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A Comparative Study between Major Crop (Potato) and Minor Crop (Onion) in Volcanic Highlands of Rwanda

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Abstract

This paper aims to assess the competition between the priority (major) crops and the non-priority (minor) crops. Competition between crops is defined as the significant major differences between two crops in terms of production costs and their performance. Data were collected using a questionnaire administered to a random sample of 226 small scale crop producers including 94 onion producers and 132 potato producers. The T-test was conducted to state whether there is significant difference of mean land sizes, mean crop yields, mean selling prices, and mean net farm incomes between the two groups of crop producers. Results showed non significant difference between the mean land size allocated to onion production and that allocated to potato farming. Results also indicate that onion yield is significantly greater than potato yield, onion selling price is significantly greater than that of potato, and the net income from onion production is far away greater than the income from potato production. It is remarkable that, in some circumstances, the authorities may prioritize and thus propose to farmers the crops that are less competitive considering their price, yield or income, if the current climatic conditions and economic settings are maintained in the medium or long term. Referring to these findings, policy efforts should encourages to the farmers to shift from potato farming to onion production, or simply inclusion of crop diversification via adopting onion may be the best option to maximize the potentials of the selected crops.

Keywords: Crop competition; T-test; Minor crops; Volcanic highlands; Rwanda.

1. Introduction

Competitive abilities among crops are based on their specific attributes. Farmer's choice of a crop can be motivated by the increasing crop yields [1]. The crop yields are induced by increasing the productivity and efficiency in production [2] under diverse environmental settings [3]. This is significant when the chosen crop enables the farmer to increase the farm production and income, as well as to stabilize his income [4] via the increase in food prices [5]. This leads to farmers' welfare improvement [6], especially secured reliable income, shelter or food [7], and result in poverty reduction especially in developing countries [8]. For Yang, *et al.* [9], the high yield is the primary indicator of crop competitivity, while Ensermu and Yalew [10] focused on the effect of a crop on food consumption and its compatibility of such an initiative with biophysical and socioeconomic conditions of small-scale farmers. Crop choice analysis is found to be very important for increasing farm productivity in Ethiopia [11]. Crop insurance may be another influential factor of crop choice since it can lead to the increase in farm investment via the reduction of risks or through the provision of subsidies [12].This would be highly dependent on the farmers' attitudes towards risks [13].

Besides the increasing crop yield, yield stability, the other motivating factor for famers to shift from one crop to another is the selling price [14]. This enables the farmers to participate in crop markets both as sellers and buyers for them to gain welfare improvement induced by increases in the mean or variance of crop prices [5]. In terms of Mubanga, *et al.* [5], «*Markets determined smallholder farmers' crop production choices more than household food security from own production or availability of climate information forecasting poor rainfall distribution*». For emphasis, it is important to state that the economic factors such as selling price [15], annual income and credit access [4], as well as market and input prices [16]. These factors could be complemented with the level of technology [3] that may provide high crop yield [1] under different agricultural risks [17], which are reflected among the most influential determinants of the behavior of small-scale crop producers. It was added farmers decide the crop shifts if the new adopted crops are most sensitive to climate change [5] with increasing yields [1]. Shift to new crop leads to an increase in the productivity and efficient use of resources along the production process [18]. However, if an

increasing number of farmers opt for one crop, its supply will increase and its price will thus be significantly affected, given that the demand for necessity (agricultural) products is price inelastic [19].

Crop diversification is another form of crop production shift. Bowman and Zilberman [20] have identified economic factors that may affect the diversification of farming systems. Such factors include namely the crop profitability, the biological constraints, the policies and regulations, public and private payments for ecosystem services. Statistically significant variables increasing probability of tobacco production over traditional crops were sales guarantee, price stability, input incentives, profit, sales-production ratio, and land neighbors' choice of cultivation [21]. Wang, *et al*. [22] modeled the farmers' behavior across crop choices and proved that cereals are selected in case of temperature warms, whereas vegetables and potatoes are likely to be selected if precipitations decrease. In contrast, Seo and Mendelsohn [23] found out that farmers decide to grow fruit and vegetables, and wheat and potato in cooler areas, rice, fruit, potato and squash in wetter locations, while maize and wheat are grown in warmer localities. They emphasized that farmers' decision about shifting from one crop to another may be reflected by predicted climate changes as well as their effects on crop yield and net farm income. That is the reason why Kurukulasuriya and Mendelsohn [24] stressed that «*As temperatures warm, farmers will shift toward more heat tolerant crops. Depending on whether precipitation increases or decreases, farmers will also shift toward drought tolerant or water loving crops, respectively*». However, farmers can sometimes show losses in rural incomes when they are forced to grow some crops [25].

In this line, the Government of Rwanda initiated the Crop Intensification program to boost the crop productivity and the profitability of six priority crops [26][1], that may be referred to as "major crops", namely maize, rice, wheat, potato, beans, soybean, and cassava so as to scale up the food security status [27]. Some other crops like onion are considered as the "minor crops". There has been salient development in Rwanda in favour of these «major» crops [28]. Besides, there are other crops that may be considered «minor» crops, which may be more competitive in terms of yield, selling price, and net farm income, thus affecting farmers' welfare more than the major crops. The production cycle seems to be the same for potato and onion: it ranges from 100 to 130 days for potato varieties grown in Rwanda [29] and the maximum of 4 months or 160 days in general [30], which makes 130 on average. As for the onion, their production cycle goes from 90 to 142 days [31], which comes to 116 days on average. Onion was qualified as a technically and economically efficient crop in Rwanda [2].

Whereas competition refers rivalry between economic agents for the same market, competition between crops is herein expressed as the significant differences between two crops in terms of production costs, as well as the level of their performance. The impossibility of extending the arable land in the current context in Rwanda, farming 1 hectare of potato requires a sacrifice of farming 1 hectare of onion and vice versa, keeping all other factors the same. This trade-offs are normally renowned as the opportunity cost. An opportunity cost of a given choice is defined as the payoff associated with the best of the alternatives that are not chosen. When a different option is chosen, the value of the next best option is sacrificed [32].

The main aim of this paper is to assess the competition between the priority (major) crops and the non-priority (minor) crops. More specifically, onion production was compared with potato (major crop) production with respect to the mean values of cultivated land, crop yield, selling price, as well as net farm income in the Volcanic Highlands in Rwanda. The results from this study are expected to shed light to the farmers' decisions who need to stabilize their incomes and to improve their welfare, as well as the government that needs to prioritize the exploitation of crops the most contributing to food security.

This paper is highlighted in 4 sections. This introduction is followed by the section on materials and methods. The section 3 presents the results and their discussion. The last section contains the conclusion and the policy implications.

2. Materials and Methods

Data used for this study were collected through a farmer survey in October to December 2019. The questionnaire used to collect data included the socioeconomic factors characterizing the farmers and their households as well as the preferred farming techniques practiced on the farms. The study considered a sample of 226 small-scale farmers randomly selected from the Volcanic Highlands of Rwanda (also known as «*Birunga*» region) with the aim to compare the mean of potato producers with the mean of onion producers in terms of the land size, the crop yield, the selling price, and the net farm income. The selection of the study area was motivated by its potential of being considered the country's silo [33] as a result of its fertile soils [34, 35].

Because the data in this analysis only covers one year and only the 2019 B season, the results are only valid at a conjunctural level. The mean comparison of two populations, n_1 and n_2, the two independent samples t-test for a population originating from [36], which is an efficient and powerful investigative tool to compare the mean of sample 1, μ_1, and the mean of the sample 2, μ_2 [37]. The T test was supplemented with value-added (VA) method [38], Benefit-Cost Analysis [39] and the budgetary method [40] to estimate the productivity and profitability indicators (the value added, the gross margin, the net farm income, and the benefit cost ratio) of both crops and consequently to estimate their opportunity costs.

The T test was used to test the level of the significance of the variability of the computed farm performance indicators between 132 small-scale potato producers (treatment group, or sample 1) and 94 small-scale onion

[1] The list of priority crops is also available in Nilsson (2019) who included also banana: the priority crops included Banana, Beans, Cassava, Irish potatoes, Maize, Rice, Soy, and Wheat.

producers (comparison group, or sample 2). This variability is not significant if the significance level (or the p-value) is greater than 10 per cent. It is significant, moderately significant or highly significant if the significance level is 10 per cent, 5 per cent, or 1 per cent, respectively.

3. Results

In this study, a Student Test was conducted to determine whether the difference between the mean size of land used, the mean crop yield, the mean selling price, and the mean net farm income between the two crop producers. For the comparison of the mean size of farms between 132 potato producers and 94 onion producers, the results from the Student Test (Table 1) show that the mean size of land cultivated by onion producers is 3,488 square meters, and that of the potato producers is 3,599 square meters, the difference being -111 square meters (t = -0.5001, p = 0.6175). Since the probability is greater than 0.05, the hypothesis of equality of the sample variances of land size held by the two groups of crop growers is accepted, which means that there is no significant difference between the land size allocated to potato production and that availed for onion production.

Table-1. Two-sample t test with equal variances of land size (square metres) by crop

Group	Obs.	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Onion production (0)	94	3,488.30	108.94	1,056.25	3,271.96	3,704.64
Potato production (1)	132	3,599.29	170.39	1,957.61	3,262.22	3,936.36
Combined	226	3,553.12	109.21	1,641.76	3,337.92	3,768.33
Difference		-110.99	221.94		-548.35	326.37
Difference=mean(0) - mean(1)				t=-0.50		
Ho: Difference=0			Degrees of freedom=224			
Ha: Difference<0		Ha: Difference ≠0			Ha: Difference>0	
Pr (T<t)=0.31		Pr (| T | > | t |)=0.62			Pr (T>t)=0.69	

After finding that the size of the land used for the potato and almost the same as for the onion farm, we compared the average costs of the potato to that of the onion. This is very important since it shows the amount of money required for a farmer to undertake one of these enterprises. The results (table 2) point to negative difference between onion costs and potato costs for seeds, manure, chemicals, transport, and rent for land, which implies that potato costs exceed onion costs, though this difference is not significant for manure and chemicals at 5% level of significance. These results also show that the difference is positive difference for pesticides, labour, and depreciation, which means that onion costs exceeds those of potato. The T-test results for the total cost reveal that the onion cost is not significantly different from that of potato, which indicates that the same amount of investment is required for both onion cultivation and potato farming in the study area.

The results (table 3) of the comparison analysis of means (Student's Test) show that the average yield of the onion is 17,420 Kgs, while that of the potato is 8,173 Kgs, the difference being 9,247 Kgs (t = 15.399, p = 0.00). Since this difference is significantly different from zero (p <0.05), the hypothesis of equality of average yields between onion and potato farms is rejected. This means that the yield of onions (17,420 Kgs) is significantly higher than that of potatoes (8,173 Kgs). From these results, agricultural producers could exploit the onion instead of the potato exploitation because the choice of the crop to be exploited is motivated by increasing yield [1, 18] and the high level of production [4].

Table-2. Two-sample t test with equal variances of production cost components by crop

Cost component	Onion cost	Potato cost	Difference	p-value
Seeds	86,719.41	130,035.70	-43,586.28	0.000
Manure	22,659.57	25,420.45	-2,760.88	0.169
Chemicals	66,930.32	86,638.54	-19,708.22	0.091
Pesticides	88,218.09	19,371.97	68,846.12	0.000
Transport	13,127.66	18,015.91	-4,888.25	0.013
Labour	86,723.40	74,666.67	12,056.74	0.017
Rent (land)	6,117.02	7,481.06	-1,364.04	0.708
Depreciation	8,702.31	7,219.83	1,482.48	0.001
Total cost	379,197.80	369,129.20	10,068.60	0.697

Table-3. Two-sample t test with equal variances of yield by crop

Group	Obs.	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Onion production (0)	94	17,420.11	533.59	5,173.32	16,360.51	18,479.71
Potato production (1)	132	8,173.09	335.45	3,853.99	7,509.50	8,836.69
Combined	226	12,019.20	423.72	6,369.84	11,184.24	12,854.16
Difference		9,247.02	600.50		8,063.66	10,430.37
Difference=mean(0) - mean(1)					t=15.40	
Ho: Difference=0					Degrees of freedom=224	
Ha: Difference<0		Ha: Difference ≠0			Ha: Difference>0	
Pr (T<t)=1.00		Pr (| T | > | t |)=0.00			Pr (T>t)=0.00	

The comparative analysis of crop yields is followed by the test of equality of the mean prices, the results of which reveal that the mean selling price of onion is FRW 462, that of the potato being FRW 198, and the difference comes to FRW 264 (t = 39.140, p = 0.00). Since the probability is less than 0.05, these results prompted us to reject the hypothesis of equality of the mean selling price of onion and that of potato that reflects that the market price of onion is significantly higher than that of the potato (table 4). Consequently, agricultural producers could shift from grow potato to opt for the production of onion, because the onion sells better than the potato in terms of the market price [9, 15].

Table-4. Two-sample t test with equal variances of selling price by crop

Group	Obs.	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Onion production (0)	94	462	7.23	70	447	476
Potato production (1)	132	198	2.41	28	193	203
Combined	226	308	9.27	139	290	326
Difference		264	6.74		250	277
Difference=mean(0) - mean(1)					t=39.14	
Ho: Difference=0					Degrees of freedom=224	
Ha: Difference<0		Ha: Difference ≠0			Ha: Difference>0	
Pr (T<t)=1.00		Pr (| T | > | t |)=0.00			Pr (T>t)=0.00	

This is possible if the increase in the supply of agricultural produce does not affect the price [41]. If an increasing number of farmers shift from producing potato towards onion production, the onion production will increase, and this increase in the supply of onion will cause significant fall in the onion price, the phenomenon which is referred to as King's effect [19]. The consequence is that the level of profitability will be deeply affected. Instead of abandoning potato in favor of onion, farmers should learn how well to rotate potato and onion to keep the market stable and to benefit from the potentials of both crops.

With regard to the comparison of net income, the results of the Student Test (table 5) revealed that the average net income of onion production is FRW 2,425,079, that of potato production raises to FRW 225,411, and that the difference amounts to FRW 2,169,668 (t = 19.38, p = 0.00). Now that the probability is less than 0.05, the hypothesis of equality between the net farm income from onion production and that from potato production is rejected. These results indicate that the mean income of an onion producer is significantly higher than the mean income of a potato producer in the Volcanic Highlands in Rwanda. Under such condition, it would follow from these results that potato growers could decide to shift towards onion production, the crop that provides farmers with increasing and stable incomes [4].

Table-5. Two-sample t test with equal variances of net farm income by crop

Group	Obs.	Mean	Std. err.	Std. dev.	[95% conf. interval]	
Onion production (0)	94	2,425,079	124,122	1,203	2,178,598	2,671,560
Potato production (1)	132	255,411	33,608	386	188,927	321,895
Combined	226	1,157,839	90,085	1,354	980,321	1,335,358
Difference		2,169,668	111,980		1,949,000	2,390,336
Difference=mean(0) - mean(1)					t=19.38	
Ho: Difference=0					Degrees of freedom=224	
Ha: Difference<0		Ha: Difference ≠0			Ha: Difference>0	
Pr (T<t)=1.00		Pr (| T | > | t |)=0.00			Pr (T>t)=0.00	

The opportunity cost of each crop was estimated (table 6) per on agricultural season. In terms of quantity produced per hectare, it requires the farmer to sacrifice 17,420 Kgs of onion (equivalent to FRW 2.831.598) if he wants to produce 8,466 Kgs of potato (equivalent to FRW 603,504), while he will sacrifice 8,173 Kgs of potato to get 17,420 Kgs of onion. In terms of incomes, a farmer will sacrifice the net farm income of FRW 2,406,904 per hectare from onion production if he decides to earn FRW 188,606 per hectare from potato production, while he will sacrifice FRW 188,606 from potato to earn FRW 2,406,904 from onion. All these results show that the opportunity cost of producing potato is greater than that of producing onion.

Different remarks were drawn from the comparative analysis of the averages of the size of the cultivated land, the yield, the selling price, and the net agricultural income between the onion producers and those of the potato in the soil region of lavas in Rwanda. Although the potato is one of the six priority crops (or major crops) under the Agricultural Intensification Program (CIP), the average size of the land used for potato farming is almost the same as the land used for onion production. Data used in this study are related to Season 2019B (March – July 2019): 132 farmers reported to grow potato while 94 reported to grow onion during the season. The region of Volcanic Highlands is characterized by regular and enough rains the whole year as well as fertile soil [42], which enables cultivation alongside the whole year. In this area, you find there an all-time vegetables market, known as Bazirete Vegetables Market, in Rubavu District, Western Province. Different varieties are sold on that market: carrot, onion, cabbage, cauliflower, celery, beetroot, green bean, pumpkin, courgette, aubergine, etc., and potato as well. Regarding the yield, the onion is more productive than the potato: 17,420 Kgs against 8,173 Kgs per hectare. The results of the comparison test also reveal that the selling price of a kilo of onion (462 FRW) is far higher than the selling price of the potato (FRW 198), and that the income net income of an onion producer (FRW 2,425,079) is almost ten times the net income of a potato producer (FRW 255,411).

Table-6. Estimation of the opportunity costs of potato and onion

Parameters	**Performance indicators of potato farming (Opportunity costs of onion)**	**Performance indicators of onion farming (Opportunity costs of potato)**
Observations (n)	132	94
Production (Kg) ***	3,048	6,129
Crop yield (Kg / ha) ***	8,173	17,420
Total revenue from labour ***	330,088	2,511,802
Quantity of labour (man-days)	75	87
Labour productivity (FRW)	4,421	28,871
Selling price (FRW per Kg) ***	198	462
Total revenue (TR) in FRW ***	624,540	2.831.598
TR per hectare in FRW	1,676,400	8,090,280
Coût variable total (CVT) in FRW ^{ns}	354,421	364,378
Intermediate consumptions (CI) ^{ns}	279,754	277,655
Value added (VA) in FRW ***	323,750	2,553,943
VA per hectare (FRW)	899,306	7,296,980
Gross Margin (GM) in FRW	957,925	3,195,976
GM per hectare (FRW)	2,660,903	9,131,360
Total fixed cost (TFC) in FRW^{ns}	60,477	60,316
Total cost (TC) in FRW^{ns}	414,898	424,694
Net farm income (NFI) in FRW ***	188,606	2,406,904
Land size (ha)^{ns}	0.36	0.35
NFI per ha (FRW)	523,906	6,876,869
Benefit-cost ratio (BCR) ***	1.45	6.67

Note: The exchange rate was FRW 1,013.93 per 1€, which was the average of three months, October, November, and December 2019, the period whereby data for this study were collected (Source: National Bank of Rwanda). *, **, and *** show that the variability of a given parameter between onion and potato producers in significant (p-value≤10%), moderately significant (p-value≤5%), or highly significant (p-value≤1%), respectively; "ns" stands for non-significant (p-value>10%).

4. Discussion

These results imply that the potato farmers could go towards onion production given the latter's potential to provide more profit. This finding is aligned with Hasan [21] who reported that an increase in farm production results in high farmers' profit. The increasing farmers' profit contributes to poverty reduction among agricultural households [8] and allows farmers to improve living conditions in their households [6]. This would be highly influenced by the farmers' attitudes towards risks (being risk lover, risk neutral, or risk averter) (see [43]) in the study area. In addition, considering the limitations of cross-sectionanalysis such as(1) the difficulty of separating cause and effect among some factors, (2) the issue of analyzing the dynamics of change, (3) the bias in statistical analysis using cross section data, (4) problem of heterogeneity in the microunits considered in the analysis, and (5) miscellaneous issues such as less informative data, less variability, more collinearity among variables, less degrees of freedom, as well as less efficiency [44], further research using longitudinal or panel data and covering the whole country would yield more reliable results.

5. Conclusion

Crop farming makes sense when it provides increasing and stable incomes to farmers. This implies that farmers prefer crops with higher productivity and best-selling prices. The Government of Rwanda initiated the crop intensification program (CIP) in 2009, and the specific objectives in this program were mainly to shift from subsistence agriculture towards market-oriented agriculture. The CIP selected six priority (or major) crops including potato, which was also considered one of the most speculative crops in terms of short production period (4 months

on average), increasing yield, and selling price, especially in Volcanic Highlands in Rwanda. However, there may be some non-priority or minor crops that are more competitive than the priority or major crops. This study aims to analyse the competition between onion production and potato farming in Rwanda.

With respect to the mean land size allocated to each crop and the required amount of money for operation, the results show that the land size allocated to and the operating cost incurred for potato farming are the same as those allocated to onion production. Concerning the crop yield comparison, the results reveal that onion yield is significantly greater than potato yield. For the selling price, the test for mean comparison shows that the selling price of onion was far greater than the selling price of potato.

As for the net farm income, the results indicate that the income gained by onion producers is greater than that gained from potato producers. These results imply that the shift from potato farming to onion production will increase the supply of onion and, consequently, lead to significant fall of onion price, which will impact significantly the onion profitability. Even though the opportunity cost of potato is greater than that of onion, the former is highly contributing to the food security in Rwanda: while potato is consumed as a staple food, onion is mainly consumed as a condiment. Farmers should learn how well to rotate crops to benefit from the potentials of both potato and onion and keep the local agricultural market conditions stable. As this study may be the first attempt on the competition among crops in Rwanda and considering the limitations of cross section analysis, more studies are suggested on a large number of crops, in all areas of the country, and using longitudinal data, which should lead the authorities to update the list of priority crops. The partners of development in agricultural sector could then avail the required inputs and production techniques specific for newly selected crops to farmers.

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References

[1] Nielsen, D. C. and Vigil, M. F., 2018. "Wheat yield and yield stability of eight dryland crop rotations." *Agronomy Journal*, vol. 110, pp. 594–601.

[2] Maniriho, A., Musabanganji, E., and Lebailly, P., 2020. "Analysis of economic efficiency of small-scale onion production in Volcanic Highlands in Rwanda." *Montenegrin Journal of Economics*, vol. 16, pp. 185-196.

[3] Bacsi, Z. and Hollósy, Z., 2019. "The yield stability index reloaded - The assessment of the stability of crop production technology." *Agriculturae Conspectus Scientificus*, vol. 84, pp. 319-331.

[4] Ashraf, M., Routray, J. K., and Saeed, M., 2014. "Determinants of farmers' choice of coping and adaptation measures to the drought hazard in northwest Balochistan, Pakistan." *Natural hazards*, vol. 73, pp. 1451-1473.

[5] Mubanga, K. H., Umar, B. B., Muchabi, J., and Mubanga, C., 2015. "What drives smallholder farmers' crop production choices in central zambia? Lessons from the 2012/2013 agricultural season." *Journal of Agricultural Studies*, vol. 3, pp. 1-16.

[6] Yirga, C. and Alemu, D., 2016. "Adoption of crop technologies among smallholder farmers in Ethiopia: implications for research and development." *Ethiopian Journal of Agricultural Sciences*, vol. 26, pp. 1-16.

[7] IFAD, 2016. *Rural finance: Sustainable and inclusive financing for rural transformation*. Rome: International Fund for Agricultural Development (IFAD).

[8] Mwangi, M. and Kariuki, S., 2015. "Factors determining adoption of new agricultural technology by smallholder farmers in developing countries." *Journal of Economics and Sustainable Development*, vol. 6, pp. 208-2016.

[9] Yang, L., Liu, M., Lun, F., Yuan, Z., Zhang, Y., and Min, Q., 2017. "An analysis on crops choice and its driving factors in agricultural heritage systems - a case of Honghe Hani Rice Terraces System." *Sustainability*, vol. 9, p. 1162.

[10] Ensermu, R. and Yalew, A., 1995. "Factors influencing crop enterprise choice by smallholders: a case study of Bahr Dar and Yilmana Densa areas. IAR Working Paper (Ethiopia)."

[11] Ayele, M., Emana, B., and Haji, J., 2015. "Determinants of farmers' crop choices on irrigated agriculture of halaba and meskan districts of Southern Ethiopia." *Journal of Economics and Sustainable Development*, vol. 6, pp. 137-143.

[12] Yu, J. and Sumner, D. A., 2018. "Effects of subsidized crop insurance on crop choices." *Agricultural economics*, vol. 49, pp. 533-545.

[13] Wauters, E., van Winsen, F., De Mey, Y., and Lauwers, L., 2014. "Risk perception, attitudes towards risk and risk management: evidence and implications." *Agricultural Economics – Czech*, vol. 60, pp. 389-405.

[14] Gemessa, S. A. and Zander, K. K., 2012. *Economic analysis of Ethiopian farmers' preferences for crop variety attributes: a choice experiment approach. In Wale, E., Drucker, A. G., & Zander, K. K. (Eds.), the economics of managing crop diversity on-farm. Case studies from the genetic resources policy initiative*. Routledge, pp. 39-58.

[15] Mignouna, D. B., Abdoulaye, T., Akinola, A. A., Kamara, A., and Oluoch, M., 2016. "Understanding market participation choices and decisions of maize and cowpea famers in northern Nigeria." *Tropicultura*, vol. 34, pp. 26-39.

[16] Chilonda, P. and Van Huylenbroeck, G., 2001. "A conceptual framework for the economic analysis of factors influencing decision-making of small-scale farmers in animal health management." *Revue Scientifique et Technique – Office International Des Epizooties*, vol. 20, pp. 687-700.

[17] Mulumeoderhwa-Munyakazi, F., Maniriho, A., Manirakiza, D., Furaha, G., Mastaki, J. L., and Lebailly, P., 2019. "Risk analysis in the peasant framework: empirical analysis of farmers in South Kivu, Democratic Republic of Congo." *Agriculture and Forestry (Poljoprivreda i Sumarstvo)*, vol. 65, pp. 35-45.

[18] Mabe, F. N., Donkoh, S. A., and Al-Hassan, S., 2018. "Accounting for rice productivity heterogeneity in Ghana: the twos-step stochastic metafrontier approach." *International Journal of Agricultural and Biosystems Engineering*, vol. 12, pp. 223-232.

[19] Endres, A. M., 1987. "The King-Devenant 'law' in classical economics." *History of Political Economy*, vol. 19, pp. 621-638.

[20] Bowman, M. S. and Zilberman, D., 2013. "Economic factors affecting diversified farming systems." *Ecology and Society*, vol. 18, p. 33.

[21] Hasan, K. M., 2019. "Factors influencing farmers turning into tobacco cultivation in the Khulna division of Bangladesh: an empirical study." In *4th ENSP-SRP International Conference on Tobacco Control*.

[22] Wang, J., Menderlsohn, R., Dinar, A., and Huang, J., 2010. "How Chinese farmers change crop choice to adapt to climate change." *Climate Change Economics*, vol. 1, pp. 167-185.

[23] Seo, S. N. and Mendelsohn, R., 2008. "An analysis of crop choice: Adapting to climate change in south american farms." *Ecological Economics*, vol. 67, pp. 109-116.

[24] Kurukulasuriya, P. and Mendelsohn, R., 2007. *Crop selection: adapting to climate change in Africa*. Washington, DC: The World Bank.

[25] Kurosaki, T., 2008. "Crop choice, farm income, and political control in Myanmar." *Journal of the Asia Pacific Economy*, vol. 13, pp. 180-203.

[26] Nilsson, P., 2019. "The role of land use consolidation in improving crop yields among farm households in Rwanda." *The Journal of Development Studies*, vol. 55, pp. 1726-1740.

[27] Cantore, N., 2011. *The crop intensification program in Rwanda: A sustainability analysis*. London: Overseas Development Institute.

[28] Minagri, 2018. *Strategic plan for agriculture transformation 2018-2024*. Kigali: Ministry of Agriculture and Animal Resources (MINAGRI).

[29] AFSR, 2007. "Fiche technique de production des semences certifiées: pomme de terre [Technical guide to produce certified potato seedlings]. Kigali: AFSR (Appui à la Filière Semencière au Rwanda)."

[30] ARC, 2013. *Production guideline for winter vegetables*. Pretoria: Agricultural Research Council (ARC).

[31] Nikus, O. and Mulugeta, F., 2010. *Onion seed production techniques. A manual for extension agents and seed producers*. Asella, Ethiopia: United Nations Food and Agriculture Organization – Crop Diversification and Marketing Development Project (FAO – CDMDP).

[32] Besanko, D. and Braeutigam, R. R., 2011. *Microeconomics*. 4th ed. John Wiley and Sons, Inc.: New Jersey.

[33] Mizero, M., Maniriho, A., Bashangwa, M. B., Karangwa, A., Burny, P., and Lebailly, P., 2021. "Rwanda's land policy reform: Self-employment perspectives from a case study of kimonyi sector." *Land*, vol. 10, p. 117.

[34] Maniriho, A. and Bizoza, A., 2013. "Financial benefit-cost analysis of agricultural production in musanze district (rwanda)." *Academia Arena*, vol. 5, pp. 30-39.

[35] Maniriho, A., 2013. *The determinants of agricultural production and profitability in musanze district, Rwanda (Master dissertation)*. Kigali: National University of Rwanda.

[36] Student and Gosset, W. S., 1908. "The probable error of a mean." *Biometrika*, vol. 6, pp. 1-25.

[37] Van Elst, H., 2019. "Foundations of descriptive and inferential statistics. Lecture notes for a quantitative - methodological module at the bachelor degree (B.Sc) level. Köln: parcIT GmbH. E-Print: arXiv:1302.2525v4 [stat.AP]."

[38] Cochet, H., 2015. *Comparative agriculture*. London: Springer.

[39] Meunier, V. and Marsden, E., 2009. *Cost-benefit analysis: Methodological guide*. Toulouse (France): Foundation for Culture of Industrial Safety.

[40] Gietema, B., 2006. *Farm accounting*. Wageningen: Agromisa Foundation.

[41] Tadasse, G., Algieri, B., Kalkuhl, M., and von Braun, V., 2016. *Drivers and triggers of international price spikes and voltality. In Kalkuhl M., von Braun J. and M. Torero (Eds.), Food price voltality and its implications for food security and policy*. Cham: Springer Open. pp. 59-82.

[42] Minagri, 1989. *Regional seminar on fertilization and peasant income issue in high altitude zones in Rwanda. Seminar held in Gikongoro, 13-19 November 1988*. Kigali: Ministry of Agriculture, Animal Resources and Forests (MINAGRI).

[43] Komarek, A. M., De pinto, A., and Smith, V. H., 2020. "A review of types of risks in agriculture: What we know and what we need to know." *Agricultural Systems*, vol. 178, p. 102738.

[44] Gujarati, D. N. and Porter, D. C., 2010. *Essentials of econometrics*. 4th ed. Boston: The McGraw-Hill Irwin.