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Business case analytics for avocado, chili and poultry value chains in Rwanda: Implications on Job Creation

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A R T I C L E I N F O

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A B S T R A C T

Globally, agricultural value chains are undergoing rapid transformation driven by technological advancement and the need for sustainable development. While developing agencies increasingly recognize agriculture's potential for job creation and economic growth, systematic approaches to evaluate business cases that combine both financial viability and social benefits remain scarce. We address this knowledge gap through employing an innovative analytical framework to assess business cases, focusing on avocado, chili and poultry value chains. We integrate predictive analytics with traditional financial assessment tools to evaluate the economic viability and job creation potential of the value chains. An artificial neural network (ANN) with early stopping combined with comprehensive financial metrics analysis assessed the social and financial viability of the business cases. Primary data from businesses in Rwanda and secondary data from national agricultural databases informed our predictive models, which were validated through a 5-fold cross-validation and evaluated for precision, accuracy and recall. The study finds that expanding Chili cultivation from 533 to 4457 hectares catalyses a cascade of employment opportunities, with >22,232 jobs predicted in production, 17,299 in storage and aggregation, and 17,024 in oil processing in a space of 5 years. The study further identified critical success factors including access to finance, technical expertise, and market linkages that significantly influence both financial performance and job creation outcomes. The study's analytical framework offers a replicable model for evaluating agricultural business cases that balance financial returns with social impact, particularly relevant for developing economies seeking to optimize their agricultural investment strategies.

Introduction

Background

In any new business activity, questions exist regarding whether the investment is financially viable or socioeconomically sound based on its goals [1]. In the real world, however, the main preferred indicator of business performance has been economic and

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financial viability, as investments are mostly assessed based on whether they are profitable. While studies aimed at assessing the financial viability of investments [2–5] have been crucial in guiding private sector investments, challenges have mostly existed when investments have both public and private sector goals [6]. Surprisingly, in recent years, there has been an increase in literature addressing social goals in decision frameworks [7–9]. Nonetheless, recent investments aimed at economic growth and development at the national level have mostly focused on public and private partnerships.

The Government of Rwanda (GoR) is not an exception to such investments. In Rwanda, Agriculture accounts for 27 % of the total national GDP [National Institute of Statistics of Rwanda] (10). The country is ranked as the second most densely populated country in Africa, with a population of around 13.2 million people expanding at a rate of 2.3 percent annually.[1] Its demographic landscape is characterised by a large youth population, with approximately 78 % of the population under 35 years of age. Rwanda is also endowed with extensive tracts of fertile soils, as 61 % (1.4million ha) of the land is suitable for agriculture [11]. Despite having vast arable lands and a burgeoning young population, Rwanda faces food shortages and challenges such as climate change, post-harvest losses and inefficient value chains [12].

Rwanda's economic trajectory is hindered by numerous challenges that constrain its ability to promote inclusive development [13]. These factors include the limited capacity of the economy to create sufficient quality jobs, poorly skilled human capital, poor economic infrastructure, and limited access to capital [14]. Notwithstanding inefficiencies in job creation, agriculture remains the predominant source of employment for young people. About 60 % of employed youth work in nonproductive jobs, such as subsistence agriculture, retail, and construction [12]. UN [15] found that 25.6 % of the youth population aged 16–30 years remain unemployed, compared to the adult unemployment rate (aged 31 years and above), which stands at 17.1 %. Furthermore, youth unemployment patterns show that 12.2 % of unemployed youth have no education, 39.4 % have achieved secondary education, and 32.4 % are university graduates (10). Nonetheless, youth face numerous hurdles in the entrepreneurship of agriculture, including a lack of finance, markets, extension services, and training [5], in addition to limited infrastructure [16].

To combat the challenges in the economic trajectory that includes Rwanda's food system deficiencies and high youth unemployment rates, the Government of Rwanda (GoR) and national and international non-government institutions are implementing a plethora of strategies. Rwanda has a long-term vision (Vision 2050) where she sees herself as self-reliant and more young people are emancipated economically. Through the implementation of the fifth strategic Plan for Agriculture Transformation (PSTA5), the GoR through the Ministry of Agriculture (MINAGRI) has committed to integrating the food systems approach towards achieving sustainable and resilient food systems (IFPRI, 2024).

Avocado, Chili, and Poultry have hence been identified in PSTA 5 as some of the high-value chains that can enhance exports and create jobs for both youth and women. Specifically, the Alliance for a Green Revolution in Africa (AGRA) has partnered with MINIAGRI to enhance the Avocado, Chili, and Poultry value chains by increasing poultry production through modern production systems and extension services and improving the quality and production acreage of Chili and Avocado to meet international standards, thereby supporting youth ownership and participation in these value chains. The institutions, through the PSTA 5, plan to increase land under avocado production from 517 ha to 4933 ha, land under chili production from 533 ha to 4457 ha, and an annual growth of 27 % in poultry production, all to be achieved by 2029 [17].

It should be emphasized that the aim of profitability analysis of business ventures is to understand competitive conditions within a market, by examining the outcomes of that market in terms of the financial performance of the participating firms.[2] Therefore, the purpose of conducting profitability analysis is to understand whether the levels of profitability (such as prices) achieved by firms and value chain actors are consistent with the levels expected in a competitive market. This study contributes to existing literature in four ways: first, it adds to the growing literature on profitability analysis of agricultural crops by going deep into mapping the entire chain, to pull out possible business cases that make up the chain, with the aim of providing youth with various profitable business pathways and enterprises that they can engage in; Second, the study goes beyond mere profitability analysis and considers the ability of business cases to create direct and indirect jobs, thus assessing their contribution to economic development; third, the study proposes advanced robust prediction methods that can address both social and economic goals of job creation in value chains through the use of machine learning predictive models; fourth, the study provides novel recommendations on both social and economic aspects of business enterprises to ensure both financial sustainability and job creation in society.

Literature review

Avocado, chili and poultry trade

Rwanda's avocado exports surged, from almost zero metric tonnes in 2010 to 1424 metric tonnes in 2021, transforming the country's global market position. By 2016, Rwanda had started making significant progress in exporting avocados to various countries, solidifying its global position. But a huge breakthrough came in 2018 when it started exporting over 170 metric tonnes of avocados and thereafter the export continued to increase sharply. This transformation in avocado exports can be attributed to the Government of Rwanda's (GoR) efforts in distributing export-grade seedlings and educating Small-scale farmers on the value of different varieties of avocado. This further facilitates the growth of several business cases along the value chains (Fig. 1).

Fig. 2 depicts that chillies (Peppers) exports were initially low from 2010 to 2014 while imports were also low but with slight

[1] NISR 2023Poulation and Housing Census 2022
[2] CMA (Competition & Markets Authority), "Profitability methodology approach," 2021

fluctuations. A gradual increase of exports began in 2015 and sharply increased in 2016 with 23.35 metric tonnes while imports continued to fluctuate and eventually increased in 2017 but remained lower than exports throughout. Overall, from 2010 to 2019 there was a shift from low exports to rapid export growth and eventually stabilization at higher levels. The Alliance for a Green Revolution in Africa (AGRA) has played a significant role in bolstering Rwanda's chilli sector, aiming to enhance agricultural productivity that has resulted in increased exports. AGRA has helped increase chilli yields and the overall quality of the chillies and is also supported by new market linkages. Other interventions by international organizations have also helped in increasing chilli exports. For instance, the International Trade Centre (ITC) supported the farmers to learn about container packing, export documentation and fumigation. This resulted in farmers under their supervision exporting about 22.5 metric tonnes to India (ITC, 2019).

Rwanda's poultry (meat) sector has mainly been importing rather than exporting as displayed in Fig. 3 from 2010 to 2019 with almost zero export quantity. However, in 2020 the export of poultry meat began and rose sharply in 2021. On the other hand, meat exports kept increasing and increased even further from 2020 to 2021 due to the high demand. Overall, the import volume exceeded exports from 2010 to 2021. A study by Cocchini and Ter Steeg (2019) revealed that Rwanda does not have the production capacity to completely provide for its ever-rising demand, let alone to compete with neighbouring countries like Uganda, Tanzania and Kenya, where the poultry industry is more advanced. However, recent data has shown significant progress in poultry meat exports. For instance, the Observatory of Economic Complexity (OEC) (2022) reported that Rwanda exported $3.53 million in poultry meat, making it the 73rd largest exporter of poultry meat in the world.

However, questions remain as to whether these sectors are profitable and the ability to create employment for the vulnerable population. Nevertheless, much needs to be assessed beyond mere profitability, which includes the capital requirements to start the different business opportunities in the value chains, and the ability of the investment to create sustainable jobs (employ whilst remaining profitable). Past studies in value chain analytics have mainly focused on production alone or one stage of the chain (e.g., processing), failing to assess business cases as interconnected nodes of a value chain (Abraham [18]; Ashoka et al. [19]). Despite the opportunities presented by the government, there remains a need for empirical evidence for entrepreneurs to make informed decisions.

For social goals such as employment creation, evidence of potential job opportunities remains lacking. Most importantly, studies that have attempted to assess the profitability of investments have ignored these social goals. For those that have attempted to assess employment generation, the methods have mostly aggregated crop and livestock production, providing insufficient evidence of specific job pathways that youth can explore inside those value chains [20].

The nexus between agribusiness investments and employment generation

The nexus between agribusiness investments, value chain development, and employment generation represents a critical area of research in contemporary agricultural economics. Recent empirical evidence demonstrates significant transformative potential across agricultural value chains, particularly in developing economies [21,22]. This comprehensive review synthesizes current research findings, examining the versatile relationships between strategic agricultural investments and sustainable job creation.

Contemporary agricultural economics research has established robust theoretical frameworks linking agribusiness investments to employment generation through multiple channels. Rahman et al. [23] developed an integrated theoretical model demonstrating how agricultural value chains function as employment multipliers through direct, indirect, and induced effects. Their longitudinal study across 15 developing countries revealed that every $1 million invested in integrated agricultural value chains generated an average of 328 jobs, significantly exceeding previous estimates. Chen and Wong [3] further substantiated these findings through their comprehensive analysis of multiplier effects, documenting employment elasticities ranging from 0.6 to 0.8 across different agricultural subsectors.

Empirical research has provided substantial evidence regarding employment potential across agricultural value chains. Thompson and Lee's [22] analysis of 50 African agribusiness projects revealed that processing activities generated 2.5 times more employment

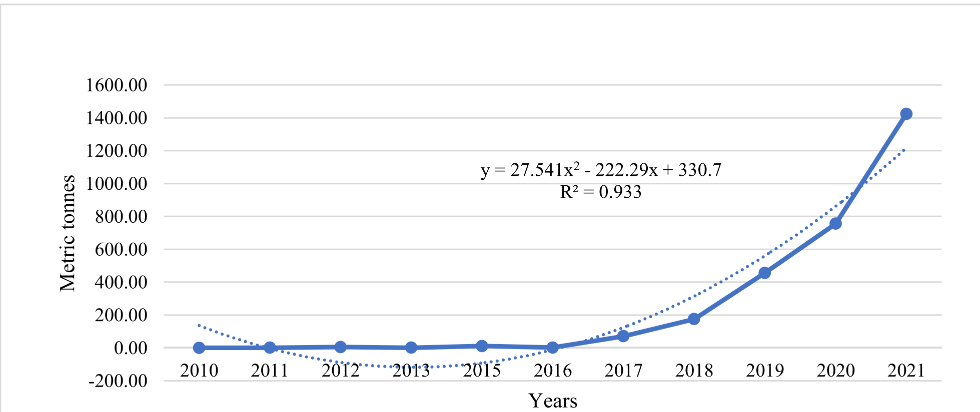

Fig. 1. Rwanda's Avocado Export Volume in the Past Decade.
Source: FAOSTAT database (2024)

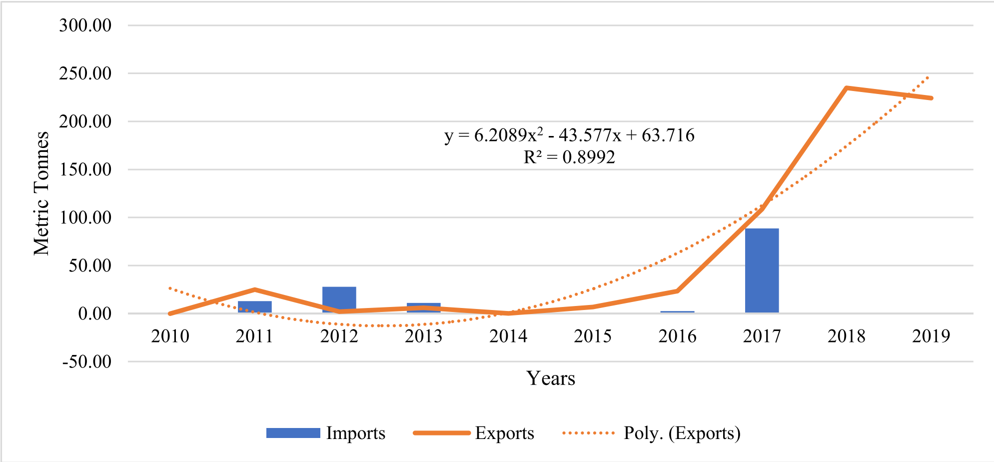

Fig. 2. Rwandan Trade in Chillies and Pepper.
Source: FAOSTAT database (2024)

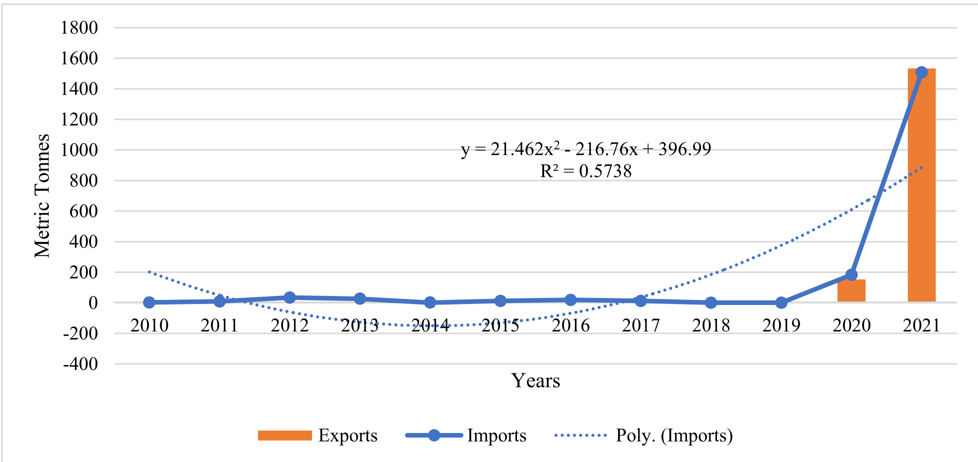

Fig. 3. Rwanda's Global Trade in Chicken Meat.
Source: FAOSTAT database (2024)

than primary production, while export-oriented value chains provided 45 % higher wages than domestic alternatives. These findings align with Jackson et al.'s [24] meta-analysis of 120 agricultural value chain studies, which demonstrated that integrated approaches generated 40 % more employment compared to traditional agricultural development strategies.

Innovation and sustainable agriculture

The digital revolution in agriculture has fundamentally reshaped the employment landscape. Kumar and Singh's [25] comprehensive study of Asian agricultural markets demonstrated that digital agriculture platforms created 150,000 new jobs during 2021–2023, with 67 % requiring digital skills. This transformation extends beyond mere job creation, as evidenced by Martinez et al.'s [26] research across Latin American countries, which documented a 40 % increase in skilled employment alongside a 35 % improvement in productivity through precision agriculture technologies.

Recent studies have established strong correlations between agricultural innovation, sustainability, and job creation. Williams and Rodriguez's [27] examination of 75 sustainable agriculture initiatives across three continents revealed that sustainable farming practices created 45 % more jobs than conventional methods, while organic farming operations employed 2.3 times more workers per hectare. Green et al.'s [28] longitudinal study of 200 agricultural enterprises further demonstrated that environmentally sustainable practices improved long-term economic viability by 40 % while generating substantial employment opportunities.

Gender and youth dynamics in modern agriculture

Contemporary research has highlighted agriculture's transformative potential for women and youth employment. The FAO's [4] comprehensive study across 20 African countries demonstrated that modern agricultural value chains employ 50 % more women and youth compared to traditional farming systems. Ahmed and Peters' [29] research documented 40 % higher income for women in value-added agricultural activities and a 65 % increase in youth participation in technology-enabled farming.

Furthermore, a deep analysis of different investment approaches has yielded important insights into employment generation patterns. Davidson et al.'s [30] comparative study found that public-private partnerships generated 35 % more sustainable jobs than private investments alone, while integrated value chain investments created three times more employment than single-stage investments. These findings are supported by Wilson and Thompson's [27] research on blended finance models, which demonstrated 25 % higher job creation efficiency.

Policy framework and future directions

Recent policy research by Anderson et al. [29] emphasizes the critical role of enabling environments in maximizing employment benefits from agribusiness investments. Their analysis of 30 countries shows that supportive policy frameworks increased job creation potential by 60 % compared to restrictive environments. Furthermore, Santos and Martinez's [31] research identify emerging trends in agribusiness that promise significant employment potential, including vertical farming, bioprocessing, and smart farming technologies.

In Morocco, El-Hassan [32] analyzed the Green Morocco Plan, which attracted over $500 million in agribusiness investments between 2020 and 2023, resulting in the creation of 75,000 new jobs across fruit, vegetable, and poultry value chains. Similarly, in Brazil, Souza et al. [33] documented how investments in digital agriculture and sustainable practices in the soybean and poultry sectors led to a 30 % increase in rural employment and a 20 % rise in average household income. In Southeast Asia, Nguyen and Tran [34] reported that public-private partnerships in the rice and aquaculture sectors generated 120,000 new jobs and improved gender equity in rural employment.

Despite these successes, several challenges persist. Access to finance, infrastructure deficits, and policy inconsistencies remain significant barriers to scaling agribusiness investments [14]. However, opportunities thrive in leveraging blended finance, fostering innovation ecosystems, and strengthening regional trade integration. Recent research by Mensah and Boateng [35] highlights the importance of capacity building and technical training in maximizing employment outcomes, particularly for youth and women in sub-Saharan Africa.

Nonetheless, while the literature demonstrates clear links between agribusiness investment and job creation, gaps remain in understanding the long-term sustainability of these jobs and the differential impacts of small and micro investment business opportunities, their investment requirements, profitability and employment potential. There is a need for more research and development towards public private partnership regimes and the necessary models for you creating jobs, especially for the youth who lack access to finance and investment capital.

Methodology

Data sources

A mixed-methods research design was adopted, which implied that the study ended up utilizing various data sources. Specifically, the study employed both primary and secondary data sources. This included secondary data collected by National Agricultural Export Board (NAEB) and Ministry of Agriculture (MINAGRI); and primary data collected from business enterprises in Rwanda.

The following are some of the guiding documents that were reviewed to capture all relevant information under the desk review: (i) MINAGRI Annual reports 2020–2022; (ii) NAEB Annual Reports 2020–2023; (iii) Rwanda packaging strategy 2022; (iv) NAEB Strategy 2019–2024; (v) National Export Strategy II; (vi) Seasonal Agricultural Survey, 2022; (vii) MINAGRI Annual report, 2021/22; (viii) Agricultural Household Survey, 2020; (ix) RAB Extension Materials; (x) RRA: Annual Reports, Brochure, and Tax Handbook; and (xi) Rwanda Packaging Strategy, 2022.

Secondary data sources included (1) NAEB Profitability Analysis data and (2) FAOSTAT data.

Primary data sources included key informant Interviews (KIIs) and In-depth Interviews. KIIs are qualitative interviews with stakeholders in key selected value chains. The purpose was to collect information from a wide range of business enterprises, including exporters, agro-dealers, processors, and logistic/transport companies that have first-hand knowledge of key products. In total, 66 KIIs were conducted. This includes six policy holders (NAEB, MINAGRI, and RDB) to understand high-level strategic frameworks within the sector, 24 with key companies within the suggested value chains, 8 with some of the aggregators, 24 with key companies involved in input supply to obtain clear information about input costing, and 4 with logistics companies involved in local and regional/international trade.

In-depth interviews included 36 farming enterprises in Avocado, Chili and Poultry (12 each segregated based on size); 24 enterprises in aggregation and storage of Avocado and Chili which include cooperatives; and 4 processors of Avocado and Chili (Fig. 4).

Sample sizes for the predictive model

For the Artificial Neural Network, two data sources were used. First, NAEB and MINAGRI had already existing data on business cases in the three value chains, including labour requirements. This secondary data of businesses and their employment opportunities randomly sampled 860 business enterprises in Avocado (300), Chili (300) and Poultry (260). Second, we collected addition primary data, through random sampling 126 business cases spread across Avocado (60), Chili (38) and Poultry (28). Thus, a total of 986 data points spread across Avocado (360), Chili (338) and poultry (288) were utilized. A list of agribusinesses across the three value chains together with addresses and phone numbers were solicited from MINAGRI and the Rwanda Agriculture Development Board (RAB). This helped in randomly sampling businesses to interview across the three value chains. The selection criteria included businesses that have operated for at least 5 years in the country to allow for a proper understanding of operational requirements and sustainability measures. The willingness of most businesses to provide financial data remained a big challenge for primary data collection. However, the secondary data from the Ministry was robust enough to supplement the primary data and implement the models.

Financial estimations

The evaluation of financial investments in the present study employed six key metrics: Net Present Value (NPV), Internal Rate of Return (IRR), Modified Internal Rate of Return (MIRR), Best Cost Ratio (BCR), Payback Period (PP), and discounted payback period (DPP).

Net present value (NPV)

Net Present Value (NPV) is the sum of the discounted cash flows associated with a specific investment [36] The determinant of a present value is based on a discount rate – the comparative value of money that is eroded or gained with time [3]. When the NPV is positive, it implies that the present value of the inflow exceeds the present value of the outflows, and the investment is deemed acceptable. Mathematically, the NPV is calculated using the following formula:

$$NPV = \sum_{t=1}^{t=n} \frac{B_t}{(1+d)^t} - \sum_{t=1}^{t=n} \frac{C_t}{(1+d)^t} \tag{1}$$

Where:
B_t = cash inflow per year
C_t = cash outflow per year
t = period (years)
n = total number of years of the investment
d= discount rate

Internal rate of return (IRR)

The internal Rate of Return (IRR) is defined as the rate at which the net cash flow must be discounted to produce a Net Present Value of 0 [37]. It acts as the highest rate of return that a project can generate, while still being considered a good investment. This metric aids investors in assessing the potential profitability of their investments. When the IRR is greater than the interest rate, it is expected to generate a return that is higher than the cost of capital. This is expressed as follows:

$$IRR = LDR + [HDR - LDR] \frac{NPV^{LDR}}{NPV^{LDR} + NPV^{HDR}} \tag{2}$$

Where:
NPV = Net Present Value
HDR = Higher discount rate
LDR = Lower discount rate

Benefit cost ratio (BCR)

The benefit-cost ratio (BCR) is an indicator that measures the overall value for money of a project by calculating the ratio of its total benefits to its total cost [38]. The project benefits must be greater than the project costs for the investment to be deemed viable. A BCR exceeding one indicates that the business case is expected to generate incremental value. The mathematical representation is as follows.

$$BCR = \frac{\sum_{t=0}^{n} \frac{Bt}{(1+r)^t}}{\sum_{t=0}^{n} \frac{Ct}{(1+r)^t}} \tag{3}$$

Where:
Bt = cash inflows
Ct = cash outflows
n= number of years of the investment
r = discount rate

Payback period

This is the time at which the initial cash outflow of an investment is expected to recover from its cash inflows generated by an

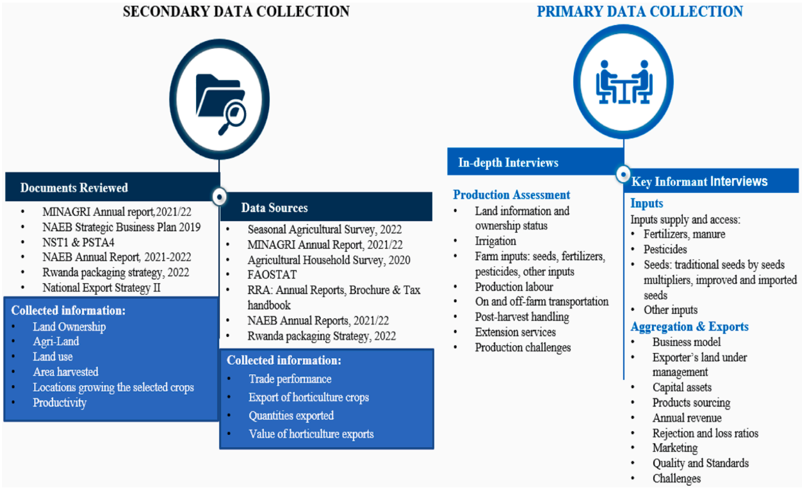

Fig. 4. Sources of Data for the Value Chain and Business Case Analytics.

investment. It is a simple metric to use and indicates the extent to which project cash is invested. Projects with shorter payback periods were determined feasible. Despite its simplicity, the major drawback of the payback period is that it ignores the time value of money and does not consider the cash flow that occurs after the payback period [4].

Sensitivity analysis

The current study employed sensitivity analysis, which is a technique used to assess how changes in key variables affect a project's financial viability. It helps investors understand how changes in assumptions might impact a project's financial performance and its ability to achieve the set objectives [39].

General assumptions

General Assumptions employed in financial analysis of the business cases include:

Currency: amounts are in dollars, and the National Bank of Rwanda (BNR) current exchange rates were followed for conversion to RWF everywhere necessary.[3]

Discount rate of 10 % for future cash flows. A value of 10 % is the recommended financial discount rate for a dollar denomination, equivalent to 13 % of the RWF.

Units: physically cultivated land sizes, area in hectare

Volumes: Large unit – metric tons (MT), small unit – kilogram (kg), where 1 MT is equal to 1000 kg.

Taxes: Value Added Tax, income tax, CIT, etc.

Projection period number of years: 10 for perennial crops like avocado and 5 years for Chili and Poultry.

Land and land management: The model evaluates the cost of production of avocados and chili per hectare of land. The results are then used to analyze the exporter's scenarios for small-scale avocado and chili production and sourcing at one hectare per year, 20 hectares per year for medium-scale production, and large-scale production at 100 hectares.

Capital expenditures (CAPEX): This information captures the investment estimates for initial and ongoing CAPEX during the production of avocados, chili, and poultry, such as land, buildings, machinery, equipment, and vehicle requirements.

Direct costs: Planting costs: land preparation, seedlings, direct labor for planting; growing costs: materials (fertilizers, pesticides, etc.); labor (fertilizer application, insecticide application, manual weeding, etc.); harvesting costs: mainly labor for harvesting, and other costs incurred in the process; processing, which captures post-harvest costs such as packing and grading, packaging, transport, equipment maintenance, and other processing costs.

Operating expenses (where applicable): land rental, management, marketing, repairs and maintenance, professional services, insurance, property taxes, and other contingencies.

Yields: harvest yield (kg/ha) or (MT/ha).

Price per unit: USD/Kg; Product price increase of 5 %; input cost increase of 3 %.

Other assumptions considered for profitability analysis are depreciation expenses and rejection rates of the exportable grade yields of avocados and chilies.

[3] BNR exchange rates values for previous periods analysis: 2018/2019 at RF 989 per USD as of June 28, 2019; 2019/2020 at RF 937 per USD as of June 30, 2020; 2020/2021 at RF 987 per USD as of June 30, 2021; 2021/2022 at RF 1,024 per USD as of June 30, 2022. An annual BNR projected exchange rate of RF 1,095 for the current period.

Jobs estimation

The dynamics of job creation within various economic interventions have drawn significant attention from various policy realms. Job creation is one of the most important pathways by which economic growth can be translated into poverty alleviation and income inequality [9]. To comprehensively grasp the complexities of job creation, it is imperative to assess the quantity, quality, inclusivity, and sustainability of jobs created through interventions. According to Chazara et al. [40], the number of jobs created can be grouped into three categories: direct, indirect, and induced. Direct jobs refer to immediate employment opportunities created as a result of a business case or intervention. This encompasses all changes in outcomes, including employment- and non-employment-related benefits that accrue to beneficiaries directly as a result of the output generated by an activity. The impact of these interventions goes beyond direct employment, extending to the creation of indirect and induced jobs.

In addition, Chazara et al. [40] discussed that indirect jobs are created as a result of increased economic activity that occurs due to the intervention. These jobs can be found in the supplier, service, and support sectors. They are often seen as changes in outcomes for individuals and businesses that are part of the target group of the business case but are not directly influenced by the outputs of the business case. Instead, they are typically triggered by direct effects on the beneficiaries and other outcome variables. On the other hand, induced jobs are a result of an increase in consumer spending due to the higher incomes generated by direct and indirect employment opportunities. These jobs are changes in the outcome variables for individuals and businesses that are not part of the intervention's target group. As a result, estimating the recipients of induced jobs is trivial because they cannot be directly observed. For this reason, we focus the study on predicting direct and indirect jobs from the business activities.

Direct jobs

The estimation of primary/direct jobs is based on sales (S_t) as a function of production ($S_t = \alpha * production$) and production is a function of manpower ($production = \beta * manpower$), consolidating both equations [40]. This is specified as follows:

$$manpower \approx \alpha * S_t + \beta \tag{4}$$

Coefficient α in the sales function represents the rate of change in defining manpower from the production function, and S_t refers to the average sales at time t. In a classical linear equation, coefficient β can be attributed to the residual manpower that emanates from the estimates [40].

According to Chazara et al. [40], manpower can however be defined as follows:

$$Manpower = \frac{Total\ Number\ of\ hours\ worked\ per\ day}{tonne\ of\ product\ produced} \tag{5}$$

In contrast, Chazara et al. [40] extended the argument of manpower and indicated that the attribute of sales to manpower does not account for investment in general. The relationship between manpower and sales is defined based on value addition. The discussion stems from the income gained from value addition, denoted as *VA* and gross income before interest, tax, depreciation, and amortization, denoted as .

The theory behind this assumption is to accommodate the income gained from aggregating the product, which is mostly associated with casual labor and undermines the quality of employment in agriculture. Further, it relaxes the linearity assumption of sales and manpower, and hence provides a robust estimate of the correlation between the two parameters. The inclusion of the value-added component is as follows:

$$manpower \approx \alpha * (|VA - EBE|) + \beta \tag{6}$$

Nonetheless, the authors note that there exists a small coefficient of determination in the estimation, which suggests the presence of other relevant variables essential in estimating jobs. In addition, in the current estimation, we note that the sales function can also create more jobs that can increase the costs of the business, preventing the business case from sustainably creating jobs while being profitable. In the current study, we address the setbacks in Chaza et al. [40] and hence present the manpower as follows:

$$manpower \approx \alpha_1 I_t + \alpha_2 R_t + \alpha_3 O_t + \alpha_4 V_t + \alpha_5 P_t + \beta \tag{7}$$

Where I_t initial investment required to build the business case, including capital and machinery, $R_t$is the revenue from the business case, O_t are the overhead costs, $V_t$are the variable costs, and P_t are the profits realized for the investment. This allows the equation to create jobs without suppressing the business growth.

Indirect jobs

The estimation of secondary jobs is based on the sub-contractors, whereby the direct jobs are created by the sub-contractors with income earned from the firm of interest. Under secondary (indirect) jobs, the estimation is based on the number of subcontracting units while mapping out income from firms of interest only. This includes all operations supporting the activities of the firm but that are not directly presented by the payroll. This is expressed as follows:

$$secondary\ jobs = pCA * N_{sub} \tag{8}$$

where *pCA* is the part of the business case turnover from the sale of the business product and N_{sub} is the number of subcontracting units or jobs in the business case, which includes maintenance jobs, and so forth.

Induced jobs

Induced jobs include mapping out the jobs created from personal spending from manpower estimated in both direct and secondary (indirect) jobs. This is more of a broad spectrum that extends to linkages between firms and sectors in the economy. This further involves jobs induced in the local economy as a result of people obtaining direct and indirect jobs.

$$TJ_{sector} = J_{Area} * PWLP * \frac{(J_{direct} + J_{indirect}) * Hsz}{N} \tag{9}$$

where J_{Area} is the number of jobs in the area of focus, $PWLP$ is the portion of the local jobs supported by the business case sector, J_{direct} and $J_{indirect}$ are direct and secondary jobs, respectively, Hsz is the average household size, and N is the population size. However, these were not predicted by the study.

Modelling business case jobs

Predictive analytics techniques

Predictive analytics models include a wide range of statistical and machine learning techniques designed to forecast future outcomes based on historical data patterns. These models include traditional regression methods (linear, logistic, and polynomial regression), decision trees, and ensemble methods like Random Forests and Gradient Boosting Machines (GBM) that combine multiple models for improved accuracy. More sophisticated approaches include Neural Networks, particularly Deep Learning models, which excel at capturing complex non-linear relationships in large datasets, and Support Vector Machines (SVM) that effectively handle high-dimensional data through kernel transformations.

Time series models such as Autoregressive Integrated Moving Average (ARIMA) models are specifically designed for temporal predictions, while Bayesian models incorporate prior knowledge and uncertainty into predictions. Each model type offers distinct advantages: regression models provide interpretability, ensemble methods offer robustness against overfitting, neural networks excel at pattern recognition, and Bayesian approaches quantify prediction uncertainty. The choice of model typically depends on factors such as data structure, prediction goals, interpretability requirements, and computational resources available. These powerful algorithms are trained on sample data, learning and adapting to the underlying rules in order to make accurate predictions for new and unpredictable situations.

Artificial neural networks (ANN)

Machine-learning predictive models are algorithms that enable computers to learn from data and make decisions without being programmed [41]. These models are grouped into two models namely supervised and unsupervised learning models. The supervised learning model uses labelled training data, whereas unsupervised learning does not. Artificial Neural Networks are fundamental components of machine learning. They are an information-processing paradigm inspired by the way the nervous system processes information [42]. In this study, a supervised artificial neural network was developed for job estimation, which contained artificial neurons arranged in a series of interconnected layers. By feeding the algorithm with financial assessment indicator data, the layers developed networks that had weights formed by determining the influence of the input layers in determining the output layers linked to direct and indirect job estimations, as presented in Eqs. (7) and 8. As the data move from one layer to another, the ANN learns from the data, eventually improving the outcome of the output layer. Unlike econometric models, the algorithm runs the equation, but instead of minimizing the error or maximizing the likelihood of outcomes, it back-propagates the error from the equations to learn and improve the accuracy of the predicted jobs.

Fig. 5 shows the architecture of the Artificial Neural Network (ANN) used in the estimation.

As shown in Fig. 5, the input layers involve the initial investment cost, sales/revenues realized from the business case, overheads, variable costs, and profitability indicators. The output layers involved job metrics, which included direct and indirect jobs. For each layer in the estimation, an error is created, which is backpropagated to learn and improve the estimation in the subsequent layer,

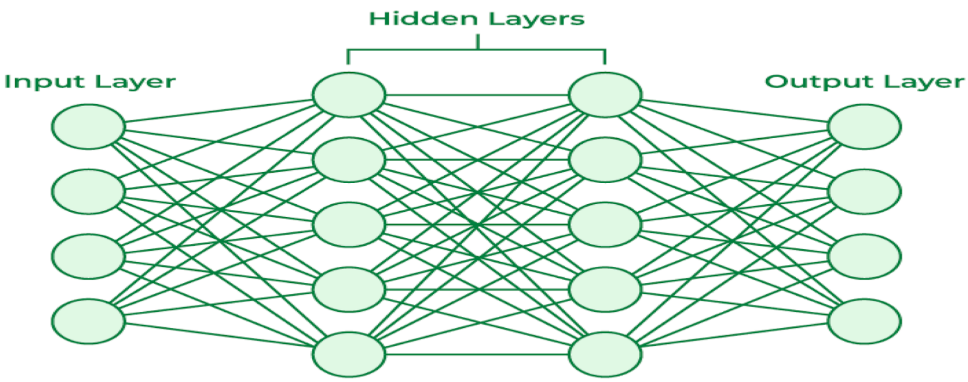

Fig. 5. Architecture of an Artificial Intelligent Neural Network.

further improving the prediction of jobs. To prevent overlearning, the model was implemented with early stopping features in the Keras Tensorflow environment. The ANN was simplified as follows:

$$y_{ij} = f(x_i) = f\left(\sum_{j=1}^{n} \omega_{ij} z_j\right) \tag{10}$$

$$y_{ij} = f(x_i) = \begin{cases} 1, & \omega_{ij}{}^T z_j \geq \theta \\ 0, & otherwise \end{cases} \tag{11}$$

where y_i is the number of jobs to be estimated for $j = 1,2,3$ implying direct and indirect jobs; x_i is a scalar of a weighted ω_i*the* sum of all its inputs z_i which is sales/revenue, costs, and investment parameters, as illustrated in Eq. (5) (Kaul et al., 2005); θ is the threshold level, and for the study, it is estimated by moving hectarage for avocado from 517 ha to 4933 ha, chili from 533 ha to 4457 ha, and poultry, which is the 27 % annual growth. The parameters first expand production and yields, which are then allocated to other business cases, such as processing and exports, to determine the response of job creation based on the alteration of investment parameters [18].

Evaluation/Validation of the performance of predictive analytics model

Predictive Analytics models continue to evolve, and it remains imperative to implement evaluation methods to gauge their performance. Much as there exists numerous techniques available to evaluate such models, the most reliable measures are accuracy, precision, and recall (Li et al., 2021). Through stratifying the data into a testing set and training set, the predicted values were further classified if they were a true positive (TP), a false positive (FP), a true negative (TN), or a false negative (FN).

To start with Precision (π_i), it is one of the measures used in the evaluation of predictive analytics models. It is the conditional

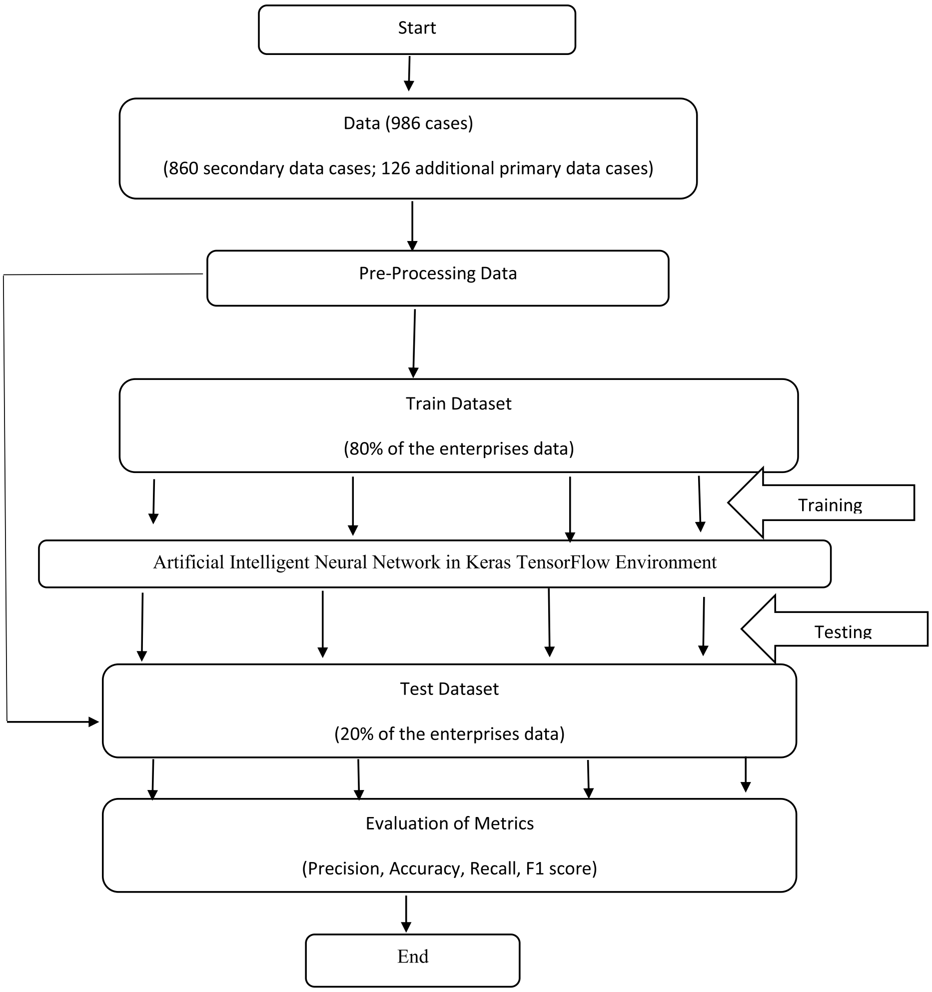

Fig. 6. A Conceptual Framework of the Artificial Neural Network Implemented.

probability that a random predicted job value j is classified under the correct category c_i. Precision thus determines the classifiers' ability to place a value correctly in its category, as opposed to all other values placed in that category, both incorrect and correct. This can be given as follows:

$$\pi_i = \frac{TP_i}{TP_i + FP_i} \tag{12}$$

Another evaluation measure employed is Recall (ρ_i). This measures the probability that a predicted job value j should be classified under its true category c_i. This can be presented as follows:

$$\rho_i = \frac{TP_i}{TP_i + FN_i} \tag{13}$$

The other measure used in evaluating predictive models is Accuracy (A_i) which measures the actual categorization technique in producing a true positive (TP). This can be presented as follows:

$$A_i = \frac{TP_i + TN_i}{TP_i + TN_i + FP_i + FN_i} \tag{14}$$

Nonetheless, it is crucial to combine precision and recall, to come up with a better perspective of the predicted values through the f1-score (F_β) as it provides a balance of both precision and recall. This is shown as follows:

$$F_\beta = \frac{(\beta^2 + 1)\pi\rho}{\beta^2\pi + \rho} \tag{15}$$

Where ρ is recall and π is precision; β is the goal of the evaluation and is always a positive parameter. In this case, if precision is deemed to be less desirable to recall, then the value of β converges to zero.

Conceptual framework for the ANN

Fig. 6 shows the conceptual framework of the algorithm implementation used in this study. It highlights the steps followed in employing the machine learning algorithm for the prediction of jobs in business case data. The diagram shows that the algorithm starts by collecting a training dataset of business case profitability and labor requirements from various sources. The data were then preprocessed in preparation for the Artificial Neural Network. The next stage involved splitting the data into training and testing datasets using the X_train, X_test, y_train, and y_test algorithms, which allowed the model to learn through the training process.

Results and discussions

Financial assessment

The following section presents the findings of the financial assessment of business cases in the three value chains of Avocado, Chili and Poultry. A sensitivity analysis of the computed indicators is presented in the appendix tables (Tables 1B – 1J).

Avocado value chain

Avocado production data highlight growing cash flow throughout the year. However, there is a greater cash outflow in the initial year up to the third year, with a net cash flow on the negative side. The Hass variety starts producing in the third year, explaining the absence of cash inflows. This trend is consistent with Velotrade's [43] observation that businesses often experience negative cash flows in the early stages due to substantial capital investments and essential expenses. The growing cash flow pattern supports the projected six-year timeframe for recovering the investment costs (payback period). Moreover, regarding profit, the investment shows a healthy balance between strategies for both prices and cost management, assuming that the business maintains its profitability trajectory while advancing growth initiatives.

The estimated Net Present Value (NPV) of $281,808 for medium-scale avocado production indicates a positive return on investment. According to the NPV decision rule, which states that investors should only invest in projects with a positive NPV [44], this investment would be accepted. To comprehend the NPV since it may not be a significant factor in instances where money is a problem, the cost Ratio (BCR) is calculated. The analysis shows that the BCR of 2.05 implies that, for every US Dollar invested, there will be a return of US$ 2.05, indicating the presence of value for money. Additionally, the estimated IRR for the business case is 32 %, which is greater than the weighted cost of capital (10 %). This finding aligns with Boniphace, [1] who reported IRRs ranging from 11.11 % to

Table 1
Evaluation Metrics of the Predictive Models.

Classification Code	Details
TP	Classified correctly in relation to its true value
FP	Classified as related to the true value incorrectly
TN	Classified as not related to the true value correctly
FN	Classified as not related to the true value incorrectly

14.60 %, higher than the fixed account rate of 2.16 %. These results collectively support the conclusion that investing in avocado production is financially viable, although with a longer payback period, which might not align with the impatience that young businesses require (Table 2).

Intercropping avocado and soybeans. To offset negative cash flows, intercropping with soybean during the first three years provides an opportunity to provide cash inflows in the initial stages of avocado production. Hence, investment highlights a growing cash flow throughout the year. However, there is a greater cash outflow in the initial year up to the third year, with a net cash flow on the negative side. Similarly, for the fourth year, the cash flow is positive but only a fraction compared to subsequent years. This trend is consistent with Velotrade's [43] observation that businesses often experience negative cash flows in the early stages because of substantial capital investments and essential expenses. A payback period of 4.8 years indicates that the investment will recover its costs within the designated timeframe (10 years). Moreover, investment demonstrates a healthy balance between pricing strategies and cost management, suggesting sustained profitability as the company pursues growth initiatives, assuming consistent performance.

The estimated Net Present Value (NPV) of $272,811 for medium-scale avocado production intercropping with soybeans indicates a positive return on investment. The NPV decision rule suggests that investors should only invest in projects with a positive Net Present Value [44]. Since the medium-scale avocado production intercropped with soybeans has a positive NPV, it is considered financially viable and therefore an acceptable investment opportunity. To comprehend the NPV, as it may not be a significant factor in instances where the money is a problem, BCR is calculated. The analysis shows that the BCR of 2.07 implies that, for every US Dollar invested, there will be a return of US$ 2.07, indicating the presence of value for money. Additionally, the estimated Internal Rate of Return (IRR) of the project was 66 %, which is greater the than the weighted cost of capital (10 %). This meets the viability criteria, which state that the IRR must exceed the prevailing interest rate [8]. Most importantly, the payback period drops to 4.8 years thus addressing the challenges of youth involvement in avocado production (Table 3).

Mechanization in intercropping avocado with beans. This model employs a hybrid approach that combines the short-term benefits of growing beans with the long-term potential of the avocados. Youths purchase and rent out 75HP tractors as a business venture and for use on their farms, cultivating beans in the initial three years and subsequently generating revenue from avocado sales. This investment highlights the growing cash flow over the entire business period. However, the business exhibits trends of negative cash flows in the early stages, and it has been heavily initiated by capital expenditure and overhead costs, amounting to a total of $173,920. Nonetheless, the investment is estimated to recover the cost in 4.9 years. The estimated Net Present Value (NPV) of $662,062 for the medium scale indicates a positive return on investment. The analysis further shows a BCR of 1.71, implying that for every US Dollar invested, there will be a return of US$ 1.71. Additionally, the estimated Internal Rate of Return (IRR) of the project is 36 % which is greater the than the weighted cost of capital (10 %). These results are consistent with Mottalib et al., [7] where the BCR had an estimated value of value of 1.41 and an IRR value of 139 %, greater than the greater than the bank interest rate (14 %) (Table 4).

Avocado cold room storage and aggregation. The storage and aggregation investment involves purchasing avocado at the farm gate price, aggregating, and storing in cold rooms for sale at export prices. The business exhibits trends of negative cash flows in the early stages due to initial capital expenditure and overhead costs amounting to a total of $210,615. Nonetheless, the investment is estimated to recover costs in the first two years, an incentive for youth involvement. Similar to on-farm business cases, the avocado cold room Storage and Aggregation case shows a healthy balance between strategies for both prices and cost management, assuming that the company upholds profitability while advancing growth initiatives.

An estimated Net Present Value (NPV) of $1108,678 indicates a positive return on investments. The analysis further shows that the BCR of the is 1.24 implying that, for every US Dollar invested, there is a return of US$ 1.24. Additionally, Additionally, the estimated Internal Rate of Return (IRR) of the project was 75 %, which is greater than the weighted cost of capital (10 %). This meets the viability criteria, which state that the IRR must exceed the prevailing interest rate [8] (Table 5).

Avocado oil processing. The machinery required in this business includes the avocado peeling and destination machine, pulping machine, oil extraction machine, hydraulic avocado oil press machine, oil purification apparatus, and oil packaging machine. Medium-scale processing requires more or larger machines than small-scale machines. A medium-scale investment of 30,000 L per year requires 300,000 kg of avocado. Similar to previous business cases, avocado oil processing exhibits trends of negative cash flows in the initial year, and this is aggravated by capital expenditure and overhead costs amounting to $475,000. Nonetheless, the investment is a quick win - estimated to recover the cost for a period of a year, 4 months and 24 days. The NPV of $613,109 indicated a positive return on investment. The BCR is 1.23, implying that for every US invested, there will be a return of US$ 1.23. Additionally, the estimated IRR of the project is 57 %, which is greater than the weighted cost of capital (10 %). Relative to the findings of Purwoko et al., [45] who reported an NPV value of $ 8895,714.5, a BCR value of 3.76, and IRR of 33.01 % for large scale production of essential oils, therefore, it can be concluded that avocado oil processing venture is financially viable (Table 6).

Chili value chain

Chili production. Chili production investment highlights growing cash flow throughout the year. However, the investment also exhibits trends of negative cash flows in the initial year, which is accelerated by capital expenditure and overhead costs, amounting to a total of $77,323. Despite this, the investment was estimated to recover the cost for a short period of 9 and 18 days. Nevertheless, the estimates

Table 2
Financial Assessment for Avocado Production (20 ha Medium Scale).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash Inflows	31,400	–	–	7598	39,887	104,704	131,927	161,611	193,933	229,084	267,264
Cash Outflows	–	47,744	33,903	37,884	39,042	39,152	33,025	33,494	35,115	35,805	37,788
Net cash flows	−31,400	−47,744	−33,903	−30,287	846	65,553	98,903	128,117	158,818	193,279	229,477
Discount factor	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
Discounted cash Inflows	31,400	–	–	5708	27,244	65,013	74,470	82,932	90,471	97,154	103,042
Discounted Cash Outflows	–	43,404	28,019	28,463	26,666	24,310	18,642	17,187	16,381	15,185	14,569
Discounted Net cashflows	−31,400	−43,404	−28,019	−22,755	578	40,703	55,828	65,745	74,090	81,969	88,473
Net Profit Margin (%)				−398.7	2.1	62.6	75.0	79.3	81.9	84.4	85.9
	One farm (20 ha)										
NPV	281,808										
BCR	2.05										
IRR	32 %										
Payback Period	6 Years										

Table 3
Financial Assessment of Intercropping Soybeans and Avocado (20 ha Medium Scale).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash Inflows	–	31,800	33,390	42,657	37,988	94,970	113,964	132,958	151,952	170,946	189,940
Cash Outflows	–	49,828	36,150	40,301	20,445	21,260	22,256	22,256	23,395	23,587	24,665
Net cash flows	−62,800	−18,028	−2760	2356	17,543	73,710	91,707	110,701	128,557	147,358	165,275
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386
Discounted cash Inflows	–	28,909.09	27,595.04	32,048.90	25,946.27	58,968.80	64,329.60	68,228.37	70,886.61	72,497.67	73,229.97
Discounted Cash Outflows	65,107.69	45,298.42	29,876.43	30,278.89	13,964.47	13,200.69	12,563.11	11,421.01	10,913.98	10,003.35	9509.38
Discounted Net Cashflows	−65,107.69	−16,389.33	−2281.3	1770.01	11,981.80	45,768.11	51,766.49	56,807.35	59,972.64	62,494.32	63,720.59
Net Profit Margin (%)					59	83	85	87	88	89	90
	One farm (20 ha)										
NPV	272,811										
BCR	2.07										
IRR	36 %										
Payback Period	4.8 Years										

Table 4
Financial Assessment of Mechanization in Intercropping Beans and Avocado (20 ha Medium Scale).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash Inflows	–	131,400	136,260	148,961	150,509	213,117	238,018	263,215	288,722	314,554	340,729
Cash Outflows	–	129,244	115,728	120,046	64,265	65,877	68,752	69,598	71,608	72,699	74,701
Net cash flows	−173,920	2156	20,532	28,915	86,244	147,240	169,267	193,617	217,113	241,856	266,028
Discount factor	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
Discounted cash Inflows	–	119,455	112,612	111,916	102,800	132,329	134,355	135,071	134,691	133,402	131,366
Discounted Cash Outflows	–	117,495	95,643	90,192	43,894	40,905	38,808	35,715	33,406	30,831	28,800
Discounted Net cashflows	−173,920	1960	16,969	21,724	58,906	91,424	95,547	99,356	101,285	102,570	102,565
Net Profit Margin (%)		1.64	15.07	19.41	57.30	69.09	71.12	73.56	75.20	76.89	78.08
	One farm (20 ha)										
NPV	518,378										
BCR	1.71										
IRR	36 %										
Payback Period	4.9 Years										

Table 5
Financial Assessment of Avocado Aggregation and Storage.

Items	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cash Inflows	–	782,401	821,521	862,597	905,727	951,013	998,564	1048,492	1100,917	1155,962	1213,760
Cash Outflows	–	651,610	672,222	692,857	714,135	736,076	758,700	782,030	806,089	830,900	856,486
Net cash flows	−210,615	130,791	149,298	169,739	191,592	214,938	239,864	266,461	294,827	325,063	357,275
Discount factor	1	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39
Discounted cash Inflows	–	711,273	678,943	648,082	618,624	590,504	563,663	538,042	513,586	490,241	467,957
Discounted Cash Outflows	–	592,373	555,556	520,554	487,764	457,045	428,266	401,305	376,047	352,383	330,212
Discounted Net cashflows	−210,615	118,901	123,387	127,528	130,860	133,459	135,397	136,737	137,539	137,858	137,745
Net Profit Margin (%)		16.72	18.17	19.68	21.15	22.60	24.02	25.41	26.78	28.12	29.44
NPV	1108,678										
BCR	1.24										
IRR	75 %										
Payback period	2 Years										

Table 6
Financial Assessment for Avocado Oil Processing.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Inflows	–	850,080	850,080	850,080	864,864	880,387
Cash Outflows	–	519,877	546,201	574,281	604,255	636,276
Net cash flows	−475,000	330,203	303,879	275,799	260,609	244,111
Discount factor	1	0.91	0.83	0.75	0.68	0.62
Discounted cash Inflows	–	772,800	702,545	638,678	590,714	546,651
Discounted Cash Outflows	–	472,615	451,406	431,466	412,714	395,077
Discounted Net cashflows	−475,000	300,185	251,139	207,212	177,999	151,574
Net Profit Margin (%)		38.84	35.75	32.44	30.13	27.73
NPV	613,109					
BCR	1.23					
IRR	57 %					
Payback	1.4 Years					

also indicate a healthy balance between strategies for both prices and cost management, assuming that the company upholds profitability, while maintaining consistent performance.

The estimated NPV of $203,488 for Chili production indicates a positive return on investment. The BCR of the medium-scale enterprise is 1.37 implying that, for every US Dollar invested, there will be a return of US$ 1.37. This is in agreement with a study by Ila et al. [46] on green chili production, where they found a BCR of 1.88. Additionally, the estimated IRR of the investment is 85 %, which is greater than the weighted cost of capital (10 %). Again, the IRR estimates are consistent with Ashoka et al., [19] who reported an IRR of 102 % in Chili nurseries. Therefore, we conclude that Chili production is financially viable (Table 7).

Chili oil processing. Chili oil processing highlights a growing cash flow throughout the years despite a greater cash outflow in the initial year. This is initiated by capital expenditure and overhead costs amounting to $697,400. The investment is estimated to recover the cost for a short period of a year, 4 months and 24 days, citing quick wins. In profit terms, the investment estimates indicate a healthy balance between strategies for both prices and cost management assuming that the company upholds profitability while maintaining a consistent performance. The estimated Net Present Value (NPV) of $601,325 for medium-scale Chili processing. The analysis further shows that a BCR of 1.22 implies that, for every US Dollar invested, there will be a return of US$ 1.22. Additionally, the estimated IRR of the project is 40 % greater than the weighted cost of capital (10 %). The estimated metrics are consistent with those in the study by Poonia et al. [47] which found an IRR of 82.5 %, a short payback period of 1.5 years and a BCR OF 1.98 on analysis of chill processing. These results collectively support the conclusion that investing in chili oil processing is financially viable (Table 8).

Poultry value chain

Broilers production. In this case, a medium-sized farm with 500 broiler birds was assessed. Broiler production exhibited a growing cash flow throughout the years despite having a greater cash outflow in the initial year. Cash flow was aggravated by capital expenditure and overhead costs, amounting to a total of $6000. The investment is estimated to recover cost for a short period of 2 years, 2 months and 12 days. The estimated NPV of $14,930.20 indicates a positive return on investment. The BCR of medium-scale broiler enterprises is 1.4, implying that for every US Dollar invested, there will be a return of US$ 1.40. Additionally, the estimated IRR of the investment is 82 % greater than the weighted cost of capital (10 %). These results are consistent with those reported by Wantasen et al. [48] in their analysis of broiler production. Their study found a Net Present Value (NPV) of $101,909.43, BCR of 1.22, and IRR of 63.18 %, with a payback period of 1 year and 7 months. These findings support the conclusion that broiler production is financially viable (Table 9).

Layers production. The layer's production cash flow and profits follow the same footprint as broiler production with only a higher capital expenditure and overhead costs that amounted to a total of $14,500. The investment has an estimated Payback period of 1 year, 4 months and 24 days, citing the business as a quick win business. The Net Present Value (NPV) of $21,790.43 indicates a positive return on investment. The analysis further shows a BCR of 1.3, implying that for every US Dollar invested, there will be a return of US$ 1.3. Additionally, the estimated IRR of the investment was 56 % greater than the weighted cost of capital (10 %). Relative to these findings is a study by Baruwa & Fabode [2] which also found that layer production was more financially viable than broiler production after exhibiting higher NPV values and a shorter payback period (Table 10).

Job estimation

The challenge that we face in the current study is to estimate the number of jobs that can be created by achieving three government goals in the next five years: (1) increasing land under avocado production from 517 ha to 4933 ha; (2) increasing land under Chili production from 533 ha to 4457 ha; and (3) increasing poultry production by 27 % annually. Much as regression can estimate that challenges arise when some factors of production are fixed. Again, the increased production from the increased investment in land must spread across different business cases that are meant to absorb production. This implies that a predictive analytics model that can

Table 7
Financial Assessment of Birds Eye Chili (20 ha Medium Scale).

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Inflows (USD)	0	181,698	190,783	200,323	210,339	220,856
Cash Outflows (USD)	0	118,246	121,793	125,447	129,210	133,087
Net cash flows (USD)	−77,323	63,453	68,990	74,876	81,128	87,769
Discount factor	1	0.909	0.826	0.751	0.683	0.621
Discounted cash Inflows (USD)	–	165,180.42	157,672.22	150,505.30	143,664.15	137,133.96
Discounted Cash Outflows (USD)	77,323.08	107,496.14	100,655.48	94,250.13	88,252.39	82,636.33
Discounted Net cashflows (USD)	−77,323.08	57,684.28	57,016.74	56,255.17	55,411.76	54,497.63
Net Profit Margin (%)		34.92	36.16	37.38	38.57	39.74
	One farm (20 ha)					
NPV	203,488					
BCR	1.37					
IRR	85 %					
Payback	1.8 years					

Table 8
Financial Assessment of Chili Oil Processing.

Items	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Inflows (USD)	0	807,692	848,077	890,481	935,005	981,755
Cash Outflows (USD)	0	467,400	505,266	546,330	590,869	639,185
Net cash flows (USD)	−697,400	340,292	342,811	344,151	344,136	342,570
Discount factor	1	0.909	0.826	0.751	0.683	0.621
Discounted cash Inflows		734,265.73	700,890.02	669,031.38	638,620.86	609,592.64
Discounted Cash Outflows	697,400.00	424,909.09	417,575.21	410,465.77	403,571.57	396,883.80
Discounted Net cashflows	−697,400.00	309,356.64	283,314.81	258,565.61	235,049.30	212,708.84
Net Profit Margin (%)		42.13	40.42	38.65	36.81	34.89
NPV	601,325					
BCR	1.22					
IRR	40 %					
Payback	1.4 years					

Table 9
Financial Assessment for Broiler Value Chain (500 Birds)[14].

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Inflows	0.00	12,825.00	13,466.25	14,139.56	14,846.54	15,588.87
Cash Outflows	0.00	8070.04	8312.14	8561.50	8818.35	9082.90
Net cash flows	−6000.00	4754.96	5154.11	5578.06	6028.19	6505.97
Discount factor	1	0.909091	0.826446	0.751315	0.683013	0.620921
Discounted cash Inflows		11,659	11,129	10,623	10,140	9679
Discounted Cash Outflows	6000	7336	6870	6432	6023	5640
Discounted Net cashflows	(6000)	4323	4260	4191	4117	4040
Net Profit Margin (%)	0	57	58	59	59	60
NPV	14,930.20					
BCR	1.4					
IRR	82 %					
Payback	2.2 years					

learn the current production features can help forecast manpower requirements when government goals are attained.

However, the study first considered implementing a linear model using the *statsmodels* library in a Python environment. This is essential for ascertaining the presence of relationships among the predictors. For instance, Chazala et al. [40] present an econometric relationship between manpower and sales revenue in the rubber, plastic, Chemical and Medical sectors. However, the authors noted a weak coefficient of determination and some large errors in the estimation. To solve this problem, this study proposes additional predictors of manpower, namely investment and overhead costs. The findings affirm this hypothesis as in three sectors, the study finds that indeed sales revenue, investment costs and overhead costs determine the ability of a firm to recruit more or less manpower. For instance, investment costs increased direct personnel in the Chili and Poultry sectors on average, sales revenue increased direct labor in all value chains, while overheads only increased direct manpower in the avocado value chain. A similar story can be told from indirect and induced manpower. However, a linear model might, in this case, be misleading in explaining how government goals can lead to increased labor requirements. Thus, we modeled using a predictive artificial intelligence neural network (Table 11).

Table 10
Financial Assessment for Layers Production[51].

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Inflows	0.00	20,081.25	22,123.77	22,139.58	24,336.94	24,408.88
Cash Outflows	0.00	12,157.50	12,522.23	12,897.89	13,284.83	13,683.37
Net cash flows	−14,500.00	7923.75	9601.55	9241.69	11,052.11	10,725.51
Discount factor	1	0.909091	0.826446	0.751315	0.683013	0.620921
Discounted cash Inflows		18,256	18,284	16,634	16,622	15,156
Discounted Cash Outflows	14,500	11,052	10,349	9690	9074	8496
Discounted Net cashflows	(14,500)	7203	7935	6943	7549	6660
Net Profit Margin (%)	0	50	54	52	55	54
NPV	21,790.43					
BCR	1.22					
IRR	56 %					
Payback	1.4 years					

The artificial neural network results

Thus far, we have established that a link exists between manpower and investment costs, sales revenue, and overhead costs. However, the low coefficient of determination and the assumption of a linear relationship go against the reality of how investments are done in the real world [6]and the need to predict investment changes due to government goals [40].

Nonetheless, the covariates make more sense in the early stages of the creation of a new activity, where firms are presented with an applicable model that can estimate labor requirements [49]. However, Chazala et al. [40] further trashed the presence of this linear relationship, calling for the need to seek another sort of relationship among the variables. Since the form of the relationship is unknown, a predictive model is useful. An artificial neural network is the best fit because of its ability to learn from a training set and is predictive in a larger context [50]. Unlike linear models, ANN are estimated with high levels of accuracy and precision.

Job estimation in avocado

First, the study starts with a qualitative assessment of the types of jobs available in each of the existing business cases. Through KIIs with business owners, this study assessed the number of employees and different types of jobs in the business. This was later transferred to the cost of business expenses in the business analytics framework. For Avocado, the study identified the production business case, mechanized production, aggregation, storage and export, and avocado oil processing.

In production, jobs include (1) direct jobs: farm enterprise ownership/co-ownership, management, agronomists, tractor operators, manual labor, and security; (2) indirect jobs: extension services, harvest and post-harvest handling, tractor maintenance, transport, and logistics; seedling sales, pesticide sales, tractor and other equipment spare parts, and insurance. In aggregation and export, jobs include: (1) direct: enterprise ownership/co-ownership, management, marketing, security, and manual labor; and (2) indirect: farmers contracted to supply export grade avocado, logistics, cold room maintenance experts, electricians, seedling sales, and pesticide sales. In avocado oil processing: (1) direct jobs: enterprise ownership/co-ownership, management, marketing, security, and manual labor; (2) indirect jobs: farmers contracted to supply export-grade avocado, loading, off-loading, logistics and transportation, machinery installation, maintenance, and machine spare part shops. It should be noted that induced jobs are difficult to count, as they are estimates of how the economy reacts [51].

From a single business, the study makes an assumption of production on 517 ha, which extends the production to be consumed in the export and processing industries. The same concept is replicated on 4933 ha, with the difference consisting of jobs created as a result of area consumption to meet government needs and goals.

As previously mentioned, the projected number of jobs in the avocado industry is determined using an Artificial Neural Network (ANN) framework. The jobs are predicted by increasing the land size under Avocado from 517 ha to 4933 ha, as planned by the Ministry of Agriculture. This will have implications for production, processing, and export quantities, and most importantly, for labor requirements. The avocado value chain creates many jobs that include cooperative ownership, agronomists, security personnel, machine operators, and secondary jobs, such as machine maintenance, casual labor, logistics, and extension. Other indirect jobs related to the local economy, such as seedling and pesticide shops, are also expected to support the chain. An estimated 15,351 jobs are expected in production, 7186 in mechanization and legume intercropping, 12,716 in aggregation and storage, and 11,785 in oil processing. These estimates align with the Avocado Institute of Mexico [52] report, which stated that avocado cultivation created approximately 78,000 direct and permanent jobs and 310,000 indirect and seasonal jobs. Thus, the estimated number of jobs was feasible. This provides a more realistic estimate as opposed to a regression line with fixed coefficients (Fig. 7).

Job estimation in chili

A similar concept was adopted for the chili value chain. In production, jobs include (1) direct: farm enterprise ownership/co-ownership, management, agronomists, tractor operators, manual labor, and security; (2) indirect: extension services, harvest and post-harvest handling, tractor maintenance, transport, and logistics; seedling sales, pesticide sales, tractor, and other equipment spare parts sales and insurance. In aggregation, jobs include: (1) direct: enterprise ownership/co-ownership, management, marketing, security, and manual labor; (2) indirect: farmers contracted to supply export-grade chili, logistics, cold room maintenance experts, electricians for cold rooms, seedling sales, and pesticide sales. In oil processing: (1) direct: enterprise ownership/co-ownership,

Table 11
Extract Coefficients of statsmodels Library Outputs[61].

Value Chain	Avocado	Chili	Poultry
Equation			
Direct Manpower			
α	7.3**	8.8**	4.6**
Investment (β_1)	−0.09	2.41**	1.08*
Sales Revenue (β_2)	11.2***	14.6***	7.9**
Overheads (β_3)	5.3*	4.6	8.1
Indirect Manpower			
α	28.7**	31.2**	19.6**
Investment (β_1)	73.5**	54.8**	22.9**
Sales Revenue (β_2)	16.5**	21.3***	11.2**
Overheads (β_3)	15.3	3.8	1.1*
Induced Manpower			
α	40.5***	42.6**	22.1*
Investment (β_1)	7.2	8.1***	3.5
Sales Revenue (β_2)	9.9**	6.2**	2.2**
Overheads (β_3)	2.5	4.8	3.1
R-squared	60.8	62.5	66.1

*** Significant at 1 %;.
** Significant at 5 %;.
* Significant at 10 %.

management, marketing, security, and manual labor; (2) indirect: farmers contracted to supply export grade chili, loading, off-loading, logistics and transportation, installation, maintenance, and machine spare part shops.

Chili value chain jobs are predicted based on an increase in land under Chili from 533 ha to 4457 ha. In the Chili value chain, each business case revealed varying job numbers across the direct and indirect roles. Notably, the production stage is expected to generate the most jobs (22,232), making Chili a highly profitable venture, with numerous opportunities in the secondary and tertiary sectors. Additionally, storage and aggregation will create 17,299 jobs, which are crucial for Rwanda's Chili exports, whereas oil processing will generate 17,024 jobs. Although the manufacturing sector is praised for its job creation potential, financial analysis shows that it requires substantial capital investment, implying that further investments are needed to realize the predicted job numbers (Fig. 8).

Job estimation in poultry

Following an approach similar to that in previous value chains, jobs in the poultry value chain include: (1) direct: enterprise ownership/co-ownership, management, animal health officers, security, and manual labor; (2) indirect: chicken parts and eggs retailing, community vets, chicken feed processors, vet drug stores, and restaurants at a tertiary level.

Through the ANN algorithm, the layers business case was predicted to create 18,843 jobs in five years, as opposed to the 20,652 jobs to be created in the broiler business case. This assumes that the sector will grow by 27 % annually, increasing the required investment by a similar amount in five years [17]. Nonetheless, it is expected that there will be more business cases in the poultry sector to address the challenges of nutritious feed, vaccination, veterinary services, processing of poultry products, restaurants, food marts, and other businesses that can create more job opportunities. Thus, from these business cases, more jobs are expected to be created indirectly as secondary jobs (10,284 in layers and 12,603 in broilers) in other related sectors. For instance, the United States of America poultry industry employs approximately 533,857 people and generates an additional 1605,760 jobs in the supplier and ancillary industries [53]. The estimates in Rwanda show hope for job creation with increased investment in the sector (Fig. 9).

Model evaluation and validation metrics

The ANN was further tested to assess the predicted values for precision, accuracy, and recall as illustrated in methodology section. It is important that the predicted values are evaluated and validated across the testing set. The ANN, as earlier illustrated follows a backpropagation procedure. This ensures that the errors arising from the prediction are propagated backwards to learn and adjust the weights and biases through calculating the gradient of the loss function with respect to each weight. This follows a forward pass where input data (in this case business financial metrics) flows through the network to make a prediction and observe the error, and a backward pass where the error is backpropagated to recalculate the weights and the gradient of the loss function. This process hence has to be validated to ensure that the predicted values are precise and accurate. Table 12 shows that through fitting a normal ANN, the accuracy levels reached 83 %, a precision of 84.5 %, Recall of 83.2 % and an F1-score of 83.9 %. However, to avoid overfitting the model, the algorithm was further implemented with early stopping technique. This improved the accuracy to 91 %, precision to 94 %, recall to 90 % and the F1-score to 92 %.

Broader applicability and cross-regional implications of the results

The insights derived from the findings of the business analytics in Rwandan agribusiness are not confined to the local context; rather, they offer diverse implications for transformative change in various regions and industries globally. The core principles which

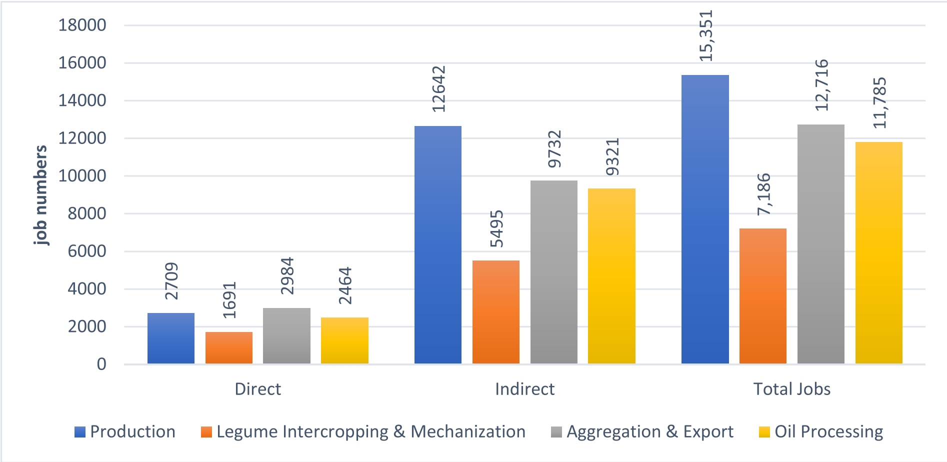

Fig. 7. Predicted Jobs in Avocado Value Chain.

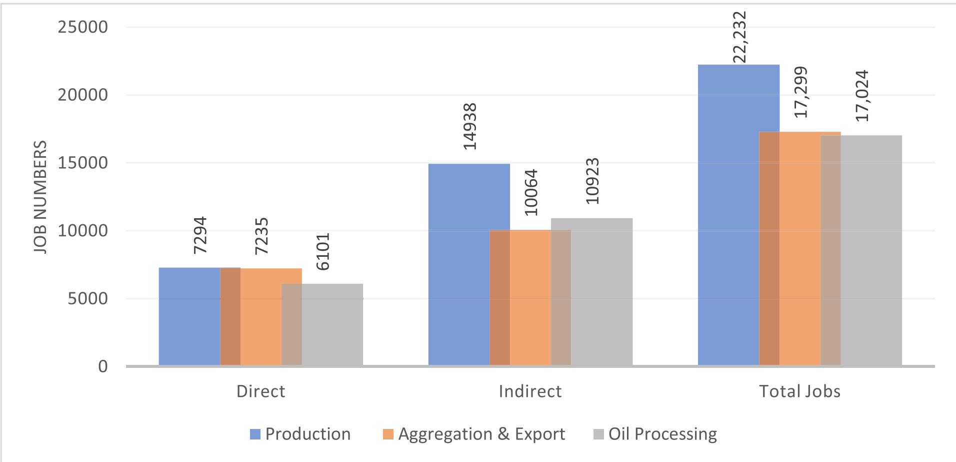

Fig. 8. Predicted Jobs in Chili Value Chain.

include data-driven decision-making, value chain optimization, and stakeholder engagement are universally relevant and adaptable to varying socio-economic and sectoral landscapes.

Emerging markets in Southeast Asia and Latin America have demonstrated similar structural challenges and opportunities as Rwanda, particularly in agriculture. For instance, Vietnam's adoption of analytics-driven rice cultivation strategies led to a 45 % increase in productivity [34], while Indonesia's use of supply chain analytics improved efficiency by 38 % (Suharto & Rahman, 2023). In Brazil, the integration of digital agriculture and analytics in soybean and poultry sectors resulted in a 30 % rise in rural employment and a 20 % increase in household income [33]. These similarities underscore the transferability of the Rwandan model, suggesting that analytics frameworks can be tailored to local crops, market structures, and policy environments to achieve similar gains.

Most importantly, the analytical framework remains equally applicable to other industries. The findings from this research not only apply to on-farm processes but also off-farm enterprises like manufacturing industries. The predictive analytics can be adapted to optimize inventory, reduce downtime, and enhance quality control in manufacturing. In retail, retailers can adopt similar analytics for stock optimization, customer segmentation, and sales forecasting, resulting in significant improvements in operational efficiency and sustainability of the business.

All in all, a key lesson from the findings is the importance of integrating diverse data sources in assessing public private partnerships goals. The scalability of these approaches is further enhanced by emerging technologies such as artificial intelligence and machine learning, which can amplify the impact of analytics across sectors.

Conclusions and recommendations

Rwanda's economic aspiration to become a middle-income country by 2035 and a high-income country by 2050 hinges on modernizing its agricultural sector, which employs over 70 % of the population with a focus on empowering youth. However,

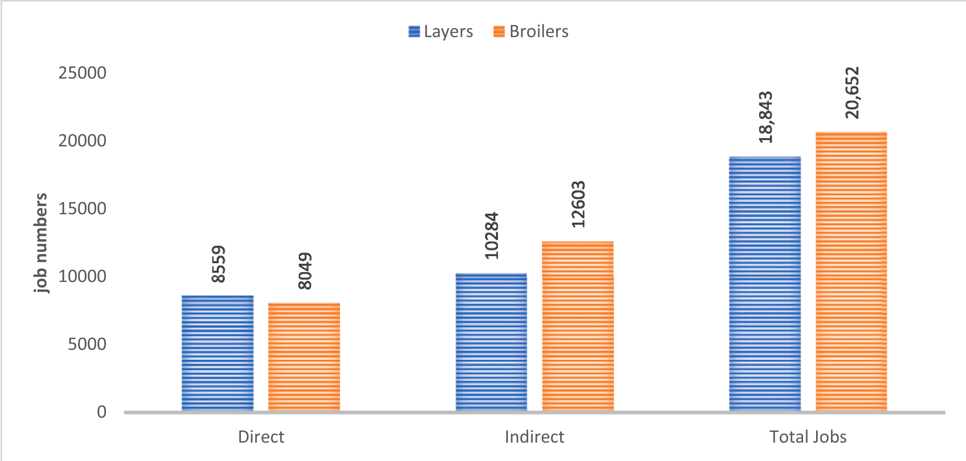

Fig. 9. Predicted Jobs in the Poultry Sector.

improving agricultural productivity requires sound decisions in areas with the greatest potential to support this economic goal. This study assessed the three value chains of Avocado, Chili and Poultry in Rwanda. The findings indicate that all three value chains have high potential for development and can contribute to sustainable economic growth. These value chains also have the potential to employ more people, thereby improving living standards.

This study employed metrics such as NPV, IRR, BCR, and payback period to assess the financial viability of these value chains. Production is considered a worthwhile investment in the avocado value chain owing to its strong financial metrics. However, the business case for avocado production faces several challenges, leading to a longer payback period. To address this, alternatives, such as intercropping with beans or soybeans and the acquisition and hiring of tractors, were considered for financial assessment. These alternatives are crucial for making avocado production more attractive to young people. Investments in avocado cold storage, exports, and avocado oil processing are lucrative at all scales.

The Chili value chain is another promising sector, particularly because of its shorter payback period. This includes the business case for Chili production, which has a shorter payback period of less than a year, unlike avocado production. Chili oil processing also demonstrated strong financial metrics, making it a viable investment opportunity for the youth. Nonetheless, despite the Chili value chain showing the highest potential for creating more youth, the sector displayed huge investment costs, which might hinder youth investment.

Finally, in the poultry value chain, layer production showed slightly better financial metrics than broiler production. However, both are considered worthwhile investments because of their relatively low capital expenditure requirements compared to other sectors, making it easier for youth to venture into. To improve poultry productivity, it is essential to introduce improved breeds and cheap improved feed, and provide direct extension services to lower production costs.

Furthermore, the analyzed business cases highlight the significant potential for job creation. The Avocado value chain, consisting of production, mechanization, aggregation, and processing, is predicted to generate 47,038 jobs. Similarly, for the Chili value chain, production, aggregation, and processing were expected to create 56,555 jobs. Meanwhile, Poultry production is predicted to create 39,495 jobs over five years, assuming a 27 % annual increase in investments.

To realize this potential, it is imperative to address critical challenges in the value chains. Most importantly is the need for developing proper financing models for boosting investment in the business cases to create the predicted jobs. As global food systems become more complex and interconnected, there will remain a need for stakeholders to increasingly turn to financial solutions to unlock growth, enhance resilience, and drive sustainable development. Looking at the longer payback periods noticed in this study, it is imperative that agricultural development banks provide subsidized interest rates, longer grace periods, and technical assistance, making investment in those business cases valuable for smallholder farmers and early-stage ventures. In recent years, innovative financing models have gained traction. Blended finance, which combines public and private capital, is increasingly used to de-risk investments and attract private sector participation. For example, first-loss guarantees, and risk-sharing facilities provided by development institutions can leverage private investment. Value chain financing such as contract farming, warehouse receipt financing, and supplier credit programs, aligns financial flows with production and marketing cycles, improving access to working

Table 12
ANN Evaluation of the Fitted Algorithm.

Algorithm	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
ANN with early stopping	91	94	90	92
ANN	83	84.5	83.2	83.9

capital and reducing risk. For smallholder farmers, collateral remains a challenge, further calling for financing models like matching grants and partial credit guarantees for increased investments.

Moreover, the digital revolution has transformed agribusiness financing. Mobile banking, fintech platforms, and blockchain-based solutions have made financial services more accessible, especially in rural areas. Digital platforms have reduced transaction costs and improved loan processing time. These solutions also enable alternative credit scoring and real-time risk assessment, broadening financial inclusion for previously underserved populations.

Lastly, risk management products such as weather index insurance, price hedging, and yield protection instruments are essential for mitigating the volatility inherent in agriculture. Structured finance solutions, including agricultural bonds and green finance instruments, can provide long-term, sustainable funding for large-scale investments. By leveraging these models and rallying on the growing demand for these agricultural products in both the domestic and international markets, the country can unlock the full potential of its agricultural sector and drive sustainable economic growth.

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CRediT authorship contribution statement

Wisdom Richard Mgomezulu: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Paul Thangata:** Project administration, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. **Sibusiso Nhlengethwa:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Davis Muthini:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jonathan Said:** Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

We hereby declare that the information in this article is correct, and that there exist no potential or apparent conflict of interest.

Appendix

Sensitivity Analysis Tables

Para:none

Appendix 1B. Avocado 5 ha (small)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	27 %	46,743	20,868	6 Years
	10 %	27 %	46,555	20,868	6.1 Years
	−10 %	27 %	46,929	20,868	5.9 Years
Yield	Original	27 %	46,743	20,868	6 Years
	10 %	30 %	57,738	23,717	5.1 Years
	−10 %	24 %	35,748	18,018	6.3 Years
Prices	Original	27 %	46,743	20,868	6 Years
	10 %	30 %	57,738	23,717	5.1 Years
	−10 %	24 %	35,748	18,018	6.3 Years

Appendix 1C. Avocado 5 ha (medium)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	27 %	186,971	83,470	6.0
	10 %	27 %	205,668	83,470	6.0
	−10 %	27 %	168,274	83,470	6.0
Yield	Original	27 %	186,971	83,470	6.0
	10 %	30 %	230,951	94,866	5.7
	−10 %	24 %	142,991	72,074	6.3
Prices	Original	27 %	186,971	83,470	6.0
	10 %	30 %	230,951	94,866	5.7
	−10 %	24 %	142,991	72,074	6.3

Appendix 1D. Avocado 5 ha (large)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	original	28 %	952,077	417,351	4.5
	10 %	28 %	1047,285	417,351	4.5
	−10 %	28 %	856,869	417,351	4.5
Yield	original	28 %	952,077	417,351	4.5
	10 %	31 %	1171,977	474,332	4.3
	−10 %	24 %	732,177	360,369	4.7
Prices	original	28 %	952,077	417,351	4.5
	10 %	31 %	1171,977	474,332	4.3
	−10 %	24 %	732,177	360,369	4.7

Appendix 1E. Chili 5 ha (small)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	original	21 %	24,612	7681	3.0
	10 %	21 %	27,074	7681	3.0
	−10 %	21 %	22,151	7681	3.0
Yield	original	21 %	24,612	7681	3.0
	10 %	45 %	49,506	12,021	2.0
	−10 %	−9 %	−281	3342	6.4
Prices	original	21 %	24,612	7681	3.0
	10 %	45 %	49,506	12,021	2.0
	−10 %	−9 %	−281	3342	6.4

Appendix 1F. Chili 20 ha (medium)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	62 %	276,098	61,627	2.4
	10 %	62 %	303,708	61,627	2.4
	−10 %	62 %	248,488	61,627	2.4
Yield	Original	62 %	276,098	61,627	2.4
	10 %	84 %	382,464	80,168	1.2
	−10 %	36 %	161,189	41,597	2.2
Prices	Original	62 %	276,098	61,627	2.4
	10 %	85 %	387,163	80,987	2.8
	−10 %	37 %	165,033	42,267	2.2

Appendix 1G. Chili 5 ha (large)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	22 %	511,470	156,977	2.9
	10 %	22 %	562,617	156,977	2.9
	−10 %	22 %	460,323	156,977	2.9
Yield	Original	22 %	511,470	156,977	2.9
	10 %	45 %	990,117	240,411	2.0
	−10 %	−9 %	−5623	66,841	6.4
Prices	Original	22 %	511,470	156,977	2.9
	10 %	46 %	1011,262	244,097	1.9
	−10 %	−7 %	11,677	69,857	6.2

Appendix 1H. Broilers (small)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	61 %	373	288	2.4
	10 %	61 %	410	288	2.4
	−10 %	61 %	335	288	2.4
Yield	Original	61 %	373	288	2.4
	10 %	61 %	373	288	2.4
	−10 %	61 %	373	288	2.4
Prices	Original	61 %	373	288	2.4
	10 %	151 %	940	495	1.7
	−10 %	−12 %	−195	80	6.4

Appendix 1I. Layers (small)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	91 %	4921.96	582	1.8
	10 %	91 %	5414	582	1.8
	−10 %	91 %	4430	582	1.8
Yield	Original	91 %	4922	582	1.8
	10 %	105 %	5650	769	1.2
	−10 %	78 %	4194	395	2.1
Prices	Original	91 %	4922	582	1.8
	10 %	105 %	5650	769	1.2
	−10 %	78 %	4194	395	2.1

Appendix 1J. Layers (medium)

Variable	% change	IRR	NPV	EBIT	Payback period
Interest rate	Original	270 %	31,772.27	6276	0.4
	10 %	270 %	34,949	6276	0.4
	−10 %	270 %	28,595	6276	0.4
Yield	Original	91 %	4922	582	1.8
	10 %	312 %	35,414	7211	0.3
	−10 %	229 %	28,130	5340	0.5
Prices	Original	91 %	4922	582	1.8
	10 %	312 %	35,414	7211	0.3
	−10 %	229 %	28,130	5340	0.5

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