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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

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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 [3,4]. 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.

2. Materials and Methods

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 km^2 and a population of 1.1 million (Figure 1). The Vhembe District is in the northern part of the province, with an area of 25,597 km^2 and a population of about 1.4 million [22]. The Capricorn District includes the capital city, Polokwane, and has an area of 21,705 km^2 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 km^2) and the lowest population (estimated at 768 thousand). The last district is Sekhukhune, with the lowest total area (about 13,528 km^2) and a population estimated at 1.2 million [22].

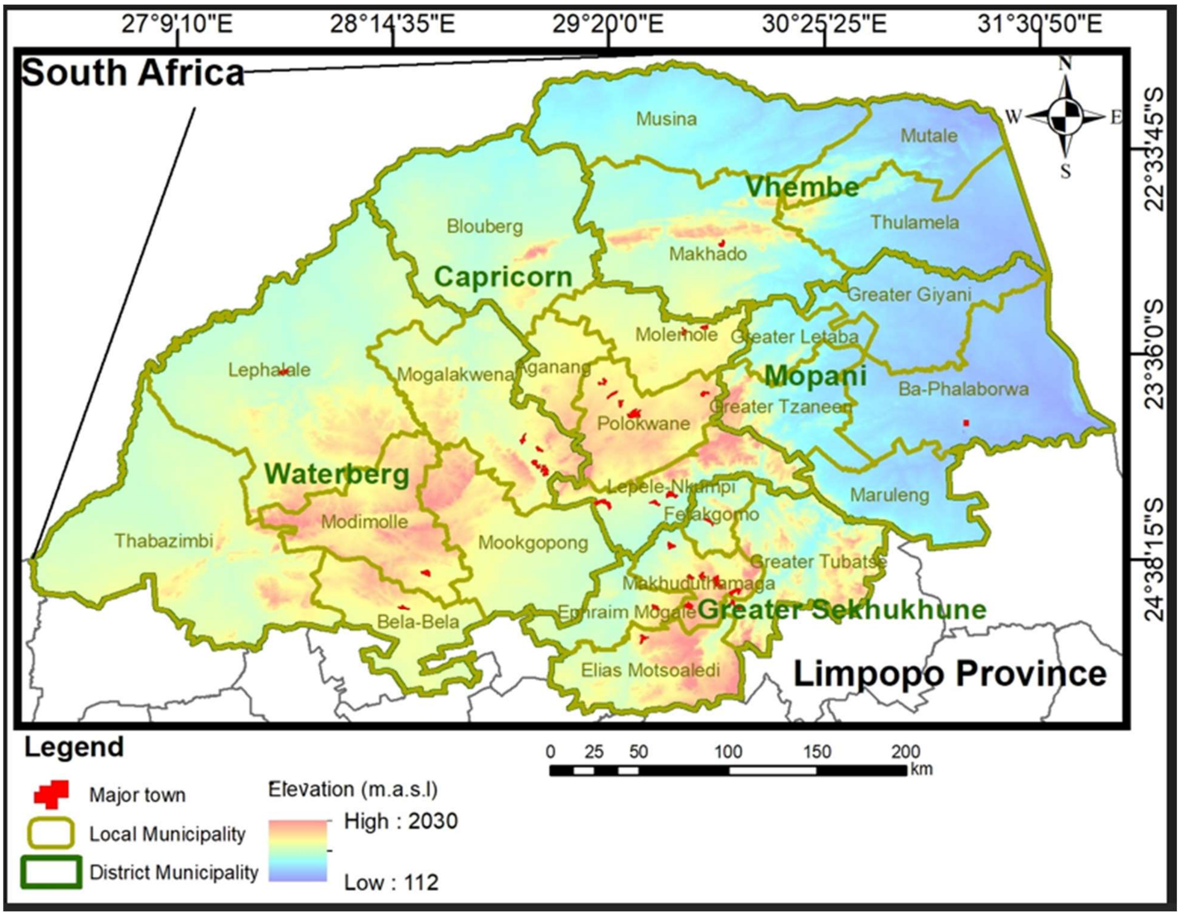

Figure 1. Map of the Limpopo Province, South Africa. Sources: Authors with the assistance of a GIS expert.

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.

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)).

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

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)):

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

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)):

$$\overline{\mathrm{x}} = \left(\mathrm{I} - \overline{\mathrm{A}}\right)^{-1}\overline{\mathrm{f}} = \overline{\mathrm{L}}\overline{\mathrm{f}} \tag{3}$$

where $\overline{\mathrm{x}}$ is an augmented output vector, whereas x is an output of industry. The matrix $\overline{\mathrm{A}}$ is the augmented direct requirement matrix, whereas $\overline{\mathrm{f}}$ 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 product-by-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)):

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

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).

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

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

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

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)):

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

By applying Equation (4) $(\mathrm{U} = \mathrm{B}\hat{\mathrm{x}})$ 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)):

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

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 $\left(\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{f}\right)$ 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):

$$\begin{gathered} e = q - (BD)q \\ e = q(I - BD) \\ q = (I - BD)^{-1}e \end{gathered} \tag{12}$$

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):

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

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):

$$\begin{gathered} Dq = D(Bx + e) \\ Dq = DBx + De \end{gathered} \tag{14}$$

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)):

$$x = DBx + De \tag{15}$$

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:

$$\begin{gathered} \mathrm{De} = \mathrm{x} - \mathrm{DBx} \\ \mathrm{De} = \mathrm{x}(1 - \mathrm{DB}) \\ \mathrm{x} = (1 - \mathrm{DB})^{-1}\mathrm{De} \end{gathered} \tag{16}$$

where $(\mathrm{I} - \mathrm{DB})^{-1}$ 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 $(1 - \mathrm{DB})^{-1}$.

Miller and Blair [31] discussed that the simple I/O model includes a single total requirements matrix (the Leontief inverse matrix $(\mathrm{I\text{-}A})^{-1}$); however, more than four total requirements matrices can be obtained from a product-by-activity SAM, as indicated in Table 1. Only three sub-matrices in the activity technology were presented in this study and were more significant than the eight submatrices shown in Table 1. 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 1). 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 1. Total requirement matrices in the product-by-activity models.

	Activity Technology	Product Technology
	Product-demand driven models	
Product-by-product	$(\mathrm{I} - \mathrm{BD})^{-1}$	$(\mathrm{I} - \mathrm{BC})^{-1})^{-1}$
Activity-by-product	$\mathrm{D}(1 - \mathrm{BD})^{-1}$	$\mathrm{C}^{-1}(\mathrm{I} - \mathrm{BC})^{-1})^{-1}$
	Activity-demand driven models	
Activity-by-activity	$(1 - \mathrm{DB})^{-1}$	$(\mathrm{I} - \mathrm{C}^{-1}B)^{-1}$
Product-by-activity	$\left[\mathrm{D}^{1}(1 - \mathrm{DB})^{-1}\right]$	$[\mathrm{C}(\mathrm{I} - \mathrm{C}^{-1}B)^{-1}]$

Source: Adopted from Miller and Blair [31].

3. Results

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).

3.1.1. Output Multipliers

Table 2 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 2. 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 2. *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.

3.1.2. Value-Added Multipliers

Table 2 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.

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 2 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).

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 3 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 3. 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 3. *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.

3.1.5. Households' Income Multipliers

This section presents the income earned by households in different districts of Limpopo in South Africa. Therefore, Table 4 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 4. 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 4. *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 4. *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. 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 similar 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.

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 A

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
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					

Table A1. *Cont.*

Industries	Commodities	Transaction	Capital	Land	Enterprises	Households
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 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					

Table A1. *Cont.*

Industries	**Commodities**	**Transaction**	**Capital**	**Land**	**Enterprises**	**Households**
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 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					

Table A1. *Cont.*

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					
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					

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.					

References

1. Hussain, I.; Turral, H.; Molden, D.; Ahmad, M. Measuring and enhancing the value of agricultural water in irrigated river basins. *Irrigation Sci.* **2007**, *25*, 263–282. [CrossRef]
2. Peacock, T.; Ward, C.; Gambarelli, G. *Investment in Agricultural Water for Poverty Reduction and Economic Growth in Sub-Saharan Africa: Synthesis Report*; Collaborative Program of African Development Bank, Food and Agriculture Organization, International Fund for Agricultural Development, International Water Management Institute, and World Bank: Columbo, Sri Lanka, 2007.
3. Turral, H.; Svendsen, M.; Faures, J.M. Investing in irrigation: Reviewing the past and looking to the future. *Agri. Water Manag.* **2010**, *97*, 551–560. [CrossRef]
4. Abdullah, K.B. Use of water and land for food security and environmental sustainability. *Irrig. Drain.* **2006**, *55*, 219–222. [CrossRef]
5. Singh, M.; Tiwari, N.K.; Kumar, N.; Dabur, K.R.; Dehinwal, A.K. Dry and Rainfed Agriculture- Characteristics and Issues to Enhance the Prosperity of Indian Farming Community. *Bull. Env. Pharmacol. Life Sci.* **2017**, *6*, 32–38.
6. Venkatesan, G.; Selvam, M.T.; Swaminathan, G.; Krishnamoorthi, S. Effect of Water Stress on Yield of Rice Crop. *Int. J. Ecol. Dev.* **2005**, *3*, F05.
7. Maru, H.; Haileslassie, A.; Zeleke, T. Impacts of small-scale irrigation on farmers' livelihood: Evidence from the drought prone areas of upper Awash sub-basin, Ethiopia. *Heliyon* **2023**, *9*, e16354. [CrossRef] [PubMed]
8. Baloyi, V.A. The Impact of Smallholder Irrigation Schemes on Poverty Reduction among Rural Households of Vhembe and Sekhukhune Districts in Limpopo Province, South Africa. Ph.D. Thesis, University of Limpopo, Limpopo, South Africa, 2021.
9. Van Averbeke, W.; Denison, J.; Mnkeni, P.N. Smallholder irrigation schemes in South Africa: A review of knowledge generated by the Water Research Commission. *Water SA* **2021**, *37*, 797–808. [CrossRef]
10. Chipfupa, U. Entrepreneurial Development Pathways for Smallholder Irrigation Farming in Kwazulu-Natal: Typologies Aspirations and Preferences. Ph.D. Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa, 2017.
11. Mbusi, N. Assessment of Sources of Livelihoods and Opportunities to Improve the Contribution of Farming within Available Food Chains. Master's Thesis, University of Fort Hare, Eastern Cape, Alica, South Africa, 2013.
12. Fanadzo, M.; Chiduza, C.; Mnkeni, P.S. Overview of smallholder irrigation schemes in South Africa: Relationship between farmer crop management practice and performance. *Afr. J. Agr. Res.* **2010**, *5*, 3514–3523.
13. Pauw, K.; Mc Donald, S.; Punt, C. Agricultural efficiency and welfare in South Africa. *Dev. S. Afr.* **2007**, *24*, 309–333. [CrossRef]
14. Ferreira, V.; Almazan_Gomez, M.A.; Nechitor, V.; Ferrari, E. The role of the agricultural sector in Ghana's development. A multiregional SAM-based analysis. *J. Econ. Struct.* **2022**, *11*, 6. [CrossRef] [PubMed]
15. Mare, F.A.; Bahta, Y.T. The impact of live sheep export trade on the South African economy. *AIM-Agric. Food.* **2022**, *8*, 25–47. [CrossRef]
16. Bahta, Y.T.; Willemse, B.J.; Grove, B. The role of agriculture in welfare, income distribution and economic development of the Free State Province of South Africa: A CGE approach. *Agrekon* **2014**, *53*, 46–74. [CrossRef]
17. Taljaard, P.R. The Macroeconomy and Irrigation Agriculture in the Northern Cape Province of South Africa. Ph.D. Thesis, University of the Free State, Bloemfontein, South Africa, 2007.
18. Kirsten, J.F.; Van Zyl, J. The economic impact of irrigation agriculture: Methodological aspects and an empirical application. *Dev. S. Afr.* **1990**, *7*, 209–224. [CrossRef]
19. Doukkali, M.R.; Lejars, C. Energy cost of irrigation policy in Morocco: A Social Accounting Matrix assessment. *In. J. Water Resour. Dev.* **2015**, *31*, 422–435. [CrossRef]
20. Brown, J.R. Irrigation development as an Instrument for Economic Growth in Saskatchewan: An Economic Impact Analysis. Master's Thesis, University of Saskatchewan, Saskatoon, SK, Canada, 2017.
21. Hassan, R.M. Economic-wide benefits from water-intensive industries in South Africa: A quasi input-output analysis of the contribution of irrigation agriculture and cultivation plantations in the Crocodile River catchment *Dev. S. Afr.* **2003**, *20*, 171–195.
22. Global Insight. *South Africa Regional Eeplorer (Rex)*; Global Insight: Johannesburg, South Africa, 2022.
23. Ramigo, P.; Bahta, Y.T.; Jordaan, H.; Joubert, C. Data on Economic Analysis: 2017 Social Accounting Matrices for South Africa. University of the Free State, Bloemfontein, South Africa. 2023. Available online: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/CVEC6I (accessed on 10 October 2023).
24. Statistics South Africa (StatsSA). *Census of Commercial Agriculture 2017*; Statistics South Africa (StatsSA): Pretoria, South Africa, 2020.
25. Statistics South Africa (StatsSA). *Supply and Use Tables (SUT) for 2017*; Statistics South Africa (StatsSA): Pretoria, South Africa, 2018.
26. Robinson, S.; Cattaneo, A.; El-Said, M. Updating and Estimating a Social Accounting Matrix Using Cross Entropy Methods. *Econ. Syst. Res.* **2001**, *13*, 47–64. [CrossRef]
27. Lamonica, G.R.; Recchioni, M.C.; Chelli, F.M.; Salvati, L. The efficiency of the cross-entropy method when estimating the technical coefficients of input-output tables. *Spat. Econ. Anal.* **2020**, *15*, 62–91. [CrossRef]
28. Lamelin, A.; Fofana, I.; Cockburn, J. *Balancing a Social Accounting Matrix: Theory and Application (A Revised Version)*; Partnership for Economic Policy (PEP): Quebec, QC, Canada, 2013.
29. Punt, C. Modelling multi-product industries in computable general equilibrium (CGE) models. Ph.D. Thesis, University of Stellenbosch, Stellenbosch, South Africa, 2013.
30. PROVIDE. *Social Accounting Matrices and Economic Modelling*; Background Paper 2003:4; Western Cape: Elsenburg, South Africa, 2003.
31. Miller, R.; Blair, P. *Input-Output Analysis: Foundations and Extensions*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2009.

32. Mupaso, N.; Makombe, G.; Mugandani, R.; Mafongoya, P.L. Assessing the Contribution of Smallholder Irrigation to Household Food Security in Zimbabwe. *Agriculture* **2024**, *14*, 617. [CrossRef]
33. Ramigo, P. Agriculture's Contribution to Economic Growth and Development in Rural Limpopo Province: A SAM Multiplier Analysis. Master's Thesis, University of Stellenbosch, Stellenbosch, South Africa, 2017.
34. Phoofolo, M.L. Analysis of the economic impact of a disaggregated agricultural sector in South Africa: A social accounting matrix (SAM) multiplier approach. Master's Thesis, University of Stellenbosch, Stellenbosch, South Africa, 2018.
35. Cousins, B. Smallholder irrigation schemes, agrarian reform, and accumulation from below: Evidence from Tugela Ferry. Kwazulu-Natal. In Proceedings of the Conference on Strategies to Overcome Poverty and Inequality: Towards Carnegie III, Cape Town, South Africa, 3–7 September 2012.