

An Economic Analysis of the Factors Influencing Avocado Production, Profitability and Sustainability in Rwanda: A Case Study of Burera, Gicumbi, and Musanze Districts

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Abstract: Agriculture plays a fundamentally important role in the economic growth and development prospects of a vast majority of developing countries including Rwanda where this sector is a main source of livelihood, providing direct employment. The aim of this study was to analyze the factors influencing avocado production, profitability and sustainability in Rwanda. A case study of Burera, Gicumbi, and Musanze Districts. A multistage sampling technique was employed in this study. Data were collected using a structured questionnaire where a sample size of 108 farmers was used. A Cobb Douglas production function and gross margin analysis were used to estimate the profitability of avocado fruits production for smallholder farmers sampled. Hass is the most cultivated avocado tree followed by fuerte, Ettinger, and traditional respectively. The profitability analysis of avocado farming in three districts indicated that fuerte generated more than other varieties followed by Hass and lastly traditional avocado for the trees aged between 3-10 years in study area. While the Net Farm Returns for avocado trees aged 11 years and above showed that Ettinger generated more than other varieties followed by fuerte and lastly Hass avocado for the trees aged between 11 years and above. This indicates that farmer should gain 26108 Rwf from 1 fuerte avocado tree per season and 22838 Rwf for the Hass tree aged between 3-10 years. However, farmer should gain 34368 Rwf from one fuerte avocado tree per season and 42313 Rwf from Ettinger aged 11 years and above. Comparing the area occupied by one avocado tree and other crops like beans, maize, wheat, Irish potato and others, for example one fuerte and Ettinger avocado tree should generate more than 1.2 and 1.7 times for maize respectively. Moreover, they should generate 2.5 and 3 times than beans crops in study area. With these results, it is economically easy to say that avocado fruit is more profitable than all other crops grown in study area. The results indicated that gender of respondents, avocado yield, farm-gate, and price, access to extension services, education level, and land size had a positive effect on profit margin. With this result, avocado fruits trees should be promoted in area as they have a successful business.

Keywords: Economic Analysis, Factors Influencing, Avocado, Production, Profitability, Sustainability

1. Introduction

Agriculture plays a fundamentally important role in the economic growth and development prospects of a vast majority of developing countries including Rwanda where this sector is a main source of livelihood, providing direct employment. In Rwanda the sector occupies 79.5 percent of the labor force, contributes one-third of GDP and generates more than 45.0 percent of the country's export revenues. Agriculture is also important for national food self-sufficiency, accounting for well over 90.0 percent of all food consumed in the country [7, 22].

The horticulture sector is an important means of fostering agricultural growth and reducing malnutrition for the people of Rwanda for both in urban and rural areas. Horticulture sector products contributes 37 percent of total agriculture sector production and 22 to 27 percent of the total agriculture products supply for export [15, 13]. This sector has proved to be an attractive economic activity, accounting for 14 percent of the total value of agriculture output and it is growing rapidly [13].

Despite the important role that horticulture currently plays in the national economy, exports are largely limited to relatively small amounts of cross border trade and to a small number of shipments to destinations outside the region [14]. Most marketing of vegetables and fruits is opportunistic and informal, with prices being negotiated at the time of sale at the farm-gate or at a local market. There is only a small amount of contract farming and little involvement of farmer cooperatives and associations in marketing, other than for produce grown collectively by their members [16].

Compared with the production of Rwanda's staple food crops, horticultural production is more labor intensive and adds more value per hectare. The average production of vegetables in 2013 was increase from to 8.4tonnes per hectare and 12.5 ha for fruits in general. Thus, employment and the value which is added within the agriculture sector can be increased by switching land from staples to the production of vegetables, fruits and flowers. Across the horticulture sector, per-hectare yields tend to be well below those that are potentially achievable due to sub-optimal input use, insufficient control of pests and diseases, and inadequate cultural practices [14, 12].

Avocado is a very special fruit and differs from all other fruits because it possesses a high oil and protein content. It is the only fruit known that contains all of the following nutrient elements: proteins, lipids, vitamins, minerals, salt, sugars as carbohydrates and water. Avocado is grown in small scale by most of small-scale farmers in Rwanda.

The avocado (*Persea americana*) is a native of Central America and the West Indies belongs to the family Lauraceae. It is divided into three sub-species or races i.e. Mexican (sub-tropical), Guatemalan (semi-tropical) and West Indian (tropical). The growth habit varies from tall and upright to well-shaped and spreading. The crop brings considerable net return per acre when compared to staple crops [4].

According to FAOSTAT, trade data the total worldwide exports of avocado had a total value of US\$ 448 million in 2002. Compared to 1994 this means that the world exports have more than doubled. The biggest exporters are Chile, Mexico, Spain and Israel. Although there is no avocado production in France and the Netherlands, they appear in the list of top exporters because they are important traders in avocados. Most of Chile is exported avocados are destined towards the USA (70%), but this will probably change rapidly in 2006 as the American import ban on Mexican Hass avocados was lifted to 47 American states at the end of 2005. The USA and France are the largest avocado importers. Together they are responsible for over 50% of the total imports [4].

Over a period of 2005 –2012, avocado production in Africa has grown but unevenly from 497,339mt in 2005 to 751,881mt in 2012. The leading producers with their volumes in Mt in 2012 were Kenya (186,292mt), Rwanda (145,000mt), South Africa (91,603mt), Cameroon (72,000mt) and DRC (70,000mt). With an exception of South Africa all, the other four top ranking producers lie closer to the equator with tropical conditions [5].

The world top 12 avocado production countries in 2013 are respectively Mexico, Dominican Republic, Colombia, Peru, Indonesia, Kenya, and use, Chile, Brazil, Rwanda, Venezuela, and China [5]. In 2014, the country was classified at 16th exporter country in the world where it was the fourth in Africa after South Africa, Kenya, and Morocco [5]. Rwanda also has the ideal conditions for avocado cultivation, which reinforce the strong cost Competitiveness. Hass avocado is the most widely consumed. In 2013, the country was also ranked as the 10th in the world top 13 avocado consuming countries and the second in Africa after Kenya [5]. The world avocado production growth in the year 2003-2013 indicated that Rwanda was the first country in the world with 396% in avocado growth followed by Peru. In Africa, the second country was Kenya with 170%, Morocco with 119%, Swaziland with 116percentage and South Africa with 17% [5].

Due to favorable agro-climatic conditions, avocado cultivation is distributed across the country. Cooperatives and small-scale farmers grow avocados almost countrywide. The South, North, East, West, and Kigali City provinces are all centres of avocado cultivation according to the avocado farming and production respectively [15]. Avocado fruit is an important commercial fruit in Rwanda both for local and export markets. The three avocado varieties such as hass, Fuertes, ettinger are the most grown for export market. Among the Fuertes, there are more than 15 species, which are produced and marketed with high content of fat. The local variety of avocado is also superior in taste and consistency [15].

The main avocado cultivars are based on these races. Although a range of cultivars are grown, the hass cultivar is the world is most widely grown and exported variety. One of the reasons for the popularity of hass is that it produces high yields of rich fruit with excellent storage and shipping

characteristics. Avocados can be grown from seeds or from seedlings [17].

Graft to improve the variety by increasing its resistance to diseases, improving yield and increasing its adaptability to different soils. The avocado seedlings are transplanted when they are about 50 cm tall. The recommended distance of planting is in the range between 7.5 meters apart accommodating 178 seedlings per hectare and 9 meters apart accommodating 125 seedlings per hectare accordingly. Align the trees in all directions and finally pack the base of the plant to let the root system recover early. Planting can be done anytime of the year but the best time is during the onset of the rainy season [17].

Agronomical and economically a tree or an orchard of avocado trees should meet two rains for a good development and success of production and productivity. For this reason, the best time to plant an avocado tree is September–October to meet the short rain season. Otherwise, April–May is best to meet the long rain season. If planted during dry season provide the seedlings with irrigation and partial shade [2]. Avocado trees can develop flowers during the period from November to February. From the moment a flower develops until it falls of the tree is 15 days, after which it takes 5 months until the fruit is ready to harvest. An avocado tree is normally harvested over a period of one month. Collectors often come back two or three times to harvest the same tree. As avocados only start ripening when they are not on the tree, so when harvested, collectors try to harvest the avocados as much as possible in the off-season period [2].

For the early season harvest, flowers set already in November, while for the main season, flowers set between January in March. One avocado tree normally only develops flowers in just one period, but during the field work a farmer was met who had a tree, which developed flowers during different periods of the year [20]. Many farmers obtained seeds from this tree, as they also wanted to have a tree with this special characteristic. There are also other cases of trees which develop flowers in for example August, which results in harvests in February. Farmers assume that this happens with trees, which have access to year round water sources, for example trees close to wells. As prices for off-season avocados are much higher, farmers are trying to get seedlings with off-season production [6].

An avocado tree yields 230–320 kg (7.5–11 t/ha) of fruit per year. Grafted trees start bearing after 3–4 years after planting but economical crop is obtainable from the fifth year. Some of the indicators of reaching maturity are a change in colour from green to black or purple in dark varieties, the fruit stems turn yellow, the skin may appear less shiny, or the end develops rust like spots on green v varieties, some varieties develop a whitish appearance. Fruits float on the surface when immersed into water [10].

Avocado orchards may be intercropped with other crops such as beans, peas, kale, or cabbage during the first 3–5 years to get economic returns from the land before the trees start bearing or produce economic returns [10]. Avocados are primarily served as food, salad vegetables, merely halved and

garnished with seasonings, lime juice, lemon juice, vinegar, mayonnaise or other dressings. Often the halves are stuffed with shrimp, crab or other seafood. Avocado flesh may be sliced or diced and combined with tomatoes, cucumbers or other vegetables and served as a salad [3].

This fruit also has medicinal properties; many crops have ant rachitic qualities and anthelmintic high power. The oil extracted can be used in friction to alleviate gout and rheumatism. The leaf infusion is used against fever, menstrual cramps and migraine. It is also used in cosmetology for skin and hair with excellent results [10]. In addition to its high nutritive values, avocados can also be used as shade trees, windbreaks, posts, and ornamentals [1]. Large plantations may play an important role in carbon storage and sequestration that mitigates environmental pollution [9]. It also serves as animal feed, source of income, firewood, stakes for other climbing crops, and timber. With these all uses above, it shows that avocado have a significant impact on smallholder welfare impact of the study area.

The increased consumer demand for avocado is the main driving force behind the higher prices. This is not only caused by a growing demand from local and national markets but also from international markets demand. A big influencing factor for the development of these markets has been the improvements in infrastructure and regular transport services the national market. Avocadoes in Rwanda particularly in study areas are hardly grown on a commercial orchard scale, but pre dominantly produced as backyard crops or scattered in farms of annual crops like beans, maize, and in some parts in banana fields. In the earlier mentioned academic researches and local government reports of the districts, it was stated that no commercial avocado orchards are present in Rwanda [18].

However, with this field study it was found that there have been some changes as we discovered during our fieldwork in tree districts namely Burera, Gicumbi, and Musanze. We met some farmers who have developed orchards of around 0.25 hectare or farmers have more than 100 avocado trees. Although still very small, but with the mission of government through NAEB to facilitate the growth of business to diversify agriculture and livestock commodity export revenues there seems to be a start of the rise of more professional avocado sector.

Despite the critical role of the avocado production contribution to household income and foreign exchange from avocado exported. The challenges included pests and diseases, postharvest losses, lack of market information, high price of inputs, limited access to resources and/or weak incentives for upgrading, weak vertical and horizontal linkages within the value chain, lack of trust among producers, brokers, and exporters and the introduction of stringent new rules and market standards following increasing consumer concerns about food safety [21].

The main diseases hind avocado production are Anthracnose, avocado root rot. The main pests are red spider mites, Avocado Thrips, Whiteflies, and Fruit Flies that should be controlled by spraying with effective pesticides. Several measures should be put into place to enhance farmers' access to such markets [21]. For instance, globalization and the use of

internet should be created for the new opportunities for smallholders to improve their position in the international market place. Contract farming is one of the most schemes to enhance backward and forward market linkages in horticultural production in Africa but, generally in Rwanda in particular for market availability and price stability.

The main field management practice for avocado cultivation such as mulching, irrigation, fertilization, pruning, and thinning, weeding, pests and diseases control should be always taken into consideration. With these challenges given, the aim of this present study is to analyse the factors influencing avocado production and profitability in Rwanda. A case study of Burera, Gicumbi, and Musanze Districts. The specific objectives are to identify the avocado varieties and quantity produced by farmers per tree, and to determine the economic profitability and sustainability of avocado trees production in study area.

2. Material and Methods

2.1. The Study Area

The study was conducted in Northern Province of Rwanda particularly in three districts namely Burera, Gicumbi, and Musanze. These districts are the entire climate of high altitude with an average temperature of 20°C and the rain that varies between 1400 mm and 1800 mm. The production of Maize, Irish potatoes, beans, wheat, sorghum, sweet potato, banana, Fruits, vegetables, flowers, tea, coffee, and pyrethrum is significantly high in region. The soils found in these districts are mainly volcanic for Musanze and Burera while that of Gicumbi is andosols [19].

2.2. Sampling Procedure and Sample Size

The study used primary data collected from the field during the months of November and December 2018. The primary data collected from a random sample of 108 smallholder avocado fruits farmers. Secondary data used was collected from published sources, and libraries. The primary data was collected by structured questionnaire where a pre-test structured interview schedules was conducted to 14 sampled farmers. The multistage sampling technique was

employed in this study. The first stage was the purposive selection of Burera, Gicumbi, and Musanze districts. In the second stage, three (3) sectors in each district were purposely selected to make (9). Then, a sample size of one hundred (108) farmers were proportionally selected from each of the nine sectors. Data were collected with the use of structured questionnaires to obtain information on farmers' socio-economic variables, farm size (ha), cost of inputs, output and value of output for the three successive farming seasons.

Table 1. Study Population and Sample Size.

District	Sector	Sampling frame	Sample size
BURERA	GATEBE	40	10
	KIVUYE	40	10
	RUHUNDE	40	10
	MUKO	50	10
GICUMBI	NYAMIYAGA	70	17
	BUKURE	60	15
	GATARAGA	50	12
MUSANZE	NYANGE	50	12
	KINIGI	50	12
Total		450	108

2.3. Data Analysis

A Cobb Douglas production function and gross margin analysis was used to estimate the profitability of avocado fruits production for smallholder farmers sampled. The model used for the estimation of the gross margin for each farm among others is the model according to [8, 11]. However, for purposes of further comparison, the Net Farm Income are also computed by deducting cost of capital and household expenses per annum from the gross margins.

$$\text{Gross Margin} = \text{Total Revenue} - \text{Total variable Costs} \quad (1)$$

$$\text{Net farm Margin} = \text{Total Revenue} - \text{Total Cost} \quad (2)$$

To identify the factors influencing production and profitability of avocado fruits farming in Burera, Gicumbi, and Musanze the gross margins were regressed on the various socioeconomic and institutional characteristics. To achieve this, the ordinary least squares approach as specified in equation three was employed.

$$\text{PROFIT} = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Gender} + \beta_3 \text{Edn} + \beta_4 \text{Landsize} + \beta_5 \text{Yield} + \beta_6 \text{Price} + \beta_7 \text{Dist} + \beta_8 \text{Ext.access} + \beta_{10} \text{infacces} + \epsilon_i \quad (3)$$

3. Results and Discussions

3.1. Socio-Economic Characteristics of Sampled Respondents

This part indicate socio-economic characteristics of sampled respondents such gender, farm size, age, and education level of respondents.

The results from 108 respondents sampled in study are. Among the interviewed farmers, 70.4% were male and 29.6% were female. This indicated that male in study area heads more households. The results also showed that in

study area the majority of avocado fruits farmers are the of the 44.4% with age ranged between 4-50 years followed by the range of 31-40 years with 31.5%. This means that majority of the avocado farmers were within the working age class. Based on results the majority in study area indicated that 66.7% of respondents had primary school education followed by vocational with 12%. This means that farmers will be more receptive to farm innovations. The majority of respondents cultivate land area less or equal to 0, 5ha ($\leq 0,5\text{ha}$) representing 78, 7% of all sampled household. The implies low number of avocado trees in region however the average tree per household sampled is two trees.

Table 2. Socio-Economic Characteristics of Sampled respondents.

	Frequency	Percentage
Gender		
Male	63	70.4
Female	45	29.6
Total	108	100
Fam size		
≤ 0.5	85	78.7
0.6-0.8	13	12
0.9-1	7	6.5
≥ 1	3	2.8
Total	108	100
Age		
≤ 30	11	10.2
31-40	34	31.5
41-50	48	44.4
≥ 51	15	13.9
Total	108	100
Education		
Illiterate	25	10.2
Primary	32	66.7
Secondary school	19	8.3
Vocation	29	12
University	3	2.8
Total	108	100

3.2. Lifespan and Productivity of Avocado in Study Area

According to the farmers the in study area, lifespan of an avocado tree was between 25 and 35 years. During the life time of an avocado tree various productive stages can be identified (Table 2). These farmers said that, the first fruits appear about 5 to 6 years after planting for an avocado tree, which was planted through a seed. A grafted avocado tree produces its first fruits after 3 to 4 years. The first higher

production/harvests are obtained from the fifth until the 10th year after which the tree achieves its main productive stage. After about the 25th year, yields decline progressively.

Table 3. Lifespan and productivity of avocado tree in study area.

Growth stage, years after planting	Average yield (kg per tree)
3	25-50
5-10	150-300
10-25	300 -400
> 25	100 -250

According to the farmer focus group discussions the average harvest of an avocado tree of eight years old, with a trunk diameter between 25-30 centimetres, is 250 to 300 kg. Trees of 15 years old and with a trunk diameter between 40-50 cm can produce 350 to 450 kg per tree. In the study area, some farmers indicated that there are some exceptional traditional trees, which produce between 600-700kg per tree. Based on discussions with all the farmers/producers and buyers, the average consistent production of avocado in study area is in the range of 250 to 350 kg per tree for trees in their main productive life stage of 10-25 years. As the harvest is always weighed with a balance and/or by counting the numbers of fruits, farmers know very well how much the harvest on one tree. Compared with the average net revenue per hectare for other crops in region this is almost more than three times higher. This difference is mainly caused by the high input costs in used for other crops. Farmers in study area also mentioned that in their experience avocado trees require less water than crops grown there.

Table 4. Description characteristic avocado varieties and production per tree.

Cultivar/Variety	3-10 years		11 years and above	
	Number of trees	Average fruits per tree/year	Number of trees	Average fruits per tree/year
Hass	920	1270	795	1527
Fuerte	800	1182	716	1418
Ettinger	385	975	520	1645
Traditional	54	850	385	1350

The results in table 3 indicated that Hass, fuerte, Ettinger, and other traditional avocado varieties that have more than 30 years old for example are the main avocado varieties grown in study area. The results showed also average fruits and average kg harvested by smallholder farmer in the study area. Considering the information and data from research, the varieties are cultivated in manner where fuerte is the most cultivated followed by Hass, ettinger, and traditional respectively. Compared the new and grafted avocado production and density, the traditional avocado trees are decreasing at a decreasing rate while, the new varieties such fuerte, hass, and ettinger are increasing at increasing rate due to the availability of market both national and international for the purpose of export.

The results in table 2 indicated that the average produce (fruits) per tree per year for 3-10 years old for hass, fuerte, ettinger, and traditional avocado varieties is 1270; 1182; 975; and 850 fruits respectively. The results also indicated that the average produce (fruits) per tree per year for 11 years and above for Hass, fuerte,

ettinger, and traditional avocado varieties is 1527; 1418; 1645; and 1350 fruits respectively. The yield of avocado cultivation depends on numbers of key factors such as the variety, plant age, soil type, soil fertility, climate conditions along with the farm management skills practiced for the cultivation. However, averagely, it is possible to obtain fruits ranging between 15- 20 tonnes per hectare after 6 to 7 years of the plantation on the main field. The yield for different avocado varieties in the study area is generally summarized in the table above.

Table 4 shows the profitability analysis of avocado farming on 12 trees of avocado fruits in three districts of Northern provinces such Burera, Gicumbi, and Musanze districts. The results indicated that, the net Farm Returns per year for avocado trees aged between 3-10 years of harvesting were 548100; 626580; 452700; and 347000 Rwf for Hass, Fuerte, Ettinger and Traditional avocado respectively. This indicated that fuerte generated more than other varieties followed by Hass and lastly traditional avocado with 347000

Rwf for the tress aged between 3-10 years in study area. While the Net Farm Returns for avocado trees aged 11 years and above were 733140; 824820; 1015500; and 767700 Rwf for Hass, Fuerte, Ettinger and Traditional avocado respectively. This showed that Ettinger generated more than other varieties followed by fuerte and lastly Hass avocado for the tress aged between 11 years and above. This indicates that farmer should gain 26108 Rwf from 1 fuerte avocado tree per season and 22838 Rwf for the Hass tree aged between 3-10years. However, farmer should gain 34368Rwf from one fuerte avocado tree per season and 42313Rwf from ettinger aged 11years and above.

Comparing the area occupied by one avocado tree and other crops like beans, maize, wheat, Irish potato and others, for

example one fuerte and ettinger avocado tree should generate more than 1.2 and 1.7 times for maize respectively. Moreover, they should generate 2.5 and 3 times than beans crops in study area. This should be one in few indicators helping policy makers to make effort in mobilization of farmers to increase number of avocado trees where possible as well as to increase production and generate income from horticulture sector. This fruit should even be planted in some unoccupied areas such household ground, along the ways and roads. With this, the Government should compete to international markets; eradicate hunger and malnutrition as quickly as to achieve food security and household nutrition. Therefore, smallholder farmers should improve their mind-set as well as to increase income through new avocado varieties farming.

Table 5. Gross margin (profitability) analysis for 12 avocado trees in study area.

Variables	ITEMS				
	Unit	Unit price	Quantity	Total cost/season	Total cost/Year
Avocado Seedling	Number	2000	12	24000	48000
FYM	Kg	50	600	30000	60000
NPK	Kg	560	3.84	2150.4	4300.8
Labour	Man/day	800	20	16000	32000
Pesticide	Litre	13000	2	26000	52000
Others				15000	30000
Total variable costs	226,300				
Fixed cost					
Land Renting	Rwf	30000	1	30000	60000
Farm Manager	Man/month	10000	4	40000	80000
Total fixed cost	140000				
Total cost	366300				

PRODUCTION AND RETURN/REVENUE					
Total production for 3-10 years old trees	Unit	Average Unit price	Average Quantity/season	Gross margin/Season	Gross margin/Year
Hass	Number	30	15240	457200	914400
Fuerte	Number	35	14184	496440	992880
Ettinger	Number	35	11700	409500	819000
Traditional	Number	35	10200	357000	714000

Total production for 11 years and above old trees	Variety	Unit price	Quantity	Gross margin/Season	Gross margin/Year
Hass	Number	30	18324	549720	1099440
Fuerte	Number	35	17016	595560	1191120
Ettinger	Number	35	19740	690900	1381800
Traditional	Number	35	16200	567000	1134000
Net farm income per year for 3-10 years old trees					
Hass	12	548100			
Fuerte	12	626580			
Ettinger	12	452700			
Traditional	12	347000			
Net Farm Income per year for 11 years and above old trees					
Hass	12	733140			
Fuerte	12	824820			
Ettinger	12	1015500			
Traditional	12	767700			

Total Cost (TC)=TVC+TFC, Gross Margin (GM)=TR-TVC

Total Revenue (TR)=Yield*Price, Net Farm Income (NFI)=GM-TFC or NFI=TR-(TVC+TFC)

3.3. Economic Analysis of Sustainability and Viability of Avocado Fruit in Study Area

Net present value analysis should be used in any analysis

supporting Government decisions to initiate, renew, or expand programs or projects that would result in a series of measurable benefits or costs extending from one to more years into the future. This study was done considering the potential of project

of avocado production and productivity for the long run designed in study area, which should be more than 20 years.

The values of NPV, BCR, PBP, and ARR are depicted in Table 5. It is evident that investment in avocado cultivation was more significant. Net Present Value (NPV) of future returns was discounted using the initial investment and the money generated from harvest. The discounted returns for avocado trees aged between 3-10 years of harvesting were 9762000; 11331600; 7854000; and 5740000 Rwf for Hass, Fuerte, Ettinger and Traditional avocado respectively. This indicated that fuerte generated more than other varieties followed by Hass and lastly traditional avocado for the tress aged between 3-10 years in study area. While the Net returns for avocado trees aged 11 years and above were 13462800; 15296400; 19110000; and 14154000 Rwf for Hass, Fuerte, Ettinger and Traditional avocado respectively. This revealed that Ettinger generated more than other varieties followed by fuerte and lastly Hass avocado for the tress aged between 11 years and above. In study, area farmers indicated that even if traditional avocado do well but its production is reduced during harvesting because of many fruits broken when harvesting due to the longest trees and lack of tools suitable to attain the production from the top branches of tree.

As the NPV is greater than zero, then the adaptation approach of avocado project can be accepted. A higher NPV indicates the most efficient and economic adaptation approach. The BCR were for the study were found to be greater than unit for both avocado tress aged between 3-10years and 11years and above. The ratios for all avocado varieties grown in study area were greater than unity. This showed that investment in these fruits crops was more economically viable.

According to the results from the study, the costs for the project should be fully recovered for avocado trees aged between 3-10 years of harvesting in 2.2; 1.9; 2.6; and 3.4 years for Hass, Fuerte, Ettinger and Traditional avocado respectively. While the costs for the project should be fully recovered for avocado trees aged 11 years and above in 1.6; 1.4; 2.2; and 1.6 years for Hass, Fuerte, Ettinger and Traditional avocado respectively. This implies that the more the years for a tree, the higher production from it and the low payback period for the project designed.

The results also found out that the Average Rate of Return for the project were 45.7; 52.5; 37.7; and 28.8 years for Hass, Fuerte, Ettinger and Traditional avocado respectively. While the Average Rate of Return for the project for avocado trees aged 11 years and above were 61.1; 68.7; 84.6; and 63.9 years for Hass, Fuerte, Ettinger and Traditional avocado respectively. The average rate of return expresses the profits arising from a project as a percentage of the initial capital cost. This implies that the more the years for a tree, the higher ARR due to the production from it and the higher significance of the income generated. Generally, the study area is potential in avocado fruit production and productivity while it has high sustainability and viability in the end.

Therefore, the values of NPV, BCR, ARR, and PBP indicate better economic viability, and sustainability of avocado trees Rwanda especially in study area. Thus, avocado farming should be encouraged particularly Hass, Fuerte, and Ettinger due to their high market demand at national and international market and their best management practices in farm from planting to harvesting and packaging. This make them more income generation for farmers and for country.

Table 6. A Comparative Status of NPV, BCR, ARR, and PCP of Avocado Fruit Trees.

Particular	Avocado tree between 3-10 years				Avocado tree of 11 years and above			
	Hass	Fuerte	Ettinger	Traditional	Hass	Fuerte	Ettinger	Traditional
NPV	9762000	11331600	7854000	5740000	13462800	15296400	19110000	14154000
BCR	1.5	1.7	1.2	0.9	2	2.5	2.7	2.1
PBP	2.2	1.9	2.6	3.4	1.6	1.4	1.2	1.6
ARR	45.7	52.2	37.7	28.9	61.1	68.7	84.6	63.9

Table 7. Regression results of factors influencing avocado production profitability.

Variables	Coefficient	Standard Error	P>t
Constant	0.1001	0.0902	0.408
Age	-0.2321	0.6193	0.0011
Gender	0.0286	0.0594	0.0072
Education level	0.0385	0.0957	0.0583
Land size	0.792	0.6567	0.0825
Avocado yield	0.0539	0.0176	0.000
Farm get price	0.0594	0.0825	0.000
Distance to market	-0.0704	0.6853	0.0517
Access to extension services	0.022	0.0528	0.0026
Access to market information	-0.0198	0.0264	0.0549

Number of obs=108, F (9, 98)=49.15

Prob > F=0.0000, R-squared=0.8781

3.4. The Factors Influencing Avocado Production Profitability in Stud Area

Socio-economic factors influencing the avocado

production profitability were age, gender, education level, land size, avocado yield, farm get price, distance to market, access to, extension services, and access to market information.

The study results indicate that, age of respondents had a negative influence on avocado profitability margin. This implies that a unit increase in age led to a decrease in profit margin by 0.2321 units at 1% level of significance. This is because the innovativeness, mental and physical abilities to do manual work decrease with age.

The study results indicated that gender of respondents had a positive effect on profit margin. This implies that 1% increase in male number in agriculture sector should increase in profit margin by 0.0286 at 1% level of significance.

The positive effect of gender on profit margin of the producers is explained by aspects of labor provision and adoption of technologies in agricultural production and significant idea on land ownership. In the other word male farmers who mainly produced avocado fruits in for selling, quickly adopted new technologies as compared to female farmers because they are the ones who mostly attend the trainings, seminars that are eventually enabled men to fetch relatively more profit compared to women.

However, avocado yield had a positive influence on profit margin. A unit increase in avocado yield led to an increase in profit margin by 0.0539 units at 1% level of significance. Actually, when smallholder farmers get more units/fruits of avocado per tree to be sold at good price, more profit is eventually gained from the quantity being sold. Smallholder farmers who realised higher output supplied larger proportion of their avocado fruits to the consumers.

In addition, farm-gate price had a positive influence on profit margin. A unit increase in farm-gate price led to an increase in the profit margin by 0.0594 units at 1% level of significance. This implies that as smallholder farmers sell at high prices, more profit is gained from the production sold at high price. Study results revealed that, access to extension services had a positive effect on profit margin. A 1% increase in number of contacts accessed by avocado producers led to an increase in the profit margin by 0.022 units at 1% level of significance. Market information access had a negative influence on profit margin. A unit increase lack of Market information led to a decrease in profit margin by 0.0198 units at 5% level of significance.

In addition, education level had a positive influence on profit margin. A unit increase in farm- education level led to an increase in the profit margin by 0.0385 units at 5% level of significance. This is because the educated farmers are directly more adopters of new technologies as compared to none educated one, because they are the ones who mostly attend the trainings, seminars that are eventually enabled to train other farmers. The study results indicated that, distance to market had a negative influence on avocado profitability margin. This implies that a unit increase in distance led to a decrease in profit margin by 0.0704 units at 5% level of significance. This is because the more the distance for perishable crops the more the losses increase as well as the reduction on profit margin.

The study results indicated that, land size had a positive influence on avocado profitability margin. This implies that a unit increase in land reserved to avocado farming led to

increase in profit margin by 0.792 units at 10% level of significance. This is because, land is the most important resource a farmer could possibly have since for any agricultural activities access to own or hired land is needed. This means that, the more the big land reserved for avocado farming, the more the number of avocado trees and the more the quantity/fruits harvested.

4. Conclusion and Recommendations

Among the interviewed farmers, the majority were male. This indicated that male in study area heads more households. The majority in study area indicated that the majority of respondents had primary school education followed by vocational. The majority of respondents cultivate land area less or equal to 0.5ha (≤ 0.5 ha). Considering the information and data from research, the avocado varieties are cultivated in manner where Fuerte is the most cultivated followed by Hass, Ettinger, Bacon, and traditional respectively. Compared the new and grafted avocado production and density, the traditional avocado trees are decreasing at a decreasing late while the new varieties such Hass, fuerte, and Ettinger are increasing at increasing late due to the availability of market both national and international for the purpose of export.

The yield of avocado cultivation depends on numbers of key factors such as the variety, plant age, soil type, soil fertility, climate conditions along with the farm management skills practiced for the cultivation. Therefore, averagely, it is possible to obtain fruits ganging between 15- 20 tonnes per hectare after 6 to 7 years of the plantation on the main field. The profitability analysis of avocado farming in three districts of Northern provinces such Burera, Gicumbi, and Musanze districts revealed that the results indicated that fuerte generated more than other varieties followed by Hass and lastly traditional avocado for the tress aged between 3-10 years in study area. While the Net Farm Returns for avocado trees aged 11 years and above showed that Ettinger generated more than other varieties followed by fuerte and lastly Hass avocado for the tress aged between 11 years and above. This indicates that farmer should gain 26108 Rwf from 1 fuerte avocado tree per season and 22838 Rwf for the Hass tree aged between 3-10years. However, farmer should gain 34368Rwf from one fuerte avocado tree per season and 42313Rwf from ettinger aged 11years and above. Comparing the area occupied by one avocado tree and other crops like beans, maize, wheat, Irish potato and others, for example one fuerte and ettinger avocado tree should generate more than 1.2 and 1.7 times for maize respectively. Moreover, they should generate 2.5 and 3 times than beans crops in study area. With these results, it economically easy to say that avocado fruit is more profitable than all other crops grown in study area.

Socio-economic factors influencing the avocado production profitability were age, gender, education level, land size, avocado yield, farm get price, distance to market, access to, extension services, and access to market

information. The study results indicated that gender of respondents, Avocado yield, farm-gate, and price, Access to extension services, Education level, and land size had a positive effect on profit margin while age, distance to market, access to market information of respondents had a negative influence on avocado profitability margin.

Recommendations

Farmers in study are should be encouraged to grow grafted avocado varieties that have both high quality and quantity at local and international market. Here the contract farming also has a potential in availing inputs to farmers and policies encouraging firms to contract smallholder farmers should be formulated as well as to reduce the losses of avocado production.

Farmers should be encouraged to remove the old/traditional avocado trees that should not facilitate effective post-harvest handling practices, reduce the area for cultivation of other intercropped crops and reduce the production due to many fruits that are broken during harvesting.

The yield of avocado cultivation depends on numbers of

key factors such as the variety, plant age, soil type, soil fertility, climate conditions along with the farm management skills practiced for the cultivation, so the farmers should be encouraged to focus on canopy management.

Due to the profitability and Perishability of avocado production, MINAGRI, MINICOM, RAB, NAEB, and Policy Makers should study on different factors includes inputs provision, price fluctuation of harvested fruits, middlemen and market stability of horticulture crops particularly for avocado fruit. This should assist in avocado price stabilization and promote greater production efficiently.

Agricultural Research institutions should work towards generating improved production technologies especially on variety and agronomic practices through cultivar diversification and practices mitigating avocado diseases.

Training, seminars, demonstration, and FFS should be offered to farmers, farmer's promoters as well as to help them to understand good agricultural practices, to become expert themselves and running a successful business in the production and marketing of avocado fruits.

Appendix

Table 8. Some Avocado Pests and Diseases and Control Measures.

Disease	Causal agent	Parts attacked	Control measures
Anthraxnose	<i>Colletotrichum gloeosporioides</i>	Leaves, flowers & Fruits	Spray copper based fungicide
Root rot	<i>Phytophthora cinnamomi</i>	Roots	Avoid planting in Waterlogged areas. Spray with a fungicide e.g. Ridomil
Fruit rot	<i>Phytophthora</i> spp	Near bottom of fruit	Prune lower limbs so they are 2 to 3 feet from the ground.
Stem-end rot	<i>Botryosphaeriaceae</i> and <i>Colletotrichum</i> spp.	Fruits	Hot water treatment of matured fruits
Scab	<i>Sphaceloma perseae</i>	Leaves, Fruits	Hot water treatment of matured fruits
Cercospora spot	<i>Pseudocercospora purpurea</i>	Roots, leaves, and fruits	Remove diseased leaves and fruits from the field and dispose in a two-feet deep pit
Pest	Causal agent	Parts attacked	Control measures
Fruit fly	<i>Ceratitis capitata</i> and <i>Dacus dorsalis</i>	Attack the mature fruits about to ripen	1) Mass trapping 2) Sterile insect technology (STI) is not permitted in organic agriculture.
Borers	<i>Nipponoclea albata</i> , <i>Nipponoclea capitoae</i> , <i>Xylosandrus compactus</i>	Attack the trunk, pith and branches	Lime wash and lime sulphur are used as repellents
Mealy bugs	<i>Aspidiotus destructor</i>	Suck the sap from the leaves, shoots and fruits.	1) Natural enemies provide satisfactory control 2) In case of high pressure: mineral oil spray.
Greenhouse thrips	<i>Heliethrips</i> , <i>haemorrhoidalis</i>	Cause fruit blemishes	Introduction of predatory mites (<i>Euseius hibisci</i> and <i>Anystis agilis</i>) and the minute pirate bug.

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