Sustainability of Agricultural Crop Policies in Rwanda: An Integrated Cost-Benefit Analysis

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Development Discussion Paper: 2021 -02

ABSTRACT

Rwanda has aimed to achieve food self-sufficiency but faces binding land and budgetary constraints. A set of government policies have been in force for 20 years and have controlled the major cropping decisions of farmers. A cost-benefit analysis methodology is employed to evaluate the financial and resource flow statements of the key stakeholders. The object of the analysis is to determine the sustainability of the prevailing agricultural policies from the perspectives of the farmers, the economy, and the government budget. A total of seven crops were evaluated. In all provinces, one or more of the crops were either not sustainable from the financial perspective of the farmers or are economically inefficient in the use of Rwanda's scarce resources. The annual fiscal cost to the government of supporting the sector is substantial but overall viewed to be sustainable. A major refocusing is needed of agricultural policies away from a monocropping strategy to one that allows the farmers to adapt to local circumstances. A more market-oriented approach is needed if the government wishes to achieve its economic development goal of having a sustainable agricultural sector that supports the policy goal of achieving food self-sufficiency.

Keywords: Rwanda, agricultural policy sustainability, land scarcity, food self-sufficiency, integrated investment appraisal

JEL Classification : D61, Q12, Q13

Revised version published as : Miklyaev, M.; Jenkins, G.; Shobowale, D. Sustainability of Agricultural Crop Policies in Rwanda: An Integrated Cost–Benefit Analysis. Sustainability 2021, 13, 48. https://doi.org/10.3390/su13010048

1. Introduction

The objective of the Rwandan Government's development framework, known as Vision 2020, has been to convert the economy from an agrarian one into a private-sector-led, knowledge-based economy and to transform the agricultural sector from subsistence-based to one that is market-oriented [1].

To reach its target goals, the Rwandan Government sets targets to which it binds subnational governments via a particular performance contract mechanism called Imihigo contracts [2]. This is one of the various home-grown systems introduced by the government. It is a top-down process whereby a regional agronomist selects crops each season following the targets set by the government [3]. This Umihigo contractual mechanism has been described as a results-based approach to public sector performance [4]. It employs competition between villages, rewarding the best on the publicly available ranking systems. Consistently underperforming mayors can also be removed.

This paper aims to contribute to the existing literature by examining the impacts of this system on the cultivation of the most prioritized crops across the four provinces of Rwanda. The focus is on their financial sustainability from the perspective of the farmers, economic sustainability from the perspective of the society, and fiscal sustainability from the perspective of the government's budget. It aims to clarify how these policies of promoting the cultivation of specific crops by the province have affected the incentive for longer-term sustainability in each of these dimensions.

Under this policy, before each growing season, households submit contracts to local authorities indicating that they will grow the selected crops. This system leads to a high level of results-based competition among local representatives of the government. Due to the high level of competition, agronomists, in conjunction with local authorities, try to ensure that government-subsidized resources such as fertilizers and improved seeds are used only on government-approved crops while enforcing land use consolidation [5]. Inevitably some of these resources do find their way to the informal markets. These mechanisms ensure that while households retain their land titles, farmers are strongly compelled to cultivate specific crops during the planting seasons. Farmers who do not comply are often marginalized without access to government benefits such as improved seeds and subsidies. This creates a distinction between the most profitable and most cultivated crops.

As the development framework, Vision 2020 ends and the nation moves on to Vision 2050, it is vital to understand the impact of the current crop policies on the cultivation of key crops. The central objective of this analysis is to determine the value chains that either are currently sustainable or could become sustainable without government subsidies in the future. It is also essential to identify the unsustainable value chains that should be modified or terminated to make the best use of the available scarce resources.

This study analyses the value chains of seven of the most cultivated crops in Rwanda, based on current practices and productivity levels, from the financial, economic, and fiscal perspectives. The analysis is conducted for the specific crops in the four regions of the country, namely the Eastern, Northern, Southern, and Western Provinces. The analysis is conducted using an integrated investment appraisal (IIA) framework [6]. The framework of analysis begins with a financial analysis from the farmers' point of view. This analysis is then adjusted through the substitution of economic values of variables for financial ones. From a comparison of the economic and financial values of each of the relevant variables, economic-welfare-based stakeholder analysis can be derived.

2. Area of study

Rwanda, with a population of 12 million people, is the most densely populated country in mainland Africa, with 498.66 people/km^2 [7]. The goals of food security and poverty alleviation have been the focus of Rwanda's economic development since the devastating genocide some 25 years ago. The state of the country now is vastly different than it was in 1994. From 2004 to 2018, it was one of the fastest-growing economies in Africa, with an average growth rate of 7.7% per annum [8]. With 66% of the labor force employed in agriculture, this sector has been at the forefront of economic policies to achieve the goals of reaching "Upper Middle-Income" country status by 2035 and "High-

Income Country" status by 2050 [9]. During the five years 2008–2012,[1] the agricultural sector contributed to more than 50% of the decrease in total poverty [10]. This was achieved by obtaining substantial yield increases across a range of crops, accompanied by improved efficiency in the marketing of agricultural produce.

The path which Rwanda has set out for itself as its principal policy aim is to increase the productivity of the agricultural sector. In this way, it will be able to reduce the volume of labor tied up in this sector. The labor resources freed for the agricultural households are expected to move over into the service and manufacturing sectors. The experiences of Rwanda regarding ecological sustainability and social differentiation has been compared to that of the former Green Revolutions [11].

Due to highly fragmented agro-ecological zones throughout the country, the historical policies used elsewhere may face challenges if applied in Rwanda. In many of the developed and developing world, the policies have promoted land consolidation with improved agricultural intensification practices that focused on a small number of crops per region. The intensive use of chemical fertilizers was usually an important input to the programs. For example, Malaysia has worked aggressively to consolidate fragmented land holdings to concentrate on rubber and oil palm production [12]. Consequently, in 2016, Malaysia ranked fifth highest in the world in its use of chemical fertilizers per unit of arable land, while Rwanda ranked 140 out of a total of 159 countries in this regard. By comparison, China ranks thirteenth, while the UK, USA, and Kenya rank 32nd, 64th, and 115th, respectively [13]. Rwanda is clearly relying much more heavily on organic fertilizers, which is an advantage when considering the long-term sustainability of the soils under intense cropping patterns [14]. The promotion of the dairy industry with its heavy fodder requirements also introduces an additional strain on the land use and challenges to cropping policies in Rwanda, but it also provides a valuable supply of organic fertilizer [15].

2.1. Crop Intensification Program (CIP)

A key instrument for the implementation of policies by the Ministry of Agriculture and Animal Resources (MINAGRI) has been the Crop Intensification Program (CIP). To gain efficiencies of scale in production and to lower the logistics costs for inputs and outputs, it has been the government's view that an increased concentration of crops grown in each region was necessary. Also, to achieve economies of scale, the consolidation of landholdings has been thought to be necessary.

Initiated in 2007, the objective of the CIP has been to boost the yield of high-potential food crops, namely beans, cassava, wheat, rice, maize, and potato. Subsequently, soybean was added to the list. These were designated as "priority crops" [16]. Being a landlocked country with a high population density, Rwanda faces a binding constraint of farmland availability. The average size of farmland is 0.72 ha, which on average is split into four parcels [17]. The government has encouraged smallholder farmers to consolidate their landholdings [16,18]. Land is recognized as such a critical constraint that the Government of Rwanda has instituted a natural capital account of land in Rwanda [18]. The land accounts will also improve access to credits, which will improve the productivity of smallholder farmers significantly [19,20]. The effects of land use consolidation have been shown to differ based on the size of the consolidated land [21-24].

Although to date, Rwanda is overall a low user of chemical fertilizers, an integral part of this program has been to increase the availability of fertilizers and improved seeds to the farmers via subsidies [25]. Elsewhere input-led agricultural intensification strategies have often led to land degradation, which significantly reduces over time the productivity of the soils [26]. As a result of setting mineral fertilizer use targets in some regions with the subsidies that come along with it has been an increase in the use of chemicals in farming practices [2,27]. The government was previously in charge of the importation and distribution of fertilizer through bulk procurement, but from 2012 to 2016, it proceeded gradually to privatize both activities [28].

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1 This was the interlocking period of the Comprehensive Africa Agricultural Development Program (CAADP I) and the second Strategic Plan for the Transformation of Agriculture (PSTA II).

Furthermore, to meet the goal of achieving "productive high value and market-oriented agriculture," the government aimed to reform the organization of the agricultural research and extension services [29]. To this end, farmers were organized into cooperatives to improve their technical know-how with support from both the government and aid agencies [30,31]. Since 2014, the farmer-to-farmer agro-extension model, known as Twigire-Muhinzi, has been predominant in the country [32]. This Twigire-Muhinzi system has been instrumental in the organization of the extensive training of the farmers to improve their technical know-how. Based on a farmer-to-farmer transfer of knowledge, this system has created an effective institution for the rapid dissemination of improved farming methods.

In Rwanda, the policies of the government have concentrated on promoting one or two solutions to improving soil management, informed by more generic tests, rather than tailoring technologies to micro soil quality indicators [33]. This contrasts starkly to the heterogeneous and diverse traditional approaches to improving soil management by the local smallholder farmers. The lack of integration of the local farmers into the decision making has been shown not to be optimal for soil management practices as the agro-ecological knowledge of the farmers helps to identify fine-scale contextual differences that help to improve the decision-making of soil management options [33]. It has led to the formulation and promotion of policies that are not always suited for the variety of agro-ecological zones in the country [33,34]. The combination of farmers' agro-ecological knowledge with scientific research in agricultural policy formulations will lead to the development of policies that are more likely to be adopted by farmers. If this is done alongside the breakdown of the forceful mechanisms of policy implementation, it will allow farmers to decide which government-promoted policies to follow and which ones to discard without the fear of societal repercussions. This would enable the agro-ecological practices that are better suited to sustainable development to improve the level of income of the farmers that adopts them. The farmer-to-farmer extension model of the "Twigire-Muhinzi" will further aid knowledge-sharing among farmers.

It is noteworthy to clarify that the goal of sustainable agricultural intensification is not a mere government target as a derivative of the sustainable development goals of their international donors. Itis also in the best interest of the farmers to improve the productivity of their farming practices in a sustainable manner. The integration of more sustainable agro-ecological practices will preserve the agricultural value of the land. The preservation of the productivity of the farmer-owned land is an especially critical factor to farmers in a region as Rwanda, where farmer-owned land is such high social and cultural status and land constraints are stringent. Regarding the ability of smallholder farmers to cope with the impacts of climate change, the forceful nature of the implementation of the crop intensification program has significantly hampered their abilities to resist the impacts of climatic shocks [35,36]. The integration of smallholder farmers into the decision making of the agricultural policies without infringing on their decision-making autonomy will allow the formulation of policies that are not just less degrading on the land but also more climate-resilient, thus ensuring more environmentally smart policies.

The analysis carried out in this paper will identify the crops where Pareto improvements in social welfare are likely to be possible by switching the policy emphasis away from promoting the growth of particular crops in a region to allowing other more economically productive crops to be grown. Excessive subsidization of the inputs of particular crops can result in a waste of resources that would have a greater social benefit if used elsewhere. Encouraging farmers to grow crops that would not be grown without subsidy is likely to cause farmers to believe that these policies are not sustainable over time. Hence, they will likely not be willing to make the investments in terms of their time and effort to engage in environmentally sustainable land husbandry practices that would have a financial and economic payoff if they were allowed to grow other more profitable crops.

2.2. Land Usage

Land usage is an integral resource component in dictating the impact of each value chain. Like other primary data used, land usage was derived by undertaking field studies. The preview of each province is shown in Figure 1 below.

Figure 1. Map of the provinces of Rwanda

Table 1 shows how land use is spread across all the appraised crops.

Table 1. Use of land resource across Rwanda (000s ha).

Crop	Eastern (1)	Southern (2)	Northern (3)	Western (4)	Total Rwanda
Bush bean	95	68	-	-	**163**
Climbing bean	-	-	41	43	**84**
Cassava	31	112	-	29	**172**
Maize	39	17	31	31	**118**
Potato	-	4	35	-	**39**
Rice	6	4	-	2	**12**
Soybean	9	10	-	4	**23**
Wheat	-	5	10	3	**17**
Total Rwanda	**179**	**220**	**116**	**111**	**627**

Source: MINAGRI, author estimates.

Beans, both climbing and bush beans, are the most cultivated crop, with about 247,000 ha dedicated to their cultivation across the country. The total use of land for bean production is split between the two varieties. The land resource that is dedicated to the cultivation of bush beans is almost double that dedicated to the climbing bean variety. Following beans, cassava is the second most cultivated crop across the entire country. Maize, the third most popular crop, is grown in all the provinces but is not the dominant crop in any of the provinces. Given the specific marshland requirement of rice cultivation, it is no surprise that it has the least amount of land dedicated to its

cultivation, with about 12,000 ha. With the further development of marshland, this number is expected to continue to rise.

Considering the cropping pattern by province, we find that the Eastern Province is dominated by the cultivation of bush beans, cassava, and maize. It is also one of the three provinces that produce rice and soybean. Cassava is by far the dominant crop planted in the Southern Province, followed by bush beans; it is also the province where the largest amount of rice is cultivated. Relatively small acreages of maize, potato, soybean, and wheat are also grown. In the Northern Province, climbing beans, cassava and maize are the dominant crops while also being the main area in the country for growing wheat. In the Western Province, the main crops are climbing beans, cassava, and maize, with relatively small amounts of land used for growing rice, soybean, and wheat.

3. Methodology and Data

The analysis is carried out by developing an annual cash flow statement that accrues to the farmers from each crop studies in each region. The analysis estimates the rates of return and the net present value of the financial gain that a single farmer is expected to earn over 12 years, over and above all their opportunity costs, including that of their labor. This cash flow is then adjusted to reflect their economic values over time to allow the creation of annual resource flows, reflecting the economic costs and benefits that accrue to Rwanda over the period of the analysis. Components of these annual statements are reporting as fiscal expenditures and revenues accruing to the government. The stakeholder analysis is essentially examining the impact on the farmers and then identifying the causes of the differences between the financial and economic values of each variable. In the case of Rwanda agriculture, these differences are primarily caused by the government subsidies of agricultural inputs, the tariff protection of some crops. Finally, the taxes that are generated indirectly because of the foreign exchange saved because the amount of foreign exchange required to be spent abroad to supply food to the population is reduced.

The data used in the analysis was gathered primarily via field studies by local agronomists in 2016 and updated in 2020. The analysis is carried out initially considering hypothetical farms of 1 hectare in size. The financial present values and the economic net benefits of cultivating each crop are initially analyzed based on the prevailing farming practices, market prices, and yield levels in that region. With information on the extent to which each crop is grown in a region, the results from the hypothetical farms are then aggregated to the regional level [37]. The detailed financial and economic models, along with the data sets used, are reported and available to the readers [37].

The appraisal of each crop is carried out for the period 2016 till 2027[2], and all crops are assumed to be mono cropped. Although, in practice, more than one crop will often be cultivated by a farmer at a given point in time, the assumption of monocropping is made to focus the analysis on the financial and economic profitability of each crop that is the target of the agricultural policies. It is also the case that monocropping is the practice that has been encouraged by the government's policies [34]. The results of our analysis are likely to be slightly more pessimistic from the perspective of the farmer than is actually realized. The farmers often disregard the government's instructions to monocrop to improve their incomes. This is particularly the case with intercropping of maize and climbing beans where the nitrogen-fixing effects of the beans increase the yield of the corn, and the corn stalks provide support for the climbing beans at no cost. The assumption that the size of the farm is 1 hectare should not create a bias because all the inputs and outputs are scaled accordingly.

3.1. Farmers' Perspective: Financial Profitability

The evaluation criteria applied to the stream of annual cash flows to determine the financial profitability from the perspective of the farmer are the farmers' modified internal rate of return (MIRR) and their financial net present value (FNPV). The MIRR is the rate at which the present value of cash inflows during operation equals the initial cash outlay. For the evaluation of the economic

[2] With 2016 being the base year of the analysis, all reported figures are in 2016 real values.

resource flows, it is the economic net present value (ENPV) that is employed[3]. It is described by equation 1.

$$\text{MIRR} = \sqrt[k]{\frac{\text{Future value (Positive cashflows} \times \text{Cost of capital)}}{\text{Present value (Negative cashflows} \times \text{Financing cost)}}} - 1, \quad (1)^{4}$$

where *k* refers to the total number of years over which the analysis is conducted.

The FNPV is described by equation 2.

$$\text{FNPV} = \sum_{t=0}^{k} \frac{R_t - C_t}{\prod_t (1+d_t)}, \quad (2)$$

where *d* refers to the discount rate, *t* to the year, R_t to the annual revenue derived from crop sales in year *t*,[5] and C_t to the total annual cost of the resources used in its production in year *t*.

The annual revenue is derived by equation 3.

$$R_t = \sum_i^m (Y_i \times F \times S) \times (1 - PHL) \times P_i^{mkt}, \quad (3)$$

where *m* is the number of different products that can be produced from the cultivation of the crop, Y_i the quantity of produce *i* produced in a farming season, *F* the number of farming seasons in a year, *S* the average farm size (1 hectare was assumed, to easily convey results), *PHL* the proportion of post-harvest losses, and P_i^{mkt} the market price of produce *i*.

The annual cost incurred is shown in equation 4.

$$C_t = \left(\sum L_{jn} \times W_{Lj} \times F \times S\right) + \left(\sum K_{qn} \times P_{Kq}^{mkt} \times F \times S\right), \quad (4)$$

where L_{jn} denotes the number of days required for labor activity *j* per seasonal cultivation and W_{Lj} refers to the prevailing daily wage rate for labor activity *j* for the region.[6] The amount of an input K_q required per seasonal cultivation is denoted by *n*, while P_{Kq}^{mkt} denotes the market price of input *q*.[7]

3.2. Country's Perspective: Economic Valuation

The net economic contribution that each crop value chain is producing in each region is measured by the economic net present value (ENPV) for each crop for 12 years. It is shown in equation 5.

$$\text{ENPV} = \sum_{t=0}^{k} \frac{R_t^{eco} - C_t^{eco}}{\prod_t (1+d_t)}, \quad (5)$$

where R_t^{eco} shows the annual revenue received for the cultivation of the crop at economic prices in time *t*, while C_t^{eco} denotes the total economic cost of resources used by the value chain for the year *t*. The discount rate used for the society is the economic opportunity cost of capital (EOCK) as specified by the government [40]. The annual value of the output at economic prices is shown in equation 6.

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[3] For a more detailed discussion of the criteria for evaluating a stream of cash flows or economic resource flows please see (Jenkins et al. 2019) [38,39]

[4] The cost of capital is equal to the financing cost. They are both represented by the 13% discount rate.

[5] In cases where a significant proportion of farmers are directly involved in a post-harvest processing value chain instead of selling the crop directly, the chain of value is also proportionately accounted for, considering both its benefits and costs.

[6] Although the use of family labor is common, the valuation of labor here accounts for the opportunity cost of family labor.

[7] The rental cost of land for each region is included as part of the input cost.

$$R_t^{eco} = \sum_i^m (Y_i \times F \times S) \times (1 - PHL) \times (P_i^{mkt} \times CF_i) \quad (6)$$

The economic cost is shown in equation 7.

$$C_t^{eco} = \left(\sum L_{jn} \times W_{Lj} \times F \times S \times CF_{lj}\right) + \left(\sum K_{qn} \times P_{Kq}^{mkt} \times F \times S \times CF_{kq}\right), \quad (7)$$

where CF_i, CF_{lj}, and CF_{kq} denote the corresponding conversion factor for outputs, labor, and inputs that converts the financial price of an item to its economic value.[8]

3.3. Stakeholder Analysis: Distributive Impacts

The stakeholder analysis evaluates the distributional impacts of all externalities. The externality, which is the difference between the financial and economic analyses, is allocated to the stakeholder that is being affected. The externalities accounted for include taxes – both direct and indirect – and subsidies; as such, the main stakeholder, apart from the farmers, is the government. The stakeholder evaluation quantifies the impact of each value chain on the government budget.

To examine the results of the stakeholder analysis, the NPVs of the various components of the analyses are estimated to be consistent with the general relationship shown by equation 8.

$$NPV_{@EOCK}^{ECON} = NPV_{@EOCK}^{FIN} + \sum PV_{@EOCK}^{EXT}, \quad (8)$$

where $NPV_{@EOCK}^{ECON}$ denotes the economic net present value, $NPV_{@EOCK}^{FIN}$ represents the financial net present value, and $PV_{@EOCK}^{EXT}$ shows the present values of all relevant externalities that accrue to society's stakeholders other than the farmers. For this relationship to hold precisely, a common discount rate needs to be used to calculate the NPV of each stakeholder [41]. For convenience, the government-measured EOCK is used.

The economic discount rate, or EOCK for Rwanda, has been estimated to be 13% [40]. Given that farmers usually face rather severe financing constraints, their discount rate is not expected to be less than 13%, so it is assumed here that this rate is also their discount rate. This assumption simplifies the reconciliation of the various aspects of the integrated analyses, as shown in equation 8 [41].

4. Empirical Results and Discussions

In this section, the results of the integrated analyses of each crop are presented and discussed.

4.1. Beans

Due to the constraint of land availability and the ability of the climbing beans to grow vertically around stakes, the government has been encouraging farmers to move towards the cultivation of the climbing bean [42]. However, due to its ease of cultivation and earlier maturity, the bush bean variety is more attractive to many farmers. The climbing bean variety is usually cultivated at high altitudes, frequently intercropped with maize, which is used to provide staking [34]. Bush bean is exclusive to lower altitudes and is often intercropped. As such, the climbing bean is cultivated mostly in the Northern and Western Provinces, on 41,073 ha and 42,716 ha of land, respectively.

The bush bean variety is cultivated mostly in the Southern and Eastern Provinces, on 68,000 ha and 95,500 ha of land, respectively. Beans have two annual cropping seasons. With the high rate of anemia, particularly in women and children [43], beans are essential for the Rwandan diet. Domestic consumption has been unable to keep up with the population growth, resulting in an upward trend in the importation of beans from neighboring Uganda and Tanzania [44].

Equations 1, 2, 3, and 4 are used to estimate the financial returns for these two crops in their respective regions, as reported in Table 2.

8 The conversion factors used are sourced from http://rwanda-cscf.cri-world.com/

Table 2. Present values of the beans value chain (2016 values).

Province (crop)	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Northern (climbing bean)	**31.01%**	**1,568**	**1,926**	**64,409**	79,122	14,713	-
Eastern (bush bean)	8.62%	−170	60	−16,199	5,716	21,915	-
Southern (bush bean)	−11.28%	−924	−744	−62,839	−50,599	12,240	-
Western (climbing bean)	−13.64%	−1,402	−1,242	−59,883	−53,036	6,847	-
Total/average Rwanda (climbing bean)	8.25%	54	311	4,526	26,086	21,560	-
Total/average Rwanda (bush bean)	0.34%	−483	−275	−79,038	−44,883	34,155	-
Total/average Rwanda (beans)	**3.02%**	**−301**	**−76**	**−74,512**	**−18,797**	**55,715**	**-**

From the perspective of the farmer, the results of the estimated MIRR and the Financial NPVs (Table 2 columns 1 and 2) indicate that the returns to the farmers from cultivating climbing and bush beans are very mixed. Only in the Northern Province is climbing beans financially highly attractive to be grown as a monocrop. In the Eastern Province, does bush bean cultivation generates a modest MIRR of 8.62% (Table 2, column 1, row 2). This return is significantly less than the prevailing discount rate of 13%.

The financial results in the Southern and Western Provinces are surprising. The notion that farmers will engage in activities that are unprofitable to them seems unlikely without a precise understanding of the government policies affecting the decision-making of many Rwandan farmers. While the top-down policy directives of the government, combined with a strict enforcement policy, have focused on monocropping, farmers often cultivate beans as a component of intercropping. The nitrogen fixation property of the bean crops provides an incentive for farmers to cultivate beans with other crops[9]. Farmers have observed that intercropping beans with maize offers greater benefits than monocropping [34]. The significant benefits of intercropping have caused the Rwandan Government to relax its monocropping regulations to some extent [5]. This has allowed farmers to cultivate crops even when they are marginally or not profitable due to their intercropping benefits. With beans being one of the most prominent CIP crops since 2011 and representing 55% of all consolidated lands in 2016 [45], it is less surprising to see such results emerging. On average, climbing beans is a financially more profitable crop than bush beans for farmers to cultivate. This is similar to the conclusion made by other researchers investigating the disparities in the profitability of both crops [46,47].

When appraised from an economic perspective, the subsequent results differ subtly from the financial perspective discussed above. As farmers across the country use subsidized fertilizers in negligible amounts for the cultivation of bean crops, the main externality effect of this activity for the government occurs in the form of increased tax revenues associated with the savings in foreign exchange that arise from domestic production of beans rather than importing this or another food item. The cultivation of climbing beans in the Northern Province yields an economic NPV return of $1,926 per hectare, in contrast to the economic NPV loss of $1,242 in the Western Province by the same crop under similar conditions (Table 2, column 3, rows 1 and 4). Cumulated across each

[9] These analyses do not quantify the value of the nitrogen fixation property of the bean crops. This is a part motivation behind their cultivation, but with the assumption of monocropping, the value of the nitrogen fixation is misplaced.

province, this shows that the farming of climbing bean in the Northern Province results in an economic NPV benefit of $79 million to the economy while soaking up economic resources worth $53 million in the Western Province (Table 2, column 5, rows 1 and 4). Combined, this results in a net economic resource gain of $26 million in NPV terms to the Rwandan economy from climbing bean cultivation (Table 2, column 5, row 5).

The economic impact analysis of the bush bean crop reveals results similar to those for climbing bean in the sense that its production is beneficial to the economy in one province and detrimental to the economy in another. Although the cultivation of bush beans in the Eastern Province is not proven to be financially prudent from the farmers' perspective, from the economic perspective, it returns a positive economic NPV of $60 per hectare planted in the province (Table 2, column 3, row 2). In contrast, the cultivation of bush beans in the Southern Province yields a negative economic NPV of $744 per hectare (Table 2, column 3, row 3). Cumulatively, bush bean cultivation across the Eastern Province generates a net economic benefit (ENPV) worth $5.7 million while there is an economic NPV loss of $63 million in the Southern Province (Table 2, column 5, rows 2 and 3). The discrepancy between the financial and economic returns of the crops in each province is identical to the tax revenue generated to the government. Typically, this shows that the cultivation of bush beans creates a negative economic NPV of $275 per hectare across the country (Table 2, column 3, row 6). Aggregated across the country, the net negative economic NPV reflects a loss of $45 million from bush bean cultivation (Table 2, column 5, row 6). Therefore, when the performances of both bean crops are aggregated, bean cultivation produces an average economic NPV loss of $76 per hectare, or $19 million countrywide (Table 2, columns 3 and 6, row 7).

4.2. Cassava

Cassava is a staple food crop in Rwanda, produced mainly to satisfy domestic consumption. In the period 2009–2017, only about 1.4% of total production was involved in cross-border trade [48]. Its cultivation is concentrated in 112,213 ha in the Southern Province, 30,695 ha in the Eastern Province, and 28,804 ha in the Western Province. About 80% of cassava farmers are involved in the production of cassava chips for immediate sale to consumers. The remaining farmers either sell to the Kinazi Cassava Plant (KCP) for processing into flour [49] or sell the tubers directly to consumers in the open market.

Severe outbreaks of cassava brown skin disease (CBSD) and cassava mosaic disease (CMD) in 2009 caused production to plummet. The industry has been trying to recover since 2015 with the development of the Namulonge selection (NASE14) variety, which is resistant to CBSD. Cuttings of this new variety have been distributed by MINAGRI to large-scale farmers and cooperatives [50]. In 2017, a CBSD control project was developed in the region to aid the combat of both CBSD and CMD [51]. The analysis of the cassava value chain carried out here assumes that the severe CBSD and CMD disease outbreaks would be contained with the development and dissemination to farmers of the disease-resistant varieties.

Cassava tubers, once harvested, tend to spoil rather quickly. To minimize post-harvest losses, they need to be dried, processed and sold into the market within a week. This is a crucial reason for the low inter-country cassava trade. Hence, cassava is a less tradable crop than many others that are analyzed in this paper. However, in the border areas, it is still regionally traded. Production is used mainly for domestic consumption. Thus, it serves as a substitute for potato, maize, or rice.

Table 3. Present values of the cassava value chain (2016 values).

Province	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Eastern	**13.09%**	**6**	**272**	**173**	8,352	8,179	-
Southern	12.07%	−63	231	−7,118	25,929	33,047	-
Western	0.27%	−453	−250	−13,055	−7,211	5,844	-
Total/average Rwanda	**10.27%**	**−116**	**158**	**−20,000**	**27,070**	**47,070**	**-**

Cassava has just one farming season per annum. The MIRR results in Table 3 show the estimated average rate of return of cultivating cassava in each province. In Table 3 column 2, the FNPVs are estimated for the farmer. In the Eastern Province, cassava farming generates an average MIRR of 13.09% for farmers (Table 3, column 1, row 1) and a positive FNPV. The slight difference between the latter return and the 13% discount rate shows that cassava cultivation will be only marginally more profitable than the average return that could be generated elsewhere. In the Southern Province, the farmers cultivating cassava are estimated to generate a MIRR of 12.07% on average (Table 3, column 1, row 2). The MIRR in the Western Province is significantly less than that in the Eastern and Southern Provinces. In the Western Province, farmers generate a financial rate of return of 0.27% from cultivating cassava given the current conditions (Table 3, column 1, row 3). This shows that the farmers in the Western Province make enough revenue to recover the funds they have invested but not enough to cover their opportunity cost. Across the country, cassava cultivation provides an average MIRR of 10.27% to farmers. Averaged across the country, this ranks cassava as less financially profitable to the farmers cultivating it than climbing bean and more profitable than the bush bean. If the conversion of the cultivation to the disease-resistant varieties is effective, the results of the estimation of the FNPVs and ENPVs according to equations 1 and 4, respectively, will be as reported in Table 3. Similar to the bean crops, with the insignificant use of subsidized inputs by the cassava production chain, the main externality occurs in relation to the tax revenue that flows indirectly to the government [52].

From the standpoint of the economy, the cultivation of cassava not only generates revenue for farmers but, as it substitutes for food that would otherwise be imported, also indirectly generates taxes for the government [52]. Consequently, the impact of cassava cultivation on the economy generally is better than its financial impact on farmers. Per hectare cultivated, farming cassava in the Eastern Province adds economic resources worth $272 to the economy in NPV terms (Table 3, column 2, row 1). When aggregated across the province, this results in an economic resource gain of $8.4 million in NPV terms from cassava cultivation in the province (Table 3, column 5, row 1). Similarly, in the Southern Province, it generates a positive economic NPV profit of $231 to the economy per hectare cultivated, which aggregates across the province as an economic NPV profit of $25.9 million to the economy (Table 3, columns 3 and 5, row 2). In contrast to what is observed in the Eastern and Southern Provinces, the cultivation of cassava in the Western Province results in economic loss. As measured by the economic NPV, this economic loss is $250 per hectare cultivated (Table 3, column 3, row 3). When aggregated over the whole province, it is found that cassava cultivation in the Western Province generates an economic NPV loss of $7 million (Table 3, column 5, row 3). The aggregation of all the provincial results demonstrates that cassava cultivation yields a positive economic NPV profit of $27 million to the Rwandan economy (Table 3, column 5, row 4). This averages out at yielding an economic NPV of $158 per hectare of cassava cultivated across the country (Table 3, column 3, row 4).

The cultivation of cassava is found to be profitable for the economy, though not always profitable financially for the farmers if it is grown for commercial sale.

4.3. Maize

Maize is the crop that is most promoted by the Rwandan Government, alongside wheat. A primary motivation behind this policy has been the desire for food self-sufficiency [53]. Intensive efforts by the Rwanda Agriculture Board (RAB) have led to an increase in the quantity of high-quality, locally produced seeds which are distributed to farmers [54]. About 30% of total Rwandan maize production is bought by the Rwanda Grains and Cereals Corporation (RGCC); it is subsequently supplied to millers both domestically and in neighboring countries. It is cultivated on 38,840 ha in the Eastern Province, 29,602 ha in the Western Province, 30,769 ha in the Northern Province, and 17,364 ha in the Southern Province. Maize has two harvesting seasons per annum in most regions of Rwanda. The array of subsidies to promote the cultivation of maize includes a subsidy of FRw 1,500 per kilogram of seed, 35% of the price of DAP fertilizer, 30% of the price of urea fertilizer, 15% of the price of $NPK_{17.17.17}$, and 50% of the cost of micro-nutrients. Slightly offsetting these expenditures is the foreign exchange premium (FEP) of 5.3% of net foreign exchange earnings.

Table 4. Present values of the maize value chain (2016 values).

Province	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Southern	**31.99%**	**1,349**	**361**	**23,417**	6,261	5,720	−22,876
Northern	16.60%	143	−707	4,410	−21,760	10,293	−36,463
Eastern	6.60%	−251	−1,234	−9,741	−47,945	12,967	−51,171
Western	−2.27%	−505	−1,567	−14,944	−46,387	9,400	−40,843
Total/average Rwanda	**10.77%**	**27**	**−942**	**3,142**	**−109,831**	**38,380**	**−151,353**

The MIRR, FNPVs, and ENPVs estimated are reported in Table 4. These results are shown in columns 4 to 7 reconciled as expressed by the relationship denoted by equation 8. The financial return of maize cultivation varies along provincial lines. In the Southern Province, maize cultivation is estimated to return 31.99% on the investment cost over the 12 years of analysis (Table 4, column 1, row 1). In the Northern Province, farmers are estimated to make an average return of 16.6% (Table 4, column 1, row 2). This rate of return experienced by the farmers cultivating maize in the Northern Province is about half that seen in the Southern Province. Given that the return experienced in the Eastern Province is higher than the 13% discount rate, the farmers will be interested in cultivating this crop in the current conditions. Meanwhile, maize cultivation in the Eastern Province is estimated to generate a return of 6.6% to farmers (Table 4, column 1, row 3), less than the discount rate. In contrast, cultivating maize in the Western Province does not generate enough revenue, in real terms, to cover its investment requirement. It returns a negative 2.27% on average to farmers (Table 4, column 1, row 4).

At the prevailing market rate, small farmers who own land might prefer to lease out their land to generate rent if they cannot escape maize cultivation due to pressure from local authorities [27]. On average, any alternative investment that will generate a 13% return rate will be preferable to cultivating maize in this province, but given the enforcement of government policies, some farmers might continue to cultivate less profitable crops for as long as they can cover their average variable costs.

Aside from the financial impact on farmers, maize farming depends on some subsidized inputs and generates taxes for the government. In the Southern Province, maize cultivation is shown to produce a mean economic NPV value worth $361 per hectare to the economy (Table 4, column 3, row 1). This translates into an economic NPV benefit of $6.3 million to the economy via maize cultivation across the entire Southern Province (Table 4, column 5, row 1). In contrast to what is observed in the Southern Province, maize cultivation in all the other regions does not appear to be beneficial to the

economy. On average, maize farming results in economic NPV losses worth $707, $1,234, and $1,567 per hectare cultivated in the Northern, Eastern, and Southern Provinces, respectively (Table 4, column 3, rows 2, 3, and 4). These translate into economic NPV losses of $21.8 million in the Northern Province, $48 million in the Eastern Province, and $46 million in the Western Province (Table 4, column 5, rows 2, 3, and 4). This means that cumulated across the country, maize cultivation results in economic NPV losses worth $110 million to the Rwandan economy (Table 4, column 5, row 5). This translates into an average economic NPV loss of $942 per hectare of maize cultivated (Table 4, column 3, row 5).

For the cultivation of maize to be economically viable in the Northern, Eastern, and Western Provinces, the yield would have to increase by 8.6%, 14.13%, and 17.99%, respectively, in these provinces. Unfortunately, Rwanda experienced an average decrease in maize yield of 5.86% annually from 2012 to 2016 [55]. Moreover, maize yield is shown to be highly susceptible to climate variability [56]. Maize yield in Rwanda is shown to be inversely related to heat and causally related to rainfall [60]. As maize is a rainfed crop, the unpredictable nature of rain across the country has been shown to result in erratic maize yields in district-based observations [27]. Due to climate change, the variability in rainfall is expected to increase, and the rainy season is expected to become shorter and more intense, with longer and dryer dry seasons leading to increased proneness to floods and droughts [58]. The average temperature in the country, which has increased by 1.4°C more than the global average since 1970, is expected to continue rising [ibid.].

Keeping other factors constant, in order to increase yields, some of the prevailing practices will have to change to include the increased use of urea per hectare, the use of $NPK_{17.17.17}$ instead of DAP fertilizer, the use of hermetic bags to combat post-harvest losses, and the employment of micro-nutrients including borax pentahydrate, ammonium sulfate, and zinc sulfate monohydrate[10].

4.4. Potato

Potato cultivation has two farming seasons each year. The price floor is determined regionally by the Ministry of Trade and Industry (MINICOM) based on production cost and distance to market, which is Kigali. A wholesale company, Regional Potatoes Trading Ltd., was created in Kigali to cut out intermediaries by managing 126 collection centers in 4 districts [59].

Potatoes are cultivated only marginally in the Western and Eastern Provinces, as most of the production comes from the volcanic region and Gicumbi district of the Northern Province, with 35,082 ha in cultivation, and the Southern Province, with 4,122 ha in cultivation. Potato has been rising in importance as a staple food in Rwanda since the mid-1960s, with per-capita consumption growing from 6 kg in 1964 to 99.86 kg in 2011 per year [60]. Potato demand is higher in urban than in rural regions. The fertilizer used in its cultivation by the farmers is $NPK_{17.17.17}$, which attracts a 35% subsidy from the government. Rwanda is still a small net importer of potatoes; hence, potato cultivation is an import substitution activity. Most imports come into the country via informal cross-border exchange with the North Kivu Province of the Democratic Republic of Congo and the Kisoro district of Uganda [61].

[10] This recommendation was given by a team of local and international agronomists that designed the optimal farming budget at the time of the primary field studies.

Table 5. Present values of the potato value chain (2016 values).

Province	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Southern	**50.79%**	**18,333**	**19,384**	**75,561**	79,891	6,333	−2,003
Northern	37.59%	12,849	13,789	450,763	483,755	50,045	−17,053
Total/average Rwanda	**38.97%**	**13,425**	**14,377**	**526,324**	**563,646**	**56,378**	**−19,056**

Potato cultivation is shown to be a highly profitable crop for farmers. On average, potato cultivation generates a MIRR of 50.79% to farmers in the Southern Province and 37.59% to those in the Northern Province (Table 5, column 1, rows 1 and 2). Taking the entire country as a whole, potato cultivation generates a financial return rate of 38.97% (Table 5, column 1, row 3). The high average financial rate of return reveals how highly profitable potato cultivation is. The FNPVs for the farmers are all positive.

Moreover, the analysis reveals that farming potatoes in the Southern Province generate about $80 million of economic NPV benefit to the economy. On a per-hectare basis, about $19,000 of economic NPV benefit is generated in the Southern Province through potato cultivation (Table 5, column 3, row 1). Similarly, in the Northern Province, cultivating potato allows farmers to generate about $14,000 in economic NPV benefit to the economy per hectare of potato cultivated (Table 5, column 3, row 2). This yields about $451 million of economic benefit to the economy of Rwanda from potato cultivation in the Northern Province (Table 5, column 5, row 2). All in all, Rwanda is estimated to generate a resource benefit worth $564 million to its economy in NPV terms by cultivating potatoes (Table 5, column 5, row 3). This is in line with an average, per hectare, of the economic benefit of about $14,000 in NPV terms (Table 5, column 3, row 3). This is the most economically competitive of all the crops examined so far by a large margin. It is demonstrated that potatoes will be a highly sustainable food crop for the foreseeable future; even without the fertilizer subsidy, farmers should be very willing to cultivate and expand the production of potatoes. However, its high vulnerability to the effects of climate change is a significant cause for concern [56].

4.5. Rice

Rwanda's rice value chain is heavily protected by the government, with an import duty of 45% [62]. The tariff is essentially a tax on consumers to the benefit of domestic producers. Rice cultivation is concentrated in the Gatsibo and Nyagatare districts of the Eastern Province, the Rusizi district of the Western Province, and the Gisagara district of the Southern Province, with 5,770 ha, 1,772 ha, and 4,126 ha of land cultivated in each province, respectively. The farmers enjoy a 15% subsidy on $NPK_{17.17.17}$ fertilizer, a 30% subsidy on urea fertilizer, a 35% subsidy on DAP fertilizer, and a 25% subsidy on KCl fertilizer, but no subsidy on urea briquettes. Even with these subsidies, the use of KCl fertilizer and DAP fertilizer is observed to be negligible.

Rice is cultivated on marshland covering about 12,000 ha, although about 48,000 ha of potential marshland has been identified. Through the Rural Sector Support Project (RSSP), the government, co-financed by the World Bank, has effectively invested significantly in marshlands and hillsides of sub-watersheds to ramp up domestic rice cultivation [63]. Rice has two farming seasons per annum, and women account for 45% of rice farmers [64]. The local production lags consumption, with imports accounting for 36% of consumption from 2010 and 2017 [48]. The short-grain rice variety makes up about 60% of domestically produced rice and is consumed by rural households, bulk buyers, and low-income urban households. In contrast, most of the imported rice consists of the fragrant, long-grain variety that goes to high-income urban households, hotels, and restaurants. Rwanda faces a dual challenge of raising both the quality and the quantity of rice production. The present values of the rice value chain are shown in Table 6.

Table 6. Present values of the rice value chain (2016 values).

Province	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $		
						Tax revenue (6)	Subsidy (7)	Tariff (8)
Eastern	**31.11%**	**2,783**	**−2,528**	**18,466**	−14,587	4,512	−3,462	−34,103
Western	31.58%	2,691	−2,617	5,551	−4,637	1,348	−1,063	−10,473
Southern	30.56%	2,620	−2,699	12,536	−11,135	3,191	−2,476	−24,386
Total/average Rwanda	**30.98%**	**2,712**	**−2,602**	**36,553**	**−30,359**	**9,051**	**−7,001**	**−68,962**

The analysis reveals that the cultivation of rice is profitable on average for farmers across all regions. The MIRR is approximately 31% on average to the farmers irrespective of the province in which it is cultivated (Table 6, column 1, row 1).

On average, farmers in the Eastern Province make a profit of $2,783 in NPV terms per hectare of rice cultivated (Table 6, column 2, row 1). In the other provinces where rice is also cultivated, farmers average similar returns on a per-hectare basis, generating average financial NPV returns of $2,691 and $2,620 per hectare in the Western and Eastern Provinces, respectively (Table 6, column 2, rows 2 and 3). The aggregate analyses for each region show that rice farming generates about $18.5 million, $5.6 million, and $12.5 million in NPV terms for farmers in the Eastern, Western, and Southern Provinces, respectively (Table 6, column 4, rows 1, 2, and 3). Therefore, rice cultivation generates $36.6 million for all the farmers in Rwanda in NPV terms (Table 6, column 4, row 4). These results reveal rice to be a profitable crop for farmers to cultivate.

The economic analysis presents a different story. Although rice cultivation is shown to have similar impacts on a per-hectare basis across provinces, it takes more resources from the economy than the benefit it creates. It generates negative economic NPV impacts, ranging from a mean value of $2,528 in the Eastern Province to a mean value of $2,699 in the Southern Province (Table 6, column 3, rows 1, 2, and 3). Across Rwanda, the economy loses $2,602 for an average hectare of rice cultivated (Table 6, column 3, row 4). This is similar, in absolute terms, to the average financial revenue generated by farmers per hectare of rice cultivated, which is $2,712 in NPV terms (Table 6, column 2, row 4). From an economic perspective, this shows that without distortions, the cultivation of rice is closer to exhibiting a rate of return that is similar to the average opportunity cost of capital. What the externalities do, essentially, is to transfer resources from the economy to the farmers, which makes rice cultivation appear more attractive than it is. The cultivation of rice across Rwanda costs the economy about $30 million in NPV terms (Table 6, column 5, row 4). Disaggregated by provinces, rice cultivation costs about $14.6 million, $4.6 million, and $11 million in the Eastern, Western, and Southern Provinces, respectively (Table 6, column 5, rows 1, 2, and 3).

Unlike the other crops that have been analyzed, which yield a negative impact on the economy, rice cultivation generates more tax revenue than the subsidy costs to the government. For instance, in the Eastern Province, where rice cultivation yields a negative $14.6 million economic NPV while farmers gain financially about $18.5 million NPV, the government gains about $4.5 million in taxes from rice cultivation in this province, spends about $3.5 million subsidizing the farmers, and loses about $34 million in tariff revenues if rather than being domestically cultivated, rice had been imported instead (Table 6, row 1, columns 4, 5, 6, 7, and 8). Rwanda imports rice mainly from Tanzania and Pakistan [65]. As domestic cultivation will displace imports, it is then essential to consider the import tariff lost as an opportunity cost. Since the tariff raises the domestic price of rice, the financial price of rice will overstate its economic value by the rate of the tariff, with further adjustments for the FEP and production subsidies; thus, the loss in tariff revenue due to the domestic production of rice has a negative impact on the government's tax revenue [66]. The analyses reveal that the Rwandan economy loses resources worth about $30.4 million in NPV terms from domestic rice cultivation, mainly as a result of overstating the financial price due to an import tariff that

transfers the surplus enjoyed by consumers to domestic producers. The results of the analysis conclude that the rice value chain is neither economically nor fiscally sustainable, albeit that it is financially profitable for farmers.

For rice farming to become economically sustainable under prevailing conditions, a break-even analysis shows that yield would have to increase by 21.96% across the country. Rwanda experienced yield increases of 8.18% from 2012 to 2016 [67]. Given this experience, it could achieve sustainability in the near future if such growth rates are maintained. Ways in which the current production practices can be improved include harnessing deep fertilizer placement technology and using soil-specific fertilizers, including 75 kg of DAP, 60 kg of KCl, and 112.5 kg of urea.

4.6. Soybean

Soybean was included in the CIP in 2012. Since then, the government has been providing support via seeds and fertilizer subsidies. Based on their current practices, farmers enjoy an 85% subsidy on imported seeds and a 66% subsidy on local seeds. Soybean is mainly cultivated in the Southern, Eastern, and Western Provinces on 10,047 ha, 8,707 ha, and 4,019 ha of land, respectively. While soybean is not a staple part of the Rwandan diet, demand has been increasing, primarily in the production of high-nutrient foods and animal feed. The government has also invested in processing plants to boost the demand for soybean. A key characteristic of soybean cultivation is that it has a more significant potential for nitrogen fixation in the soil than the next best alternative, common beans [68]. The soybean seed production in Rwanda is still being developed. There is usually a substantial shortage in the supply of seeds in the domestic market, and this is being bridged via imports by the government, non-governmental organizations, agro-dealers, and independent seed multipliers [69]. For this analysis, the proportions of domestic and foreign seeds are taken to be equal; that is, half the seeds are assumed to be sourced domestically while the remaining half is imported. Soybean can produce two crops per annum; hence, the annual results reported here are the aggregations of both crops. Table 7 shows the impacts of soybean cultivation, financially to the farmers and government budget as well as economically to society as a whole.

Table 7. Present values of the soybean value chain (2016 values).

Province	MIRR (1)	FNPV – $ (2)	ENPV – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Southern	**1.53%**	**−355**	**−1,494**	**−3,369**	−15,008	2,269	−13,908
Western	−15.66%	−1,145	−2,366	−4,601	−9,509	655	−5,563
Eastern	−19.29%	−1,498	−2,726	−13,044	−23,736	1,361	−12,053
Total/average Rwanda	**−9.46%**	**923**	**2,119**	**−21,014**	**−48,253**	**4,285**	**−31,524**

The analysis of soybean cultivation shows that its profitability varies along provincial lines. It is revealed to be a slightly positive activity in the Southern Province, generating a return rate of 1.53% (Table 7, column 1, row 1). In contrast, the negative 15.66% and negative 19.29% rates of return of soybean cultivation in the Western and Eastern Provinces, respectively, suggest that the soybean farmers in these two provinces do not even cover their accounting costs, let alone the opportunity cost of their capital (Table 7, column 1, rows 2 and 3). If the country is examined as a whole, it is estimated that soybean cultivation results in a loss for the farmers on average, generating an average MIRR of negative 9.46% (Table 7, column 1, row 4).

From the results of the evaluation criteria, on average, farmers will not be interested in cultivating this crop without external motivations to do so. Similar to beans, soybean has proved to be beneficial when intercropped with maize and sorghum due to its nitrogen fixation property. This

is a factor that allows farmers to continue cultivating it even though it is not profitable when monocropping.

The result of the impact of soybean cultivation on the economy is even worse than its financial outcomes. While the cultivation in the Southern Province results in the least negative impacts, it is still not an economically profitable activity in any of the provinces. In NPV terms, its cultivation averages net economic NPV losses of resource to the economy worth $1,494, $2,366, and $2,726 per hectare cultivated in the Southern, Western, and Eastern Provinces, respectively (Table 7, column 3, rows 1, 2, and 3). The aggregate economic NPV losses from farming this crop in the Eastern Province are equivalent to the combined losses from its cultivation in the Southern and Western Provinces. Overall, the cultivation of soybean costs the Rwandan economy approximately $48 million in NPV terms (Table 7, column 5, row 4). These results demonstrate the critical need for the revision of this value chain to make the best use of the country's scarce land resources.

To achieve economic viability, the yield of soybean will have to increase by about 32%, 69%, and 82% in the Southern, Western, and Eastern Provinces, respectively. Unfortunately, data shows that from 2012 to 2016, the yield declined at an annual average of 7.96% [55].

4.7. Wheat

Wheat, together with maize, is one of the most promoted crops in Rwanda and is harvested bi-annually. While it does not have any tariff protection [62], a 75% subsidy is given for the purchase of wheat seed alongside 35% and 30% subsidies on DAP and urea fertilizers, respectively. Wheat cultivation is concentrated in the Northern, Southern, and Western Provinces, on 9,525 ha, 4,539 ha, and 3,030 ha, respectively. The wheat market is rapidly expanding, with domestic consumption increasing by 155% during the last decade [70]; with most of the demand coming from urban consumers, it is projected to increase further. Straw, which is a by-product of wheat, also provides a valuable source of revenue for wheat farmers. It is an essential input for the button mushroom growing industry, which is expanding in the country [71].

Table 8. Present values of the wheat value chain (2016 values).

Province	MIRR (1)	FNPV per ha – $ (2)	ENPV per ha – $ (3)	Agg. FNPV – 000s $ (4)	Agg. ENPV – 000s $ (5)	Externalities – 000s $	
						Tax revenue (6)	Subsidy (7)
Northern	**15.04%**	**133**	**−1,317**	**1,268**	−12,545	4,243	−18,056
Western	−2.45%	−606	−2,144	−1,837	−6,495	1,086	−5,744
Southern	−4.38%	−774	−2,311	−3,514	−10,491	1,627	−8,604
Total/Average Rwanda	**6.79%**	**−239**	**−1,728**	**−4,083**	**−29,531**	**6,956**	**−32,404**

Wheat cultivation exhibits varying degrees of financial profitability across the country. It generates a return rate of 15.04% on average to farmers cultivating it in the Northern Province (Table 8, column 1, row 1), but less than the average return from maize in the same province (16.6%). In contrast, wheat cultivation is not capable of generating enough revenue to cover its costs in the Western and Southern Provinces. This is reflected in the negative 2.45% and negative 4.38% average rates of return from farming wheat in these provinces, respectively (Table 8, column 1, rows 2 and 3). Although it generates losses on average for the farmers in the latter provinces, when the country is examined as a whole, wheat cultivation is estimated to generate an average MIRR to farmers of 6.79% financially (Table 8, column 1, row 4).

While wheat cultivation is revealed to be profitable financially in a province, from an economic perspective, cultivating wheat is not favorable at all. From the societal perspective, wheat cultivation in the Northern, Western, and Southern Provinces on a per-hectare basis results in an economic NPV loss worth $1,317, $2,144, and $2,311, respectively (Table 8, column 3, rows 1, 2, and 3). This results

in an average loss of resources worth $1,728 in NPV terms per hectare of wheat cultivated across the country (Table 8, column 3, row 4). Aggregately, the wheat value chain costs the economy an economic NPV of $12.5 million in the Northern Province, $6.5 million in the Western Province, and $10.5 million in the Southern Province (Table 8, column 5, rows 1, 2, and 3). This adds up to a cost of about $29.5 million worth of resources in NPV terms to the economy of Rwanda (Table 8, column 5, row 4).

From the results, the cultivation of wheat is proven not to be a profitable activity for the economy. Although the government and international donors have been massively subsidizing this activity, it is still not profitable for farmers to cultivate, except for the Northern Province. The financial cost of subsidizing wheat cultivation is greater than the tax revenue that is generated indirectly by the output production. This shows that the cultivation of wheat is not a profitable crop for the Rwandan economy under prevailing conditions. For the economy to break even on the production of wheat, with the current policies and valuations in place, the per-hectare yield will have to increase by 10.22% in the Northern Province, 17.79% in the Western Province, and 18.92% in the Southern Province. In reality, across the country, productivity has only increased by an average of 1.24% from 2012 to 2016 [55].[11] At this rate, it will take about 8 years to achieve sustainability in the Northern Province and about 15 years in the Southern and Western Provinces. A key recommendation for improving yields is to increase mechanization of post-harvest processes such as threshing, winnowing, and warehousing to reduce the post-harvest losses faced by many smallholder farmers. This is still a work-in-progress by the RAB.

5. Conclusion and Policy Recommendations

The financial and economic returns of seven of the most cultivated crops in Rwanda, namely beans, cassava, maize, potato, rice, soybean, and wheat, have been analyzed to determine their sustainability if the current agriculture policies are continued in Rwanda.

This integrated cost-benefit analysis shows the cultivation of beans, cassava, and potato to be financially, economically, and fiscally sustainable, but rice, wheat, and soybean cultivation to be financially unsustainable without continued subsidization. Maize production is found to be economically sustainable in the Southern Province but not in any of the other provinces where it is cultivated. The land and climatic zones in Rwanda are highly segmented. It is critical to select the crops to be grown in each zone so that farmers have a financial incentive to grow the crop and so that it is economically feasible in order to be sustainable.

Table 9. Annualized fiscal impacts of the agricultural policies of Rwanda (000s $ - 2016 values).

Crops	Western	Eastern	Southern	Northern	Total
Bush beans		3,703	2,068		**5771**
Climbing beans	1,157			2,486	**3643**
Cassava	988	1,382	5,584		**7954**
Maize	-5,313	-6,456	-2,899	-4,422	**-19090**
Potato			732	5,575	**6307**
Rice	-1,722	-5,586	-4,000		**-11308**
Soybean	-830	-1,807	-1,967		**-4604**
Wheat	-787		-1,179	-2,334	**-4300**
Total	**-6507**	**-8764**	**-1661**	**1305**	**-15627**

[11] Latest FAO data was to 2017, but the final year was not considered owing to the drought which severely hampered productivity for the year.

In Table 9, the fiscal impacts of the agricultural policies are annualized. The values represent the average annual overall fiscal burden of the government that combines the cost of the direct subsidies, the indirect taxes gained and the tariff revenues lost from the domestic production of rice. The net impact is approximately 15,627 million annually. This is equal to approximately 1 percent of the annual government budget. While this is a substantial fiscal drain of the government, it is not likely to be an unsustainable fiscal burden. A disproportionate amount of the net costs is created by the government's promotion of the cultivation of rice, soybean, and wheat. While they account for only 8 percent of the total land cultivated in crops, the combined losses account for more than 100 percent of the net annualized fiscal losses of the government. Of these three crops, only rice has some potential to become a sustainable crop without direct subsidization or protection from international competition. While maize is imposing a significant fiscal burden at the present time, this loss is coming about principally because of the low productivity of maize in the Western Province. For all the crops, it is the Western Province that has the lowest level of return to the farmers except for rice and wheat, which are being heavily subsidized. In particular, wheat has little possibility of ever being economically sustainable.

Although the present agriculture policies can be fiscally sustainable overall, it is the low rates of financial returns earned by the farmers engaged in the cultivation of certain crops in specific provinces that is likely to be signaling weakness in Rwanda's agricultural policies. The crops that need to be adjusted are bush beans in the Southern Province, maize and soybean in the Eastern Province, and climbing beans, cassava, maize soybean, and wheat in the Western Province. It is clear that it is the Western Province where major efforts must be made to improve the yields and lower the costs for sustainable cultivation of these crops. A major refocusing of agricultural policies to make them much more market-driven rather than command-directed is necessary if the government wishes to achieve its economic development goals. Particular attention should be paid to the potential benefits of intercropping. This is most important when considering the returns to climbing beans and maize if grown together in the Northern and Western provinces. A limitation of this research is that we were not able to study the benefits and costs of more extensive intercropping.

Future research needs to be focused on both yield-enhancing interventions that would be applicable to the climatic and soil conditions of the Western Province. Farmers in this province are benefiting the least from the current agricultural cropping policies. Experimentation needs to be done to determine if there are new crops that could be introduced that could be profitably cultivated in the Provinces that are faring poorly under the current policies.

In the absence of subsidization, forcing farmers to grow specific crops in regions where they do not cover their opportunity costs will likely lead to failure in the sustainable development of these segments of Rwanda's agriculture sector. In the preparation of Vision 2050 economic policies, including the formulation of the regional agricultural policy directives, it is vital that the government and international donors consider all aspects of sustainability – financial, economic, fiscal, and environmental.

Author Contributions: Conceptualization, M.M. and G.J.; methodology, M.M., G.J., and D.S.; formal analysis, M.M., and D.S.; investigation, M.M.; resources, G.J.; data curation, M.M., and D.S.; writing—original draft preparation, M.M. and G.J.; writing—review and editing, G.J. and D.S.; visualization, D.S.; supervision, G.J.; project administration, G.J. All authors have read and agreed to the published version of the manuscript.

Funding: The original research for this study was financed by the World Bank Group. Contract 7179970. Neither the World Bank nor any of its staff is responsible for any of the views expressed or the conclusions reached in this paper.

Acknowledgments: We acknowledge the contributions of Noel Ujeneza, Shahryar Afra, Brian Matanhire, Primrose Basikiti, and Alice Nsenkyire, who contributed in various ways in producing materials leading up to this research article.

Conflicts of Interest: The authors declare no conflict of interest.

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