multiplier effects were more significant for rainfed agriculture compared to irrigation agriculture. However, irrigation agriculture had the highest institutional income, land return, and value-added multiplier compared to rainfed agriculture. The type of crop did not influence the findings, with irrigation consuming more input per unit of output. We conclude that investing in irrigation agriculture and increasing the efficiency and sustainability of existing irrigation agriculture in Limpopo is significant and profitable because dry land production is hazardous when there is insufficient rainfall or recurrent drought.

Keywords: food security; land; rainfed; output; value added; income

4.1. Introduction

The agricultural sector supports approximately 60–80% of the population in developing countries and is a major contributor to national income and economic growth [1]. In developing areas, approximately 183 million hectares of agricultural land are under some form of water management and storage infrastructure. Therefore, water storage infrastructure is essential for managing changes in rainfall [2]. In many regions, agricultural production is rainfed, which is often insufficient and unreliable. As water is crucial in agricultural production, the sector is a major user of water resources. Improving irrigation efficiency is crucial to ensure that food is produced with limited water.

In many countries, irrigation development is a primary strategy to achieve or improve food security and attain the Sustainable Development Goals (SDGs 2) of ending hunger and poverty [36]. Irrigation enhances agricultural production by increasing agricultural output (yields) and cropping intensities [4]. Rainfed agriculture is an important farming method that relies solely on rainfall for irrigation. It is practiced extensively in regions with little access to supplemental irrigation. Rainfed agriculture is practiced under a variety of soil types and agroclimatic and rainfall conditions. Rainfed agriculture leaves farmers exposed to ill-distributed and limited annual rainfall as well as the occurrence of climatic hazards such as drought and floods. Undulating soil surfaces, practices of extensive agriculture, relatively large field sizes, and low crop yields compound the issue. Irrigation, on the other hand, is the artificial application of water to the soil for crop production. Controlled amounts of water are applied to land to grow crops, landscape plants, and lawns [5,6]. There are different types of irrigation agriculture. Farmers are more resilient when using irrigation than when relying on rainfed practices. Irrigation increases the availability and quality of water in agricultural production compared to rainfed agriculture. Thus, agricultural sustainability and livelihoods for many households are improved [7].

In several regions of South Africa, the distribution of rainfall, which is the primary source of water for food production, is becoming more erratic and insufficient [8]. Therefore, irrigation plays a crucial role in raising productivity in the agricultural sector. According to Baloyi [8], irrigation can enhance agricultural productivity and income. Irrigation can generate jobs in marginalized communities, both directly and indirectly, through the multiplier effect (forward and backward linkages) [9]. Chipfupa [10], Mbusi [11], and Fanadzo et al. [12] reported that the South African government attempted to restore smallholder irrigation, stimulate productivity, and enhance food security and income for households. Despite these efforts, the return on the amount invested in irrigation infrastructure remains low. The irrigation sector continues to rely on the government for maintenance and operational costs for restoring or improving some of the irrigation infrastructure, such as water pumps, canals, pipes, and other agricultural machinery and equipment that are required for irrigation infrastructure. In addition, the government still helps some irrigation schemes with operational cost charges for using water (electricity and water) and the administration of irrigation schemes. This support is due to the limited implementation plans for cost recovery and maintenance and the need for the transfer of management and ownership.

Within agricultural sector policy analyses and strategies, social accounting matrix (SAM) based models with computable general equilibrium (CGE) and SAM multipliers are applied for policy analyses and to influence policy decisions. Most local and international studies use these applications. Pauw et al. [13] studied agricultural efficiency and welfare in South Africa using a CGE model. The authors found that technological advances in agriculture should not be resisted because of their negative impact on agricultural employment. Pauw et al. [13] showed that the welfare gains from declining prices were too significant, while employment gains in other (growing) sectors were likely to outweigh the loss of agricultural employment. Ferreira et al. [14] used SAM multiplier analysis to examine the role of the agricultural sector in Ghana's development. The authors highlighted the sectors that should be promoted because they generated the highest increases in output, employment, and economic value added, as well as those with a significant impact on household income generation. Maré and Bahta [15] used a partial equilibrium model to assess the export trade of live sheep in South Africa. They found that with a higher demand for live sheep exports, the prices and economic impact were also higher. Additionally, South Africa lost value-adding opportunities, such as output from abattoirs (hides and skin, offal, head, and consumable internal organs) and employment, when live lambs were exported and slaughtered in destination markets. Bahta et al. [16] used the CGE model to show the role of the agricultural sector in the dissemination of income and economic development in the Free State province. The authors found that the agricultural sector played a significant role in reducing poverty and improving income distribution. However, considering poverty, the results suggested that the manufacturing sector increased income more than other sectors. Taljaard [17] applied CGE and SAM multiplier analysis to study the macroeconomy and irrigation agriculture in the Northern Cape Province of South Africa. The author found that the significant economy-wide impacts resulted from market risks or other exogenous factors influencing local irrigation agriculture, especially in a region where irrigation agriculture played such an important role. Kirsten and Van Zyl [18] used an input–output (I/O) model to assess the economic impact of irrigation development and found that through forward and backward linkages, irrigation agriculture made an essential contribution to the regional economy in the Free State Province of South Africa. Doukkali and Lejar [19] studied the energy costs of the irrigation policy in Morocco and highlighted that the policy, which targeted water-saving techniques, increased the use of subsidized energy. Subsequently, the indirect effects through energy subsidies exceeded the direct impact of agricultural subsidies. Brown [20] used input–output models to evaluate the economic impact of irrigation development in Saskatchewan, Canada, and found that irrigation provided an impetus for economic growth.

Although Brown [20] and Kirsten and Van Zyl [18] studied the impact of irrigation on agriculture, the authors did not include data on irrigated versus rainfed agriculture. Furthermore, the technique applied to the I/O model included a single production account and excluded information on household incomes at the district level. This meant that industries produced different commodities, and some industries produced multiple commodities. Doukkali and Lejar [19] categorized agriculture according to irrigated and rainfed conditions but did not include detailed disaggregation information for factors and household incomes. Taljaard's [17] study did not include agricultural activities and land accounts. The study's scope did not address whether the returns came from rainfed or irrigation agriculture, and the SAM did not consider the types of land and farms used for agricultural production/activities. Therefore, a new composition of the Northern Cape SAM is required to address the issues of agricultural activities. Additionally, a study at the district level is needed, which can be achieved by incorporating multiple production/industry accounts and incorporating land accounts (irrigated and rainfed).

Research generally uses multiplier analysis, input–output models, SAM-based input– output models, and CGE models to analyse the inter-sectoral linkages (multiplier effect) in any economic change in a specific sector, which will have a ripple effect in other sectors of the economy. However, empirical research in irrigated and rainfed agriculture is neglected, and models are limited to a single production account, which excludes detailed information on factors and household incomes at provincial and district levels. Therefore, an explicit understanding of the effect of irrigation agriculture on output, land return, institutional and household incomes, and value added is needed to develop a strategy for irrigation policies that contribute to economic development.

Limpopo is an exciting province to see the relationship between irrigation access and household incomes due to the fact that the government aimed to invest massively in irrigation infrastructure in the regions that are experiencing a shortage of water. Most farmers in the province still cultivate under challenging conditions of water shortages or insufficient irrigation. Taljaard [17] and Hassan [21] showed that many producers compete for limited water resources. Thus, water is not used for basic human needs. However, it is also utilized to support productive economic activities that generate employment and income for the province's inhabitants. Given the significance of inter-sectoral linkages (multiplier effect) in any economy, changes in a specific sector will have a ripple effect in other sectors of the economy in Limpopo and the rest of South Africa. Therefore, it is imperative to have an explicit understanding of the effect of irrigation agriculture on output, land return, institutional income, and GDP to have a necessary strategy for prioritizing irrigation policies that will contribute to economic development. Questions on the regional and district components of irrigation in Limpopo Province, South Africa, include:

- What are the economic impacts of irrigation in Limpopo, and how are these impacts diffused on a district/regional basis?

- How will the future of irrigation development impact the districts/regions within the province?
- What is the economic impact of irrigation and non-irrigation at the regional level?

Therefore, the study determined whether irrigated agriculture was significant in improving agricultural output and generating better land returns. The effect of irrigation agriculture on the economy of the Limpopo Province in South Africa was evaluated by constructing a 2017 national SAM with detailed information on irrigation and rain-fed agricultural activities and land accounts, and the effect of exogenous shock (irrigation development) on output, land return, institutional (household and enterprise) income, and value added/GDP was computed.

This study plays a role in examining the multiplier effect of irrigation agriculture within the districts of the Limpopo Province of South Africa. It addresses policies for irrigation that will alleviate risk, enhance the financial feasibility of farming, and establish a policy that is effective for water management in regions where irrigation plays a significant role in the economy.

4.2. Materials and Methods

4.2.1. Study Area

The Limpopo Province of South Africa borders Botswana, Zimbabwe, and Mozambique. The Mopani District of the Limpopo Province is situated in the northeastern part of the province, with an area of 20,011 km2 and a population of 1.1 million (Figure 4). The Vhembe District is in the northern part of the province, with an area of 25,597 km2 and a population of about 1.4 million [22]. The Capricorn District includes the capital city, Polokwane, and has an area of 21,705 km2 and a population of about 1.38 million. The

Waterberg District is found on the western side of the province and shares a border with the Sekhukhune and Capricorn districts. The district has the largest area in the province (about 44,913 km2) and the lowest population (estimated at 768 thousand). The last district is Sekhukhune, with the lowest total area (about 13,528 km2) and a population estimated at 1.2 million [22].

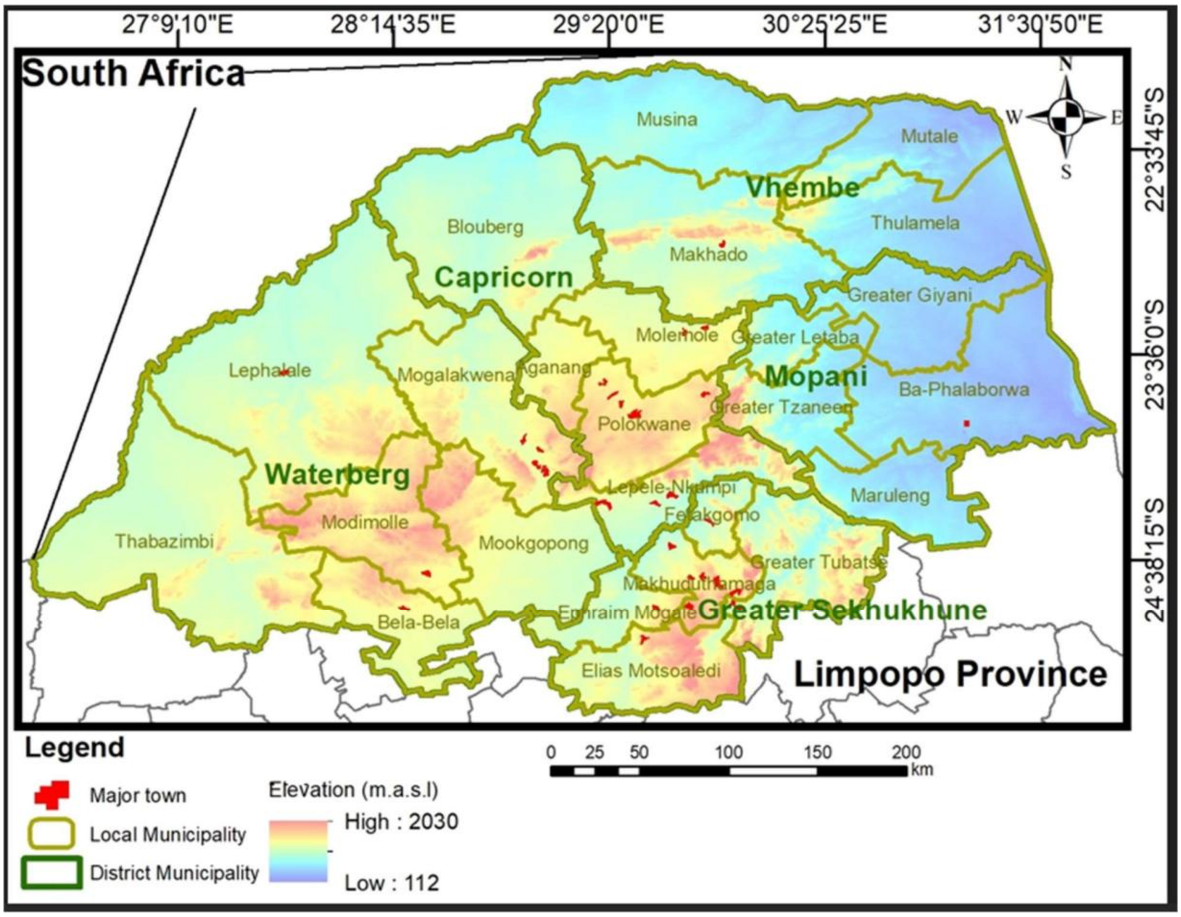

Figure 4. Map of the Limpopo Province, South Africa. Sources: Authors with the assistance of a GIS expert.

4.2.2. Data

This study used the 2017 national SAM for South Africa with details about regional accounts for agricultural activities and households, as constructed by Ramigo et al. [23] (see Appendix A, Table A1). Agricultural industries were identified by production activities within regions (provinces and districts), meaning each agricultural industry represented all farming activities in the regions, and each farming activity in the regions (provinces and districts) was assumed to be provided with fixed land for production. Two agricultural industries (irrigated and rainfed) were identified per province and district in South Africa. In the context of development, these agricultural industries were of substantial interest to policymakers, politicians, academia, and civil society. Agricultural commodities were identified by the choice of commodities obtained from Statistics South Africa [24]. These commodities were categorized according to the consistent availability of information. The SAM provided sufficient information for the agricultural sector to indicate the essential policies and strategies required for economic growth in South Africa. The agriculture, forestry, and fisheries accounts were then reported individually in a 2017 SAM to show the importance of these sectors in the economy. In addition, the commodities and industries in the economy of South Africa were reported according to Statistics South Africa [25]. The Supply and Use Tables (SUT) contained 104 commodities and 62 industries, as reported by Statistics South Africa. There was only a single agriculture, forestry, and fisheries commodities and industries account recorded in the SUT for 2017 (see Appendix A, Table A1).

Both households and labour (factor) categories were disaggregated according to provinces and districts: Eastern Cape, Northwest, Northern Cape, Mpumalanga, Western Cape, Free State, Gauteng, KwaZulu Natal, and Limpopo (Sekhukhune, Capricorn, Vhembe, Mopani, and Waterberg district municipalities). These factors incorporated about

13 labour accounts (Eastern Cape, Northwest, Northern Cape, Mpumalanga, Western Cape, Free State, Gauteng, Kwazulu-Natal, and Limpopo (Sekhukhune, Capricorn, Vhembe, Mopani, and Waterberg district municipalities)), a single capital account, and two land accounts. The land accounts were further disaggregated into irrigation land and dry land. These types of land accounts recorded land returns for each farming activity separately. The land income was captured and then distributed to various households (provinces and districts). Government tax accounts incorporated accounts such as activities (production) taxes, product taxes, direct household taxes, and corporate taxes. Within a SAM, there was an account of general government accounts that received tax revenue and transferred income from different sources of accounts and then transferred it to other accounts. The single international trade accounts represented transactions for exports and imports [25].

The different sources used to build the SAM showed that it may have been unbalanced. This occurred when constructing a database for SAM because of incomplete and inconsistent data sources. Therefore, different methods or techniques such as technique/procedure/algorithm (RAS), cross-entropy, and Excel manual estimation were employed to evaluate the missing data to balance SAM for policy analyses. Robinson et al. [26] and Lamonica et al. [27] stated that different approaches estimated the difference between estimated and prior values in various ways. The authors mentioned that not all approaches clearly estimated the difference; however, for methods that did not, there was always a way to reduce the difference in the estimates. Furthermore, they mentioned two problems found in balancing:

- When balancing and adjusting the input–output (I/O) tables, certain constraints were known in the rows and columns.
- Another problem occurred when the constraints for balancing the row and column total in a SAM were not found.

The RAS approach is used in I/O tables when constraints are known, but other approaches, such as cross entropy (CE) and generalised cross entropy (GCE), are applied when constraints are not found. Even though

RAS is mostly used for balancing I/O tables, it still finds a place in balancing SAM [26,27]. This application helps in cases where a SAM for a prior period is used with the purpose of adjusting it for a later period, provided new information on row and column totals are used where there is inconsistent information within a SAM. Lamelin et al. [28] pointed out another limitation of the RAS approach: it cannot accommodate information other than those required for row and column totals. The CE is an extension of the RAS approach and provides a clear and robust approach for measuring SAM when working with scattered and inconsistent information.

The advantage of the CE approach is that it produces a reasonable estimate for column coefficients in a SAM and provides the availability of a general algebraic modelling (GAMs) code. This approach assumes the availability of information that is subject to different types of estimation errors, which are not specified for the information being estimated [29]. As part of the measurement process, this approach applies a prior for each piece of information used as well as the characteristics of the estimation errors used to differentiate the estimation errors against estimates.

The original SAMs always had accounts that were not equal in the row and column totals; therefore, manual balancing estimation in Excel was utilized to balance the SAM. To construct a SAM, the initial point was to ensure that all accounts in the macro-SAM were balanced. The next step was disaggregating the macro-SAM into different group classifications for the submatrices. The overall values of the disaggregated submatrices are always unequal to the overall values of the submatrices prior to disaggregation. This means that the accuracy of ensuring the disaggregation of a balanced SAM helps in the estimation of submatrix disaggregation. At this stage, the macro-SAM included households, taxes, agricultural commodities, and industries. The macro-SAM was then disaggregated according to household and taxes to contain complete information.

The next step was to disaggregate the agricultural commodities and industry accounts according to the SUT for 2017 and additional information obtained from the Census of Commercial Agriculture 2017 to ensure consistency within the SAM. Irrigation and rain-fed agriculture were disaggregated according to land returns from farming activities. The process of disaggregation was completed, and the SAM was balanced using an Excel manual. Maré and Bahta [15] and PROVIDE [30] defined a SAM as a transaction that transpired in the economy for one year. This transaction includes receipts and payments in the economy. In addition, a SAM is considered square if the column totals and row totals are equal.

4.2.3. Method (Multiplier Analysis)

A SAM-based model can use either open or closed models. Only production accounts were considered in the open models for computation of the total requirement matrix. In contrast, in closed models, other accounts, such as households and enterprises, were incorporated into the computation of the total requirement matrix [31]. Government, investment, and exports were considered exogenous accounts. The SAM-based model derived from closed models was larger than that found in open models because of additional consumption linkages (induced effect). The basic open SAM-based model can be derived whereby total output equates to the total demand (Equation (1)).

$$X = Ax + f \tag{1}$$

where x represents a vector of total output, Ax denotes the sum of endogenous demands, and f represents exogenous demands. The matrix, A, is referred to as the direct requirement matrix. This matrix shows whether the model solution relies on a singular, square, or rectangular matrix. The basic open SAM-based model can be written in this form

(Equation (2)):

$$X = (I - A)^{-1} f = Lf \tag{2}$$

where L represents the total requirement matrix, or Leontief inverse matrix, of the basic open model, which plays a key role in connecting final demand to industry output. In a basic closed model, the model is expanded to incorporate factor and household accounts (Equation (3)):

$$\bar{x} = (I - \bar{A})^{-1}\bar{f} = \bar{L}\bar{f} \tag{3}$$

where x is an augmented output vector, whereas x is an output of industry. The matrix A is

the augmented direct requirement matrix, whereas f report the augmented final demand, and L denotes th**e** total requirement matrix or inverse matrix of the basic closed models.

In complex SAM-based models, the total activity output (x) and total product output (q) are included in the development of the product-by-activity-based model technique [31]. This technique is applied in two ways: when the number of product accounts exceeds the number of activity accounts, it is known as the non-square product-by-activity system technique. When the number of product accounts equals the number of activities accounts, it is referred to as the square product-by-activity system technique. The SAM dataset in this study had fewer activities than product accounts; therefore, the non-square productby-activity technique was used in developing the complex SAM-based model.

To identify the relevant model technology assumption, there are two model technologies under the product-by-activity technique, which are known as product-based technology and activity-based technology.

Product-based technology refers to products/commodities produced by more than a single industry. These commodities/products have similar input structures irrespective of the activities that produce them. Activity-based technology records all products/commodities produced by an activity assumed to have a similar input structure. The product/commodity-based technology model cannot create a technical coefficient matrix when the number of commodities is greater than the number of activities; however, activity-based technology can generate a technical coefficient matrix. Therefore, the activity-based technology assumption was used in this study as a suitable technology assumption over product-based technology.

Using the product-by-activity SAM-based multiplier model, it is also possible to compute the direct requirements matrix (technical coefficient matrix). Therefore, the product-by-activity submatrix of the direct requirement is (Equation (4)):

$$B = U\hat{x}^{-1} \qquad \text{(thus } U = B\hat{x}\text{)} \tag{4}$$

where matrix B denotes direct coefficients obtained in the use matrix U and x represents the output of the activity. $\hat{x}^{-1}$ denotes the matrix inverse of the diagonal matrix of x. For this reason, matrix B contains the proportions of the product needed to produce a single unit of output per activity.

The information prepared in a make matrix V records all the products supplied by the activities. Equation (5) records total activity output x obtained through summing symbol V in row matrix (transposed to make matrix V' In the column sum.

$$x = Vi \qquad \left(\text{or } x' = i'V'\right) \tag{5}$$

The total product output q records column sum in the make matrix V (or sum of V' in the row matrix (Equation (6)):

$$q = (V')i \qquad (\text{or } q' = i'V) \tag{6}$$

The total product output q is found by summing input uses of each product by all activities (adding row for use matrix U) and the demand for final product e (Equation (7)):

$$q = Ui + e \tag{7}$$

By applying Equation (4) ($U = B\hat{x}$) and substituting into Equation (7), an accounting matrix can be extracted, which is equal to total product output q to input uses for Bx and final demand e (Equation (8)):

$$q = Bx + e \tag{8}$$

Equation (8) has a problem of creating a total requirements matrix, which is similar to the inverse Leontief matrix for the ordinary input–output (I/O) model ($x = (I - A^{)-1}f$) because Equation (5) capturing output (x) of the activity on the one side (right) and output (q) of the product on the other side (left). The only way to resolve the issue is to change the product dimension into the activity dimension. The information needed to change this dimension is found in the make matrix (V), which shows the activity-by-product matrix. The proportion of the product output in the matrix D records the overall product output q obtained by each activity (i.e., column proportions of the make matrix V) (Equation (9)):

$$D = V\hat{q}^{-1} \qquad \text{thus } (D\hat{q} = V) \text{ or } (Dq = Vi) \tag{9}$$

For this reason, matrix D reports the activity sources of product outputs, which are represented by shares of the market matrix. Activity technology models are applied similarly to this paper. Replacing Equation (5) with Equation (9), we find the following (Equation (10)):

$$Dq = x \qquad \text{thus } \left(q = D^{-1}x\right) \tag{10}$$

It clearly shows a linear transformation from activity output x to product output q, x is substituted for Dq (according to Equation (10)) in Equation (8). Equation (11) reports the same matrix as Equation (8):

$$q = B(Dq) + e \tag{11}$$

Equation (11) has production dimensions; therefore, it can be applied according to a matrix of the total requirements, which is similar to a matrix for a simple Leontief inverse in the I/O model. Thus, rearranging Equation (11) can drive Equation (12):

$$e = q - (BD)q$$

$$e = q(I - BD) \tag{12}$$

$$q = (I - BD)^{-1}e$$

where $(I - BD^{)-1}$ represents the *product-by-product total requirements matrix* for the SAM model. Equation (12) translates product demand **e** to product output q through product by-product (P-by-P) total requirements matrix $(I - BD^{)-1}$.

Equation (12) can be changed from a product output q equation to an activity output x equation by substituting q for $D^{-1}x$ (from Equation (10)) into Equation (12) and rearranging to get Equation (13):

$$D^{-1}x = (I - BD)^{-1}e \tag{13}$$

$$x = D(1 - BD)\ e$$

where $D(I - BD)^{-1}$ is the *activity-by-product total requirements matrix* for the SAM model. Equation (13) translates product demand **e** into activity output **x** through the A-by-P total requirements matrix $D(1 - BD)^{-1}$.

The models in Equations (12) and (13) are known as product demand–driven models [31]. However, there is an activity demand–driven model. These models assume demand for activity output (as opposed to product output) expands as an initial shock.

For this reason, the role is to change the identity of a product dimension into that of an activity dimension. Starting again from the identity accounting in Equation (13) and pre-multiplying both sides by D and rearranging yields Equation (14):

$$Dq = D(Bx + e) \quad (14)$$

$$Dq = DBx + De$$

Because $Dq = x$, then substitute Dq for x and rearrange to obtain Equation (14), where Equation (15) is an identity for the activity dimensions, that is, equating total output activity output x to intermediate input use per industry DBx and final output demand De (Equation (15)):

$$x = DBx + De \quad (15)$$

DB indicates the required inputs from activities per unit of activities output **x**. Its dimensions are activity-by-activity (A-by-A). Equation (15) comprises the activity dimension; hence, this equation is utilized to attain a total requirements matrix similar to the Leontief matrix for the simple I/O model. Therefore, by rearranging Equations (15) and (16) can be derived:

$$De = x - DBx$$

$$De = x(1 - DB) \quad (16)$$

$$x = (1 - DB)^{-1}De$$

where $(I - DB)^{-1}$ is an activity-*by-activity total requirements matrix* for the SAM model. Equation (16) translates activity final demand De into activity output **x** through the A-by-A total requirements matrix $(1 - DB)^{-1}$.

Miller and Blair [31] discussed that the simple I/O model includes a single total requirements matrix (the Leontief inverse matrix $(I-A)^{-1}$); however, more than four total requirements matrices can be obtained from a product-by-activity SAM, as indicated in Table 12. Only three sub-matrices in the activity technology were presented in this study and were more significant than the eight submatrices shown in Table 12. The submatrices obtained in the product technology could not be presented for the results in this study because they generated negative results, and the only possible way was to convert them to a supply-driven model (Table 12). This negative result was caused by a number of different factors: some of the products were produced by different technologies, which caused the products' technology assumption to be invalid; production classifications were different; and the use and supply data had discrepancies in measurements. Therefore, activity technology was selected for this study because it produced non-negative results. In addition, the activity-by-activity (A-by-A) total requirement matrix was used to compute the multiplier analysis. The activity-by-product (A-by-P) total requirements matrix was used to simulate a 20% increase in the demand for irrigation investment infrastructure on output, institutional incomes, and value added.

Table 9. Total requirement matrices in the product-by-activity models.

	Activity Technology	**Product Technology**
	Product-demand driven models	
Product-by-product	$(I - BD)^{-1}$	(I − BC)−1)−1
Activity-by-product	$D(1 - BD)^{-1}$	C−1(I − BC)−1)−1
	Activity-demand driven models	
Activity-by-activity	$(1 - DB)^{-1}$	(I − C−^{1} *B*)−1
Product-by-activity	h 1(1 − DB)−1] D	[C(I − C−1 *B*)−1]

Source: Adopted from Miller and Blair [31].

4.3. Results

4.3.1. SAM Multiplier Analysis

The SAM multiplier allows the quantification of the different ways in which the exogenous effect is shared across the economy. Therefore, multiplier analysis also reports the results of an exogenous shock on the dissemination of sectoral output, land, and institutional income. The SAM multiplier analysis records information on the impact of changes in final demand output, land, value added/GDP, and institutional (households and enterprises) incomes within the economy. These multipliers are significant in terms of evaluating the effect in the economy of changing the elements that are exogenous to the model of the economy, which can be obtained from the elements of the total requirement matrix. Therefore, the output, land, value-added, and income multipliers are computed using the SAM total requirement matrix based on the industry-by-industry (activity-by-activity) total requirement matrix (Leontief inverse matrix).

4.3.1.1. Output Multipliers

Table 13 shows that the output multiplier effects are most significant for rainfed agriculture (R0F (R- Rand (South African Currency- IUSD = 13.3055 ZAR), Average exchange rate in 2017: 13.3055 ZAR (South African Rand (ZAR)) 2.42 million) compared to irrigation agriculture (R 2.02 million) in the Limpopo Province. The Sekhukhune District of the Limpopo Province had the highest output multiplier effect for irrigation agriculture, followed by the Waterberg, Vhembe, Mopani, and Capricorn districts. This implies that an R1 million injection in the Sekhukhune irrigation agricultural industry leads to an R2.27 million output increase in the economy. In contrast, an R2.15 million output increase occurs when an injection occurs in the Waterberg irrigation agricultural industry. At the provincial level, the Northern Cape, Limpopo, and Mpumalanga provinces of South Africa had the most significant output multiplier effects for irrigation agriculture compared with other provinces (Western Cape, Eastern Cape, Free State, Kwazulu-Natal, Northwest, and Gauteng).

Table 10**.** Output, value-added, and institutional income multipliers.

Industries	Output	Ranks	Value Added	Ranks	Incomes	Ranks
	R'Millions					
Irrigation agriculture Western Cape (WC) Province	1.924	81	1.313	5	1.440	8
Rainfed agriculture WC	2.359	44	0.793	71	0.878	73
Irrigation agriculture Eastern Cape (EC) Province	2.065	73	1.289	9	1.427	11
Rainfed agriculture EC	2.349	47	0.792	72	0.881	72
Irrigation agriculture Northern Cape (NC) Province	2.348	49	1.161	26	1.299	25
Rainfed agriculture NC	2.020	76	1.171	22	1.306	23
Irrigation agriculture Free State (FS) Province	1.721	86	1.265	14	1.387	14
Rainfed agriculture FS	2.130	70	0.761	77	0.844	78
Irrigation agriculture KwaZulu-Natal (KZN) Province	1.868	82	1.324	4	1.460	5
Rainfed agriculture KZN	2.295	55	0.713	80	0.792	80
Irrigation agriculture North-West (NW) Province	1.771	85	1.294	7	1.416	12
Rainfed agriculture NW	2.445	35	0.848	64	0.943	64
Irrigation agriculture Gauteng (GP) Province	1.786	84	1.268	13	1.387	13
Rainfed agriculture GP	2.500	26	0.635	85	0.708	85
Irrigation agriculture Mpumalanga (MP) Province	2.058	74	1.426	1	1.616	1
Rainfed agriculture MP	2.349	48	0.635	84	0.712	84

	Limpopo District municipalities					
Irrigation agriculture Mopani	1.945	80	1.307	6	1.446	6
Rainfed agriculture Mopani	2.241	60	1.114	30	1.236	30
Irrigation agriculture Vhembe	1.957	79	1.287	10	1.444	7
Rainfed agriculture Vhembe	2.399	39	0.897	56	1.004	56
Irrigation agriculture Capricorn	1.817	83	1.292	8	1.470	4
Rainfed agriculture Capricorn	2.501	25	0.910	52	1.023	53
Irrigation agriculture Waterberg	2.151	68	1.238	15	1.357	15
Rainfed agriculture Waterberg	2.337	51	1.005	41	1.108	42
Irrigation agriculture Sekhukhune	2.279	57	1.217	16	1.340	17
Rainfed agriculture Sekhukhune	2.608	15	0.855	63	0.951	63
Forestry	2.283	56	0.932	47	1.050	47
Fishing	2.090	72	1.210	17	1.334	18
Mining of coal and lignite	2.178	67	1.165	25	1.296	26
Mining of gold and uranium ore	2.480	30	1.169	24	1.314	20
Mining of metal ores	2.226	64	1.129	29	1.258	28
Other mining and quarrying	2.366	42	1.102	31	1.233	31
Food	2.397	40	0.896	57	0.998	57
Beverages and tobacco	2.454	33	0.927	48	1.036	49
Spinning, weaving, and finishing of textiles	2.412	38	0.694	82	0.781	82
Knitted, crouched fabrics, wearing apparel, fur articles	2.521	22	0.756	78	0.854	77

Table 13. *Cont.*

Industries	Output	Ranks	Value Added	Ranks	Incomes	Ranks
	R'Millions					
Tanning and dressing of leather	1.552	87	0.448	87	0.499	87
Footwear	2.129	71	0.594	86	0.668	86
Sawmilling, planing of wood, cork, straw	2.592	18	1.055	34	1.181	33
Paper	2.602	17	0.861	61	0.965	61
Publishing, printing, recorded media	2.647	10	0.908	53	1.026	52
Coke ovens, petroleum refineries	2.138	69	0.778	75	0.863	76
Nuclear fuel, basic chemicals	2.433	36	0.736	79	0.827	79
Other chemical products, man-made fibres	2.484	29	0.794	70	0.895	69
Rubber	2.425	37	0.817	67	0.917	67
Plastic	2.453	34	0.902	55	1.020	54
Glass	2.509	24	0.943	46	1.067	45
Non-metallic minerals	2.233	61	0.782	74	0.873	75
Basic iron and steel, casting of metals	2.952	3	0.903	54	1.011	55
Basic precious and non-ferrous metals	2.817	4	0.947	45	1.061	46
Fabricated metal products	3.065	2	1.005	42	1.133	38

Machinery and equipment	2.613	13	0.927	49	1.043	48
Electrical machinery and apparatus	2.718	7	0.791	73	0.890	70
Radio, television, communication equipment, and apparatus	2.316	53	0.806	69	0.907	68
Medical, precision, optical instruments, watches and clocks	2.354	45	0.860	62	0.961	62
Motor vehicles, trailers, parts	2.541	20	0.700	81	0.788	81
Other transport equipment	2.048	75	0.774	76	0.875	74
Furniture	2.001	77	0.650	83	0.731	83
Manufacturing n.e.c, recycling	2.342	50	0.966	44	1.070	44
Electricity, gas, steam, and hot water supply	2.265	59	1.179	20	1.307	22
Collection, purification, and distribution of water	2.612	14	1.206	18	1.343	16
Construction	2.395	41	0.826	66	0.924	66
Wholesale trade, commission trade	2.361	43	1.059	32	1.184	32
Retail trade	2.488	27	1.147	27	1.281	27
Sale, maintenance, and repair of motor vehicles	2.515	23	1.179	21	1.320	19
Hotels and restaurants	2.310	54	0.925	51	1.031	51
Land transport, transport via pipelines	2.228	63	1.048	36	1.163	36
Water transport	1.989	78	0.807	68	0.887	71
Air transport	2.266	58	0.841	65	0.933	65
Auxiliary transport	2.326	52	1.007	40	1.123	40
Post and telecommunication	2.354	46	0.871	58	0.971	59
Financial intermediation	2.665	8	1.286	11	1.439	9
Insurance and pension funding	2.787	5	1.285	12	1.432	10
Activities in financial intermediation	3.070	1	1.340	2	1.506	3
Real estate activities	2.209	66	1.020	38	1.122	41
Renting of machinery and equipment	2.728	6	1.028	37	1.148	37
Computer and related activities	2.576	19	0.863	59	0.971	58
Research and experimental development	2.230	62	1.184	19	1.314	21
Other business activities	2.650	9	1.048	35	1.176	35
Government	2.488	28	1.326	3	1.507	2
Education	2.455	32	1.055	33	1.181	34
Health and social work	2.471	31	1.010	39	1.131	39
Sewerage and refuse disposal	2.615	12	1.170	23	1.300	24
Activities of membership organisations	2.532	21	0.991	43	1.107	43
Recreational, cultural, and sporting activities	2.603	16	0.862	60	0.965	60
Other activities	2.619	11	0.926	50	1.036	50
Non-observed, informal, non-profit, households	2.212	65	1.131	28	1.256	29
Average	2.352		0.993		1.108	

Source: Author's Calculations based on 2017 SAM.

4.3.1.2. Value-Added Multipliers

Table 13 summarizes the value-added multipliers for the regional economy of South Africa. Irrigation agriculture had a higher value-added multiplier in all the districts of Limpopo compared to rainfed agriculture. This is reasonable irrespective of the type of crops that are produced in Limpopo, and irrigation consumes more inputs per unit of output. The findings can be interpreted as a R1 million increase in demand for output from irrigation agriculture in the Mopani District; the value added in the economy increases by R1.31 million. R1.29 million increases in value added to the economy when injection occurs in the Vhembe and Capricorn districts' irrigation agriculture industry. The Waterberg District's irrigation agriculture had the lowest value-added multiplier, with an increase of R1.23 million.

4.3.1.3. Institutional Income Multipliers

A summary of the results of the institutional income multiplier for the regional economy of South Africa is presented. Table 13 shows that irrigation agriculture has a higher institutional income than rainfed agriculture. A R1 million injection into the Capricorn District's irrigation agricultural industry led to an R1.470 million income increase in the economy. Most of the institutional incomes in the Limpopo Province come from the Capricorn irrigation agricultural industry, followed by Mopani (an increase of R1.446 million),

Vhembe (an increase of R1.444 million), Waterberg (an increase of R1.357 million), and Sekhukhune (an increase of R1.340 million).

The Mpumalanga irrigation agricultural industry had the most significant institutional income (R1.616 million) multiplier effect compared to other provinces. This was followed by KwaZulu-Natal (an increase of R1.460 million), Western Cape (an increase of R1.440 million), North West (an increase of R1.416 million), Eastern Cape (an increase of R1.427 million), Limpopo (an increase of R1.411 million), Free State and Gauteng (both increasing by R1.387 million), and, lastly, Northern Cape (an increase of R1.299 million).

4.3.1.4. Land Return/Multipliers

Land is one of the key assets in South Africa in both the agricultural and non-agricultural sectors. Land multipliers measure the value of returns from production activities in South Africa. Land multipliers indicate the value of land for every R1 million injected in production for a particular activity. The results in Table 14 show that for every R1 million injected in the Mopani District of the Limpopo Province of South Africa for irrigation agricultural production, the total return values of agricultural land were worth R6,580. Of this particular total return value of land, the highest returns went to irrigated land, with R5,820, followed by Capricorn irrigated land with a return value of R5,950. For every R1 million injected into the Vhembe and Waterberg irrigated lands, the return values of agricultural land were worth R5,140 and R4,720, respectively. In the case of the province, Northern Cape had the highest land return, worth R111,040 for every R1 million injected into the irrigation agricultural industry, followed by Eastern Cape (R58,000), Western Cape (R11,500), Free State (R6,750), Limpopo (R6,260), and Mpumalanga, which had the lowest land return (R2,420) generated in the economy. Regarding dry land, the Free State had the highest values of R14,900 in the economy, whereas the Limpopo Province had a land return worth about R6,800. The value of irrigated land is greater than that of dry land in all provinces.

Table 11. Land return/multipliers.

Industries	Land Returns					
	Irrigated Land	Ranks	Dryland	Ranks	Total	Ranks
	R'Millions					
Irrigation agriculture Western Cape (WC) Province	0.01150	3	0.00066	22	0.0122	5
Rainfed agriculture WC	0.00013	35	0.00247	12	0.0026	25
Irrigation agriculture Eastern Cape (EC) Province	0.05807	2	0.00102	17	0.0591	2
Rainfed agriculture EC	0.00011	56	0.00433	9	0.0044	19
Irrigation agriculture Northern Cape (NC) Province	0.11104	1	0.00235	13	0.1134	1
Rainfed agriculture NC	0.00014	33	0.00569	6	0.0058	16
Irrigation agriculture Free State (FS) Province	0.00675	4	0.00035	29	0.0071	9
Rainfed agriculture FS	0.00015	28	0.01491	2	0.0151	4
Irrigation agriculture KwaZulu-Natal (KZN) Province	0.00271	12	0.00038	27	0.0031	22
Rainfed agriculture KZN	0.00014	31	0.00358	10	0.0037	21
Irrigation agriculture North-West (NW) Province	0.00637	5	0.00032	31	0.0067	10
Rainfed agriculture NW	0.00021	22	0.02689	1	0.0271	3
Irrigation agriculture Gauteng (GP) Province	0.00403	11	0.00036	28	0.0044	20
Rainfed agriculture GP	0.00009	77	0.00075	21	0.0008	28
Irrigation agriculture Mpumalanga (MP) Province	0.00242	13	0.00039	26	0.0028	24
Rainfed agriculture MP	0.00014	29	0.00752	5	0.0077	8
Limpopo District municipalities						

Irrigation agriculture Mopani	0.00582	7	0.00076	19	0.0066	11
Rainfed agriculture Mopani	0.00030	17	0.01140	3	0.0117	6
Irrigation agriculture Vhembe	0.00514	8	0.00076	20	0.0059	15
Rainfed agriculture Vhembe	0.00023	21	0.00546	7	0.0057	17
Irrigation agriculture Capricorn	0.00595	6	0.00043	24	0.0064	12
Rainfed agriculture Capricorn	0.00014	30	0.00514	8	0.0053	18
Irrigation agriculture Waterberg	0.00472	9	0.00146	15	0.0062	14
Rainfed agriculture Waterberg	0.00050	15	0.00788	4	0.0084	7
Irrigation agriculture Sekhukhune	0.00428	10	0.00190	14	0.0062	13
Rainfed agriculture Sekhukhune	0.00028	19	0.00259	11	0.0029	23
Forestry	0.00019	23	0.00034	30	0.0005	31
Fishing	0.00016	26	0.00028	34	0.0004	34
Mining of coal and lignite	0.00011	49	0.00020	51	0.0003	51
Mining of gold and uranium ore	0.00011	61	0.00019	62	0.0003	62
Mining of metal ores	0.00011	51	0.00020	53	0.0003	53
Other mining and quarrying	0.00011	53	0.00019	56	0.0003	55
Food	0.00062	14	0.00110	16	0.0017	26
Beverages and tobacco	0.00047	16	0.00082	18	0.0013	27
Spinning, weaving, and finishing of textiles	0.00030	18	0.00053	23	0.0008	29
Knitted, crouched fabrics, wearing apparel, fur articles	0.00016	25	0.00029	33	0.0004	33
Tanning and dressing of leather	0.00005	87	0.00008	87	0.0001	87
Footwear	0.00011	60	0.00019	61	0.0003	61
Sawmilling, planing of wood, cork, straw	0.00012	37	0.00022	39	0.0003	39
Paper	0.00011	59	0.00019	60	0.0003	60
Publishing, printing, recorded media	0.00012	43	0.00021	45	0.0003	45
Coke ovens, petroleum refineries	0.00007	86	0.00013	86	0.0002	86
Nuclear fuel, basic chemicals	0.00008	81	0.00015	81	0.0002	81
Other chemical products, man-made fibres	0.00010	66	0.00018	67	0.0003	67
Rubber	0.00024	20	0.00042	25	0.0007	30
Plastic	0.00010	67	0.00018	68	0.0003	68
Glass	0.00011	57	0.00019	59	0.0003	58
Non-metallic minerals	0.00008	82	0.00015	82	0.0002	82
Basic iron and steel, casting of metals	0.00009	73	0.00017	74	0.0003	74

Table 14. *Cont.*

Industries	Land Returns					
	Irrigated Land	Ranks	Dryland	Ranks	Total	Ranks
	R'Millions					
Basic precious and non-ferrous metals	0.00010	69	0.00018	70	0.0003	70
Fabricated metal products	0.00011	58	0.00019	58	0.0003	59
Machinery and equipment	0.00011	62	0.00019	64	0.0003	64

Electrical machinery and apparatus	0.00009	74	0.00017	75	0.0003	75
Radio, television, communication equipment, and apparatus	0.00009	76	0.00016	77	0.0002	77
Medical, precision, optical instruments, watches, and clocks	0.00009	72	0.00017	73	0.0003	73
Motor vehicles, trailers, parts	0.00008	83	0.00015	83	0.0002	83
Other transport equipment	0.00010	70	0.00018	71	0.0003	71
Furniture	0.00008	84	0.00014	84	0.0002	84
Manufacturing n.e.c, recycling	0.00013	34	0.00023	37	0.0004	37
Electricity, gas, steam, and hot water supply	0.00011	54	0.00019	57	0.0003	57
Collection, purification, and distribution of water	0.00012	41	0.00021	43	0.0003	43
Construction	0.00009	80	0.00016	78	0.0002	78
Wholesale trade, commission trade	0.00011	50	0.00020	52	0.0003	52
Retail trade	0.00012	42	0.00021	44	0.0003	44
Sale, maintenance, and repair of motor vehicles	0.00012	39	0.00021	41	0.0003	41
Hotels and restaurants	0.00017	24	0.00031	32	0.0005	32
Land transport, transport via pipelines	0.00010	71	0.00018	72	0.0003	72
Water transport	0.00007	85	0.00013	85	0.0002	85
Air transport	0.00009	78	0.00015	79	0.0002	79
Auxiliary transport	0.00011	63	0.00019	63	0.0003	63
Post and telecommunication	0.00009	79	0.00015	80	0.0002	80
Financial intermediation	0.00013	36	0.00023	38	0.0004	38
Insurance and pension funding	0.00012	38	0.00022	40	0.0003	40
Activities in financial intermediation	0.00014	32	0.00024	36	0.0004	36
Real estate activities	0.00009	75	0.00016	76	0.0002	76
Renting of machinery and equipment	0.00011	52	0.00020	54	0.0003	54
Computer and related activities	0.00011	55	0.00019	55	0.0003	56
Research and experimental development	0.00012	44	0.00020	46	0.0003	46
Other business activities	0.00011	45	0.00020	47	0.0003	47
Government	0.00016	27	0.00027	35	0.0004	35
Education	0.00011	48	0.00020	50	0.0003	50
Health and social work	0.00011	46	0.00020	48	0.0003	48
Sewerage and refuse disposal	0.00011	47	0.00020	49	0.0003	49
Activities of membership organisations	0.00010	64	0.00018	65	0.0003	65
Recreational, cultural, and sporting activities	0.00010	68	0.00018	69	0.0003	69
Other activities	0.00010	65	0.00018	66	0.0003	66
Non-observed, informal, non-profit, households,	0.00012	40	0.00021	42	0.0003	42
Average	0.00275		0.00142		0.004	

Source: Authors' calculations from 2017 SAM.

4.3.1.5. Households' Income Multipliers

This section presents the income earned by households in different districts of Limpopo in South Africa. Therefore, Table 15 shows that the income multiplier effect for irrigation agriculture was higher than that for rainfed agriculture. The Vhembe District had a high household income for the irrigation agriculture industry, with an increase of R352,100, followed by Sekhukhune (an increase of R322,400), Waterberg (an increase of R31,510), Capricorn (an increase of R300,300), and the Mopani District, which had the lowest incomes (an increase of R298,400). Capricorn has the highest household income earned from the agricultural irrigation industry in all provinces within the economy.

In the case of rainfed agriculture, Mopani households had the highest income increase (R191,700), followed by Waterberg (R180,500), Vhembe (R123,400), Capricorn (R89,100), and Sekhukhune household incomes (R73,900).

Capital household income increased by R0.0144 million in the economy when demand for commodities from the mining of coal and lignite increased by R1 million. While Sekhukhune household incomes increased by R0.0724 million in the economy, the demand for commodities from the metal ore mining industry increased by R1 million. On the other hand, the food, beverage, and tobacco industries were the most significant in Capricorn, with a household income of R0.0137 million, increasing the economy.

Table 12**.** Household incomes.

Industries	**Household Income by Industries**						
	Mopani	**Vhembe**	**Capricorn**	**Waterberg**	**Sekhukhune**	**Total**	**Ranks**
	R'Million						
Irrigation agriculture Western Cape (WC) Province	0.0138	0.0104	0.0156	0.0093	0.0069	0.0561	42
Rainfed agriculture WC	0.0092	0.0077	0.0108	0.0062	0.0057	0.0395	74
Irrigation agriculture Eastern Cape (EC) Province	0.0132	0.0106	0.0154	0.0093	0.0073	0.0557	43
Rainfed agriculture EC	0.0091	0.0076	0.0106	0.0061	0.0058	0.0392	76
Irrigation agriculture Northern Cape (NC) Province	0.0130	0.0111	0.0152	0.0097	0.0081	0.0570	39
Rainfed agriculture NC	0.0128	0.0098	0.0145	0.0088	0.0073	0.0532	46
Irrigation agriculture Free State (FS) Province	0.0133	0.0098	0.0150	0.0090	0.0064	0.0535	45
Rainfed agriculture FS	0.0089	0.0071	0.0101	0.0062	0.0056	0.0378	79
Irrigation agriculture KwaZulu-Natal (KZN) Province	0.0140	0.0104	0.0159	0.0094	0.0069	0.0566	41
Rainfed agriculture KZN	0.0085	0.0070	0.0098	0.0059	0.0056	0.0368	81

Irrigation agriculture North-West (NW) Province	0.0143	0.0105	0.0162	0.0096	0.0069	0.0574	36
Rainfed agriculture NW	0.0107	0.0088	0.0122	0.0073	0.0071	0.0460	63
Irrigation agriculture Gauteng (GP) Province	0.0143	0.0105	0.0162	0.0096	0.0069	0.0576	35
Rainfed agriculture GP	0.0079	0.0069	0.0093	0.0055	0.0058	0.0354	82
Irrigation agriculture Mpumalanga (MP) Province	0.0123	0.0095	0.0140	0.0081	0.0065	0.0504	54
Rainfed agriculture MP	0.0079	0.0066	0.0088	0.0058	0.0062	0.0353	83
Limpopo District municipalities							
Irrigation agriculture Mopani	0.2984	0.0099	0.0148	0.0089	0.0067	0.3387	4
Rainfed agriculture Mopani	0.1917	0.0098	0.0139	0.0085	0.0075	0.2314	6
Irrigation agriculture Vhembe	0.0124	0.3521	0.0139	0.0083	0.0063	0.3930	1
Rainfed agriculture Vhembe	0.0105	0.1234	0.0120	0.0072	0.0070	0.1601	9
Irrigation agriculture Capricorn	0.0131	0.0098	0.3003	0.0088	0.0065	0.3386	5
Rainfed agriculture Capricorn	0.0109	0.0093	0.0891	0.0073	0.0071	0.1237	10
Irrigation agriculture Waterberg	0.0122	0.0095	0.0135	0.3151	0.0067	0.3569	3
Rainfed agriculture Waterberg	0.0115	0.0093	0.0126	0.1805	0.0079	0.2218	7
Irrigation agriculture Sekhukhune	0.0120	0.0095	0.0131	0.0083	0.3224	0.3654	2
Rainfed agriculture Sekhukhune	0.0115	0.0098	0.0126	0.0087	0.0739	0.1165	11
Forestry	0.0194	0.0177	0.0145	0.0073	0.0071	0.0660	21
Fishing	0.0140	0.0103	0.0184	0.0087	0.0102	0.0615	32
Mining of coal and lignite	0.0137	0.0103	0.0144	0.0132	0.0105	0.0619	31

Table 15. *Cont.*

Industries	Household Income by Industries						
	Mopani	Vhembe	Capricorn	Waterberg	Sekhukhune	Total	Ranks
	R'Million						
Mining of gold and uranium ore	0.0282	0.0129	0.0154	0.0100	0.0114	0.0779	18
Mining of metal ores	0.0375	0.0145	0.0267	0.0599	0.0724	0.2110	8
Other mining and quarrying	0.0200	0.0233	0.0186	0.0160	0.0244	0.1023	13
Food	0.0110	0.0095	0.0132	0.0071	0.0064	0.0471	62
Beverages and tobacco	0.0112	0.0100	0.0137	0.0070	0.0065	0.0485	60
Spinning, weaving, and finishing of textiles	0.0084	0.0077	0.0105	0.0053	0.0054	0.0373	80
Knitted, crouched fabrics, wearing apparel, fur articles	0.0088	0.0084	0.0115	0.0053	0.0054	0.0393	75
Tanning and dressing of leather	0.0053	0.0046	0.0066	0.0033	0.0030	0.0229	87
Footwear	0.0069	0.0065	0.0089	0.0043	0.0043	0.0309	86
Sawmilling, planing of wood, cork, straw	0.0132	0.0111	0.0140	0.0075	0.0070	0.0528	50

Paper	0.0109	0.0093	0.0117	0.0064	0.0061	0.0443	65
Publishing, printing, recorded media	0.0102	0.0090	0.0117	0.0059	0.0060	0.0427	68
Coke ovens, petroleum refineries	0.0121	0.0095	0.0117	0.0113	0.0127	0.0574	37
Nuclear fuel, basic chemicals	0.0087	0.0075	0.0100	0.0067	0.0073	0.0403	72
Other chemical products, man-made fibres	0.0084	0.0075	0.0103	0.0060	0.0062	0.0384	78
Rubber	0.0087	0.0074	0.0105	0.0063	0.0061	0.0391	77
Plastic	0.0086	0.0078	0.0110	0.0063	0.0063	0.0400	73
Glass	0.0101	0.0089	0.0120	0.0080	0.0088	0.0478	61
Non-metallic minerals	0.0109	0.0088	0.0117	0.0093	0.0104	0.0511	53
Basic iron and steel, casting of metals	0.0165	0.0097	0.0144	0.0177	0.0208	0.0792	17
Basic precious and non-ferrous metals	0.0158	0.0097	0.0143	0.0160	0.0190	0.0749	19
Fabricated metal products	0.0134	0.0096	0.0133	0.0117	0.0144	0.0624	30
Machinery and equipment	0.0110	0.0095	0.0127	0.0092	0.0098	0.0522	51
Electrical machinery and apparatus	0.0108	0.0085	0.0115	0.0097	0.0110	0.0515	52
Radio, television, communication equipment, and apparatus	0.0094	0.0083	0.0110	0.0077	0.0081	0.0445	64
Medical, precision, optical instruments, watches, and clocks	0.0094	0.0086	0.0117	0.0065	0.0061	0.0424	70
Motor vehicles, trailers, parts	0.0086	0.0072	0.0097	0.0073	0.0079	0.0408	71
Other transport equipment	0.0072	0.0063	0.0087	0.0055	0.0057	0.0334	84
Furniture	0.0078	0.0067	0.0087	0.0049	0.0051	0.0332	85
Manufacturing n.e.c, recycling	0.0115	0.0090	0.0126	0.0084	0.0079	0.0494	57
Electricity, gas, steam, and hot water supply	0.0190	0.0124	0.0206	0.0132	0.0148	0.0800	16
Collection, purification, and distribution of water	0.0220	0.0202	0.0269	0.0109	0.0156	0.0954	14
Construction	0.0112	0.0104	0.0127	0.0077	0.0081	0.0501	55
Wholesale trade, commission trade	0.0132	0.0136	0.0174	0.0079	0.0087	0.0608	34
Retail trade	0.0144	0.0145	0.0188	0.0086	0.0093	0.0656	22
Sale, maintenance, and repair of motor vehicles	0.0145	0.0131	0.0190	0.0089	0.0094	0.0649	24
Hotels and restaurants	0.0111	0.0096	0.0137	0.0071	0.0074	0.0490	59
Land transport, transport via pipelines	0.0123	0.0104	0.0148	0.0080	0.0075	0.0530	48
Water transport	0.0101	0.0079	0.0114	0.0070	0.0061	0.0424	69
Air transport	0.0103	0.0088	0.0114	0.0068	0.0063	0.0437	66
Auxiliary transport	0.0117	0.0105	0.0130	0.0071	0.0067	0.0491	58
Post and telecommunication	0.0099	0.0090	0.0124	0.0064	0.0059	0.0436	67

Financial intermediation	0.0138	0.0131	0.0194	0.0080	0.0085	0.0628	29
Insurance and pension funding	0.0140	0.0130	0.0192	0.0084	0.0083	0.0630	28
Activities in financial intermediation	0.0137	0.0135	0.0202	0.0077	0.0087	0.0638	26
Real estate activities	0.0130	0.0106	0.0151	0.0081	0.0074	0.0541	44
Renting of machinery and equipment	0.0142	0.0129	0.0163	0.0079	0.0100	0.0613	33
Computer and related activities	0.0132	0.0124	0.0144	0.0067	0.0103	0.0570	38
Research and experimental development	0.0175	0.0152	0.0190	0.0092	0.0120	0.0730	20

Table 15. *Cont.*

Industries	Household Income by Industries						
	Mopani	**Vhembe**	**Capricorn**	**Waterberg**	**Sekhukhune**	**Total**	**Ranks**
	R'Million						
Other business activities	0.0119	0.0114	0.0154	0.0072	0.0073	0.0532	47
Government	0.0248	0.0346	0.0323	0.0099	0.0130	0.1145	12
Education	0.0194	0.0216	0.0243	0.0093	0.0135	0.0881	15
Health and social work	0.0146	0.0152	0.0175	0.0078	0.0089	0.0641	25
Sewerage and refuse disposal	0.0145	0.0146	0.0185	0.0093	0.0086	0.0655	23
Activities of membership organisations	0.0122	0.0132	0.0162	0.0076	0.0075	0.0567	40
Recreational, cultural, and sporting activities	0.0107	0.0114	0.0140	0.0068	0.0070	0.0498	56
Other activities	0.0114	0.0121	0.0150	0.0072	0.0072	0.0529	49
Non-observed, informal, non-profit, households,	0.0139	0.0144	0.0181	0.0090	0.0082	0.0636	27
Average	0.0180	0.0160	0.0185	0.0143	0.0134	0.0802	

Source: Author's calculations from 2017 SAM.

4.4. Discussion

The study determined whether irrigated agriculture was significant in improving agricultural output and generated better land returns. The effect of irrigation agriculture on the economy of district municipalities and provinces of South Africa showed mixed results for irrigated and rain-fed agriculture. Multiplier analysis included output, value added, institutional income, land, and household income. The output multipliers indicated that rainfed agriculture was higher than irrigation agriculture in the Limpopo Province. At the district level, Sekhukhune in the Limpopo Province had the highest output multiplier effect for irrigation agriculture compared to other districts. This implies that investment in irrigation agriculture can lead to the enhancement of output in the economy at provincial and district levels. This finding is in line with a study by Mapuso et al. [32], which found that access to irrigation enhances agricultural output (yield).

At the provincial level, the Northern Cape, Limpopo, and Mpumalanga provinces of South Africa had the largest output multiplier effect for irrigation agriculture compared with other provinces. As indicated by Ramigo [33], agricultural production is rainfed in Limpopo due to insufficient and unreliable rainfall in most regions, and water is the most crucial factor hindering agricultural production, which uses most of the water. To achieve development in most parts of Limpopo, more focus should be placed on the water and finance industries because of the large output multiplier. Investing in rainfed agriculture is as significant for profitability as investing in irrigation agriculture. Although irrigation plays an essential role in other provinces, agricultural policies should be balanced to incorporate rainfed agriculture. This finding is similarly to research by Taljaard [17], who found irrigation to be significant in the economy of the Northern Cape because the province is mostly desert, and many farmers rely on irrigation to increase yield. A R1 million injection in the Northern Cape irrigation agricultural industry led to an R2.35 million output increase in the economy, followed by Mpumalanga and Limpopo, with output increases of R2.04 million and R2.03 million, respectively. The multiplier output in this study was higher for irrigation agriculture compared to the multiplier output obtained by Kirsten and Van Zyl [18], but lower than the results of Taljaard [17]. They found that irrigation agriculture plays a vital role in increasing yield because of the contribution generated by intermediate sectors and households in the regions.

The value-added multipliers of irrigation agriculture had the highest value-added multipliers in all districts of the Limpopo Province of South Africa compared with rainfed agriculture. At the provincial level, irrigation agriculture in the Mpumalanga Province had the most significant value added compared to other provinces of South Africa. The policy implication of this is that irrespective of the type of crop produced, irrigation consumes more inputs per unit of output. This finding contradicts that of Doukkali and Lejar [19], who found that rainfed agriculture had a higher value added than irrigation agriculture. Additionally, they explained that considering the multiplier effects of agriculture, investment in rainfed agriculture would be more profitable for the Moroccan economy. Moreover, irrigated agriculture increases the energy import bill and energy dependency in the country. This study's findings are consistent with those of Taljaard [17], who found that the Northern Cape had a higher value added for irrigation agriculture compared to other provinces, but a lower value added than in this study.

Irrigation agriculture had higher institutional incomes than rainfed agriculture, ranging from R1.357 million to R1.470 million, as a result of a R1 million injection in Limpopo district municipalities. At the provincial level, the Mpumalanga irrigation agricultural industry had the most significant institutional income (R1.616

million) multiplier effect compared to other provinces, which ranged from R1.299 million (Northern Cape) to R1.460 million (KwaZulu-Natal). As pointed out by Baloyi [8], irrigation can increase income; it further preserves the national agricultural sector against changes in weather, stabilizes economic growth, and alleviates poverty. Brown [20] highlighted that irrigation agriculture plays a more significant role than rain-fed agriculture in the regional economy through income generation. These findings indicate the effect of income generated from irrigated agriculture and its potential to be significantly higher than that generated from rainfed agriculture. The results of this study were much higher than those obtained by Phoofolo [34].

Land multipliers measure the value of returns from production activities in South Africa. Land multipliers indicate the importance of land for every R1 million injected into production for a particular activity. At the Limpopo district municipality and provincial levels, the land multiplier/land return values of agricultural land vary from R2 420 to R14 900. This implies that the value of irrigated land is greater than that of dry land in all provinces of South Africa. As mentioned by Cousin [35], irrigation farming is a priority in South Africa, as dryland crop production is hazardous because of inadequate rainfall and recurrent agricultural droughts. Easing poverty and enhancing food security in marginalized areas are the main reasons for initiating irrigation in the country.

The household income multiplier effect for irrigation agriculture was higher than that for rain-fed agriculture. The Vhembe District had the highest share of household income for the irrigation agriculture industry, with an increase of R352 100, compared to other districts in the Limpopo Province. As mentioned by Brown [20], irrigation agriculture plays a more significant role than rain-fed agriculture in the regional economy through income generation. These findings indicate the effect of income generated from irrigated agriculture and its potential to be significantly higher than that generated from rainfed agriculture. Doukkali and Lejars [19] pointed out that even though irrigation is a crucial component in stimulating income for households, it is also beneficial for policy to be more balanced in favour of rainfed agriculture to create income for households. Even if irrigation can secure part of the agricultural production, rainfed agriculture also has a high potential to contribute to food security and poverty alleviation. However, in rainfed agriculture, the Mopani District's households had the highest income increase (R191 700) compared to other districts in the Limpopo Province. As stated by Ramigo [33], agricultural production is rainfed in Limpopo because of insufficient and unreliable rainfall. Therefore, this sector is still significant in generating more household income for farmers who depend on rainfed agriculture, and investment in this sector could play a significant role in income generation.

4.5. Conclusions

This research evaluated the effect of irrigation agriculture on the economy of the Limpopo Province of South Africa. Empirical studies related to irrigated and rainfed agriculture are neglected, and models are limited to single production accounts and exclude detailed information on household income at provincial and district levels. Therefore, this empirical study assessed the effect of irrigation agriculture on output, land return, institutional and household incomes, and value added to have a necessary strategy for prioritizing irrigation policies, which contribute to economic development.

This study used a 2017 national social accounting matrix (SAM) with detailed information on irrigation and rainfed agricultural activities and land accounts to compute the effect of exogenous shock (irrigation development) on output, income, land, and value added. The findings showed that the output multiplier effects were more significant for rainfed agriculture (R2.42 million) than for irrigation agriculture (R 2.02 million) in the Limpopo Province of South Africa. Agricultural production is rainfed in Limpopo, with insufficient and unreliable rainfall in most of the municipalities of the provinces. Furthermore, farmers in the province rely on rain, surface water, and groundwater for agriculture, and water is the most crucial factor hindering production in a sector that uses most of the water. The Sekhukhune District of the Limpopo Province had the highest output multiplier effect for irrigation agriculture compared to the other districts.

Irrigation agriculture had the highest land return (R6580), value added (R1.31 million), and institutional income (R1.470 million) multiplier compared with rainfed agriculture in the regional economy of South Africa. This is reasonable irrespective of the type of crop that is produced, and irrigation consumes more input per unit of output. To achieve development in most regions in South Africa, more focus should be placed on the water and finance industries due to the significant contribution (the large multiplier).

The findings imply that innovative technology practices will improve water efficiency and increase the financial advantage of farmers while minimizing environmental burdens. Investing in irrigation agriculture and increasing the efficiency and sustainability of existing irrigation agriculture in the districts of Limpopo play a significant economic role and are profitable because dry land agricultural production is hazardous because of insufficient rainfall and recurrent drought. Investing in rainfed agriculture is important for profitability when investing in irrigation agriculture. Even though irrigation plays a massive role in other regions of the province, agricultural policies should incorporate rainfed agriculture. Therefore, the government should assist in educating farmers to implement different irrigation strategies, such as deficit irrigation, irrigation scheduling, crop water use, and mulching, as irrigation strategies improve food security.

The results of this study are limited to the range of irrigated and rainfed agricultural industries, income, land, output, and value added. Furthermore, the data did not display racial or gender group classifications for households. The data could not identify the types of irrigation systems used for agricultural production in the regions of South Africa. Detailed data on the agricultural sector at the regional level in South Africa are difficult to find and are often based on the period of agricultural surveys and the detailed information mentioned in the surveys. It is challenging to obtain all the information required to construct a SAM. Most datasets for SAMs are used by the public sector, private sector, researchers, academia, and policymakers for a period of five to ten years. Therefore, this study is relevant in the current period.

The findings may not be applicable to other South African provinces due to regional variations in climate, resources, and agricultural practices. The environmental impact of irrigation, particularly water scarcity, is not explicitly addressed in terms of sustainability concerns. The study emphasizes innovative technologies without acknowledging potential limitations in access or affordability for farmers lacking technology. The sole focus on profitability might overlook broader social or environmental considerations. Water scarcity was the most limiting factor due to climate change. However, an improvement in water availability is required through the implementation of technologies to improve water management for sustainable agricultural production.

Future research should consider disaggregating agriculture according to different crops to evaluate the economic impact of irrigation and rainfall at the regional level. The data should display racial and gender group classifications of households. The SAM did not include all districts in South Africa; therefore, researchers, academia, and stakeholders must consider focusing on other districts and possibly adding other accounts (sectors) from local municipalities. Further research is needed to compare the long-term economic, social, and environmental impacts of irrigation and rainfed agriculture in Limpopo by extending the SAM model to capture the environmental impact of irrigation on water resources and assessing the social equity implications of irrigation, including access to water and land for small scale farmers.

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Appendix

Table A1. A: Accounts in the national SAM for South Africa.

Industries	**Commodities**	**Transaction**	**Capital**	**Land**	**Enterprises**	**Households**
Irrigation Agric WC	Agriculture	Transaction	Capital	Irrigated land	Enterprises	Western Cape households
Rainfed Agric WC	Live animal			Dryland		Eastern Cape households
Irrigation Agric EC	Forestry					Northern Cape households
Rainfed Agric EC	Fishing					Free State households
Irrigation Agric NC	Coal and lignite					Kwazulu-Natal households
Rainfed Agric NC	Metal ores					Northwest households
Irrigation Agric FS	Other minerals					Gauteng households
Rainfed Agric FS	Electricity and gas					Mpumalanga households
Irrigation Agric KZN	Natural water					Mopani households
Rainfed Agric KZN	Meat					Vhembe households
Irrigation Agric NW	Fish					Capricorn households
Rainfed Agric NW	Vegetables					Waterberg households

Table A1. *Cont.*

Irrigation Agric GP	Fruit and nuts					Sekhukhune households
Rainfed Agric GP	Oils and fats					
Irrigation Agric MP	Dairy products					
Rainfed Agric MP	Grain mill products					
Irrigation Agric Mopani	Starches products					
Rainfed Agric Mopani	Animal feeding					
Irrigation Agric Vhembe	Bakery products					
Rainfed Agric Vhembe	Sugar					
Irrigation Agric Capricorn	Confectionary products					
Rainfed Agric Capricorn	Pasta products					
Irrigation Agric Waterberg	Food n.e.c.					
Rainfed Agric Waterberg	Alcohol, beverages					

Industries	**Commodities**	**Transaction**	**Capital**	**Land**	**Enterprises**	**Households**
Irrigation Agric Sekhukhune	Soft drinks					
Rainfed Agric Sekhukhune	Tobacco products					

Table A1. *Cont.*

Forestry	Textile fabrics
Fishing	Made-up textile, articles
Mining of coal and lignite	Carpets
Mining of gold and uranium ore	Textile n.e.c.
Mining of metal ores	Knitting fabrics
Other mining and quarrying	Wearing apparel
Food	Leather products
Beverages and tobacco	Footwear
Spinning, weaving, and finishing of textiles	Wood products
Knitted, crouched fabrics, wearing apparel, fur articles	Paper products
Tanning and dressing of leather	Printing
Footwear	Petroleum products
Sawmilling, planing of wood, cork, straw	Basic chemicals
Paper	Fertilizers, pesticides

Table A1. *Cont.*

Industries	Commodities	Transaction	Capital	Land	Enterprises	Households
Publishing, printing, recorded media	Paint, related products					
Coke ovens, petroleum refineries	Pharmaceutical products					
Nuclear fuel, basic chemicals	Soap, cleaning, perfume					
Other chemical products, man-made fibers	Chemical products, n.e.c.					
Rubber	Rubber tyres					
Plastic	Other rubber products					
Glass	Plastic products					
Non-metallic minerals	Glass products					
Basic iron and steel, casting of metals	Non-structural ceramic					
Basic precious and non-ferrous metals	Structure non-refractory clay					
Fabricated metal products	Plaster, cement					
Machinery and equipment	Articles of concrete					

Table A1. *Cont.*

Electrical machinery and apparatus	Non-metallic products n.e.c.
Radio, television, communication equipment, and apparatus	Furniture
Medical, precision, optical instruments, watches and clocks	Jewellery
Motor vehicles, trailers, parts	Manufactured products n.e.c.
Other transport equipment	Wastes, scraps
Furniture	Iron, steel products
Manufacturing n.e.c, recycling	Non-ferrous metals
Electricity, gas, steam, and hot water supply	Structural metal products
Collection, purification, and distribution of water	Tanks, reservoirs
Construction	Other fabricated metal
Wholesale trade, commission trade	Engines, turbines
Retail trade	Pumps, compressors
Sale, maintenance, repair of motor vehicles	Bearings, gears
Hotels and restaurants	Lifting equipment

Table A1. *Cont.*

Land transport, transport via pipelines	General Machinery
Water transport	Special machinery
Air transport	Domestic appliances
Auxiliary transport	Office machinery
Post and telecommunication	Electrical machinery
Financial intermediation	Radio, television
Insurance and pension funding	Medical appliances

Industries	**Commodities**	**Transaction**	**Capital**	**Land**	**Enterprises**	**Households**
Activities in financial intermediation	Motor vehicles, parts					
Real estate activities	Ships and boats					
Renting of machinery and equipment	Railway and trams					
Computer and related activities	Aircrafts					
Research and experimental development	Other transport equipment					
Other business activities	Construction					
Government	Construction services					

Table A1. *Cont.*

Education	Trade services
Health and social work	Accommodation
Sewerage and refuse disposal.	Catering services
Activities of membership organisations	Passenger transport
Recreational, cultural, and sporting activities	Freight transport
Other activities	Supporting transport services
Non-observed, informal, non-profit, households,	Postal, courier services
	Electricity distribution
	Water distribution
	Financial services
	Insurance, pension
	Other financial services
	Real estate services
	Leasing, Rental services
	Research, development

Table A1. *Cont.*

	Legal, accounting
	Other business services
	Telecommunications

Table A1. *Cont.*

Industries	Commodities	Transaction	Capital	Land	Enterprises	Households
	Support services					
	Manufactured services n.e.c.					
	Public administration					
	Education services					
	Health, social services					
	Other services n.e.c.					

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Chapter 5: Data on small-scale and commercial agricultural industries: South Africa SAM for 2021

Pfunzo, R.; Bahta, Y.T., and Jordaan, H. (2024).Data on Economic Analysis (on a small scale and commercial agricultural activities): 2021 Social Accounting Matrices (SAM).
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Abstract:

The main objective of the study is to develop data on small-scale and commercial agricultural industries using 2021 Social Accounting Matrices (SAM) for South Africa. The data sources for constructing SAM for South Africa are found from different sources such as South African Reserve Bank Quartely bul-letin, Quantec Easy data, Quartely Labour Force Survey (QLFS), and General Household Survey (GHS). The data reports Northern Cape, Free State, and North West had higher (34.52%, 15.30% and 10.67%) used of land as input in the commercial agricultural production level. Whereas Western Cape commercial agricultural industry used more inputs on labour (0.36%) and gross operating surplus (1.5%). The total commodities demanded by provinces show that nearly all the households consumed more than 70% of the commodities in almost all the provinces except the Western Cape province with less than 50% of commodities consumed by households. Most agricultural commodities exported come from the Western Cape with about 28.15%, whereas Gauteng had the largest imported commodities demanded. In the case of household incomes, most incomes come from renting a commercial farm than renting a small-scale farm. The Gauteng and Kwazulu-Natal had trade deficits, whereas other provinces experienced trade surplus.

Dataset: https://doi.org/10.38140/ufs.26008588.v1

Keywords: Small-scale agriculture, commercial agriculture, Factors income, and International Trade

5.1. Introduction

This article contributes to constructing the regional South African SAM using 2021 prices. The SAM is a representation of the System of National Accounts (SNA) in the matrix format as stated by the United Nations (2011), which further explains the interaction between Supply and Uses Tables (SUT) and institutional accounts (Punt, 2013). The SNA is the accounting framework that is used by the National Statistical Agencies (NSA) to incorporates data in a coherence, consistence way, and integrates macroeconomic accounts. It plays a massive role in displaying the economic transactions that are taking place within the economy as explained by Round (2003). The SAM is developed in the basic framework of National Accounts matrix (NAM). Where each entry of the submatrix receipts (rows) and expenditure (columns) identify groups transactions in the economy. The total from the NAM are further used as control viewed in the SAM. The database in a SAM could be used for government strategies and policies. Several empirical studies have been conducted over the past years within and outside South Africa. Ramigo et al. (2023) constructed a 2017 national SAM for South Africa which incorporates agricultural activities, labour, and households by regions. Further constructed a 2020 South Africa SAM which shows disaggregated agricultural activities (Ramigo et al., 2024). Phoofolo (2018) provided a 2014 SAM with a disaggregated agricultural sector and single account for agricultural land in South Africa. Chitiga et al. (2021) used a 2015 SAM for South Africa constructed by Van Seventer et al. (2019) and updated it to 2020. Van Seventer and Davies (2023) built a 2019 SAM for South Africa with a disaggregation wages, capital stocks and households. Juana and Mabugu (2005) used 1991 SAM for Zimbabwe developed by Thomas and Bautista (1999) comprised of large scale and small-scale farms classifications. Davies et al. (2019) used a 2013 SAM for Zimbabwe with a disaggregated farm according to three different categories such as large-scale, small-scale commercial and communal farms. Randriama-monjy and Thurlow (2017) constructed a 2015 SAM for Tanzania with disaggregated agricultural activities and commodities, labour, gross operating surplus (GOS), and households. Pauw et al (2021) used a 2019 SAM for Zambia with a disaggregation agricultural activity, and commodity, labour and households.

Most of the SAMs mentioned above reported that Ramigo et al. (2023), Van Seventer et al. (2019), Van Seventer and Davies (2023), Phofoolo (2018), Pauw et al. (2021), and Randiamamonjy and Thurlouw (2017) are designed for policy analysis as they provide detailed information for factors and households accounts. However, the South African SAMs developed by Phofoolo [5]; and Van seventer et al. [28] don't comprises of dualist agricultural activities (small-scale vs large-scale) in the regional level. Even though the study done by Juana and Mabugu (2005) and Davies et al. (2019) used a SAM built in 1991 and 2013 for Zimbabwe with dualist agriculture for small-scale and large-scale, but the SAM was mostly focused on the national agricultural sectors for Zimbabwe, and not explicitly highlight the issues in the regional level. Ramigo et al. (2023) comprises of regional agricultural activities, labour, and households but was not categorized according to small scale and commercial agriculture per each activity in the regions. This study intends to disaggregate agricultural activities according to small-scale and commercial agricultural activities by regions in South Africa. Factors of production will comprise of labour, gross operating surplus/mixed income (capital), and land. Labour and households will then further be categorized according to regions of South Africa, whereas land as factor income will be disaggregated according to small-scale and commercial farms. According to the knowledge of the researcher, no study has been done to evaluate the regional economic data for South Africa comparing small scale and commercial agricultural activities using the 2021 SAM.

The main objective of the study is to develop data on small-scale and commercial agricultural industries using 2021 Social Accounting Matrices (SAM) for South Africa. The specific objectives are used to: compute total output; intermediate consumptions; factors income; household incomes and Trade (exports and im-ports).

5.2. Data Description

Table 16 reported the South Africa macro-SAM for 2021 derived from the aggregated balanced SAM (million ZAR (Rand), national currency of South Africa, USD 1 = ZAR 15.96). As part of the intermediate input, the demand products recorded 46% (ZAR 6 678 088) of the total products demand (ZAR 14 459 370). The domestic final demand was reported at 40% (ZAR 5 849 647), and products exports accounted for 13% (ZAR 1 931 635). Products imported recorded 11% (ZAR 1 550 539) with the tariff's imports of 4% (ZAR 635 437) of the total ZAR 14 459 370 supply. At the basic prices, the total domestic production was ZAR 6 678 088, which includes expenditure to primary inputs of 45% (ZAR 5 478 695) and producer taxes of 1% (ZAR 116 611). South Africa was reported to be a net exporter of goods and services to the rest of the world in 2021 (ZAR 381 096), causing the country to have a net surplus on the current account.

In the case of household income (ZAR 5 635 839), as captured from the developed SAM, most of the income came from labour services, with a reported 60% (ZAR 2 866 723). In the case of the South African Savings, most of savings are received from the enterprises with only 57% (ZAR 457 960), followed by households with about 22% (ZAR 174 649), savings from abroad is only 20% (ZAR 161 429) and government saved approximately 2% (ZAR 15 897). The South African government received majority of the incomes from the direct taxes of which includes corporates and personal taxes with approximately 47% (ZAR 676 714), followed by product taxes with only 44% (635 437), production taxes with about 8% (ZAR 116 611) and the incomes received from abroad is only 0.12% (ZAR 1 652). The households spent majority of their incomes on purchasing products, of which is about 68% (ZAR3 838 229), followed by enterprises with only 16% (ZAR 894 461), 7% (ZAR 388 061) on paying taxes, and some of the incomes from the households are further dis-tributed abroad and saved with about 6% (ZAR 340 439) and 3% (ZAR 174 649) respectively. In terms of households' incomes, about 51% (2 864 656) of the incomes are generated in the forms of wages, salaries, and commissions; whereas 23% (ZAR 1 299 774, and ZAR 1 299 959) each is earned through rental of building, land, and interests and other incomes received by households comes abroad in the form's remittance, pensions, and grants from the government with only 0.16% (ZAR 8 740) and 3% (ZAR 162 709).

Table 13: A 2021 Social Accounting Matrix for South Africa (ZAR Millions)

	Activities	Commodities	Labour	Capita	Enterprise	Households	Governments	Activities Tax	Prod Tax	Direct Tax	Change in Inventory	Investment	ROW	Total
Activities	0	12 273	0	0	0	0	0	0	0	0	0	0	0	12 273
Commodities	6 678	0	0	0	0	3 838	1 201	0	0	0	−8	818	1 931	14 459
Labour	2 866	0	0	0	0	0	0	0	0	0	0	0	13	2 880
Capital	2 611	0	0	0	0	0	0	0	0	0	0	0	153	2 765
Enterprise	0	0	0	1 195	280	894	0	0	0	0	0	0	756	2 371
Households	0	0	2 864	1 299	1 299	0	162	0	0	0	0	0	8	5 635
Government	0	0	0	0	0	0	0	116	635	676	0	0	1	1 430
Activity tax	16	0	0	0	0	0	0	0	0	0	0	0	0	116
Product taxes	0	635	0	0	0	0	0	0	0	0	0	0	0	635
Direct tax	0	0	0	0	288	388	0	0	0	0	0	0	0	676
Change in inventory	0	0	0	0	0	0	0	0	0	0	0	−8	0	−8
Savings	0	0	0	0	457	174	15	0	0	0	0	0	161	809
ROW	**0**	1 550	15	270	44	340	50	0	0	0	0	0	0	2 271
Total	12 273	14 459	2 880	2 765	2 371	5 635	1 430	116	635	266	−8	809	2 271	

Source: SARB National Accounts and author estimations

Table 17 shows the shares of total components of output of intermediate inputs, capital (gross operating surplus/mixed income), labour (compensation of employees), land, and net production taxes categories within the SAM. The commercial agricultural industries in the provinces of South Africa used more inputs compared to the small-scale agricultural industries. In the case of commercial agricultural industry, Northern Cape, Free State and North West provinces used 34.52%, 15.30% and 10.67% of the land as an input in the production level. Whereas Western Cape commercial agricultural industry spent about 0.36% and 1.5% on labour and gross operating surplus (GOS). Gauteng, Kwazulu-Natal, and Western Cape agricultural industries utilized about 1.58%, 1.08%, and 0.82% of intermediate inputs respectively. Community and social services used about 38.09% of labour and 12.69% of the GOS, whereas approximately 28.69% and 14.34% of the GOS was utilized as an input in the finance services and wholesale industries. Manufacturing industry paid 23.69%, 9.77%, and 10.27% of the intermediate inputs, labour and GOS respectively. Finance service industry paid about 37.87% to the production taxes, whereas community services and wholesale industries paid approximately 13.61% and 12.63% to the production taxes respectively.

Table 14: Components of total Output by industries

Industries	Intermediate	Factors	Labour	Capital	Land	Activities taxes	Total
	%s (%)						R'million
Commercial Agric_WC	0.82	0.93	0.36	1.51	8.21	0.10	106 400
Small scale Agric_WC	0.06	0.06	0.01	0.11	0.25	0.00	7 523
Commercial Agric_ EC	0.32	0.22	0.15	0.19	11.45	0.06	33 396
Small scale Agric _EC	0.02	0.04	0.06	0.01	1.92	0.00	4 067
Commercial Agric_NC	0.11	0.45	0.07	0.58	34.52	0.02	32 344
Small scale Agric_NC	0.01	0.02	0.00	0.04	0.05	0.00	1 740
Commercial Agric_FS	0.26	0.26	0.14	0.26	15.30	0.04	31 313
Small scale Agric FS	0.02	0.01	0.00	0.02	0.16	0.00	1 925
Commercial Agric KZN	1.08	0.13	0.17	0.06	3.69	0.12	79 292
Small scale Agric KZN	0.08	0.07	0.11	0.00	2.68	0.00	9 134
Commercial Agric_NW	0.21	0.19	0.11	0.18	10.67	0.05	24 636
Small scale Agric_NW	0.02	0.01	0.00	0.01	0.17	0.00	1 551
Commercial Agric_GP	1.58	0.05	0.08	0.01	0.77	0.28	108 603
Small scale Agric_GP	0.12	0.00	0.00	0.00	0.15	0.00	8 055
Commercial Agric_MP	0.39	0.17	0.20	0.08	4.94	0.06	34 995
Small scale Agric _MP	0.03	0.01	0.02	0.01	0.50	0.00	2 671
Commercial Agric_LP	0.28	0.18	0.26	0.06	3.45	0.07	28 236
Small scale Agric_LP	0.02	0.03	0.05	0.00	1.12	0.00	3 147
Mining and Quarrying	8.50	8.41	5.41	11.80	0.00	5.30	1 034 857
Food processing	6.63	3.23	2.40	4.16	0.00	3.32	623 249

Manufacturing	23.69	9.98	9.77	10.29	0.00	8.18	2 138 490
Electricity, gas, and water	3.26	3.04	1.92	4.29	0.00	7.86	393 197
Construction	4.37	2.56	3.09	1.99	0.00	2.98	435 546
Wholesale and trade, catering & accommodation	7.66	13.49	12.83	14.34	0.00	12.63	1 265 706
Transport, storage, and communication	9.65	7.17	5.94	8.59	0.00	7.45	1 046 201
Finance Intermediation, Insurance, real estate	16.21	23.37	18.73	28.69	0.00	37.87	2407117
Community and social services	14.59	25.93	38.09	12.69	0,00	13.61	2410918
Total	100.00	100.00	100.00	100.00	100.00	100.00	12 274 309

Sources: Own estimation from South African SAM 2021

Table 18 reports the share of the total demand of intermediate commodities, consumption by households and government, change in inventory, gross fixed capital formation (investment) and exports for the commodities. Majority of the commodities exported comes from the Western Cape with about 28.15%, followed by Eastern Cape with only 4.15% of the exports demanded to the rest of world. Approximately 25.30% of the intermediates commodities demanded comes from the Western Cape provinces, followed by Kwazulu-Natal (KZN) with the demand for intermediate commodities of 3.71% in the economy. Almost all the households consumed more than 70% of the commodities in almost all the provinces except the Western Cape province with less than 50% of commodities consumed by households. Westen Cape Agricultural sectors demanded about 2.86% of investment commodities, followed by Eastern Cape and Kwazulu-Natal Agricultural sectors demanded about 0.70% each in the economy of South Africa.

In the case of non-agricultural sectors, financial sectors had the highest (43.02%) commodities used as an intermediate demand, followed by manufacturing (35.50%), and community services (26.92%). Manufacturing sectors demanded about 17.44% of exports commodities, followed by the mining sector demanded only 7.81% of exports commodities, and food processing sector exports demanded only 2.78% in the economy of South Africa.

Table 15: Components of total demand by commodities

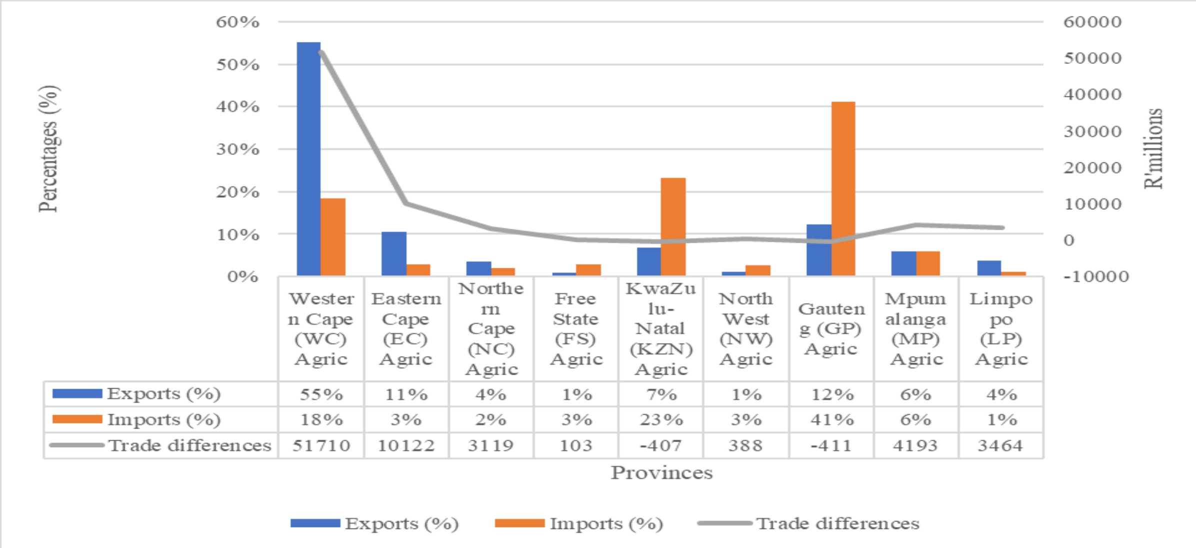
Industries	Intermediate	Factors	Labour	Capital	Land	Activities taxes	Total
	%s (%)						R'million
Commercial Agric_WC	0.82	0.93	0.36	1.51	8.21	0.10	106 400
Small scale Agric_WC	0.06	0.06	0.01	0.11	0.25	0.00	7 523
Commercial Agric_ EC	0.32	0.22	0.15	0.19	11.45	0.06	33 396
Small scale Agric _EC	0.02	0.04	0.06	0.01	1.92	0.00	4 067
Commercial Agric_NC	0.11	0.45	0.07	0.58	34.52	0.02	32 344
Small scale Agric_NC	0.01	0.02	0.00	0.04	0.05	0.00	1 740
Commercial Agric_FS	0.26	0.26	0.14	0.26	15.30	0.04	31 313
Small scale Agric FS	0.02	0.01	0.00	0.02	0.16	0.00	1 925
Commercial Agric KZN	1.08	0.13	0.17	0.06	3.69	0.12	79 292
Small scale Agric KZN	0.08	0.07	0.11	0.00	2.68	0.00	9 134
Commercial Agric_NW	0.21	0.19	0.11	0.18	10.67	0.05	24 636
Small scale Agric_NW	0.02	0.01	0.00	0.01	0.17	0.00	1 551
Commercial Agric_GP	1.58	0.05	0.08	0.01	0.77	0.28	108 603
Small scale Agric_GP	0.12	0.00	0.00	0.00	0.15	0.00	8 055
Commercial Agric_MP	0.39	0.17	0.20	0.08	4.94	0.06	34 995
Small scale Agric _MP	0.03	0.01	0.02	0.01	0.50	0.00	2 671
Commercial Agric_LP	0.28	0.18	0.26	0.06	3.45	0.07	28 236
Small scale Agric_LP	0.02	0.03	0.05	0.00	1.12	0.00	3 147
Mining and Quarrying	8.50	8.41	5.41	11.80	0.00	5.30	1 034 857
Food processing	6.63	3.23	2.40	4.16	0.00	3.32	623 249
Manufacturing	23.69	9.98	9.77	10.29	0.00	8.18	2 138 490
Electricity, gas, and water	3.26	3.04	1.92	4.29	0.00	7.86	393 197
Construction	4.37	2.56	3.09	1.99	0.00	2.98	435 546
Wholesale and trade, catering & accommodation	7.66	13.49	12.83	14.34	0.00	12.63	1 265 706
Transport, storage, and communication	9.65	7.17	5.94	8.59	0.00	7.45	1 046 201
Finance Intermediation, Insurance, real estate	16.21	23.37	18.73	28.69	0.00	37.87	2407117
Community and social services	14.59	25.93	38.09	12.69	0,00	13.61	2410918
Total	100.00	100.00	100.00	100.00	100.00	100.00	12 274 309

Source: Own estimation from South African SAM 2021

Figure 5 records shares of the agricultural commodities exported or imported by different provinces in the South African economy. The Western Cape Agricultural sector had a largest share of exported commodities to abroad, followed by Gauteng agricultural sector with 12%, Eastern Cape agricultural sector (11%), and Kwazulu-Natal agricultural sector with an exports demand of 7% in South African economy. Limpopo and Northern Cape agricultural sectors had an exports demand of 4% commodities. In the case of imported commodities, Limpopo had the lowest imports demand of 1% commodities in the economy. Whereas the Gauteng agricultural sector province had the largest (41%) imported demand commodities, followed by

Kwazulu-Natal (23%), and Western Cape agricultural sector with an import demanded commodities by 18%. The Gauteng and Kwazulu-Natal agricultural sectors had a trade deficit of R411 and R407 respectively, whereas other provincial sectors experienced a trade surplus in the economy of South Africa.

Figure 5: Agricultural commodities traded by South African provinces.



Source: Own estimation from South African SAM 2021

Table 19 reports the main sources of income from various provinces of the South Africa. Over 50% of the households in the Western Cape, Kwazulu-Natal, Mpumalanga, and Limpopo provinces received their incomes in form of labour remunerations (wages/salaries). Less than 10% of the households in Mpumalanga and Limpopo received their income from gross operating surplus (capital). Majority of the households in the provinces of South Africa received more incomes from renting or using a commercial farm than renting/using a small-scale farm. Over 5% of the households in Eastern Cape and Limpopo provinces in South Africa received incomes in the forms of grants.

Table 16: Households incomes by South African provinces

Households' incomes	**Wages**	**Capital**	**Commercial**	**Small scale**	**Enterprise**	**Government**	**ROW**	**Total**
	%s (%)							R' million
WC_Households	52.31	32.01	0.22	0.02	14.61	0.82	0.02	822 421
EC_Households	47.09	25.93	0.18	0.01	19.09	7.43	0.27	507 512
NC_Households	36.80	38.16	0.26	0.02	20.05	4.56	0.15	164 226
FS_Households	42.76	30.36	0.21	0.01	23.15	3.35	0.15	309 646
KZN_Households	51.19	13.80	0.09	0.01	31.21	3.51	0.19	862 738
NW_Households	44.03	36.44	0.25	0.02	16.69	2.42	0.16	464 363

GP_Households	47.01	33.10	0.23	0.02	18.64	0.94	0.07	1 912 539
MP_Households	54.31	9.26	0.06	0.00	32.43	3.63	0.31	406 240
LP_Households	53.87	7.13	0.05	0.00	32.63	5.97	0.36	439 392

Source: Own estimation from South African SAM 2021

5.3. Methods and Materials

The base year for the Macro-SAM for South Africa (SA) is 2021 (Table 20). The Macro-SAM for SA provides the control totals for each of the sub-matrices. The data sources for macro-SAM are obtained from the Quartely Bulletin of December 2023 published by the South African Reserve Bank (SARB) (SARB, 2024). The Quartely Bulletin contains the following information in the national accounts: Output at basic prices; intermediate consumption; fixed consumption expenditure by household and government; compensation of employees; gross operating surplus (GOS); compensation of SA residents working abroad; compensation of non-residents working in South Africa; investment (Gross fixed capital formation); stock changes (Change in inventory); and export and imports of goods and services. The macro-SAM has a total of 13 accounts.

Despite being a national SAM, the SAM comprises of provincial details for agricultural industries, labour, and households, which makes it particularly significant for evaluating at provincial level. Agriculture, forestry, and fisheries are categorized according to different production engaged in the province, implying each agricultural, forestry and fisheries industries signifies all the production taking places in the provinces. Each farming production is assumed to be given a fixed farm for production. The South Africa national accounts do not provide information of land accounts; therefore, estimation was done on gross operating surplus (GOS)/mixed income. It is assumed that 20% of the return to agricultural land comes from the gross operating surplus (GOS)/mixed income for each farming production that is taking place in the economy. Agricultural, forestry, and fisheries industries will further be disaggregated according to small-scale and commercial agriculture, forestry, and fisheries per each province. The information for small-scale and commercial agriculture were sourced from the Quartely Labour Force Survey (QLFS) for 2021, General Household Surveys (GHS) for 2021, and 2017 Census of Commercial Agriculture (StatsSA, 2020; StatsSA, 2022a, and StasSA, 2022b).

Due to limited information obtained from Quartely Bulletin: National Accounts (SARB, 2024). Other details economic activity for compensation of employees, gross operating surplus/mixed income, gross fixed capital formation, change in inventory, international trade (exports and imports) was sourced from Easy Data Quantec and Statistics South Africa (StatsSA). Living

Condition Surveys (LCS) 2014/15 were used to distributes shares for savings from enterprise, households, and for the rest of world. In addition, the data for government taxes (activities taxes, import tariff, personal taxes, and corporates taxes) was extracted from the South Africa Revenue Services (SARS) (SARS, 2022a; SARS, 2022b). Agricultural commodities are identified according to the geographical regions obtained from the Easy Quantec Data (2024a). A SAM provide sufficient information for agricultural sector to clearly indicates regional accounts for capital stocks, investments, and trade (exports and imports) in the economy of South Africa.

The 2021 national account recorded a single account for household and labour. Therefore, both households and labour accounts are disaggregated according to provinces: Western Cape, Eastern Cape, Northern Cape, Free State, Kwazulu-Natal, North West, Gauteng, Mpumalanga, Gauteng, and Limpopo. The factor account comprises of 9 labour, two land, and single capital accounts. The land accounts are further disaggregated into small-scale and commercial farms. These farm accounts report farm return for each agricultural industry separately. The farm income is recorded and then further shared to different households who are the owner of farms. The 2021 South Africa national account has the single account on the intermediate consumptions, change in inventory, gross fixed capital formation, and exports. The intermediate consumptions, change in inventory and gross fixed capital formation and exports accounts was further disaggregated according 10 sectors (agriculture, forestry & forestry; mining; food processing; manufacturing; utility (electricity, gas &water); construction services; wholesales & real trade; transport service; finance service; and community and personal services) of the economy in South Africa (Quantec, 2024a; Quantec, 2024b).

Table 17: Data Sources for 2021 South African SAM

Type of accounts	**Data Sources**
Commodities and Industries/activities	2021 Supply and Use Tables (StatsSA, 2024)
	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)
	Census Commercial Agriculture for 2017 (StatsSA, 2020)
	Easy Quantec Data (Quantec, 2024)
Factors of production	2021 Supply and Use Tables (StatsSA, 2024)
	Living Condition Surveys 2014/15 (StatsSA, 2017)
	Easy Quantec Data (Quantec, 2024)
	Quarterly Labour Force Surveys (QLFS) 2021 (StatsSA, 2022)
	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)
Households	Living Condition Surveys 2014/2015 (StatsSA, 2017)
	General Household Survey (GHS) 2021 (StatsSA, 2022)
	Quarterly Labour Force Surveys (QLFS) 2021 (StatsSA, 2022)
	Easy Quantec Data (Quantec, 2024)

	South Africa Reserve Bank Quarterly Bulletin (SARB, 2022)
	Supply and Uses Tables for 2021 (StatsSA, 2022)
Enterprises	Living Condition Surveys 2014/15 (StatsSA, 2017)
	General Households Surveys (GHS) 2021 (StatsSA, 2022)
	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)
Government	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)
	General Household Survey (GHS) 2021 (StatsSA, 2022)
	Supply and Use Tables for 2021 (StatsSA, 2022)
	Data for taxes incomes for 2021 (SARS, 2022)
	Data for production taxes for 2021 (SARS, 2022)
	Easy Quantec Data (Quantec, 2024)
	Data for commodities taxes for 2021 (SARS, 2022)
Capital stocks/ Gross capital fixed formation	Supply and Use Tables for 2021 (StatsSA, 2022)
	Easy Quantec Data (Quantec, 2024)
	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)
International trade	Supply and Use Tables (SUT) for 2021 (StatsSA, 2022)
	Data for exports and imports for 2021 (SARS, 2022)
	Easy Quantec Data (Quantec, 2024)
	South Africa Reserve Bank Quarterly Bulletin (SARB, 2024)

Source: Own compilation

5.4. User Notes

This dataset is of paramount importance to policy makers, stakeholders, and academia. In addition, the data can be modified through disaggregation of the sectors to suit purpose of the research. The dataset could be transformed into the models such as Computable General Equilibrium (CGE), and multiplier models.

5.5. Conclusion

The main objective of the study is to develop data on small-scale and commercial agricultural industries using 2021 Social Accounting Matrices (SAM) for South Africa. The data sources for constructing SAM for South Africa are found from different sources such as South African Reserve Bank Quartely bulletin, Quantec Easy data, Quartely Labour Force Survey (QLFS), and the General Household Survey (GHS). The commercial agricultural industries in the provinces of South Africa used more inputs compared to the small-scale agricultural industries. The Northern Cape, Free State, and North West had higher (34.52%, 15.30% and 10.67%) used of land as input in the comercial agricultural production level. Whereas Western Cape commercial agricultural industry used more inputs on labour (0.36%) and gross operating surplus (1.5%). The total commodities demanded by provinces shows that nearly all the households consumed more than 70% of the commodities in almost all the provinces except the Western Cape province with less than 50% of commodities consumed by households. Majority of the agricultural commodities exported comes from the Western Cape with about

28.15%, whereas Gauteng had a largest imported commodities demanded. In the case of household incomes, majority of incomes comes from renting a commercial farm than renting a small-scale farm. The Gauteng and Kwazulu-Natal had trade deficit, whereas other provinces experienced trade surplus in the economy of South Africa. The major challenges that developers find it difficult when constructing a SAM is the scarcity of data sources from the regional sectors. It is recommended that future researcher should focuses on introduced dataset that incorporates regional accounts for non-agricultural sectors.

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Chapter 6: The impact of electricity tariffs increases on the agricultural industry in South Africa: A SAM price model.

Abstract

Researchers rarely empirically assess the impact of electricity tariffs increases on agricultural sectors at provincial and district level. This study contributes by quantifying the changes in the electricity prices impact on prices in other sectors of the economy. The main objective of the study is to determine the impact of electricity tariffs increases on agricultural industry in South Africa. Using a 2017 national Social Accounting Matrix (SAM) for South Africa as a dataset, this paper computes the effect of electricity tariffs increases on agricultural sectors, with the uses of SAM price model. The SAM price model is significant as it indicates an evaluation of the impacts of changes in prices of electricity in the agricultural production. This study further contributes by quantifying how these changes in the electricity prices impact on prices in other sectors of the economy. The findings show the cost of production for rainfed agriculture is much higher than costs of irrigation agriculture in all regions in South Africa. Limpopo and Northern Cape Provinces of South Africa had the highest costs of production increases for irrigation agriculture compared to other provinces. The increase in the costs of production is attributed to decline of the electricity production by 7.4 % between the period of 2019 and 2021, which has not reached the production level of 2004. The policy implication of expanding electricity sector will not only boost agricultural sector in one region/province but will also increase output in other regions/provinces of the economy. The electricity prices increase, and shortage of electricity provide an incentive for agricultural industries to invest in appropriate mitigation strategies such as investing in renewable energy source. This study further suggests various policy implications for the government of South Africa to overcome the negative impact of electricity price increases through moderating monetary policy, where the monetary policy should neither lead to inflationary problems nor resulting in the growth reduction. It suggested that South Africa government should focus on the investment increase in the electricity transmission lines and power grinds projects to provides lower costs of producing electricity inputs to industries.

Key words: Price, Production, Rain fed, irrigation, Limpopo Province, Northern Cape Province

6.1. Introduction

Several countries (such as Pakistan, China, Bangladesh, India, Ethiopia, Nigeria, Cameroon Senegal and South Africa) across the world have been experienced the chronic issue of the electricity shortage which had resulted in the load shedding that has severely impacted the business operations (Mutambo et al., 2023; Aboubakar et al., 2022; Alo & Adeyemo, 2021 and Shah et al., 2021). Kazmi et al. (2019) pointed out that Pakistan over the previous years since 2007 faced a severe power crisis which negatively affect production, causing a declined of 6000 Megawatts and widespread shutdowns. The authors further stated the severe energy crisis experienced in Parkistan has had a profound repercussion across all the sectors of the economy. According Kundur (1994) cited by Kazmi et al. (2019) reported the imbalanced for supply and demand of electricity is caused by grid not function properly. The purpose of grid is to able identified discrepancies and major imbalances between demand and supply. Abdisa (2018) stated the insufficient electricity supply is a constraint to conducting economic operations in Ethiopia. In Senegal and Bangladesh, the power disruptions had a negatively impacted the productivity of the small and medium enterprises (Cissokho, 2019). According to Alam (2013) reported that only 9% of global populations had no electricity during in 2012 due to severely crisis of the loadshedding.

South Africa continues to produce less electricity compared to previous years. Evidence of such, is the decline of 7.4 % of electricity generation in South Africa between 2019 and 2021 (StatsSA, 2023a). Despite the country managed to produce more electricity in 2021 (244 322 Gwh) in comparison with 2020, the level of production has not reached the one in 2004, which was 244 605 Gwh (Figure 6). Furthermore, extended periods of load shedding, which is the government's strategy to reduce electricity usage, was yet another evidence of decreased electricity generation which was 3.6 % in the year 2022. As highlighted by De Lange (2010) the shortage of power in 2007 that led to load shedding that occurred in the period of 2008 had negative impact on job creation due to a decreased in the production and resultant in the limited supply of electricity. This limited supply of electricity forced Eskom (The South African electricity supply commission) to raise its power production capacity. According to StatsSA (2023a), this decrease in the production of electricity resulted in approximately 2 574 people losing their jobs, from 56 621 employed in 2019 to 54 047 employed in 2021. This records a decline of 4.5 %. In his budget speech, the finance minister, Enoch Godongwana reported in 2023 that Eskom would require approximately R254 billion for debt relief in order to continue expands its power generation capacity. As stated by Pegels (2011) high public spending should be able to resolve socio-economic problems such as unemployment, poverty, and electricity generation capacity.

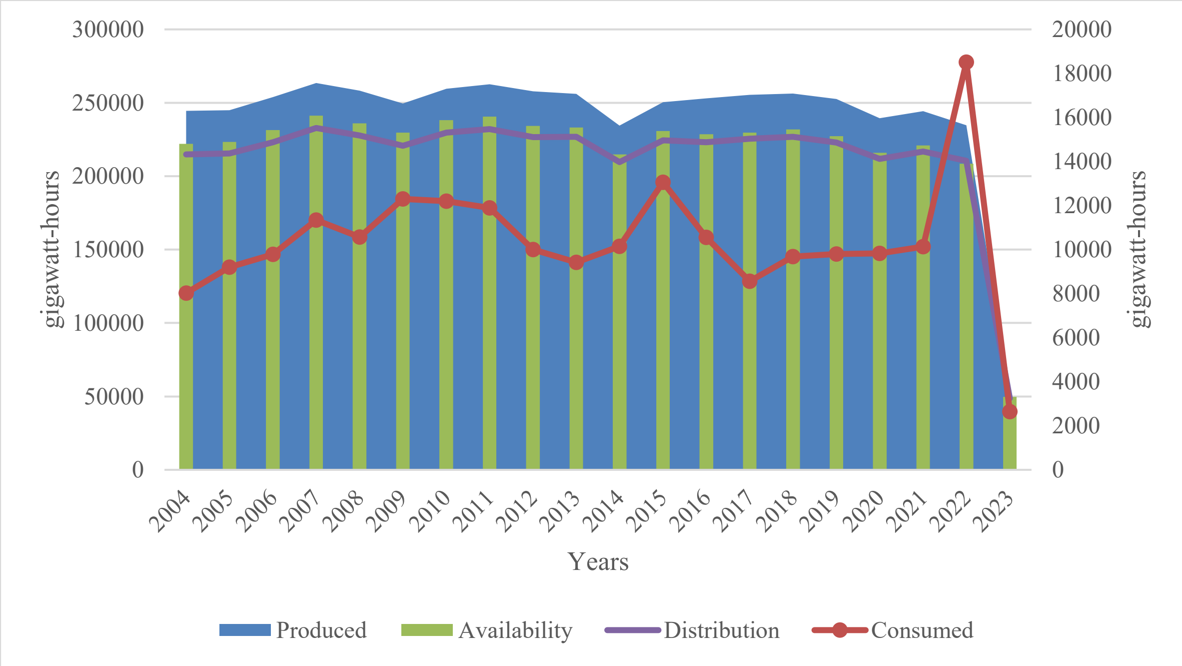

Figure 6: Electricity generated, consumed, availability and distribution in South Africa

Source: StatsSA (2023a).

In the past electricity tariff increases used to fall between the inflation target causing a real decrease in electricity price. This happened because Eskom used to follow a pricing strategy of supplying South Africa with the lowest electricity costs. However, Eskom then changed their pricing strategy in the early 2000s and electricity prices have been increasing at rates that is above inflation. In January 2023, the National Energy Regulator of South Africa (NERSA) increased prices of the electricity by 18.65 % and caused the inflation rate to remain outside the inflation target (Figure 7). The increase in the electricity tariff is anticipated to have an important change on various levels of agricultural sub-sectors and other sectors of the economy such as mining, manufacturing, and service sector. South African energy sector plays a crucial role in the agricultural, mining and manufacturing sectors. Mpatane (2015) pointed out that most of the commodities in the manufacturing industry are linked to mining activities through beneficial of the mineral and mental production. The production of these activities is known to consume more electricity due to their dependence on the availability of coal to produce electricity.

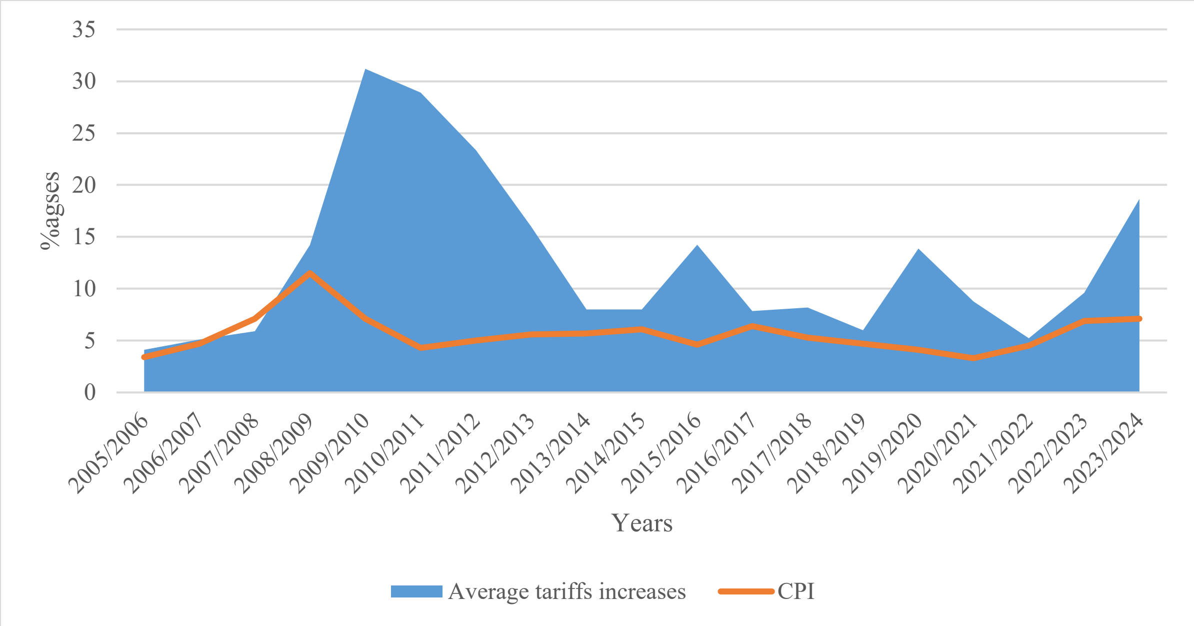

Figure 7: Average electricity tariffs increases vs Consumer Price Index (CPI)

Source: StatsSA (2023b).

The Agricultural industry is under difficult financial pressure due to factors such as the cost of electricity, which in the past was not a problem until the period of 2018-2019 when faced with energy crisis (BFAP, 2023). Electricity is considered an important cost component for irrigation farming in South Africa, taking into consideration the country is experiencing challenges for paucity of water (NAMC, 2010). Therefore, for the farmers to pump water for irrigation from various sources of water, they must rely on electricity. Troskie (2012) reported that the continued increase in the electricity prices will put more pressure in the cost of agricultural production to many farmers across the country. This is an indication that the 2023 increased electricity tariff reached approximately more than 650 % from 2007 to 2022. This proved that the announced increase in tariff for electricity during January 2023 will not only affect the agricultural sector, but also sub-sectors within agricultural production.

The concern for the agricultural industry is how many sectors will be affected and to what level will the increase in tariffs of electricity affect the agricultural industry. Mbanda and Bonga-Bonga (2018) pointed out that electricity prices hike will lessen the agricultural production, which will then further expand the market price for agricultural commodities due to high production costs. Electricity plays a crucial part towards the economy, in terms of its contribution as input and for consumption purpose. Any change that occurs in the prices will importantly have an impact in the economy. This sector demands more inputs, which then causes the sectors that provide electricity to raise their production. This sector requires more labour from other sectors of the economy, which then causes the electricity sector to increase the expenditure for wages to attract labour. It will potentially raise overall production in different sectors of the economy and then further lead to positively increase in GDP and employment.

Akkemik (2011) and He et al. (2010) pointed out that changes in electricity prices would affect producing sectors such as mining and manufacturing sectors, whereas producers' prices are affected more than consumers' prices and adversely affect GDP. Silva et al. (2009) debated that change in electricity prices requires policy measures that favour poor households as they would be affected by increase in price. Mbanda and Bonga-Bonga (2018) highlighted the price of electricity increases would have both negative and positive effects in the output of production and labour demand. Shihepo (2022) state that political factor, source of energy, lack of management and insufficient resources are some of the reasons contributed to the high electricity tariffs. High energy prices can possibly reduce welfare for households by increasing household's expenditure (Bahta et al., 2014). As highlighted by Qeqe et al. (2022) it is imperative for political leaders to review the structure for electricity tariffs in order to accommodate households that cannot afford.

Most of studies had been conducted in South Africa and abroad using the SAM price models applications. Tlhalefang and Galebotswe (2013) used a SAM price multiplier analysis to study welfare effects of higher energy and food price. While Hartono and Nugroho (2019) applied a SAM price model to find the impact of increasing the prices on the economy of Indonesia. Lambert and Gong (2010) studied energy price changes in the United States of America by measuring the degree of farm responsiveness. Van der zee (2014) reported on the modelling of electricity cost risks and opportunity in the mining industry. Mbanda and Bonga-Bonga (2018) conducted a study on the CGE microsimulation analysis of electricity tariff increase in South Africa. Doukkali and Lejars (2015) completed a study on the energy cost of irrigation policy in Morocco. Whereas Tarancon et al. (2010) reported a study on the evaluating the influence of manufacturing sectors on the demand of electricity. Nguyen (2008) wrote a study on the impact of a rise in electricity tariff on prices of other commodities in Vietnam. While Zhao and You (2008) assessed the impact of electricity price reform in the economy of China. Akkemik (2011) done a study on the impacts of electricity price changes on price formation in Turkey economy. Lastly, Seymore et al. (2009) looked on the impact of electricity generation tax on the South African economy. Most of the studies mentioned above have found that the impact of electricity price increases had a negative impact on the economy in terms of decline in GDP and increase in unemployment. These studies further reported that affordability is a big concern due to high total cost of production and increases the market prices for commodities. Researchers rarely empirically assess the impact of electricity tariffs increases on agricultural sectors at provincial and district level. This study contributes by quantifying the changes in the electricity prices impact on prices in other sectors of the economy.

The main objective of this paper is to evaluate the impact of electricity tariff increases on agricultural sector. In order to achieve the main objective, specific objectives are used to discusses the process of constructing 2017 national Social Accounting Matrices (SAM) for South Africa and further indicates the SAM price model. The SAM price model is significant to evaluate the impacts of the changes in prices of electricity on both the consumers and producers. In furtherance, the paper will contribute by quantifying how these changes in the electricity prices impact on prices in other sectors of the economy. It is therefore believed that this paper will add value to the body of knowledge which can be used during periods, just like the one South Africa is currently finding itself in, whereby there is a strong debate on the mismatch of demand and supply for electricity, and a huge crisis for energy, which is cause by this problem.

6.2. Data and approaches

6.2.1 Data

This study used 2017 national SAM for South Africa which incorporates details about regional accounts for agricultural, and electricity activities which is constructed by Ramigo et al. (2023) (See Appendix A., Table A1). Agricultural industries are identified by various production activities within regions (provinces and districts), meaning each agricultural industry represents all farming activities in the regions and each farming activities in the regions (provinces and districts) is assumed to be provided with a fixed land for production. There are two agricultural industries (irrigated and rainfed) identified per provinces and districts in South Africa. These agricultural industries are important interest to policy maker, politician, academia, and civil society in the context of development. Agricultural commodities are identified based on choice of commodities obtained from the Census of Commercial Agriculture of 2017 (StatsSA, 2020). The selected commodities are categorized according to consistence availability information for commodities. Electricity industries was categorised according to electricity generation and distribution. A SAM provide sufficient information for agricultural sector to clearly indicates important policies and strategies required for economic growth in South Africa.

Different sources used to build the SAM, as a result, SAM unbalanced. As a matter of principle, the SAM must be balanced. This problem often happens when constructing database for a SAM due to incomplete and inconsistent data sources. Therefore, different methods or techniques such as RAS, cross entropy and excel manual estimation are employed to evaluate the missing data and balanced SAM to be utilized for policy analyses. In this particular case excel manual estimation method applied. Round (2003) stated that difference approaches estimate the different between the estimated values and prior values in various ways. The author further mentioned that not all approaches clearly estimate the difference, however for those methods that don't, there is always a way to reduce a difference in estimate. Round (2003) mentioned two problems that are found in balancing: When balancing and adjusting the Input and Output tables (I/O) and SAM based input- output table certain constraints are known in the row and column; and other problem occurs when the constraints for balancing row and column total in a SAM are not found. The RAS approach is often used in the I/O tables when constraints are known, but other approaches such as Cross Entropy (CE) and Generalised Cross Entropy (GCE) are often applied when constraints are not found.

The original SAMs always has accounts that are not equals in the row and column totals, therefore the manual balancing estimation in excel was utilized for balancing the SAM. This approach often used when there is incomplete and inconsistence data source. The micro-SAM had a single account for electricity which was then disaggregated according to electricity generation and distribution to contain complete information. The next step was to disaggregate the agricultural commodities and industries. The overall values of disaggregation sub-matrices are always not equal to the overall values of sub-matrices before disaggregation. Therefore, some of the shares from electricity was then distributed to all the sectors of the economy that depends on the electricity for production purpose. This process of disaggregation was completed, and the SAM balanced using excel manual. Punt (2013) and Provide (2003) defines SAM as transaction that are transpire in the economy for a period of one year. This particular transaction shows receipts and payment in the economy (Mare and Bahta, 2022). In addition, a SAM is considered square if the column totals and row totals are equals (Round, 2003).

6.2.2. SAM price model

There are many literatures that explains on how a SAM database are changed to SAM based Input-output model to calculate multiplier (Miller and Blair, 2009). The starting point of changing a SAM database to a model is to identify some of the behaviour assumptions. These assumptions are as follows:

- Prices are independently determined of quantities;
- Inputs coefficients are fixed for endogenous accounts such as producers and consumptions patterns for households
- There is an excess capacity in the economy

Under the above-mentioned assumptions, changes in exogenous prices will lead to an adjustment of endogenous prices.

The SAM structure focus on activity of endogenous sectors. These sectors are opted based on the assumption to undertaking economic activities. Furthermore, the accounts in a SAM comprises of the endogenous and exogenous sectors. Accounts in the endogenous are those accounts that expenditure are set independently from income. For this study, the 2017 national accounts in a SAM are selected in a way that accounts for industries, primary inputs and households are endogenous and other accounts are exogenous such government, investment and exports.

The important assumption for price model is that prices are evaluated according to production costs with supplier transferring the burden to the consumer whereas at the same time consumers are known as the price takers (Mare and Bahta, 2022). The prices are evaluated by costs of exogenous values of primary factors inputs (Miller and Blair, 2009). This implied that changes in factor input prices results to changes in production unit costs (e,g changes in output prices not output quantities) through fixed production sectors rows (receipts) in the direct total requirement matrix. Let A_{ij} represents the column of technical coefficients obtained by dividing the transactions in the SAM matrix (X_{ij}), and ($[1 - A]^{-1}$) denotes the total requirement matrix, which transpose to present in row matrix.

The SAM price multiplier is expressed by the equation below as:

$$P = V^1[1 - A]^{-1} \tag{17}$$

$$P = V^1 MP_1 \tag{18}$$

$$\Delta P = \Delta V^1 MP \tag{19}$$

Where Δ represents change and MP denote price multiplier matrix and attained by reading across the rows of the inverse matrix of Leontief ($[1 - A]^{-1}$) of the endogenous income determination model. This equation indicates that the changes on prices of the endogenous sectors because of a unit change in the price of exogenous sector, provided that each sector is determine by the price multiplier (MP). The overall change of a shock on each sector in the economy is a result of price multiplier and the size of the shock (V). The price model is referred as the cost push price model, and within the model quantities are fixed and prices are flexible (changes). The values obtained in cost push price model is used to estimate the effect on prices throughout the economy of new primary factor input costs in various sectors (Miller and Blair, 2009). Therefore, the prices are evaluated through costs of exogenous values of primary factors inputs. Hence, the output prices are set to be equal to total production costs, which then lead to each price equal to 1.

In order to assess the effect of electricity price changes on agricultural sector in different regions/provinces and districts of South Africa, the SAM price modelling technique was applied. According to Miller and Blair (2009) changes in the costs of primary input are transferred in the economy which then distributed by producers in the forms of prices of their commodities which are bought by intermediate users who also raise their prices accordingly.

In the past, electricity tariff increases used to fall between the inflation target, causing a real decrease in electricity prices. This happened because Eskom (The South African Electricity Supply Commission) followed a pricing strategy to supply South Africa with the lowest electricity costs. However, Eskom then changed its pricing strategy in the early 2000s, and electricity prices have been increasing at rates that are above inflation. This year, in January 2023, the National Energy Regulator of South Africa (NERSA) increased the prices of electricity by 18.65 % and caused the inflation rate to remain outside the inflation target. The recent increase in the electricity tariff is anticipated to bring about an essential change at various levels of agricultural sub-sectors and other sectors of the economy, such as mining, manufacturing, and service sectors. South African energy sector plays a crucial role in the agricultural, mining, and manufacturing sectors.

6.3. Results

This section is based on the empirical application that mainly focuses on an initial calibration of the model that produces all the prices to be equal to one. This makes it explicitly doable to interpret the values in matrix "M" by displaying the shares of different prices. The information recorded in the SAM prices model shows the impacts on endogenous prices resulting from exogenous costs received. This perspective of price effects allows the identification of changes in the relative prices of production sectors. Table 21 indicates that the price for rainfed agricultural industry is much higher than the price for irrigation agricultural industry in all the regions in South Africa. The North West, Mpumalanga and Limpopo province had a highest prices increased for the rainfed agricultural production with an increased prices of 0.56, 0.55 and 0.48 %s respectively. Whereas the irrigation agricultural production costs were higher in the Northern Cape province with an increase of 0.11 %, followed by Limpopo and Eastern Cape provinces with an increased prices of 0.04 and 0.03 %s respectively.

The prices for rainfed in the Limpopo districts found to be much higher than the prices for irrigation agricultural industry. This is due to the creases of prices of the electricity which caused the production inputs costs to go up. the districts with the highest prices were Sekhukhune district rainfed agricultural industry with an increase of 0.82 %, whereas prices for irrigation agricultural industry increased by 0.08 %.

Table 18: Effect of electricity prices increases on agricultural sectors.

Industries	**Value Added**	**Old Price**	**Exogenous costs**	**New Price**	**% Change**
Irrigation Agric Western Cape (WC) Province	0.9236	1	0.9266	1.0002	0.0194
rainfed Agric (WC) Province	0.2303	1	0.2305	1.0026	0.2560
Irrigation Agric Eastern Cape (EC) Province	0.8469	1	0.8531	1.0004	0.0389
rainfed Agric (EC) Province	0.2415	1	0.2416	1.0030	0.2997
Irrigation Agric Northern Cape (NC) Province	0.6009	1	0.6019	1.0011	0.1054
rainfed Agric (NC) Province	0.7293	1	0.7293	1.0021	0.2149
Irrigation Agric Free State (FS) Province	0.9626	1	0.9630	1.0001	0.0098
rainfed Agric (FS) Province	0.3138	1	0.3141	1.0030	0.3046
Irrigation Agric Kwazulu-Natal (KZN) Province	0.9598	1	0.9615	1.0001	0.0102
rainfed Agric (KZN) Province	0.1975	1	0.1983	1.0034	0.3381
Irrigation Agric North West (NW) Province	0.9709	1	0.9715	1.0001	0.0075
rainfed Agric (NW) Province	0.2352	1	0.2360	1.0056	0.5619
Irrigation Agric Gateng (GG) Province	0.9359	1	0.9630	1.0001	0.0098
rainfed Agric (GG) Province	0.0264	1	0.0277	1.0038	0.3782
Irrigation Agric Mpumalanga (MP) Province	0.9817	1	0.9823	1.0000	0.0047
rainfed Agric (MP) Province	0.1044	1	0.1049	1.0055	0.5535
Irrigation Agric Limpopo (LP) Province	0.8397	1	0.8412	1.0005	0.0420
Rainfed Agric (LP) Province	0.3424	1	0.3430	1.0049	0.4855
Irrigation Agric Mopani	0.9120	1	0.9134	1.0002	0.0229

Industries	Value Added	Old Price	Exogenous costs	New Price	% Change
rainfed Agric Mopani	0.5808	1	0.5817	1.0036	0.3616
Irrigation Agric Vhembe	0.8897	1	0.8914	1.0003	0.0288
rainfed Agric Vhembe	0.3010	1	0.3016	1.0032	0.3154
Irrigation Agric Capricorn	0.9480	1	0.9494	1.0001	0.0134
rainfed Agric Capricorn	0.2569	1	0.2573	1.0049	0.4935
Irrigation Agric Waterberg	0.7602	1	0.7618	1.0006	0.0631
rainfed Agric Waterberg	0.4318	1	0.4327	1.0044	0.4381
Irrigation Agric Sekhukhune	0.6885	1	0.6901	1.0008	0.0821
rainfed Agric Sekhukhune	0.1414	1	0.1417	1.0082	0.8188
Forestry	0.4110	1	0.4230	1.0029	0.2890
Fishing	0.7406	1	0.7436	1.0009	0.0888
Mining of coal and lignite	0.6695	1	0.6773	1.0018	0.1814
Mining of gold and uranium ore	0.5300	1	0.5455	1.0126	1.2565
Mining of metal ores	0.6209	1	0.6246	1.0043	0.4256
Other mining and quarrying	0.5268	1	0.5318	1.0027	0.2662
Food	0.3224	1	0.3238	1.0023	0.2305
Beverages and tobacco	0.3406	1	0.3486	1.0016	0.1597
Spinning. weaving and finishing of textiles	0.1724	1	0.1759	1.0041	0.4096
Knitted. crouched fabrics. wearing apparel. fur articles	0.2162	1	0.2226	1.0029	0.2856
Tanning and dressing of leather	0.2211	1	0.2210	1.0008	0.0811
Footwear	0.1708	1	0.1798	1.0017	0.1704
Sawmilling. planing of wood. cork. straw	0.3956	1	0.3996	1.0026	0.2553
Paper	0.2359	1	0.2371	1.0040	0.3956
Publishing. printing. recorded media	0.2761	1	0.2841	1.0022	0.2207
Coke oven. petroleum refineries	0.2445	1	0.2498	1.0019	0.1916
Nuclear fuel. basic chemicals	0.1837	1	0.1747	1.0102	1.0231
Other chemical products. man-made fibres	0.2143	1	0.2195	1.0055	0.5464
Rubber	0.2884	1	0.2900	1.0039	0.3858
Plastic	0.3477	1	0.3470	1.0035	0.3539
Glass	0.3019	1	0.3080	1.0071	0.7104
Non-metallic minerals	0.2320	1	0.2350	1.0033	0.3275
Basic iron and steel. casting of metals	0.1027	1	0.1059	1.0101	1.0086
Basic precious and non-ferrous metals	0.2130	1	0.2151	1.0112	1.1237
Fabricated metal products	0.2678	1	0.2689	1.0060	0.5952
Machinery and equipment	0.3268	1	0.3272	1.0034	0.3415
Electrical machinery and apparatus	0.1608	1	0.1661	1.0045	0.4485

Industries	Value Added	Old Price	Exogenous costs	New Price	% Change
Radio. television. communication equipment and apparatus	0.2914	1	0.2927	1.0019	0.1896
Medical. precision. optical instruments. watches and clocks	0.3155	1	0.3258	1.0022	0.2210
Motor vehicles. trailers. parts	0.1704	1	0.1709	1.0033	0.3349
Other transport equipment	0.3665	1	0.3705	1.0026	0.2573
Furniture	0.2129	1	0.2161	1.0029	0.2903
Manufacturing n.e.c. recycling	0.4097	1	0.4130	1.0019	0.1863
Electricity generation	0.6235	1	0.7407	1.1247	12.4716
Electricity distribution	0.5250	1	0.6246	1.0990	9.9009
Collection. purification and distribution of water	0.4958	1	0.4918	1.0014	0.1368
Construction	0.3001	1	0.3039	1.0019	0.1853
Wholesale trade. commission trade	0.5102	1	0.5226	1.0013	0.1278
Retail trade	0.5272	1	0.5396	1.0017	0.1730
Sale. maintenance. repair of motor vehicles	0.5451	1	0.5555	1.0016	0.1573
Hotels and restaurants	0.3878	1	0.3999	1.0020	0.1953
Land transport. transport via pipelines	0.5489	1	0.5582	1.0017	0.1684
Water transport	0.4218	1	0.4338	1.0010	0.0953
Air transport	0.3511	1	0.3564	1.0011	0.1068
Auxiliary transport	0.4604	1	0.4671	1.0013	0.1278
Post and telecommunication	0.3390	1	0.3451	1.0012	0.1218
Financial intermediation	0.5794	1	0.5904	1.0007	0.0693
Insurance and pension funding	0.4523	1	0.4632	1.0004	0.0440
Activities to financial intermediation	0.4450	1	0.4507	1.0001	0.0132
Real estate activities	0.4938	1	0.5702	1.0030	0.3029
Renting of machinery and equipment	0.3035	1	0.3104	1.0017	0.1681
Computer and related activities	0.2349	1	0.2396	1.0025	0.2469
Research and experimental development	0.6736	1	0.6733	1.0009	0.0902
Other business activities	0.3614	1	0.3647	1.0031	0.3116
Government	0.6925	1	0.7006	1.0006	0.0613
Education	0.4738	1	0.4927	1.0024	0.2411
Health and social work	0.4086	1	0.4195	1.0021	0.2093
Sewerage and refuse disposal	0.5351	1	0.4444	1.0013	0.1261
Activities of membership organisations	0.3717	1	0.4014	1.0024	0.2384
Recreational. cultural and sporting activities	0.2341	1	0.2561	1.0025	0.2466
Other activities	0.2654	1	0.2910	1.0032	0.3220

Industries	Value Added	Old Price	Exogenous costs	New Price	% Change
Non-observed. informal. non-profit. households.	0.6371	1	0.6371	1.0010	0.0958

Source: Own Calculations

6.4. Discussion

This study main purpose is to determine the impact of electricity tariffs increases on the agricultural industry in South Africa using the cost push price model. The study found that the price for rainfed agricultural industry is much higher than the price for irrigation agricultural industry in all the regions in South Africa. The increased in the prices for rainfed agricultural industry across various provinces in South Africa maybe attributed to the increased of electricity prices as announced by the NERSA. In addition, agricultural production is mostly rainfed due to insufficient and uneven rainfall across South African provinces. The North West, Mpumalanga and Limpopo province had a highest prices increased for the rainfed agricultural production with an increased prices of 0.56, 0.55 and 0.48 %s respectively. As stated by QeQe et al. (2022) and Troskie (2012), the electricity price hike will lessen agricultural production due to reduced available resources, which will then further expand the market price for agricultural products due to high production costs. The increase in electricity prices and the shortage of electricity provide an incentive for agricultural industries to invest in appropriate mitigation strategies such as renewable energy sources.

The irrigation agricultural production costs were higher in the Northern Cape province with an increase of 0.11 %, followed by Limpopo and Eastern Cape provinces with an increased prices of 0.04 and 0.03 %s respectively. As stated by NAMC (2010) electricity is considered a vital cost component for irrigation farming in South Africa because most of the farmers rely on electricity to pump water for irrigation. In addition, irrigation is significant in the economy of Northern Cape and Limpopo because these provinces are mostly desert, and many farmers rely on irrigation to increase yield. Sekhukhune district had the highest production costs for both rainfed and irrigation agriculture compared to other districts in Limpopo province.

6.5. Conclusions, policy implications and recommendations

Using a 2017 National Social Accounting Matrix (SAM) for South Africa as a dataset, this paper computes the effect of electricity tariff increases on agricultural sectors with the use of the SAM price model. This study further contributes by quantifying how these changes in electricity prices impact prices in other sectors of the economy. This paper concluded that the rainfed agricultural industry had higher prices compared to irrigation agricultural industry in across South African province. This was attributed to the fact that most of the provinces in the country cultivate their agricultural production in the rainfed due to insufficient or uneven rainfall caused by climate change. An increased prices in the irrigation agricultural industry in Northern Cape, Limpopo and Eastern Cape provinces was the results of the majority of the farmers used irrigation methods to increase their yield. Adequate production and availability of electricity play an imperative role in increasing agricultural output in any economy. Therefore, it is significant that policymakers, academics, and stakeholders formulate policies and strategies that reduce the costs of electricity generation. The expansion of the electricity sector will not only boost the agricultural sector in one region but will also increase output in other regions of the economy. This study suggested that the South African government should focus on increasing the investment in electricity transmission lines and power grinds projects to provide lower costs of producing electricity inputs to industries.

The results of this paper are limited to the range of irrigated and rainfed agricultural industries, electricity (generations and distributions). Future researchers could consider disaggregating agriculture according to different crops in order to evaluate the economic impact of electricity price increases on agricultural subsectors at the regional level. The data did not include all the districts in South Africa; therefore, it is imperative that researchers, academia, and stakeholders consider focusing on other districts and possibly adding other accounts from local municipalities.

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Appendix A.

Table 2.A: Accounts in the national SAM for South Africa

Industries	Commodities	Transaction	Labour	Capital	Land	Enterprises	Households
Irrigation Agric WC	Agriculture	Transaction	Western Cape Labours	Capital	Irrigated land	Enterprises	Western Cape households
rainfed Agric WC	Live animal		Eastern Cape Labours		Dry land		Eastern Cape households
Irrigation Agric EC	Forestry		Northern Cape Labours				Northern Cape households
rainfed Agric EC	Fishing		Free State Labours				Free State households
Irrigation Agric NC	Coal and lignite		Kwazulu_Natal Labours				Kwazulu_Natal households
rainfed Agric NC	Metal ores		North West Labours				North West households
Irrigation Agric FS	Other minerals		Gauteng Labours				Gauteng houeholds
rainfed Agric FS	Electricity and gas		Mpumalanga Labours				Mpumalanga households
Irrigation Agric KZN	Natural water		Mopani_Labours				Mopani households
rainfed Agric KZN	Meat		Vhembe_Labours				Vhembe households
Irrigation Agric NW	Fish		Capricorn_Labours				Capricorn households
rainfed Agric NW	Vegetables		Waterberg_Labours				Waterberg households
Irrigation Agric GP	Fruit and nuts		Sekhukhune_Labours				Sekhukhune households
rainfed Agric GP	Oils and fats						
Irrigation Agric MP	Dairy products						
rainfed Agric MP	Grain mill products						

Irrigation Agric Mopani	Starches products
rainfed Agric Mopani	Animal feeding
Irrigation Agric Vhembe	Bakery products
rainfed Agric Vhembe	Sugar
Irrigation Agric Capricorn	Confectionary products
rainfed Agric Capricorn	Pasta products
Irrigation Agric Waterberg	Food n.e.c.
rainfed Agric Waterberg	Alcohol, beverages
Irrigation Agric Sekhukhune	Soft drinks
rainfed Agric Sekhukhune	Tobacco products
Forestry	Textile fabrics
Fishing	Made-up textile, articles
Mining of coal and lignite	Carpets
Mining of gold and uranium ore	Textile n.e.c.
Mining of metal ores	Knitting fabrics
Other mining and quarrying	Wearing apparel

Food	Leather products
Beverages and tobacco	Footwear
Spinning, weaving and finishing of textiles	Wood products
Knitted, crouched fabrics, wearing apparel, fur articles	Paper products
Tanning and dressing of leather	Printing
Footwear	Petroleum products
Sawmilling, planing of wood, cork, straw	Basic chemicals
Paper	Fertilizers, pesticides
Publishing, printing, recorded media	Paint, related products
Coke oven, petroleum refineries	Pharmaceutical products
Nuclear fuel, basic chemicals	Soap, cleaning, perfume
Other chemical products, man-made fibres	Chemical products, n.e.c.
Rubber	Rubber tyres
Plastic	Other rubber products
Glass	Plastic products
Non-metallic minerals	Glass products

Basic iron and steel, casting of metals	Non-structural ceramic
Basic precious and non-ferrous metals	Structure non-refractory clay
Fabricated metal products	Plaster, cement
Machinery and equipment	Articles of concrete
Electrical machinery and apparatus	Non-metallic products n.e.c.
Radio, television, communication equipment and apparatus	Furniture
Medical, precision, optical instruments, watches and clocks	Jewellery
Motor vehicles, trailers, parts	Manufactured products n.e.c.
Other transport equipment	Wastes, scraps
Furniture	Iron, steel products
Manufacturing n.e.c, recycling	Non-ferrous metals
Electricity, gas, steam and hot water supply	Structural metal products
Collection, purification and distribution of water	Tanks, reservoirs

Construction	Other fabricated metal
Wholesale trade, commission trade	Engines, turbines
Retail trade	Pumps, compressors
Sale, maintenance, repair of motor vehicles	Bearings, gears
Hotels and restaurants	Lifting equipment
Land transport, transport via pipe lines	General machinery
Water transport	Special machinery
Air transport	Domestic appliances
Auxiliary transport	Office machinery
Post and telecommunication	Electrical machinery
Financial intermediation	Radio, television
Insurance and pension funding	Medical appliances
Activities to financial intermediation	Motor vehicles, parts
Real estate activities	Ships and boats
Renting of machinery and equipment	Railway and trams
Computer and related activities	Aircrafts

Research and experimental development	Other transport equipment
Other business activities	Construction
Government	Construction services
Education	Trade services
Health and social work	Accommodation
Sewerage and refuse disposal	Catering services
Activities of membership organisations	Passenger transport
Recreational, cultural and sporting activities	Freight transport
Other activities	Supporting transport services
Non-observed, informal, non-profit, households,	Postal, courier services
	Electricity distribution
	Water distribution
	Financial services
	Insurance, pension
	Other financial services
	Real estate services
	Leasing, Rental services
	Research, development
	Legal, accounting

	Other business services
	Telecommunications
	Support services
	Manufactured services n.e.c.
	Public administration
	Education services
	Health, social services
	Other services n.e.c.

Chapter 7: Modelling the effect of irrigation systems and water uses on Maize industry in the economy of Limpopo Province

Pfunzo, R., Bahta, Y.T. and Jordaan, H. 2024.Modeling the effect of irrigation systems and water uses on the Maize industry in the economy of Limpopo Province. Discover Sustainability.

Abstract

Enhancing the irrigation system and efficient use of water is key to reducing food insecurity and hunger with the alignment of Sustainable Development Goals (SDGs) of ending hunger and poverty and the National Development (NDP) of South Africa. The purpose of the research is to evaluate irrigation systems and water uses on maize output, income, land returns, and value-added/GDP in Limpopo province, South Africa. This study applied a 2021 provincial Social Accounting Matrix (SAM) database and SAM multiplier analysis. The results reported that micro and drip irrigation systems had a most considerable output multiplier effect. However, pivot, sprinkler, drip, and micro-irrigation generate less value added and institutional incomes than other irrigation systems such as canal, flood, and coupling line irrigations. This implies that irrigation systems play a significant role in terms of increasing maize output, saving water, and improving food security, which further allows farmers to adopt these irrigation systems. To enhance the value addition of pivot irrigation, farmers should significantly restrict water application to farms with reduced hectares to maximize profit. Water schemes and groundwater had the highest farm return on maize in the province. The study concludes that the groundwater and water schemes play a significant role in growing and sustaining the maize industry and other agricultural industries in reducing food insecurity and as a catalyst to attain the SDGs of ending hunger and poverty. Therefore, investment in irrigation infrastructure for these systems would improve affordability and accessibility for all farmers and further create better incomes.

Keywords: Irrigation systems · Value added · Maize · Output · Incomes · Land · Climate

7.1. Introduction

In arid and semi-arid areas of Sub-Saharan Africa, including Southern Africa, droughts frequently cause significant economic losses and increase food insecurity [1]. The agricultural sector relied on climate for crop productivity, quality, and profitability. The industry has been negatively affected by climate change due to severe drought, and the ongoing drought that El Nino caused in different parts of Southern Africa is expected to decrease maize yields in South Africa by 17% [2].

Globally, maize has played an essential role in meeting world food requirements, and its yield records for nearly 30% of the world's agricultural production [2-3]. In South Africa, only 90% of the maize is produced in dry land due to insufficient rainfall. Water availability has become a big issue in South Africa due to climate change. It poses the most significant crop production risks to irrigated agriculture in different parts of South Africa [4]. The ongoing severe droughts in other parts of regions caused by climate change and growing competition for limited water resources from different users threatened the sustainability and growth of irrigated agriculture [1]. Ntshidi et al. [5] stated that the agricultural sector recorded only 60% of the country's freshwater resources for irrigation agriculture to support the insufficient rainfall. Therefore, irrigation agriculture is essential for sustaining and growing the agricultural industry, for achieving food security, and for alleviation of poverty and hunger [6].

South Africa is one of the significant maize exporters in the global market, representing 2.3% of the export market share, and it is ranked 8^{th} in the world. South Africa exported 80% of maize and imported 2% of maize, with a trade surplus of R21.8 million (1.2 million US dollars) in the period of 2023 [7]. The main production areas for maize in the country are Free State, North West, and Mpumalanga provinces, which exported only 59%, 89%, and 98%, respectively, of the total grain industry [8]. This is due to the country's being self-sufficient in the production of maize and making significant crops in terms of raw materials for food, textiles, and animal feed industry [9]. However, many households in Limpopo province are food insecure [10-11]. This could be attributed to a lack of access to food, which is directly linked to income, and low production and yield caused by drought that led to a small market share of about 2% of maize exports in the Limpopo province [8, 12]. Thus, there is a need to sustain and grow the maize industry by enhancing water use efficiency, efficient irrigation management, and water-saving technologies.

As pointed out by Jovanivic et al. [13], irrigation agriculture in the South African maize industry has a mandate of using less but adequate irrigation water to meet the water requirement for crops without reducing the quality, yield, and profit for maize farmers. The available sources of water for farming won't meet the continuous increase of demand due to water scarcity, which changes with weather patterns. Hence, water scarcity in South Africa is also deeply linked with food insecurity.

Dzikiti et al. [14] reported that only 45% of irrigation water in South Africa is misused or wasted through poor irrigation scheduling, pipe leakage, and non-beneficial water use. This is an indication that the country needs to be more efficient in using water for irrigated agriculture. Limpopo province is experiencing water scarcity, and water accessibility and management are critical issues experienced by various farmers in the province [15]. The challenge of insufficient and inefficient use of various irrigation systems is linked with investment and operational costs, leading to irrigation techniques and yield. There is a need to protect water resources on multiple catchments in the country to support and improve the efficiency of agriculture. Therefore, irrigation systems play an essential role in achieving food security and in the generation of income. As stated by Ramigo et al. [16], increasing the efficiency and sustainability of existing irrigation agriculture in Limpopo is of paramount importance and profitable due to insufficient rainfall in the province.

International and National studies reveal that maize performs better under the drip and furrow irrigation systems, and the water used requirement was estimated to be between 351 and 685 mm [17]. In addition, the study reported that the drip-irrigated maize had a higher yield and profit compared to the furrow-irrigated crops. Wang et al. [18] reported different results for drip irrigation and flood irrigation for maize; drip irrigation was found to consume more groundwater than flood irrigation. The authors further stated that yield under drip irrigation increases compared with that of flood irrigation. Irfan et al. [19] pointed out that maize crop yield and water use efficiency are higher for drip irrigation with good-quality water. The authors further highlighted that drip irrigation would be more suitable for adoption where groundwater quality would be used to achieve high crop production and increase water efficiency.

Zhang et al. [20] found that drip and furrow irrigation obtained good yield and net profit with a reduced water application. This is due to drip irrigation with a high-water consumption coefficient in Maize compared to furrow and border irrigations. Hence, furrow and drip irrigations have been preferred to produce highly efficient irrigation and increase water use efficiency across the world compared to flood irrigation, which reduced water use efficiency. Parvar et al. [21] estimated the impact of water reduction on the production sectors of Iran's economy. They found that water resource constraints lead to a decrease in production and incomes and an increase in poverty across various economic sectors. In addition, water resources constraints have a more significant impact on gross operating surplus than on labor. Hence, the optimization of water consumption in crop production is more critical due to the relative share of water use in the agricultural sector being higher than in other economic sectors.

Xu et al. [22] modelled the effect of irrigation systems and water use efficiency on maize yield in China. They found that the significance of drip irrigation over border irrigation reduced evaporation without affecting the transpiration rate for cereals crops. They further highlighted that drip irrigation improves grain quality and water use efficacies and reduces water loss through runoff and drainage. Liu et al. [23] studied the impact of different irrigation techniques on the water productivity of wheat. They found higher water productivity for drip-irrigated wheat compared to sprinkler-irrigated wheat. Drip irrigation is a better technique in terms of saving irrigation water and increasing.

Kotze et al. [24] pointed out that improving water allocation with better use of groundwater savings would lead to better water management and further enhance irrigation efficiency. Ketsela et al. [25] recommended the adoption of a water harvesting method to reduce water scarcity problems. This method was proposed due to the net volume of water harvested during night storage, and it significantly helps to enhance water management and sustainability. Jordaan and Bahta [26] studied the mitigation of water use irrigation agriculture in South Africa. They reported that the pivot irrigated maize and wheat yield decreased because of increased input costs, such as fertilizer and oils. They further highlighted that to improve the maize and wheat yield for pivot irrigation, it is significant to restrict water applications using a limited number of hectares to maximize profit. However, studies have yet to directly compute in detail various irrigation systems by the source of water used in crop production, such as maize in the arid and semi-arid conditions of Limpopo province, using Social Accounting Matrix (SAM) based modelling. This research aimed to close this significant gap by evaluating irrigation systems and water uses on maize output, income, land returns, and value-added/GDP in Limpopo province, South Africa. The study intends to address a research question: What is the economic effect of irrigation systems/techniques on Maize output and income, land returns, and value-added/GDP in Limpopo province, South Africa? What is the economic effect of water use on Maize farm return? Hypothesizing irrigation technique has significantly enhanced crop yield and household incomes.

The following sections will briefly discuss the data and method used in this research, then analyze the results and further present a conclusion.

7.2. Data and methods

7.2.1. Data

This study applied a 2021 provincial SAM database for Limpopo province to model the effect of irrigation systems and water uses on the Maize industry on the economy of Limpopo province, South Africa. The 2021 SAM is the most recent data available for Limpopo province and is suitable for analysis of this research. This provincial SAM was developed by the author (Ramigo) [27] (See Appendix A: Table 24), which includes details of disaggregation for agricultural industries. In developing a 2021 Limpopo SAM with detailed agricultural accounts is to combine data from the provincial accounts and 2021 Supply and Use Tables (SUTs.). This is done by deriving the shares accounts of Limpopo province from the SUTs. The 13 provincial accounts were used as a starting point to obtain more detailed information from the populated shares in the SUTs [8, 28]. The original SUTs for 2021 have 124 activities and 108 commodities.

The Limpopo SAM comprises details of agricultural industries and products, labor, land, and households, which makes it particularly significant for modelling the effect of irrigation systems and water use on the Maize industry in Limpopo province. Agricultural sectors are categorized according to various production activities engaged in the Limpopo, meaning each agricultural industry represents all the production taking place in the province. Agricultural production is assumed to be provided fixed agricultural land for production. The Limpopo SAM needed to provide information on farm accounts. Therefore, an estimation of farm accounts was made based on gross operating surplus (GOS)/mixed income. It is assumed that 7% of the farm returns from GOS for each farming production that is taking place in the economy. In addition, the farm accounts were further disaggregated according to the source of water used for crop production: municipal water supply, river, dam, water schemes, groundwater, rainwater harvesting, and other sources of water). Agricultural industries and products were disaggregated according to 43 commodities (Maize, Wheat, Grain Sorghum, Barley, Oats, Sunflower, Soybeans, Dry beans, Lucerne, Other field crops, Potatoes, Onions, Tomatoes, Cabbages, Carrots, Sweet Potatoes, Beetroot, Pumpkins, Oranges, Nartjies, Lemons, Grapefruits, Watermelons, Mangoes, Avocados, Bananas, Pineapples, Apples, Peaches, Tables grapes, Macadamia nuts, Pecan nuts, Other fruits, Cattle_Beef, Cattle dairy, Sheep_non wool, Sheep_wool, Goats, Pigs, Chicken's broilers, Chicken's layers, Ostriches, and Others live animals) agricultural subsectors in the province.

The maize industry was the only account disaggregated according to irrigation systems such as sprinkler, drip, pivot, micro, and other irrigation accounts. The disaggregation information on the output values for agricultural industries was obtained from the Limpopo Provincial Census Commercial of Agriculture 2017 [29].

The single labor and household accounts were disaggregated according to district levels: Capricorn, Mopani, Sekhukhune, Vhembe, and Waterberg. This information was obtained from the Quantec Easy Data [30] and Stats SA-Living Condition Surveys 2014/2015 [31]. The data information for trade (exports and imports) was obtained from the Quantec Easy Data [8]. In addition, the trade accounts were split according to the rest of South Africa and the Rest of the world. It is assumed that some of the commodities produced in the Limpopo province are distributed to other provinces in South Africa and reminder are further exported to the rest of the world.

7.2.2. Methods

The SAM-based model derived from the closed models is higher than the open models due to an additional consumption linkage (induced effect) obtained from the closed models [16]. The open SAM-based model was obtained whereby the total output equates to the total demand, as recorded below:

$$\mathbf{X=Ax+f} \tag{20}$$

Where "**(x)**" represents a vector of total output, "**Ax**" denotes the sum of endogenous demands, and "**f**" signifies exogenous demands. The matrix "**A**" is reported to be the direct technical coefficient matrix. Assuming **"A"** is parametric, then any change that occurred in "**f**" must be accompanied by a similar change in **"X"**. This matrix indicates whether the model solution relies on a singular, square, or rectangular matrix.

$$\mathbf{X} = (\mathbf{I}-\mathbf{A})^{-\mathbf{1}}\mathbf{f} \ = \mathbf{Lf} \tag{21}$$

Where "**L**" signifies the Leontief inverse matrix of the open model, which plays a significant role in linking final demand to industry output, in a close model, the model is added to include factors of production and household accounts as indicated by Miller and Blair [32], and it is reported as:

$$\bar{\mathbf{x}} = (\mathbf{I}-\bar{\mathbf{A}})^{-\mathbf{1}}\bar{\mathbf{f}} \ = \bar{\mathbf{L}}\bar{\mathbf{f}} \tag{22}$$

Where "$\bar{\mathbf{x}}$" is an augmented vector output, whereas x is an industry output. The Matrix "$\bar{\mathbf{A}}$" is the augmented direct technical coefficients matrix, whereas "$\bar{\mathbf{f}}$" recorded the augmented final demand and "**L**" represent the Leontief inverse matrix of the closed models. This study uses the SAM close models to compute Output, Incomes (Households and Enterprises), Labour, Land returns, and Gross Value added (GVA) multipliers in the industry-by-industry (I-by-I) Leontief inverse matrix.

7.3. Results

This section presents the results and discussions of maize output, gross value added, income, and Land return from the industry-by-industry Leontief inverse matrix.

7.3.1. Output

Figure 8 records that, on average, the Output multiplier effects for maize irrigation systems generate R1.7 million output for every R1 million injected into the economy of Limpopo ((South African Currency-US Dollar = 15.96 ZAR (Average exchange rate in 2021)). Micro irrigation had the most significant output multiplier of R1.9 million, followed by drip irrigation with an increase of R1.8 million, Sprinkler irrigation (R1.7 million), pivot irrigation (R1.6 million), and other irrigation systems (R1.5 million).

7.3.2. Gross Value-Added (GVA)

In terms of the Gross Value Added (GVA), on average, as shown in Figure 1, the maize industry had a GVA of R583 412 in the economy of Limpopo province. Of these, the most significant maize industry GVA was for other irrigation systems such as canal, flood, and coupling line irrigation systems, with an increase of 693 119 Value added. The pivot irrigation increased maize value by R634 011 for every R1 million invested in the economy, followed by sprinkler, drip, and micro irrigation systems. This finding shows that pivot, sprinkler, and drip irrigation generates less GVA than other irrigation, such as canal and flood irrigation. Maize pivot irrigation generates the most considerable labor remuneration of about R120 321 in the economy, followed by Sprinkler irrigation with only R116 890, drip irrigation (R115 870), micro-irrigation (R111 726), and other irrigation systems with the least labor remuneration of R93 789.

7.3.3. Institutional incomes

A summary of the results of the institutional income multiplier for the regional economy of Limpopo province is reported in Figure 8. The results show that other irrigation systems such as canal, flood, and coupling lines had the highest institutional income of R749 620 in the Maize industry compared to pivot, sprinkler, drip irrigation, and micro irrigation. Overage Maize industry increases incomes by R664 537 in the economy of Limpopo province.

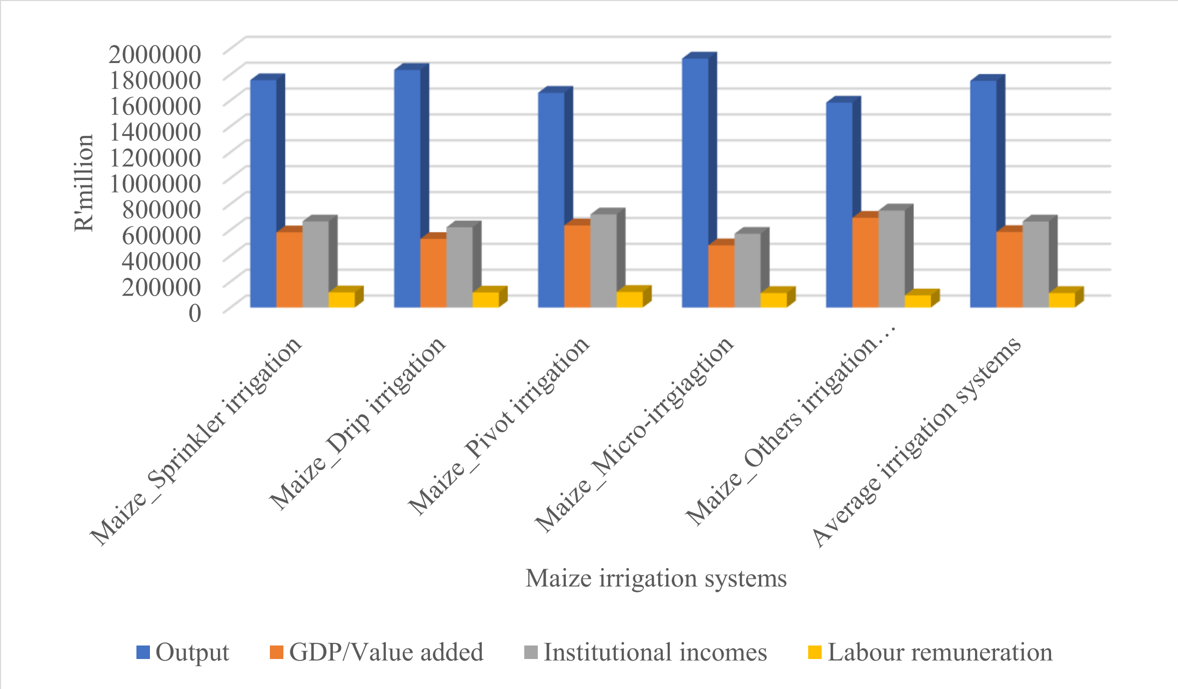

Figure 8: Output, Value added, Labour, and Institutional incomes multiplier analysis.

Source: Authors calculations from 2021SAM for Limpopo province

7.3.4. Land return

Land multipliers represent the values of farm income generated for every million invested in Maize production. The results in Figure 9 show that the highest land returns in Limpopo province came from the Water Schemes and Groundwater. On average, land returns worth R96 622 for the use of groundwater in irrigation systems. The Water Schemes worth R163 346 farm return for other irrigation systems such as canal and flood irrigation in the economy of Limpopo province.

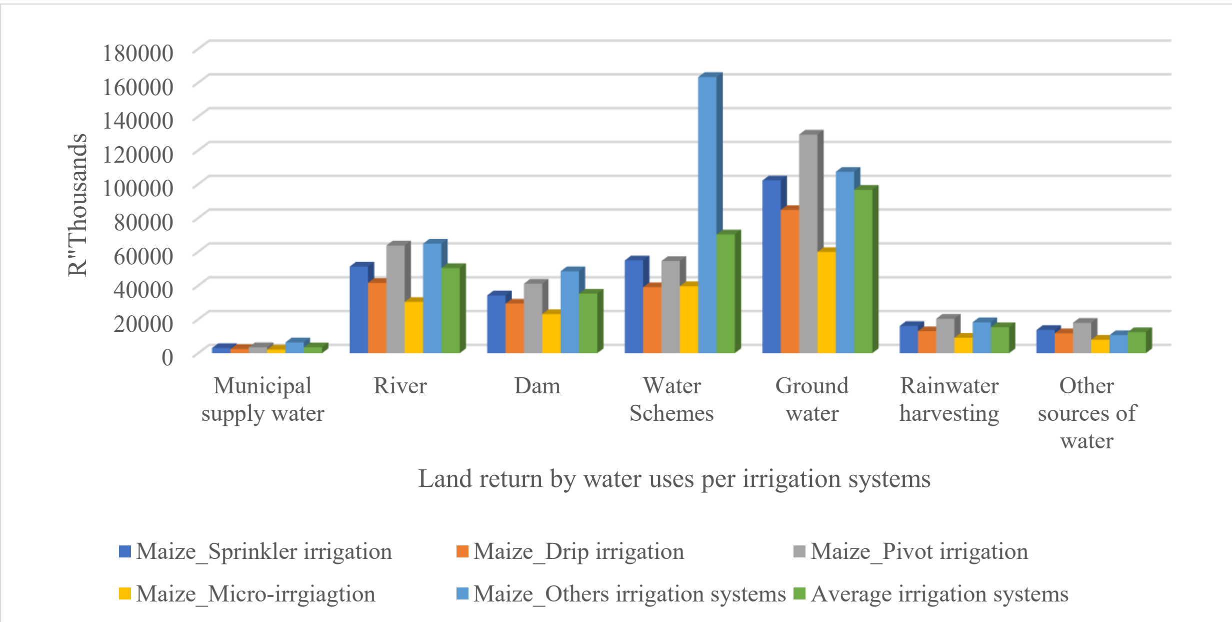

Figure 9:Maize land returns through irrigation systems and sources of water used in the economy.

Source: Authors calculations from 2021SAM for Limpopo province

7.4. Discussions

This study determined the effect of irrigation systems and water uses on maize output, income, land returns, and value-added/GDP in Limpopo province, South Africa, using the multiplier analysis. The results reported that micro and drip irrigation systems had a most considerable output multiplier effect. This implies that these irrigation systems play a significant role in terms of increasing maize output, saving water, and improving food security, which further allows farmers to adopt these irrigation systems. Angom and Viswanathan [33] highlighted that micro-irrigation helps save water, substantially increases output (yield), and achieves food security, which further makes farmers adopt this irrigation system. They further pointed out that farmers who adopted micro irrigation technology aimed at improving their crop yield and alleviating pressures on the water used for ground waters or enhancing water security. In addition, the significance of installing an automated micro-irrigation system is that it saves time and reduces the quantity of water used in crop production. The importance of drip irrigation was attested by Liu et al. [23] and Zhang et al. [20], stating that drip irrigation obtained sound output and profit with less water application. The authors further reported that drip irrigation improves maize quality and water use efficiencies and reduces water loss through runoff and drainage. This implies that increasing the efficiency and sustainability of micro-irrigation agriculture in Limpopo is of paramount importance and profitability due to insufficient rainfall in the provinces.

However, pivot, sprinkler, drip, and micro-irrigation generate less value added and institutional incomes than other irrigation systems such as canal, flood, and coupling line irrigations. As indicated by Jordan and Bahta [26], the reason pivot, drip, and sprinkler irrigation systems have less income than other irrigation systems, such as canals and floods, is due to rising input costs of fertilizer and oils that are imported from abroad. These increases in input costs have a negative effect on farmers' revenues. By adopting pivot, drip, and sprinkler irrigation techniques, Limpopo farmers can optimize water usage, further reduce waste, and improve maize productivity. This trend shows the significance of policies and incentives in the adoption and implementation of irrigation systems. This implies that the government should consider introducing financial incentives to farmers who are currently experiencing challenges in installing irrigation systems in their farms. Therefore, investment in irrigation infrastructure for these systems would improve affordability and accessibility for all farmers and further create better incomes.

The highest land returns in Limpopo province came from the Water Schemes and Groundwater. Kotze et al. [24] stated that improving water allocations with better uses of groundwater savings would lead to better water management and further improved irrigation efficiency, which, in the end, produces better farm returns. This implies there is a need to sustain and grow the maize industry by enhancing water use efficiency, efficient irrigation management, and water-saving technologies. As noted by Jovanivic et al. [13], irrigation agriculture in the maize industry has a mandate of using adequate irrigation water requirements to meet water requirements for crops while reducing the quality, yield, and profit for maize farmers. Therefore, farms with water access, such as the groundwater and water schemes, play a significant role in growing and sustaining the agricultural industry, achieving food security, and alleviation of poverty and hunger in Limpopo province. In furtherance, increasing water access in Limpopo province would significantly influence the likelihood of farmers engaging in irrigation farming. The farm's return from municipal water, rivers, and dams was less than those of groundwater due to severe drought, which threatened the crop production and livelihood of many households. In furtherance, the small return on the farm is due to insufficient water resources, which reflects the fact that the production of maize is highly reliant on the amount of water. Hence, there is a need for significant changes in the Limpopo province to invest in modern irrigation systems and water resources infrastructure for rainwater harvesting, dams, and water supply from the municipal to reduce water consumption and improve water efficiency for crop production.

7.5. Conclusions and recommendations

The irrigation systems have significantly contributed to the improvement of production and income in the Limpopo province. The results reported that micro and drip irrigation systems had the most significant output multiplier effect. This implies that these irrigation systems play an essential role in terms of increasing maize output, saving water, and improving food security, which further allows farmers to adopt these irrigation systems. However, pivot, sprinkler, drip, and micro-irrigation generate less value added and institutional incomes than other irrigation systems such as canal, flood, and coupling line irrigations. This implies that to enhance the value addition of pivot irrigation, farmers should significantly restrict water application to farms with reduced hectares to maximize profit.

Water schemes and groundwater had the highest farm return on maize in the province. The study concludes that the groundwater and water schemes play a significant role in growing and sustaining not only the maize industry but also other agricultural industries in reducing food insecurity. The government should consider introducing financial incentives to farmers who are currently experiencing challenges in installing irrigation systems and borehole water on farms. Therefore, investment in irrigation infrastructure for these systems would improve affordability and accessibility for all farmers and further create better incomes. It is recommended that the government and the stakeholders develop long-term strategies for optimizing or reducing water consumption in agricultural production, inform or educate farmers about the challenges caused by the water resources, and make a significant change in the use of modern irrigation techniques such as micro-irrigation, drip, and sprinkler irrigation systems instead of canal and flood irrigation systems.

The findings of this study were not applicable to assess the irrigation systems for other crop subsectors. Still, future research is recommended to incorporate these systems into various crop subsectors in Limpopo. This will require future researchers to compare the long-term economic, social, and environmental impacts of irrigation systems on various agricultural sub-sectors in Limpopo by extending the SAM model to capture the environmental impact of irrigation systems on water use.

Appendix A

Table 3.A: Accounts in the provincial SAM for Limpopo Province 2021

Activities	Commodities	Land	Labor	Households
Maize_Sprinkler irrigation	Maize	Capricorn_Farm by municipal water supply	Capricorn_Labour	Capricorn_HHD
Maize_Drip irrigation	Wheat	Capricorn_Farm by River	Mopani_Labour	Mopani_HHD
Maize_Pivot irrigation	Grain Sorghum	Capricorn_Farm by Dam	Sekhukhune_Labour	Sekhukhune_HHD
Maize_Micro-irrigation	Barley	Capricorn_Farm by Water Schemes	Vhembe_Labour	Vhembe_HHD
Maize_Others irrigation systems	Oats	Capricorn_Farm by Groundwater	Waterberg_Labour	Waterberg_HHD
Wheat	Sunflower	Capricorn_Farm by Rainwater harvesting		
Grain Sorghum	Soybeans	Capricorn_Other sources of water		
Barley	Dry beans	Mopani_Farm by the municipal water supply		
Oats	Lucerns	Mopani_Farm by River		
Sunflower	Other field crops	Mopani_Farm by Dam		
Soybeans	Potatoes	Mopani_Farm by Water Schemes		
Dry beans	Onions	Mopani_Farm by Groundwater		

Lucerns	Tomatoes	Mopani_Farm by Rainwater harvesting
Other field crops	Cabbages	Mopani_Other sources of water
Potatoes	Carrots	Sekhukhune_Farm by municipal water supply
Onions	Sweet potatoes	Sekhukhune_Farm by River
Tomatoes	Beetroot	Sekhukhune_Farm by Dam
Cabbages	Pumpkins	Sekhukhune_Farm by Water Schemes
Carrots	Oranges	Sekhukhune_Farm by Ground water
Sweet potatoes	Naartjies	Sekhukhune_Farm by Rainwater harvesting
Beetroot	Lemons	Sekhukhune_Other sources of water
Pumpkins	Grapefruits	Vhembe_Farm by municipal water supply
Oranges	Watermelons	Vhembe_Farm by River
Naartjies	Mangoes	Vhembe_Farm by Dam
Lemons	Avocados	Vhembe_Farm by Water Schemes
Grapefruits	Bananas	Vhembe_Farm by Ground water
Watermelons	Pineapples	Vhembe_Farm by Rainwater harvesting

Mangoes	Apples	Vhembe_Other sources of water
Avocados	Peaches	Waterberg_Farm by municipal water supply
Bananas	Tables grapes	Waterberg_Farm by River
Pineapples	Macadamia nuts	Waterberg_Farm by Dam
Apples	Pecan nuts	Waterberg_Farm by Water Schemes
Peaches	Other fruits	Waterberg_Farm by Ground water
Tables grapes	Cattle_Beef	Waterberg_Farm by Rainwater harvesting
Macadamia nuts	Cattle_dairy	Waterberg_Other sources of water
Pecan nuts	Sheep non-wool	
Other fruits	Sheep wool	
Cattle_Beef	Goats	
Cattle_dairy	Pigs	
Sheep_non wool	Chicken's_broilers	
Sheep_wool	Chicken's _layers	
Goats	Ostriches	

Pigs	Others_live animals
Chicken's_broilers	Forestry
Chicken's _layers	Fish
Ostriches	Coal, lignite; peat
Others_live animals	Crude petroleum, gas
Forestry	Metal ores
Fishing	Stone, sand, clay
Coal	Other minerals
Petroleum	Electricity, steam
Gold	Natural water
Metal ores	Meat
Stone	Prepared fish
Services	Prepared vegetables
Meat, fish, fruit, vegetables, oils and fats	Prepared fruit, nuts
Dairy	Oils, fats

Grain and animal feeds	Dairy products, egg
Other food products	Grain mill, starches and syrup products
Beverages	Animal feeding
Tobacco	Bakery products
Textiles	Sugar
Other textiles	Cocoa, chocolate
Knitted fabrics	Macaroni, noodles and food n.e.c.
Wearing apparel	Alcohol beverages
Leather	Soft drinks
Footwear	Tobacco products
Sawmilling of wood	Yarn, thread; textile
Wood products	Made-up textile
Paper	Carpets
Publishing	Textile n.e.c.
Printing and reproduction	Knitted, crocheted

Coke products	Wearing apparel
Petroleum refineries	Leather
Basic chemicals	Footwear
Other chemicals	Wood
Rubber	Pulp, paper
Plastic	Printing
Glass	Coke oven
Non-metallic minerals	Petroleum oils
Iron and steel	Basic chemicals, fertilisers and pesticides
Precious metals	Paints, varnishes
Casting of metals	Pharmaceutical
Structural metal	Soap, perfumes
Other fabricated metal	Chemicals n.e.c.
General purpose machinery	Rubber tyres, tubes and other rubber
Special purpose machinery	Plastics

Household appliances	Glass
Computing machinery	Non-structural ceramic
Electric motors	Clay products
Other electric	Plaster, lime, cement
Other electric components	Concrete, cement, plaster
Television and radios	Other non-metallic
Medical appliances	Furniture
Transport equipment	Jewellery
Furniture	Other manufacturing
Other manufacturing	Wastes, scraps
Recycling	Basic iron, steel
Electricity	Iron, steel products
Water	Basic precious metals
Construction services	Structural metal, tanks and reservoirs
Wholesale trade	Other fabricated metal

Hotels	Engines, turbines, pumps, compressors, bearings and gears
Restaurants	Lifting, handling equipment
Railway transport	Other general machinery
Other land transport	Special-purpose machinery
Water transport	Domestic appliances
Air transport	Office machinery
Supporting transport activities	Electrical machinery
Postal courier activities	Radio, television
Telecommuni-cations	Medical appliances
Monetary	Motor vehicles, parts
Other financial	Bodies (coachwork)
Insurance and pensions	Ships, boats
Auxiliary financial	Railway, rolling stock
Activities to insurance and pension	Aircraft, spacecraft
Other business activities	Other transport equipment

Central government	Construction services
Education	Wholesale trade
Human health	Retail trade
Other services	Accommodation
	Food serving services
	Passenger transportation
	Freight transport services
	Rental, supporting transport
	Postal, courier services
	Electricity, gas distribution
	Water distribution services
	FISIM
	Other financial services
	Insurance, pension services
	Auxiliary to financial services

	Owner occupied
	Other real estate services
	Leasing or rental services
	Research and development
	Legal, accounting services
	Other business services
	Telecommunications
	Support services
	Publishing, printing
	Public administration
	Education services
	Human health, social care
	Membership organisations
	Recreational, cultural
	Other services n.e.c.

Domestic services

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Chapter 8: Summary, Conclusion and Recommendations

8.1. Introduction

This chapter summarises the findings, achievements and contributions, conclusions, policy implications, recommendations, study limitations, and further studies. The policy guidance is based on the SAM multiplier findings and the cost-push-price model for South Africa. The policy recommendations are based on the research questions and objectives that were proposed in the first chapter of this study.

8.2. Summary of the results

8.2.1. First objective: Construction of 2017 and 2021 Social Accounting Matrix

The first sub-objective was constructing the 2017 SAM for South Africa with disaggregated agricultural activities, land, and household accounts. The dataset recorded that land returns for irrigation agriculture were highest (18.2%) in the Northern Cape Province of South Africa compared to other provinces, whereas the Free State Province of South Africa's rainfed agriculture had the largest shares (22%) for payment to land. Regarding intermediate inputs, rainfed agriculture in the Western Cape, Free State, and Kwazulu-Natal provinces paid approximately 0.4% for using intermediate inputs. In terms of the districts, land returns for irrigation were highest in the Vhembe district of Limpopo Province of South Africa, at 0.3%. Despite the Mopani district of Limpopo Province of South Africa having the lowest land returns for irrigation agriculture, it had the highest share (1.6%) of payment to land from rainfed agriculture. The manufacturing and community service sectors had a trade deficit, whereas other sectors experienced a trade surplus.

The second sub-objective was constructing a 2021 National SAM database for South Africa. This research evaluated the contribution of the small-scale agricultural sector to the economy of South Africa. The main objective of the study was to evaluate the contribution and comparison of the commercial and small-scale agricultural sectors towards the economy of South Africa. This study used the 2021 National Social Accounting Matrix (SAM) for South Africa with detailed information on small-scale and commercial large-scale agricultural industries, land accounts, labour accounts, and household accounts to compute the effect on output, gross value added (GVA), labour, land, and incomes (households and enterprises) using the Leontief Inverse Matrix in the SAM multiplier analysis. The findings revealed that, on average, the commercial (large-scale) agricultural industry had a higher output than the small-scale agricultural industry. However, the small-scale agricultural industries generate the largest gross value added (GVA) and incomes (households and enterprises) compared to commercial (large-scale) agricultural industries. This meant that the commercial (large-scale) agricultural industry was paramount in raising the industry's output in the economy of South Africa.

8.2.2. Third objective: Impact irrigation agriculture on the economy of Limpopo Province

The main objective was to compute the effect of exogenous shock (irrigation development) on output, value-added/GDP, and institutional income (households and enterprises) using the Industry by Industry (I-by-I) total requirement matrix. The findings showed that the output multipliers indicated that rainfed agriculture was higher than irrigation agriculture in the Limpopo Province. At the district level, Sekhukhune in the Limpopo Province had the highest output multiplier effect for irrigation agriculture compared to other districts. This study implied that investment in irrigation agriculture could enhance output in the economy at provincial and district levels. In addition, the study found that access to irrigation enhances agricultural output. At the provincial level, the Northern Cape, Limpopo, and Mpumalanga provinces of South Africa had the largest output multiplier effect for irrigation agriculture compared with other provinces.

8.2.3. Fourth objective: Electricity price increase in the agricultural sector

The fourth sub-objective was to compute the cost-push-price model for electricity price tariffs. The SAM price model was significant as it indicated an evaluation of the impacts of changes in the price of electricity in agricultural production. The important assumption for the price model is that prices are evaluated according to production costs, with the supplier transferring the burden to the consumer, whereas at the same time, consumers are known as the price takers. The findings showed that the cost of production for rainfed agriculture is much higher than the costs of irrigation agriculture in all regions in South Africa. Limpopo and Northern Cape provinces of South Africa had the highest costs of production increases for irrigation agriculture compared to other provinces. The increase in production costs is attributed to a decline in electricity production by 7.4 % between 2019 and 2021, which has not reached the production level in 2024.

8.2.4. Fifth objective: The effect of irrigation systems and water use on the maize industry

The purpose of the research was to significantly evaluate irrigation systems and water uses on maize output, income, land returns, and value-added/GDP in Limpopo Province, South Africa. This study applied a 2021 provincial SAM database for Limpopo Province to model the effect of irrigation systems and water uses on the maize industry on the economy of Limpopo

Province, using SAM multiplier analysis. The results reported that micro and drip irrigation systems had the largest output multiplier effect. This implied that irrigation systems play a significant role in terms of increasing maize output, saving water, and improving food security, which further allows farmers to adopt these irrigation systems. However, pivot, sprinkler, drip, and micro-irrigation generate less value added and institutional incomes than other irrigation systems such as canal, flood, and coupling line irrigations. This meant to enhance the value addition of pivot irrigation; farmers should significantly restrict water application to farms with reduced hectares to maximise profit. Water schemes and groundwater had the highest farm return on maize in the province. Thus, groundwater and water schemes play a significant role in growing and sustaining the maize industry and other agricultural industries in reducing food insecurity.

8.3. Achievement and contributions of the study

The contribution of the study was explained in detail in Chapter 2 by presenting similar studies. In brief, the study contributed to constructing the 2017 national SAM for South Africa and the 2021 provincial SAM for Limpopo Province. The 2017 SAM for South Africa was significantly contributed by the disaggregation of agricultural activities, labour, land, and household accounts according to regions (provinces and districts). The agricultural activities and land accounts were disaggregated according to irrigation and rainfed accounts, whereas labour and household accounts were split according to provinces and districts for South Africa.

On the other hand, the significance of the 2021 Limpopo SAM was seen through disaggregating agricultural activities according to crop production in the provinces. This crop production was further linked to the sources of water use. Only the maize industry was further disaggregated according to various irrigation techniques such as drip, sprinkler, canal, and pivot irrigations.

Most of the studies on the impact of electricity price increases had a negative impact on the economy in terms of a decline in GDP and an increase in unemployment. Different empirical studies reported that affordability is a big concern due to the high total cost of production and increases in the market prices for commodities. This study contributed by evaluating the price of electricity increases according to irrigation and rainfed agricultural industries. In addition, the study also contributed by categorising electricity according to distribution and production. The study on the impact of electricity tariff increases on provincial and district agricultural sectors was successfully evaluated using the cost-push-price SAM model.

The modelling studies significantly contributed to evaluating various irrigation systems by sources of water use on crop production, such as maize in arid and semi-arid conditions of Limpopo Province using SAM-based modelling. The outcomes of this research were achieved by applying various irrigation systems (e.g., drip irrigations, pivot irrigation, micro irrigation and coupling irrigation systems) and sources of water use (e.g., dams, rivers, surfaces, boreholes and rain harvesters) on maize production in the Limpopo Province to determine the distribution of incomes by households, and labour remunerations, output, and land returns.

8.4. Conclusions of the study

This study concluded that investment in irrigation agriculture and increasing the efficiency and sustainability of existing irrigation agriculture in Limpopo Province is significant and profitable because dry land production is hazardous when there is sufficient rainfall or recurrent drought. The overall study concluded that irrigation is more advantageous in alleviating poverty than non-irrigation in Limpopo Province. The findings imply that investment in irrigation infrastructure is critical for improving irrigation access for many financially disadvantaged farmers.

The study evaluated the contribution and comparison of the commercial and small-scale agricultural sectors towards the economy of South Africa and concluded that the potential of small-scale farming to catalyse the country's economic growth should not be undermined; this industry could be economically viable if the farmers adopt the right approach not only in the production stage to increase agricultural output but also in the stage of marketing for agricultural products.

The study on the effect of electricity price increases on the agricultural industry concluded that the electricity price increase and shortage of electricity provide an incentive for agricultural industries to invest in appropriate mitigation strategies, such as investing in renewable energy sources. Electricity is a significant cost component for irrigation farming in South Africa because most farmers rely on electricity to pump water for irrigation. The increases in electricity prices disturb the growth of the agricultural sector and other sectors of the economy in terms of return on the equity market.

The study on the effect of irrigation systems and water uses on the maize industry concluded that groundwater and water schemes play a significant role in growing and sustaining the maize industry and other agricultural industries in reducing food insecurity. The irrigation systems play a substantial role in terms of increasing maize output, saving water, and improving food security, which further allows farmers to adopt the irrigation systems.

8.5. Policy implications and recommendations

Based on the main objectives and research questions of this study, the following recommendations are made:

- The study found that at the district level, Sekhukhune in Limpopo Province had the highest output multiplier effect for irrigation agriculture compared to other districts. This implied that innovative technology practices would improve water efficiency and increase the financial advantage of farmers while minimising environmental burdens.
- Investing in irrigation agriculture and increasing the efficiency and sustainability of existing irrigation agriculture in the districts of Limpopo play a significant economic role and are profitable because dry land agricultural production is hazardous because of insufficient rainfall and recurrent drought.
- Investing in rainfed agriculture is essential for profitability when investing in irrigation agriculture. Even though irrigation plays a massive role in other regions of the province, agricultural policies should incorporate rainfed agriculture.
- The study suggested that the South African government should focus on increasing investment in electricity transmission lines and power grid projects to lower the costs of producing electricity inputs for industries.
- The government should consider introducing financial incentives to farmers currently experiencing challenges installing irrigation systems and borehole water in farms. Therefore, investment in irrigation infrastructure for the systems would improve affordability and accessibility for all farmers and further create better incomes.

8.6. Study limitations and areas for further studies

The findings may not be applicable to other South African provinces due to agro-ecological variations such as regional variations in climate, resources, and agricultural practices. The environmental impact of irrigation, particularly water scarcity, is not explicitly addressed in terms of sustainability concerns. The study emphasised innovative technologies without acknowledging potential limitations in access or affordability for farmers lacking technology. The sole focus on profitability might overlook broader social or environmental considerations. Water scarcity was the most limiting factor due to climate change. However, improving water availability is required by implementing technologies to improve water management for sustainable agricultural production.

Future research should consider disaggregating agriculture according to different crops to evaluate the economic impact of irrigation and rainfall at the regional level. The data should display racial and gender group classifications of households. The SAM did not include all districts in South Africa; therefore, researchers, academia, and stakeholders must consider focusing on other districts and possibly adding other accounts (sectors) from local municipalities. Further research is needed to compare the long-term economic, social, and environmental impacts of irrigation and rainfed agriculture in Limpopo by extending the SAM model to capture the environmental impact of irrigation on water resources and assessing the social equity implications of irrigation, including access to water and land for small scale farmers.

The results of this paper are limited to the range of irrigated and rainfed agricultural industries, electricity (generations and distributions), and labour, land, and institutional accounts. Future researchers could consider disaggregating agriculture according to different crops to evaluate the economic impact of electricity price increases on agricultural subsectors at the regional level.

The main challenges found in developing a SAM are the scarcity of data to attain the information needed for disaggregation for the sub-matrices and the insufficient information from different data sources to estimate missing information and ensure the row and column totals of the SAM are consistent and complete. Specific challenges were as follows:

- The 2017 QLFS does not provide detailed information for disaggregated sectors; it only records information in the aggregated format. In addition, the QLFS does not incorporate information for labour remuneration from the district level.
- The 2021 dataset was not applicable to assess the irrigation systems for other crop subsectors, but future research is recommended to incorporate these systems into various crop subsectors in Limpopo. This will require future studies to compare the long-term economic, social, and environmental impacts of irrigation systems on various agricultural subsectors in Limpopo by extending the SAM model to capture the environmental impact of irrigation systems on water use.
- This study may not be applicable to the small-scale agricultural subsectors due to the challenges of accessing regional data in South Africa. Future studies should consider constructing a SAM that includes disaggregation of crops for small-scale agricultural sectors across various regions in South Africa.

- Detailed data on the agricultural sector at a regional level in South Africa are difficult to find and often released based on the period of agricultural surveys and the detailed information mentioned in the surveys. It is challenging to obtain all the required information to construct a SAM.
- Due to data limitations, this study was not able to investigate poverty estimation for skilled irrigation farmers compared with unskilled farmers using the multidimensional poverty index. The authors recommend that future research include skill categories of farmers to assess its implications for poverty.

9. Proof of Published and Submitted Articles

9.1. Article 1

data MDPI

Data Descriptor

Data on Economic Analysis: 2017 Social Accounting Matrices (SAMs) for South Africa

Ramigo Pfunzo, Yonas T. Bahta * and Henry Jordaan

Department of Agricultural Economics, University of the Free State, Bloemfontein 9300, South Africa; 2007090091@ufs4life.ac.za (R.P.); jordaanh@ufs.ac.za (H.J.)
* Correspondence: bahtay@ufs.ac.za

Abstract: The purpose of the Social Accounting Matrix (SAM) is to improve the quality of the database for modelling, including, but not limited to, policy analysis, multiplier analysis, price analysis, and Computable General Equilibrium. This article contributes to constructing the 2017 national SAM for South Africa, incorporating regional accounts. Only in Limpopo Province of South Africa are agricultural industries, labour, and households captured at the district level, while agricultural industry, labour, and household accounts in other provinces remain unchanged. The main data sources for constructing a SAM are found from different sources, such as Supply and Use Tables, National Accounts, Census of Commercial Agriculture, Quarterly Labour Force Survey, South Africa Revenue Service, Global Insight (regional explorer), and South Africa Reserve Bank. The dataset recorded that land returns for irrigation agriculture were highest (18.2%) in the Northern Cape Province of South Africa compared to other provinces, whereas the Free State Province of South Africa rainfed agriculture had the largest shares (22%) for payment to land. Regarding intermediate inputs, rainfed agriculture in the Western Cape, Free State, and Kwazulu-Natal Provinces paid approximately 0.4% for using intermediate inputs. In terms of the districts, land returns for irrigation were highest in the Vhembe district of Limpopo Province of South Africa with 0.3%. Despite Mopani district of Limpopo Province of South Africa having the lowest land returns for irrigation agriculture, it has the highest share (1.6%) of payment to land from rainfed agriculture. The manufacturing and

9.2. Article 2

agriculture

MDPI

Article

Insights into the Impact of Irrigation Agriculture on the Economy of the Limpopo Province, South Africa: A Social Accounting Matrix Multiplier Analysis

Ramigo Pfunzo, Yonas T. Bahta * and Henry Jordaan

Department of Agricultural Economics, University of the Free State, Bloemfontein 9300, South Africa; 2007090091@ufs4life.ac.za (R.P.); jordaanh@ufs.ac.za (H.J.)

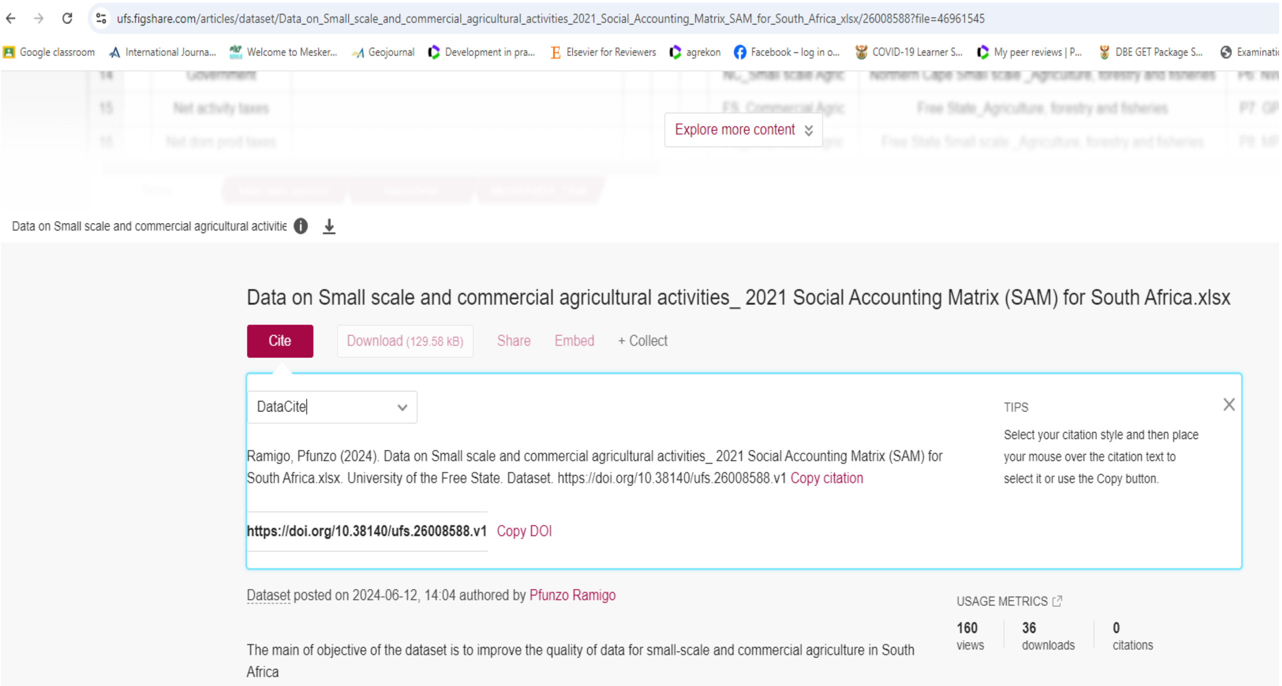
* Correspondence: bahtay@ufs.ac.za

Abstract: The development of irrigation systems is strategically used to improve food security and achieve the Sustainable Development Goals (SDGs 2) of ending hunger and poverty. The objective of this research was to evaluate the effect of irrigation agriculture on the economy of the Limpopo Province, South Africa. This study used the 2017 national social accounting matrix (SAM) as a database with detailed information on irrigation and rainfed agricultural activities and land accounts to compute the effect of exogenous shock on output, income, land, and value added using SAM multiplier analysis. The findings showed that output multiplier effects were more significant for rainfed agriculture compared to irrigation agriculture. However, irrigation agriculture had the highest institutional income, land return, and value-added multiplier compared to rainfed agriculture. The type of crop did not influence the findings, with irrigation consuming more input per unit of output. We conclude that investing in irrigation agriculture and increasing the efficiency and sustainability of existing irrigation agriculture in Limpopo is significant and profitable because dry land production is hazardous when there is insufficient rainfall or recurrent drought.

Keywords: food security; land; rainfed; output; value added; income

9.3. Article 3- 2021 constructed Data Set (SAM) Online

https://doi.org/10.38140/ufs.26008588.v1



9.4 Article 4 - The impact of electricity tariffs increases on the agricultural industry in South Africa (Unpublished)

Pfunzo, R., Bahta, Y.T. and Jordaan, H. 2024. The impact of electricity tariff increases on the agricultural industry in South Africa: A SAM price model (Unpublished).

9.5. Article 5 - Modelling the effect of irrigation systems and water uses on the Maize industry in the economy of Limpopo Province (unpublished)

Pfunzo, R., Bahta, Y.T. and Jordaan, H. 2024.Modeling the effect of irrigation systems and water uses on the Maize industry in the economy of Limpopo Province. Discover Sustainability (Unpublished).