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Full Length Research Paper

Economic Analysis of Rubber Agroforestry Systems in Ghana

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Abstract

Even though rubber contributes significantly to Ghana's economy, smallholder rubber farmers' inability to wait for 6 years to see the benefits constrains establishment and expansion. To lessen the waiting time to the benefits, an option exists to intercrop rubber with food crops. Cost benefits analysis of rubber and plantain intercropping system under different treatments on two experimental plots were carried out. The treatments were sole crop plantain (P) and three intercropping of one (PR), two (PPR) and three (PPPR) rows of plantain each between two rows of rubber to assess the most viable. Discounted Cost/Benefit analysis was used to determine the viability at 25% interest rate. All the systems were found to be profitable. The highest return of GH₵40, 331 (USD 9,379)/ha from plantain over the period of two years was realized from the PPPR cropping system. Additionally, varying the price of plantain, discount rate and the total cost of production, the systems were all profitable. The PPPR was the most profitable with the highest income to smallholder farmers. Extension education by the government through the Tree Crops Development Authority (TCDA) and support to rubber farmers to access credit can help in farmers' adoption of rubber agroforestry system.

Keywords: Rubber, plantain, profitability, agroforestry, Ghana.

INTRODUCTION

Rubber, *Hevea Brasilliensis,* is a major income provider for millions of resource poor farmers in the world (Fox et al., 2013). The International Rubber Study Group (IRSG 2017) has indicated that the global consumption of natural rubber has exceeded 12 million metric tons in the last three years. The rubber sector plays a significant role in the generation of income for smallholder farmers within sub-humid and humid tropics. Bissonnette et al. (2015) reported that smallholders produce more than 80% of the production of natural rubber in the world although there are large estates. In the last three decades there has been varying technological changes in rubber production in Ghana. Policy makers and planners are faced with the challenge of devising a strategy to ensure increased productivity among smallholder rubber farmers in Ghana in climate changing situations whiles at the same time reaping the benefits of technological developments. This has necessitated the formation of the Tree Crops Development Authority (TCDA) of Ghana in 2019 to improve the production of six tree crops of which rubber is part. Under normal plant spacing, the establishment phase of rubber production occupies about one-fifth of

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the total planted area (Tetteh et al., 2019; DFID, 2014). The remaining unoccupied spacing can be utilized by intercropping rubber with shorter duration annual and perennial crops. Motivating more smallholder farmers in Ghana to cultivate rubber to meet the world demand has been met with varying challenges. Among the serious challenges is the long gestation period of 6 years before rubber becomes due for tapping, causing capital tied up. Even though farmers are aware of the lucrativeness of establishing rubber plantation, their inability to wait for up to 6 years to see the benefits also constrains the establishment of rubber. To lessen the waiting time, intercropping rubber with food crops like plantain (*Mussa spp*) can minimize this impact. Plantain can be harvested throughout the year; it ensures food and income security particularly at the household level. Many smallholder farmers in Ghana mostly intercrop young rubber trees with shorter duration cash crops to improve their income (Tetteh et al., 2019). Malezieux et al., (2009); Langenberger et al., (2016); Tetteh et al., (2019) indicated that complex rubber intercropping systems have many multiple benefits which includes maintaining biodiversity, retaining soil water capacity, and sequestering carbon from the atmosphere. According to Vernooy (2015) and Sankalpa, et al., (2020), income diversification through introduction of food crops, timber trees or livestock in rubber production systems is a common methodology used in most rubber producing countries. Stroesser et al., (2016) and Sankalpa, et al., (2020) found that apart from overall economic gain from rubber, agroforestry systems can be beneficial for the growth of rubber trees. Rubber trees intercropped with certain species were ready for tapping four months earlier than those growing on their own (Rodrigo *et al*. 2001; Verheye, 2010; Dongling, et al., 2015). According to Langenberger et al. (2016), given the extent of land covered by plantations, it seems to be essential to rethink this practice to mitigate associated negative environmental impacts and economic dependency and assess potential alternative management options. According to Joshi (2005); Langenberger et al. (2016), these practices have however not yet been officially suggested nor well known thus creating a gap in knowledge.

The adoption of agroforestry systems depends on many factors such as access to information on agroforestry, training opportunities, good quality seeds, property rights on land, size of available land, flexibility, and compatibility of agroforestry to existing farming systems. However, the adoption of agroforestry among smallholder farmers has generally been slow and has not attracted much attention from planners and development professionals (Kumar et al., 2015). Socioeconomic and biophysical interactions greatly affect farmers' decisions in readily adopting some technologies more than others. One of the reasons why agroforestry development projects have failed was lack of attention to socioeconomic issues in the development of such systems (Mercer et al., 1997; Matata et al. 2008; Langenberger et al., 2016). Economic considerations and short-term profitability alone have not fully explained farmers' adoption behaviors. The main objective of the study is to assess financial viability of rubber and plantain intercropping system under different treatments on two experimental plots.

MATERIALS AND METHODS

Study area

The field trials were conducted at two different locations in the Western region of Ghana where rubber production was common from 2014 to 2017. The locations were Council for Scientific and Industrial Research- Crops Research Institute (CSIR-CRI) field in the Ellembelle district for the first trial and Tikobo No. 2 - Ehiamadwen in the Jomoro district for the second and farmer participatory on-farm trial. The Ellembelle district is between longitudes 2º05' W and 2º35' W and latitude 4º40 N and 5º20 N. The district shares boundaries with Jomoro district to the West, Wassa Amenfi West district to the North, Nzema East Municipal to the South – East, Tarkwa – Nsuaem Municipal to the East and a 70 km stretch of sandy beaches to the south (GSS, 2013). The area falls within the wet semi-equatorial climatic zone of the West African Sub-region and Axim belt where we experience an all – year-round rainfall with the maximum monthly mean of rainfall occurring around May and June (GSS, 2013). Jomoro District is located in the South-western part of the Western Region of Ghana. It is located between Latitudes $4^0$80" N and 5^0, 21" N and Longitudes 2^0, 35' W and 3^0, 07" W. It shares boundaries with Wassa-Amenfi and Aowin-Suaman to the North, Ellembelle District to the East, La Côte D'Ivoire to the West and the Gulf of Guinea to the South. The district covers a total land area of 1,495 square kilometers which is about 5.6 % of the total land area of the Western Region (Ghana Districts, 2013). The first trial, located at the Ellembelle district was conducted on CSIR-Crops Research Institute Aiyinasi field at the geographical coordinates of N $05^0$03.517' and W $002^0$29.782' whiles the second was at Tikobo No. 2 – Ehiamadwen village at a geographical coordinate of N $05^0$10.234' and W $002^0$28.768'.

Experimental design

An experiment, which comprised five treatments, sole crop rubber (R), sole crop plantain (P) and three intercropping treatments consisting of an additive series of one (PR), two (PPR) and three (PPPR) rows of plantain to two rows of rubber. Treatments were laid out in three randomized blocks and in plots of 540 m^2. In all intercrop treatments, rubber was planted at a spacing of 3 m within, and 6 m between rows. A spacing of 3 m x 2 m was employed for the planting of sole plantain crops whiles 6 m × 3 m was employed for the sole rubber crop. In the intercrop treatments, intra-row spacing for both rubber and plantain was kept constant at 3 m whilst varying the inter-row spacing according to number of plantain rows, ranging from 3 m in the PR, 2 m in the PPR to 1.5 m in the PPPR treatments. Planting density of plantain was 555, 1111, 1666 and 1666 plants/ha in the PR, PPR, PPPR and P treatments.

Financial assessment of intercrop performance

A financial assessment of rubber and plantain intercropping was made using data available from the experiment. The yield data available for analysis was for only two years, although plantain, in general, could be grown as a rubber intercrop for three or more years. Few plantain suckers were not harvested in the third year of the production cycle in all the treatments due to prolonged dryness. Both cost and benefit were calculated on a per hectare basis. Labour cost was based on wages in the plantation sector and each unit referred to eight working hours, whilst values for plantain bunch was determined by the general farm gate price at Nzema Aiyinasi, Ghana. Tables on cash flow were constructed for each of the different spacings for the rubber/plantain intercrop and the associated profit was estimated in GH¢/hectare (Ghana cedis/ha). All the values were based on October 2016 prices and held constant throughout the analysis. The costs associated with rubber-plantain intercropping system were all identified and included in the cost–benefit analysis. The costs of rubber-plantain intercropping system include the cost of farmland, costs of planting, and initial cost related to the management of food crops and rubber. The costs of planting and management of plantain and rubber trees were considered as direct costs of rubber and plantain intercropping system. The benefit component included income from the plantain. Revenues from the plantain was obtained by multiplying the price per kg of plantain by the total number of kg realized each year. Revenues from the latex of the rubber tree was not considered since it would be realized six years after planting.

Conceptual and Analytical Framework

An investment appraisal method was used in the current study to examine the Cost Benefit Analysis of the rubber-plantain intercropping system. Cost benefit analysis (CBA) systematically analyses the economic justification of a potential investment decision. According to Gittinger, (2001), it involves identifying, measuring and placing monetary value on costs and benefits of a particular project proposal and then comparing these costs and benefits as an aid for decision making. The advantages of CBA include its wide acceptability, use of a common unit of currency (money) and it has the potential to quantify and compare a broad range of factors, inputs and outputs. Despite these advantages CBA however, has its shortcomings. These include the use of monetary unit as a measure of all costs and benefits. CBA has difficulties in accommodating social and environmental tangibles and its assumption that a favorable income distribution exists does not always hold (Jenkins et al., 2011). Plantain like any other perennial crop generates a stream of costs and benefits over a given period, which is more than one year. A discounted method is mostly used to enable comparisons of the future costs and benefits with the present values, due to the time values of money. This leads to discounting where future benefit and cost are ‘reduced’ to their ‘present worth’. The profitability of rubber-plantain intercropping system was evaluated using discounting indicators, such as Net Present Value (NPV), Benefit–Cost Ratio (BCR), and the Internal Rate of Return (IRR). Benefit–cost analysis is a set of procedures for defining and comparing benefits and costs, as well as organizing and analyzing data. The BCR is a ratio of the present worth of the benefit stream to the present worth of the cost stream. The rubber-plantain intercropping system is profitable if the BCR ratio is greater than one, indicating a profitable system whose accrued revenue is more and could cover the costs incurred, and a ratio of less than one indicates a non-profitable rubber and plantain intercropping system.
The mathematical expression is given by:

$$BCR = \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t} \div \sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}$$

Where: $B_t =$ benefits in each year, $C_t =$ cost in each year, $i =$ discount rate and $t = 1, 2, 3, 4, ...n,$ $n =$ number of years.

The decision rule is that, a BCR ratio of one (1) indicates a breakeven point, a ratio of greater than one (1) indicates a profitable investment whose revenues accrued is more and can cover the costs incurred, and a ratio of less than one (1) indicates a non-profitable venture. According to Henisz (2016) and Gittenger, (2001) the net present value (NPV) is interpreted as the present worth of benefit stream generated by an investment. The net present value (NPV) is usually computed by finding the difference between present worth of benefit stream minus present worth of cost stream. Juhász, (2011) stated that traditional investment theory demonstrates the concept of net present value (NPV) by using a cost of capital based on the inherent project risk. The NPV is the present worth of income stream generated by a rubber and plantain system. The decision rule of this technique is to accept those projects (rubber plantain intercrop systems), which have positive or zero NPV and the projects (systems) having negative NPV are rejected. In our case where there will be evaluation of more than one system, selection would be made for the highest net present value with high benefit cost ratio.

The mathematical expression is given by:

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

Where: $B_t =$ benefits in each year, $C_t =$ cost in each year, $i =$ discount rate and $t = 1, 2, 3, 4, ...n,$ $n =$ number of years.

The internal rate of return (IRR) is another investment appraisal method used for rubber-plantain intercropping systems that was examined in this research. IRR represents the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even (Gittenger, 2001). The rubber and plantain intercropping system would be viable if the IRR is greater or equal to the market rate of interest.

$$\sum_{t=1}^{t=} \frac{B_t - C_t}{(1+i)^t} = 0$$

Where: $B_t =$ benefits in each year, $C_t =$ cost in each year, $i =$ discount rate and $t = 1, 2, 3, 4, ...n,$ $n =$ number of years.

In rubber and plantain intercrop system, the costs were stratified into fixed costs and variable costs, depending on whether they are incurred only once during the establishment of a project (hence establishment costs) or whether they recur even after the project is established (hence operating costs). In this study, the costs of land preparation, digging of holes, planting material and planting labour were classified as fixed costs (FC) since they were incurred only once during the establishment of the plantain crop, while the costs of the various types of inputs, including the labour for their application, weeding and harvesting were classified as variable costs (VC) since they recur even after the crop is established. A benefit is the production obtained from the first as plantain can produce bunches in the first year of establishment and up into the other subsequent years. The produced bunches and suckers were valued according to the prevailing market prices to get the current money value per production. The projections of costs and benefits assumed in this study were associated with the production per ha over a 2-year period of the plantain in the rubber-plantain intercropping system. The costs and benefits were discounted using the 25% interest rate. The net present value, cost–benefit ratio, and the internal rate of return were computed on per hectare basis.

Sensitivity Analysis

According to Latunde et al., (2018), a sensitivity analysis is a form of measurable analysis that studies how net present values, total cost, or other results vary as individual expectations are changed. This analysis mostly determines how sensitive the financial decision-making criteria such as benefit cost ratio, net present value and internal rate of return are to vary in selected costs and benefits. It helps to test, what happens to a parameter when altered to give a picture of the possible variation when a given risky variable is wrongly estimated. For rubber-plantain intercropping system, the project can be variable in prices of plantain, labour and borrowing rate.

RESULTS AND DISCUSSION

Results on Yield Trends of Plantain

Yield levels of plantains are affected by several factors. They nurture best in bunches due to the protection they offer to each other from the harsh rays of the sun. Maintaining the favorable humidity for the plantain plantation is very essential. It is therefore essential to enhance an environment where the plantain plants are sheltered either because they are bunched up together or there are other trees to protect them. It is therefore more important to maintain the humidity of the plantain plantation. Tables 1 and 2 showed plantain bunch weight that ranges between 3983 to 11453 and 3287 to 11794 kilograms per ha for trials 1 and 2 respectively. The bunch weight increased as the number of plantain trees in the rubber and plantain intercropping system increased for the study. The study confirmed a study by Athani et al. (2009), who indicated that closer spacing recorded maximum plant height and yield. In recent times, High Density Planting according to Sarrwy (2012) is one of the novel concepts and most effective measures to increase productivity per unit area without affecting the quality of the fruit. The results from the yield data also showed significant differences at 5% probability level between the various spacing among the rubber and plantain intercropping systems. Similar result was reported by Odeke *et al*., (1999) who explained that a bunch weight, cluster and finger size were directly affected by plant spacing over time. Also, there is minimal competition between plants within the ideal planting density. This could be achieved by lessening reciprocated shading and overlapping of root zones. Plantain cultivation within rubber-plantain intercropping system at high density spacing such as three (PPPR) rows of plantain to two rows of rubber gave very high yield and profit.

Results on cost benefits analysis

The benefits and cost analysis explaining the cost benefits of the rubber and plantain intercropping system for five treatments have been analyzed under this section. The empirical results on the benefit and cost analysis for sole rubber crop (R), sole plantain crop (P)

Table 1. Yield and yield components of plantain at harvest under various treatments at study site 1.

Treatments	Number of hands per bunch	Number of fingers per hand	Number of suckers per plant	Bunch weight/ha
P	6	5	4	9972
PR P	6	5	3	3983
PPR P	7	5	4	7036
PPPR P	7	5	4	11453
SED (5 %)	1	NS	NS	1717.60
CV (%)	5.30	7.50	18.90	10.60

Table 2. Yield and yield components of plantain at harvest under various treatments at study site 2.

Treatments	Number of hands per bunch	Number of fingers per hand	Number of suckers per plant	Bunch weight/ha (kg)
P	5	5	5	9765
PR P	5	4	5	3287
PPR P	6	5	5	7851
PPPR P	6	5	6	11794
SED (5 %)	NS	NS	NS	426.40
CV (%)	10.20	18.90	11.20	6.40

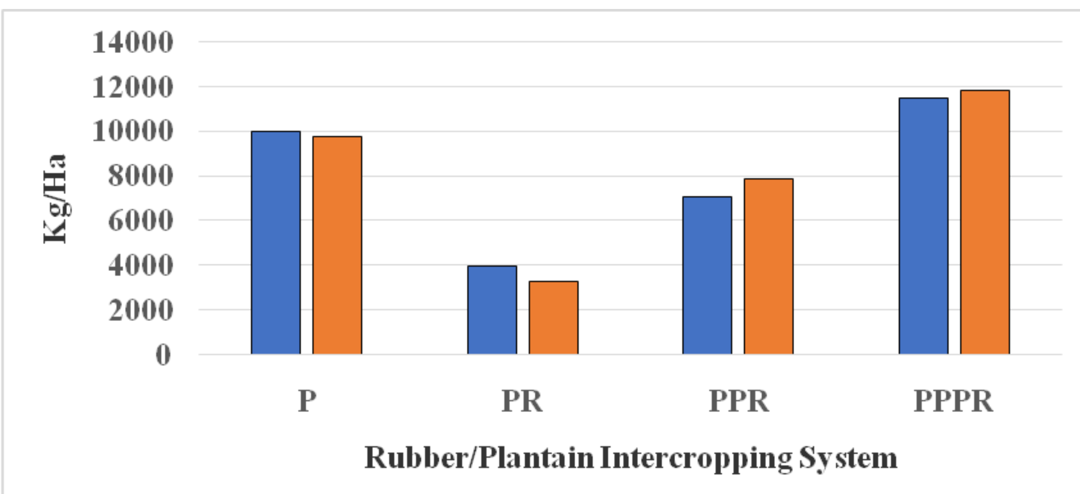

Figure 1. Bunch weight of plantain under different spacing for rubber and plantain intercropping system.

and three intercropping treatments consisting of an additive series of one (PR), two (PPR) and three (PPPR) rows of plantain to two rows of rubber for field 1 and field 2 are presented in Table 3 and 4 respectively. The initial costs at the beginning of production under each treatment were relatively high. The early years of production recorded the highest cost in the land clearing, planting materials, holing, and initial management.

The costs increased as the number of intercrops per unit area increased. The benefit component of rubber and plantain intercropping system was realized from the plantain sales. The three (PPPR) rows of plantain to two

Table 3. Summary of 2 years' cash flow for the rubber and plantain intercropping system for first trial.

ACTIVITIES				
Revenue (GHC/Ha)	**Sole plantain**	**PR**	**PPR**	**PPPR**
Plantain bunches	21190	8463.75	14951.25	38940
Plantain suckers	8330	2081.25	5555	8330
Total Revenue	**29520**	**10545**	**20506.25**	**47270**
Cost				
Field Clearing	300	300	300	300
Trees felling	500	500	500	500
Crosscutting	300	300	300	300
Burning	100	100	100	100
Lining and pegging	195	141	221	293
Cost of pegs	83	28	56	83
Holing	500	334	500	667
Planting material cost	834	1555	1833	2111
Planting	117	91	130	176
1st weeding	450	450	450	450
2nd weeding	400	400	400	400
3rd weeding	100	200	100	100
4th weeding	200	200	100	100
Harvesting	699.8	366.5	533.3	699.8
Carrying: farm-mkt	583.2	361	472.2	583.2
Farm implement (Cutlass)	20	20	20	20
Fertilizer cost	618	398	533	667
Fertilizer application cost	42	28	42	56
Total Cost	**6042**	**5772.5**	**6590.5**	**7606**

rows of rubber gave the highest revenue of GHȻ40,331 (USD 9,379) per hectare from the plantain in the rubber and plantain intercropping system. Relatively, the treatments with one (PR), two (PPR) and three (PPPR) rows of plantain to one row of rubber lasted for about 2 years. After the 2 years, the initiation for canopy formation began thus the rubber began outgrowing the plantain. The three (PPPR) rows of plantain to two rows of rubber recorded the highest cost of GH¢ 6903 (USD 1,605) per hectare whilst the lowest cost of GH¢ 5,420 (USD 1260) per hectare was recorded under the sole plantain. Although the three (PPPR) rows of plantain to two rows of rubber had the highest cost of the intercropping system, the cost was directly proportional to the revenue accrued from the plantain. The results on benefit and cost cash flow has been presented in Table 5 and Table 6. The different plot of experiments generally showed that one (PR), two (PPR) and three (PPPR) rows of plantain to two rows of rubber were profitable.

The results of cost benefit analysis in respect to the different intercropping systems has been presented in Tables 5 and 6. The results from this analysis showed that after discounting all benefits and costs at a rate of 25%, all the systems showed positive Net Present Value, which means that in all spacing dynamisms the costs can be recovered. Cost Benefit Ratio was above one for all the intercropping systems and this is an indication that investing in all the systems, all costs will be recovered at the end of assumed economic life of the plantain. However, the internal rate of return observed was above the cost of borrowing capital estimate of 25 %. From the table 5 and 6, it can be seen that the three rows of plantain to two rows of rubber (PPPR) is the most profitable rubber and plantain intercropping system with BCR of 5.8, NPV of GH¢ 28485 (USD 6624.42) per hectare and IRR of more than 96%. The one row of plantain to one row of rubber (PR) is the least profitable for both study 1 and 2 with BCR of 1.80, 1.69 and NPV of GH¢ 3616 (USD 325) and GH¢2843 per hectare respectively. The results on internal rate of return (IRR) further indicated that the existing rubber and plantain intercropping system will not be a viable venture if the rate of borrowing money exceeds 100% for the different planting rows. From these results on decision criterion selected, the cost benefit analysis indicates that all the rubber intercropping systems are worth undertaking.

Table 4. Summary of 2 years' cash flow for rubber and plantain intercropping system second trial.

ACTIVITIES				
Revenue (GHC/Ha)	**Sole plantain**	**PR**	**PPR**	**PPPR**
Plantain bunches	20750	6985	16825	25062.25
Plantain suckers	8331.25	2081.25	5555	8331.25
Total Revenue	**29081.25**	**9066.25**	**22380**	**33393.5**
Cost (GHC/Ha)				
Field Clearing	300	300	300	300
Trees felling	500	500	500	500
Crosscutting	300	300	300	300
Burning	100	100	100	100
Lining and pegging	195	141	221	293
Cost of pegs	83	28	56	83
Holing	500	334	500	667
Planting material cost	834	1555	1833	2111
Planting	317	291	330	376
1st weeding	450	450	450	450
2nd weeding	200	200	200	200
-3rd weeding	100	200	100	100
4th weeding	200	200		
Harvesting	450	450	450	450
Carrying: farm-mkt	250	250	250	250
Farm implement (Cutlass)	870	870	870	870
Total Cost	**5649**	**6169**	**6460**	**7050**

Table 5. Cost benefit estimates for rubber/plantain intercropping system with discount rate 25 % plot 1.

Measure of project worth	**Sole Plantain**	**Rubber + plantain PR**	**Rubber+ Plantain PPR**	**Rubber+ Plantain PPPR**
NPV	17973.76	3616.56	10612.4	28485.44
BCR	4.83	1.80	3.0	5.8
IRR	69	57	66	84

Table 6. Cost benefit estimates for rubber/plantain intercropping system with discount rate 25 % for plot 2.

Measure of project worth	**Sole Plantain**	**Rubber + plantain PR**	**Rubber+ Plantain PPR**	**Rubber+ Plantain PPPR**
NPV	18631.2	2843.68	12835.84	20822.24
BCR	6.03	1.69	3.95	5.32
IRR	70	52	67	79

However, to make a choice among the various systems, the criterion was to select the higher value for the calculated discounting measures which is higher in rubber and plantain intercropping system at the selected discount rate for productive life of the plantain.

Table 7. Sensitivity of the Cost Benefits Analysis of Rubber/Plantain Intercropping System for Ellembelle site.

Sensitive Variables Measured	Sole plantain	PR	PPR	PPPR
Increase in opportunity cost to 45%				
NPV	15683.45	2378.15	10789.	17506.69
BCR	6.01	1.68	3.93	5.27
IRR	62	51	65	70
Increase in plantain price by 10%				
NPV	19601.15	4266.57	11760.66	31289.12
BCR	5.17	1.95	3.28	6.26
IRR	71	58	67	85
Fall in plantain price by 10%				
NPV	15110.01	3021.9	8901.2	23012.65
BCR	4.79	1.80	3.04	5.54
IRR	60	53	62	72
Increase in total production cost by 30%				
NPV	16564.48	2271.96	9071.48	26700.8
BCR	3.71	1.39	2.35	4.45
IRR	62	49	63	75
Fall in total production cost by 30%				
NPV	19383.04	4961.16	12153.32	30270.08
BCR	6.70	2.58	4.38	8.27
IRR	71	59	66	83

Table 8. Sensitivity of the Cost Benefits Analysis of Rubber/Plantain Intercropping System for Jomoro site.

Sensitive Variables Measured	Sole plantain	PR	PPR	PPPR
Increase in opportunity cost to 45%				
NPV	15804.73	2499.43	10910.72	17627.94
BCR	6.26	1.74	4.06	5.44
IRR	63	52	65	69
Increase in plantain price by 10%				
NPV	20224.8	3380.128	14128	22747.02
BCR	6.46	1.82	4.24	5.72
IRR	72	56	65	82
Fall in plantain price by 10%				
NPV	17037.6	2307.23	11543.68	18897.46
BCR	5.60	1.56	3.65	4.92
IRR	62	50	60	70
Increase in total production cost by 30%				
NPV	17520.24	1607.92	11530.24	19375.04
BCR	4.64	1.30	3.03	4.09
IRR	63	45	63	71
Fall in total production cost by 30%				
NPV	19742.16	4079.44	14141.44	22269.44
BCR	8.62	2.41	5.64	7.59
IRR	69	57	67	72

Sensitivity Analysis

Tables 7 and 8 showed the cost and output variables that were varied to see the sensitive nature of the profitability indicators. The price at farm gate of GH¢ 1.70 per kilogram of plantain was increased by 10 percent to GH¢ 1.87 per kilogram and was also reduced by 10 percent from GH¢ 1.70 to GH¢ 1.53 to determine how the viability indicators will vary as a result of change in the plantain prices. Under this condition all the rubber and plantain intercropping systems were still profitable although it was quite sensitive to this variation in plantain prices. For the rise in the plantain price by 10 percent, the IRR values raised proportionately across all the rubber and plantain intercropping systems between 2 and 5 percent. The PPPR system had the highest NPV of GH¢31289 and GH¢22747, BCR of 6.26 and 5.72 for both field 1 and 2 respectively followed by the PPR and PR in that order. A fall in the plantain price by 10 percent saw a fall in the IRR by 1 to 2 percent. Observations were made for the one (PR), two (PPR) and three (PPPR) rows of plantain to two rows of rubber if opportunity cost of capital is raised up by 45%, increase and fall of total costs to about 30% and when prices of plantain produce is increased or reduced by 10%.

CONCLUSION AND RECOMMENDATION

This research examined yield trends and cost benefit analysis of rubber agroforestry system using experimental data which comprised five treatments namely: sole rubber crop (R), sole plantain crop (P) and three intercropping treatments consisting of an additive series of one (PR), two (PPR) and three (PPPR) rows of plantain to one row of rubber in the Western region of Ghana. The planting distance mostly used for rubber agroforestry system differs throughout Ghana and also in other rubber producing countries. From the study it was concluded that cultivation of plantain in three (PPPR) rows of plantain to two rubber rows is the best planting distances to obtain the highest yield. With the help of various investment appraisal methods and sensitivity analysis, the profitability of the rubber and plantain intercropping systems were estimated. The empirical results indicate that rubber and plantain intercropping systems are profitable at 25 % interest rate within 2 years of economic life of plantain within the rubber and plantain intercropping system. Empirical evidence further showed that the three (PPPR) rows of plantain to two rows of rubber is more profitable than intercropping treatments of one (PR) and two (PPR) rows of plantain to two rubber rows. Results through sensitivity analysis on the profitability of the rubber and plantain intercropping systems revealed that varying the opportunity cost of capital by 45%, the price of plantain by 10%, and the total production cost by 30%, profitability was realized from all the rubber and plantain intercropping systems.

The growing demand for rubber worldwide and as a result of new planting of rubber trees, there is the need to intensify policy effort towards introducing simple but profitable innovations that provide economic benefits to rubber farmers and that are also more food securing. Encouraging the three (PPPR) rows of plantain to two rubber rows, as the results have shown, would be the right policy instrument for ensuring the welfare of smallholder rubber farmers and promoting environmental sustainability. To reach this policy goals, training programs and relevant extension services must be put in place especially by the Tree Crops Development Authority (TCDA) of Ghana to educate rubber farmers on the three (PPPR) rows of plantain to two rubber rows in rubber plantation establishments as a necessary intensification strategy.

REFERENCES

Athani, S.I., Revanappa R. and Dharmatti P. R. (2009). Effect of plant density on growth and yield in banana. Karnataka. Journal of Agricultural Science 22: 143-146.

Bissonnette, J. F., and De Koninck, R., (2015). Large plantations versus smallholdings in Southeast Asia: historical and contemporary trends. Paper presented at the Conference on Land Grabbing, Conflict and Agrarian-Environmental Transformations: Perspective from East and Southeast Asia: Chieng Mai.

Department for International Development, DFID (2014). Rubber/banana intercropping. Published on TECA (http://teca.fao.org).

Dongling, Q., Zhou, J., Xie, G., and Zhixiang, W., (2015). Optimizing Tapping-Tree Density of Rubber (Hevea brasiliensis) Plantations in South China. Small-scale Forestry. 14. 1-12.

Fox J., and Castella J.C., (2013). Expansion of rubber (Hevea brasiliensis) in Mainland Southeast Asia: What are the prospects for smallholders? Journal of Peasant Studies 40(1), 155-170.

Ghana districts (2013). Ellembelle Western Region accessed from www.ghanadistricts.gov.gh/districts on 02/11/2013.

Ghana Statistical Service (2013), 2010 PHC: National Analytical Report, Accra.

Gittinger, J. P. (2001). Economic Analysis of Agricultural Projects. The John Hopkins University Press, London. 200pp.

Henisz J. W. (2016). The Costs and Benefits of Calculating the Net Present Value of Corporate Diplomacy. Field Actions Science Reports. Special Issue 14 2016: Environmental and social acceptability of major industrial projects: from risk management to shared prosperity.

IRSG (2017). Statistical Summary of World Rubber Situation (Singapore: International Rubber Study Group) (www.rubberstudy.com/statistics)

Jenkins, G.P., Kuo, C.Y., Harberger, A.C., (2011). Chapter 2: A Strategy for the Appraisal of Investment Projects, Cost–Benefit Analysis for Investment Decisions. JDI Development Paper Series, Queen's University, DDP 2011-02.

Joshi, L. (2005). Improving the Productivity of Rubber Smallholdings through Rubber Agroforestry Systems: a project supported by the Common Fund for Commodities. 8 p. In: Appraisal meeting on "Improving the Productivity of Rubber Smalholdings through Rubber Agroforestry Systems", September 5.-8.2005,

Hat Yai. Scientific report.
Juhász, L., (2011). Net Present Value Versus Internal Rate of Return, Economics and Sociology, Vol. 4, No 1, 2011, pp. 46-53.
Kumar, C., Saint-Laurent, C., Begeladze, S. and Calmon, M. (eds.). (2015). Enhancing food security through forest landscape restoration: Lessons from Burkina Faso, Brazil, Guatemala, Viet Nam, Ghana, Ethiopia and Philippines. Gland, Switzerland: IUCN. pp. 5-217.
Langenberger, G., Cadisch, G., Martin, K., Min, S., & Waibel, H. (2016). Rubber intercropping: a viable concept for the 21st century? Agroforestry Systems, 91(3), 577–596.
Latunde, T., and Bamigbola, O. M. (2018). Parameter Estimation and Sensitivity Analysis of an Optimal Control Model for Capital Asset Management. Advances in Fuzzy Systems, 2018, 1–11.
Malezieux E., Crozat Y., Dupraz C., Laurans M., Makowski D., Ozier-Lafontaine H., Rapidel B., Tourdonnet S. de 5, Valantin-Morison M. (2009). Mixing plant species in cropping systems: concepts, tools and models. A review. Agronomy and Sustainable Development 29 (2009) 43–62.
Matata P. Z., Ajayil, O.C. Oduol P.A. and Agumya A. (2008). Socio-economic factors influencing adoption of improved fallow practices among smallholder farmers in western Tanzania International NGO Journal Vol. 3 (4), pp. 068-073.
Mercer D.E and Miller R.P (1997). Socioeconomic research in agroforestry: progress, prospects, priorities Agroforestry Systems, 38, pp. 177-193
Odeke, M., Rubaihayo, P. R. and Osiru D. S. O, (1999). Effect of spacing, stage and method of desuckering on bunch size and yield of banana cultivar Kibuzi (AAA-EA). African Crop Science Journal 7: 349-353.
Rodrigo, V.H.L, Stirling, C.M, Naranpanawa, R.M.A.K.B and Herath, P.H.M.U (2001). Intercropping of immature rubber; present status in Sri Lanka and financial analysis of rubber intercrops planted with three densities of banana. Agroforestry Systems 51, 35-48.
Rubber Statistical Bulletin (2000). International Rubber Study Group, London. 54 (9), Wembley, UK.
Sankalpa, J.K.S., Wijesuriya, W. and Ishani, P.G.N. (2020). Do rubber-based agroforestry practices build resilience upon poverty incidence? A case study from Moneragala district in Sri Lanka. Agroforest Syst (2020).
Sarrwy, S.M.A., Mostafa E.A.M., and Hassan H.S.A., (2012). Growth, Yield and Fruit Quality of Williams Banana as Affected by Different Planting Distances. International Journal of Agricultural Research, 7: 266-275.
Senkondo, E. M. M, Msangi, A. S. K., Xavery, P., Lazaro, E. A. and Hatibu, N. (2000). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-arid Areas of Tanzania. SUA, Morogoro, Tanzania. 10pp.
Stirling, C M, Rodrigo, V H L, Janowski, M and Gray, A (2000). High density banana/rubber intercrops: Productivity, Livelihood/Stakeholder and Market Analysis. Final Technical Report, Department For International Development Plant Science Programme, UK, pp 41.
Stroesser, L., Penot E., Isabelle M., Tongkaemkaew U., and Chambon B., (2016). Income diversification for rubber farmers through agroforestry practices: How to overcome rubber price volatility in Phatthalung province, Thailand. CRRI and IRRDB International Rubber Conference 2016, Siem Reap, Cambodia.
Tetteh E.N., Abunyewa A.A., Tuffour H.O., Berchie J.N., Acheampong P.P., Twum-Ampofo K., Dawoe E., Logah V., Agbenyega O., Ennin S.A., Nunoo I., Melenya C., Danquah E.O., Barnes V.R., Partey S.T., (2019). Rubber and plantain intercropping: effects of different planting densities on soil characteristics. PLoS One. 2019;14:e0209260.
Verheye, W. (2010). Growth and Production of Rubber. In: Verheye, W. (ed.), Land Use, Land Cover and Soil Sciences. Encyclopedia of Life Support Systems (EOLSS), UNESCO-EOLSS Publishers, Oxford, UK. http://www.eolss.net
Vernooy R. (2015). Effective implementation of crop diversification strategies for Cambodia, Lao PDR and Vietnam: Insights from past experiences and ideas for new research. Bioversity International, Rome, Italy. ISBN: 978-92-9255-011-0.