Economic evaluation of cocoyam (*Xanthosoma* sp.) and maize (*Zea mays*) in a mixed cropping system

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ABSTRACT

Cocoyam (*Xanthosoma* sp.) and maize (*Zea mays*) are major food crops often grown in association. On-farm testing at Sunyani, Sankore and Begoro in the forest ecology of Ghana evaluated the agronomic performance and economic productivity of both crops grown as mixed crops and sole crop. The cropping system had a significant effect on the yields of the component crops. Maize yields were reduced by 10 per cent for double-row maize between single rows of cocoyam, and by 26 per cent for double-row cocoyam between single rows of maize in the intercrop systems. Cocoyam yields were reduced by 70 to 75 per cent. The cost-benefit analysis had gross farm gate benefits of 7.6 million cedis per hectare ($894 ha^{-1}) for sole maize production, and 20.9 million cedis per hectare ($2459 ha^{-1}) for sole cocoyam production. All farm enterprises tested on farmers' fields were viable and profitable, giving cost-benefit ratios of more than one. The results further showed that marginal rate of returns (MRR) for changing from sole maize to sole cocoyam, double rows of cocoyam between single rows of maize, and double rows of maize between single rows of cocoyam are 1279 , 348 and 146 per cent, respectively. These are all greater than the acceptable minimum rate of returns (AMRR), which range from 40 to 130 per cent at the various locations. Residuals and cost-benefit ratios also follow similar trend. From the analysis, the best farm enterprise would have been sole cocoyam, but for some socio-economic reasons and efficient land use, double rows of cocoyam between single rows of maize is the recommended intercrop system within the limits of the experiment.

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RÉSUMÉ

SAGOE, R., HALEEGOAH, J. & MARFO, K. A.: *Évaluation économique de taro* (Xanthosoma *sp.*) *et de maïs* (Zea mays) *dans un système de cultures associées en mélange.* Le taro (*Xanthosoma* sp.) et le maïs *(Zea mays)* sont les cultures vivrières principales souvent cultivées en association. Les essais sur le champ étaient entrepris à Sunyani, Sankore et Begoro dans l' écologie de forêt du Ghana, pour évaluer le rendement agronomique et la productivité économique de deux cultures cultivées comme cultures associées en mélange et la culture seule. Le système de culture avait un effet considérable sur les rendements de cultures constituantes. Les rendements de maïs étaient réduits par 10% pour double lignes de maïs entre les seules lignes de taro et par 26% pour double lignes de taro entre les seules lignes de maïs dans le système de culture associée. Les rendements de taro étaient réduits par 70 à 75%. L' analyse coûts-bénéfices dégageait à la production des bénéfices bruts de 7.6 million cedis par hectare ($894 ha^{-1}) pour la production de maïs seul et 20 .9 million cedis par hectare ($2459 ha^{-1}) pour la production de taro seul . Tous les entreprises agricoles mises à l' essais sur les champs d'agriculteurs étaient viables et rentables dégageant les proportions coûts-bénéfices de plus d'une. Les résultats montraient davantage que les taux de rendement faible (TRF) pour le changement de maïs seul au taro seul, double lignes de taro entre les seules lignes de maïs et double lignes de maïs entre les seules lignes de taro sont respectivement 1279, 348 et 146% . Ce sont plus élevés que les taux de rendement minimum acceptables, qui varient de 40 à 130% aux différents emplacements. Les reliquats et les proportions coûts-bénéfices aussi suivaient la tendance semblable. D' après l'analyse la meilleure entreprise agricole devrait être le taro seul mais pour quelques raisons socio-économiques comprenants utilisation ou la vente de la culture associée pour améliorer leur revenus. L' efficacité d'utilisation de terre, double lignes de taro entre les seules lignes de maïs sont les systèmes de culture associée recommandés dans les limites de l' expérience.

Introduction

Cocoyam (*Xanthosoma* sp.) is an important cash and food crop in Ghana especially in the forest areas of the country. It forms an integral part of most cropping systems practised in the forest and southern parts of the transitional zones of Ghana (Sagoe, Marfo & Dankyi, 1998). It is available in reasonable quantities throughout the year, ensuring regular income and food for the resource-poor farmer.

Population growth and expansion of cash cropping has resulted in land shortages for root crops such as cocoyam and, subsequently, yield declines commonly associated with the prolonged cropping period as a result of reduced fallow periods (Rangai, 1982). Clark & Myers (1994) confirmed the use of multiple cropping as an effective use of resources to increase productivity. In areas where maize production is very popular in Ghana, most maize fields are intercropped with cocoyam. This system has been found to be very productive, and its productivity can be enhanced through proper management practices (Ennin, Asafu-Agyei & Dapaah, 1999; Crookston & Hill, 1979).

The crop's growth under intercropping is normally affected, but adding soil amendments significantly improves its performance and, subsequently, yield. The gross returns per unit area of land are usually higher than in sole cropping (Crookston & Hill, 1979). This system offers farmers insurance against crop failures, checks erosions, weeds and insects, and ensures a more even distribution of labour. The food security of these farmers will, therefore, depend on their ability to develop more intensive cropping practices that do not degrade the fertility status of the soils as suggested by Midmore (1993). Lynam, Sanders & Mason (1987) observed a significant interaction between location and cropping system, indicating a better performance for some systems in certain agro-ecologies. Factors that determine profitability are, therefore, specific to site, time and input level; hence, the need to assess the profitability on farmers' fields. Based on these, the cropping systems were established on farmers' fields for verification and as demonstrations.

Farmers, according to Adesina & Zinnah (1993), consider many factors before changing from one production to the other. These include agro-ecological requirements, availability of required production resources, additional costs and income, compatibility of the new technology with sociocultural circumstances, goals, and the whole farming system (Negatu & Parikh, 1999). Farmers would also want to know the implication of the proposed technological changes on cost and income.

This paper, therefore, discusses the economic feasibility of the various cropping systems under farmers' conditions.

Materials amd methods

On-farm testing

Different sites on farmers' fields in the forest zones of Ghana were used for the study from 2000 to 2002. The protocol for on-farm testing, comprising four cropping systems and three fertilizer rates, was designed as an incomplete block with a farmer representing a block. Twelve to 16 farmers were identified per location, with each farmer establishing three cropping systems (2 sole crop + 1 intercrop) and any two of the fertilizer rates (farmer's practice inclusive).

The cropping system treatments applied on a main plot size of 10 m × 10 m were as follows:

1. Double rows of maize between single rows of cocoyam (CMMCMMC); spaced 50 cm (inter row) × 100 cm (intra row for cocoyam) and 40 cm (intra row for maize).
2. Double rows of cocoyam between single rows of maize (MCCMCCM); spaced 50 cm (inter row) × 100 cm (intra row for cocoyam) and 40 cm (intra row for maize).
3. Sole maize (MZ) spaced 80 cm × 40 cm (2 plants /hill).
4. Sole cocoyam (CY) spaced 100 cm × 100 cm.

The fertilizer was applied at a rate of 5 t ha^{-1} of poultry manure, or 5 t ha^{-1} of poultry manure plus 30 kg P ha^{-1} on sub plot 1 to 2 weeks after planting. The locations were Sankore, Sunyani and Begoro districts, all within the forest ecology of Ghana.

Farmers had the option to use any improved maize variety, Obaatanpa or Dorke, and any of the known planting materials, seedlings or corms, for establishing cocoyam. These options were on location basis, and it created some plasticity within the cropping systems being tested as suggested by Abalu (1976). Records were kept on all field operations, and yield and yield prices of both crops were assessed.

Partial budget analysis

A cost-benefit questionnaire was administered to the farmers involved in the project. These included questions on the number of persons by source (household or hired), gender, and age. The number of hours each person spent on the farm and by farm operation was assessed. They were also asked questions on the types and quantities of various farm inputs used.

Yield was estimated by sample plot size. Data were collected on variable inputs. These were labour for field preparation, planting, carting and applying manure, weeding and harvesting, as well as cost of fertilizers used and planting materials. Types of labour used were household, hired, and contract labour. Data were then analysed using the computer software, Microsoft Excel. A partial budget was prepared from an outline described by Alimi & Manyong (2000).

Results and discussion

Agronomic analysis

Yields from farmers' fields were different, resulting in highly significant (P<0.0001) maize and cocoyam yields within the cropping system and fertilizer treatments (Table 1). This could be explained by the variability in soil types and nutrient status. Intercropping maize with cocoyam reduced maize yields from 10 per cent (MCCMCCM) to 26 per cent (CMMCMMC). The maize also significantly reduced tuber number and size and, subsequently, cormel yield by 70 to 75 per cent because of competition for nutrient, light, and moisture as observed by Awah & Mboussi (1999) when they studied the performance of cassava and other tuber crops. Population densities of the various crops within the system were reduced and this could have lowered the number of tubers per unit area. This is in contrast to the findings of Mclntyre *et al.* (2001) who observed no significant difference in banana fruit production associated with legume intercrop and, therefore, suggested an efficient land use by incorporating food legumes into such cropping systems. Land equivalent ratio, which represents the increase in biological efficiency recorded by growing the two crops together, was more than 1, indicating a productive system (Ennin *et al*., 1999). Values for crop performance ratio (CPR) were 2.2 and 2.5 for CMMCMMC and MCCMCCM, respectively.

TABLE 1

Average Effect of Treatments on Cocoyam Cormel Yield and Maize Grain Yield

Treatment	*Cocoyam cormel yield (kg ha^{-1})*	*Maize grain yield (kg ha^{-1})*
Location (L)		
Sankore	5456.3	3162.5
Sunyani	3045.7	3938.3
Begoro	6585.8	2804.0
Cropping system (CS)		
MCCM	2592.5(75%)	2763.3(26%)
CMMC	3695.4(70%)	3348.8(10%)
Sole maize	-	3792.7
Sole cocoyam	8799.8	-
SE	3421.7	1365
Prob. L	<0.01*	<0.05*
CS	<0.0001*	NS

NS – not significant; * – significant at the probability indicated

Economic analysis

To compare the economic benefits of the cropping systems tested on farmers' fields, a partial budget was used. This quantifies and compares the effects of the proposed technology and gives the farmer the option to invest in.

Resources for production and variable cost

The resources used to produce output included land, labour, capital, and management. Within a location, land was not a variable resource; so land was not cost during the partial budget analysis. However, cost of planting materials, labour, capital, and of management varied between the locations.

Cost of planting materials for the various crops were the same at all locations. But the total cost for establishing the mixed crop fields differed and were higher because of the differences in quantities used as a result of different spacings and spatial arrangements.

Farm labour cost per day varied between the locations. The number of persons per day per hectare for an activity varied within the location. Hired labour was cheaper in Begoro than in Sunyani and Sankore. These confirm the fact that labour is a critical input for cocoyam production in Ghana as observed by Sagoe *et al.* (1998).

Labour for planting varied within and between the locations, contributing about 6 to 10 per cent of the total variable input cost (TVIC). Percent contribution of labour and planting materials ranged between 15 and 20 per cent of the TVIC, the third highest contribution to TVIC. The highest percentage was on the mixed cropping system.

Differences in labour cost for fertilizer carting and application, weeding, and harvesting were observed among locations. The cost of weeding varied because of the differences in soil types, resulting in differences in the number of times one had to weed the field or farm. The frequency of weeding fields in Sankore and Sunyani were higher than in Begoro where farmers cropped on virgin forest or newly opened forest; therefore, their crops established faster and formed a canopy which prevented early re-growth of weeds.

Labour distribution for the various farm enterprises averaged over the three locations were similar or followed the same trend (Fig. 1). Labour requirement was higher at weeding and harvesting, using about 25 to 40 per cent of the total labour force for all the enterprises (Fig. 1). A similar situation was reported by Nweke,Ugwu & Asady (1991) on yam-based systems in Nigeria. Labour required for weeding the intercrop system (29-30%) was lower than that required for containing weeds under sole cocoyam crop (33%), but higher than that for sole maize crop (25%).

This could be explained by the fact that the frequency of weeding under sole maize enterprises was lesser because of the shorter maturity period of 4 months compared with 12 to 16 months maturity period for cocoyam. The fact that mixed cropping reduced the number of times one had to weed because of the close crop spacing is evinced by this study and others (Maina *et al*., 1996; Doku, 1988; Osiru & Willey, 1972).

The variable input cost was determined under four models or scenarios because of differences in labour cost and frequency of realising the various farm operations. The sum of these input costs gave the TVIC, which was consistently higher at Sunyani and lowest at Begoro because of the high labour cost per person. Table 2 shows the TVIC averaged over the locations. More money would be needed, according to the assessment, to produce maize and cocoyam together on the same piece of land.

Farm gate benefits

Table 3 shows the gross farm gate benefits, based on the average cocoyam cormel and maize grain yields over the three locations (Table 1). Gross farm gate benefit values of about 7.6 million cedis ($894) to 21 million cedis ($2459) per hectare were recorded for the various farm enterprises. Sole cocoyam had the highest gross farm gate benefit and sole maize had the least benefit.

Net benefit is the difference between the gross farm gate benefit and the TVIC, and it indicates the profitability of the enterprise. Net benefit values ranged between 4 and 20 million cedis

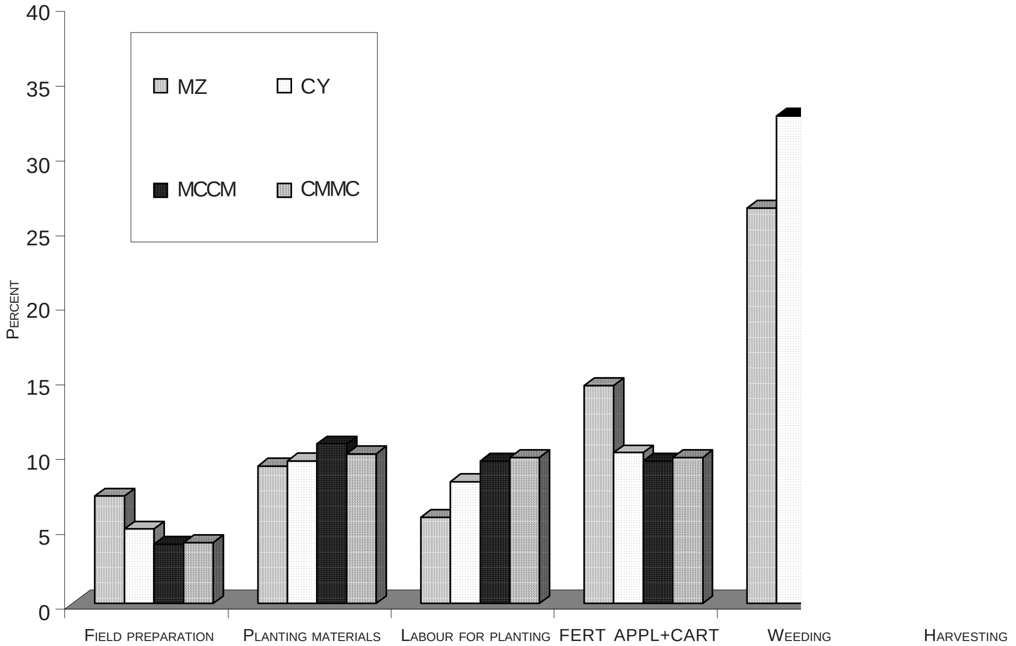

Fig. 1. Percentage distribution of labour on farmers' fields.

TABLE 2

Variable Cost as Affected By the Various Cropping Systems Averaged Over the Locations

Input	*Cropping system (cost in cedis per hectare)*			
	Sole maize	*Sole cocoyam*	*Intercrop (MCCMCCM)*	*Intercrop (CMMCMMC)*
Field preparation	156,250	156,250	156,250	156,250
Planting materials	200,000	300,000	420,000	385,000
Labour for planting	125,000	256,250	375,000	375,000
Labour for carting fertilizer/manure	183,500	183,500	183,500	183,500
Labour for fert. application	133,250	133,250	191,750	191,750
Labour for weeding	575,000	1,025,000	1,162,500	1,162,500
Harvesting	800,000	1,087,500	1,450,000	1,387,500
TVIC	2,173,000	3,141,750	3,939,000	3,841,500

within the locations and enterprises. Table 3 shows the averaged net benefits per enterprise tested. The highest benefit was on cropping sole cocoyam and the least was on sole maize.

Decision criteria and recommendation

To decide on which farm enterprise was more profitable, the cost-benefit ratio, marginal rate of return, and residual analysis were used. The cost-

TABLE 3

Partial Budget Averaged Over Locations of Various Farm Enterprises Tested on Farmers' Fields

	Maize (MZ)	*Cocoyam (CY)*	*MCCM*		*CMMC*	
			CY	*MZ*	*CY*	*MZ*
Average yield (kg ha^{-1})	3793	8800	3695	3349	2593	2763
Unit price per kg (¢)	2000	2380	2380	2000	2380	2000
Gross farm gate benefit (¢)	7,588,000	20,944,000	15,492,100		11,697,340	
Total variable input cost (TVIC) (¢)	2,173,000	3,141,750	3,939,000		3,841,500	
Net benefit (NB) (¢)	5,413,000	17,802,250	11,553,100		7,855,840	
Residuals (¢)	3,781,275	15,462,400	8,664,925		5,053,540	
Marginal rate of returns (%)	_	1279	348		146	

**$ is equivalent to ¢8,500

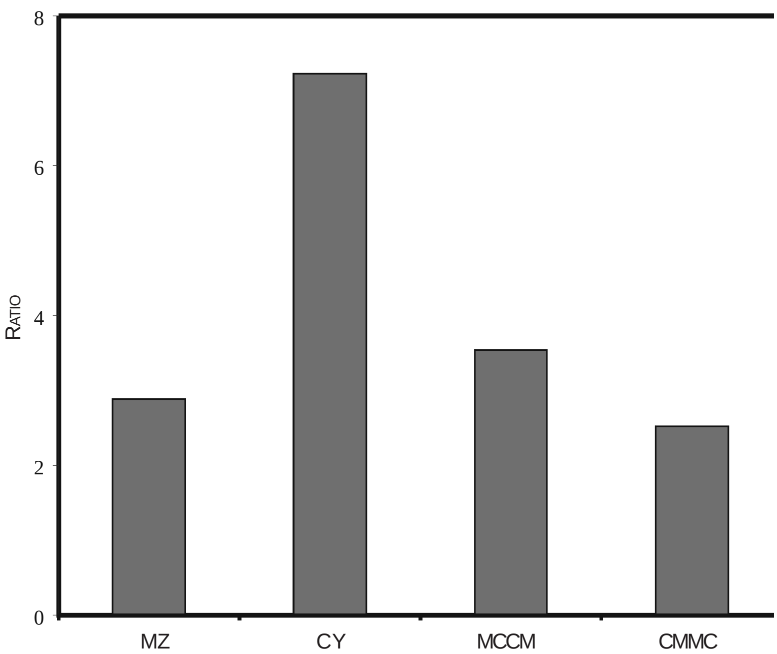

Fig. 2. Average cost-benefit ratio of the various farm enterprises.

by adding the cost of capital to the returns to management. This indicates the minimum return the farmer expects to earn from the enterprise. The cost of capital (Table 4) is normally the interest rate of the informal loan, and this ranged between 20 and 100 per cent per growing period. The growing period refers to one cocoa season, or from planting to harvesting of any crop. Therefore, the cost of capital did not vary between the cropping system or the type of crops being grown in the

benefit ratio indicates the outstanding success of the enterprise (Fig. 2). All the four farm enterprises tested had cost-benefit ratios of more than one. The highest of 6.5 was on sole cocoyam and the least were on sole maize (2.5) and the intercrop system – CMMCMMC (2).

Under the residual analysis, farmers' acceptable minimum rate of returns (AMRR) was determined

study area. The benefits farmers expect for managing the enterprises (returns to management) were the same within a location, and it was between 20 and 30 per cent (Table 4). The AMRR values were 40 per cent for Sunyani, 70 per cent for Begoro, and 130 per cent for Sankore. The acceptable minimum returns were determined by multiplying AMRR values by the TVIC; the

TABLE 4

Location Effect on Cost of Capital, Returns to Management, and Acceptable Minimum Rate of Returns

	Sunyani (%)	*Begoro (%)*	*Sankore (%)*
Cost of capital	20	50	100
Returns to management	20	20	30
Acceptable minimum rate of return (AMRR)	40	70	130

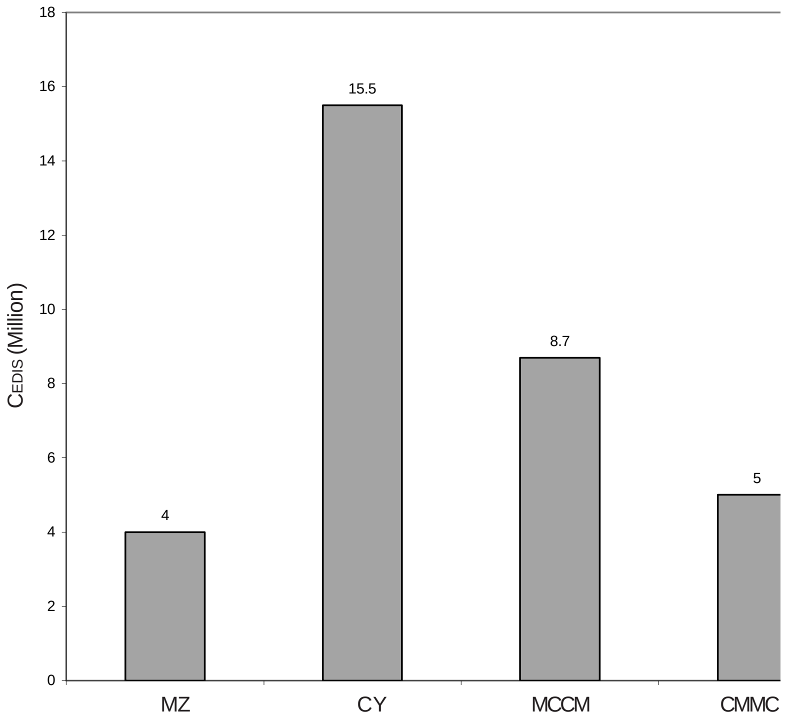

Fig. 3. Residual of farm enterprises.

difference between this value and the net benefit is referred to as the residual. Residual values (Fig. 3) ranged from 4 to about 17 million cedis, following the same trend as the cost-benefit ratio (Fig. 2).

The marginal rate of return (MRR) of changing from cropping sole maize to either sole cocoyam or any of the mixed cropping systems was higher than the AMRR (Table 3). This, therefore, makes cropping cocoyam as a sole crop or mixed with maize a lucrative farm enterprise in the experimental areas.

Between the two intercrop systems, using their residuals and MRR, double-row cocoyam between single rows of maize (MCCMCCM) is recommended because of its high residual and MRR values.

Conclusion

From the study, all farm enterprises evaluated were viable and profitable, giving cost-benefit values of more than one. The MRR for changing from sole maize to sole cocoyam or any of the intercrops was greater than the AMRR. Although sole cocoyam had the highest net benefit, cost-benefit ratio, MRR and residuals, farmers would prefer to go into mixed cropping for food security reasons and, specifically, to get some buffer income after 4 months of starting the farm enterprise. This is in line with the findings of Schulz *et al*. (2003) which emphasize the need for short-term economic returns for successful introduction and widespread adoption of improved technologies. Because cocoyam has been proven to be economically efficient in a perfect competitive system (Sagoe *et al*., 1998), thereby guaranteeing a relatively stable price, farmers would definitely include cocoyam in their maize fields. Growing only the two crops together needs further investigation.

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