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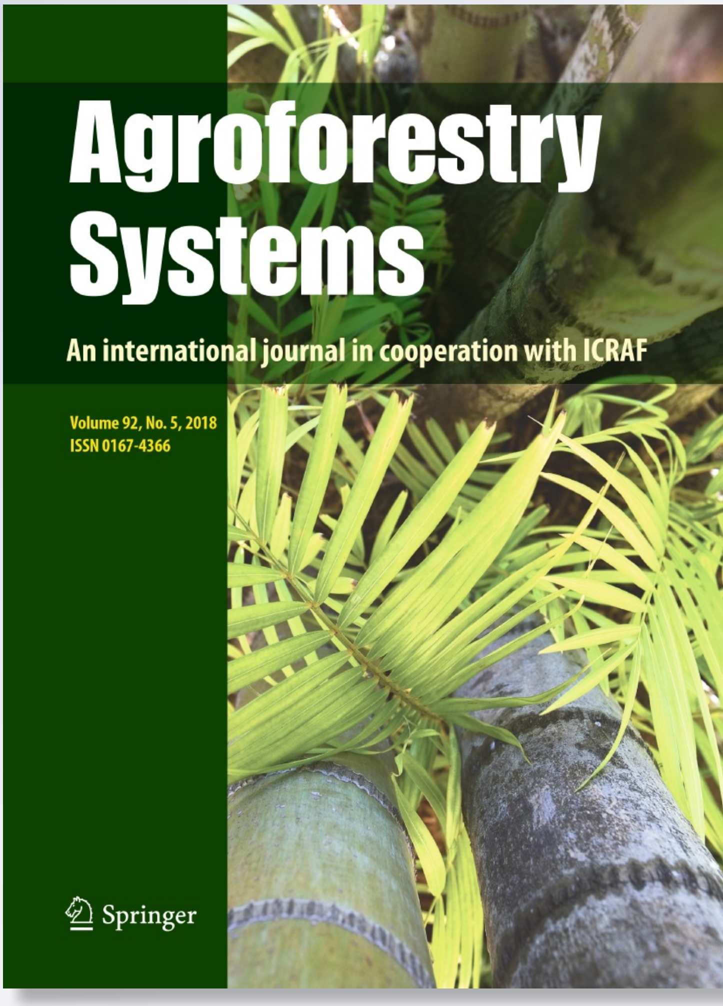

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Abstract To address the growing global demand for cocoa, sustainable intensification of its production in West Africa is considered crucial. This paper analyzes the determinants of cocoa productivity and profitability by smallholder farmers in Ghana to provide insights into challenges for future cocoa farming, which will guide the formulation and prioritization of tailored policies to address them. A four-stage sampling technique was used to select a total of 731 cocoa farmers from various districts in all six cocoa growing regions in Ghana. Selected farmers were interviewed using a semi-structured questionnaire. The results show that cocoa productivity and profitability was very low with an average of 234 kg ha^{-1} and Gh¢ 568 (ca. US$ 150) per ha, respectively. Farm management practices, namely control of capsid and black pod disease, fertilizer application and pruning, significantly ($p < 0.05$) influenced cocoa productivity. Capsid control and fertilizer application showed the highest impact on productivity. Farm size, however, had a negative impact, which implies that increase in farm size results in decreased smallholder cocoa productivity. Farmers should be encouraged to sustainably intensify farm management through controlling black pod disease and capsids, regular pruning and efficient application of fertilizer rather than focusing on excessive land expansion, which eventually hampers productivity and biodiversity.

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Keywords Cocoa · Ghana · Productivity · Smallholder farmers · Sustainable intensification

Introduction

Sustainable production of agricultural products is an important research subject as sustainable agriculture plays a crucial role in the provision of food, income, employment and raw materials for industry in both socially responsible and environmentally friendly ways (Dillon et al. 2016; Peprah 2015). One such agricultural product receiving a lot of attention in terms of sustainable development is cocoa. It forms the backbone of the economy of producing countries like Côte d'Ivoire, Ghana, Nigeria and Cameron (Afoakwa et al. 2011). In West and Central Africa, this crop generates over \$8 billion to the region's national economies (International Fertilizer Development Center [IFDC] 2014) and supports about two million smallholder farm households. With an estimated 1.45 million hectares of cocoa farms in Ghana (Anim-Kwapong and Frimpong 2008), cocoa farming employs approximately 800,000 families spread over six of the ten regions of the country (Ghana Cocoa Board [COCOBOD] 2015), with around 6.3 million Ghanaians ($\sim$30% of the total population) depending on cocoa for their livelihood (Gockowski et al. 2011). The steady growth and transformation of the chocolate confectionary market into a global industry with an annual value of \$80 billion (Goodyear 2014) is largely a consequence of the traditional cocoa production especially in West and Central Africa. Therefore, sustaining the production of high quality cocoa beans is crucial for the millions of smallholder family farmers depending on cocoa for their livelihoods and the millions of chocolate consumers.

Research by Euromonitor International reported that global chocolate demand hit a record high of 7.1 million tons in 2015, but at the same time cocoa production, according to the International Cocoa Organization (ICCO), dropped by 4% to 4.2 million tons (Wexler 2016). West Africa, which provides about 70% of the world's total cocoa production (Wessel and Quist-Wessel 2015), is confronted with a 2% annual decline in production (IDH Sustainable Trade Initiative 2015). Furthermore, West African cocoa productivity is substantially lower than other key producing countries. While the average cocoa yield in Malaysia is ca. 1800 and ca. 1000 kg ha^{-1} in Indonesia, it is ca. 800 kg ha^{-1} in Côte d'Ivoire and only ca. 400 kg ha^{-1} in Ghana (Laven and Boomsma 2012; Wessel and Quist-Wessel 2015). The consequence of this low cocoa productivity is the extremely reduced profit margins, which inhibits farmers' abilities to adopt more advanced farming practices including the use of fertilizers and pesticides (Hainmueller et al. 2011) thereby, forcing farmers to progressively convert forests into farmlands due to depletion of nutrients in cocoa farms and the use of unapproved chemicals to control insect pests. As such, low productivity not only affects cocoa farmers, whose annual household income (70–100% of total income) heavily depends on cocoa (Anang et al. 2013; Nunoo et al. 2014), but also has a devastating impact on the environment and biodiversity.

Reasons for the low productivity includes poor farm management practices, planting low-yielding varieties, aging cocoa trees and loss of soil fertility due to inadequate or no use of fertilizers (Wessel and Quist-Wessel 2015). Incidence of pests such as capsids and diseases like black pod and cocoa swollen shot virus disease (CSSVD) have been reported to affect productivity (Akrofi et al. 2015; Baah and Anchirinah 2011). Black pod disease is reported to cause mean annual pod losses of about 40% in Ghana and Côte d'Ivoire (N'Guessan 2013), while CSSVD could substantially reduce yield by about 70% (Ameyaw et al. 2014). Capsids are also reported to cause annual crop losses of about 25% in Ghana (Padi and Owusu 2003) and 30–40% in Côte d'Ivoire (N'Guessan 2013).

There is also the issue of temperature rise in the context of climate change which could have a negative impact on this heat sensitive crop as it inhibits the development of pods, thus, reducing yield (Gordon 2011). Climate change could also alter stages and rates of development of cocoa pests and pathogens, modify host resistance and result in changes in the physiology of host-pathogen/pests interaction (Anim-Kwapong and Frimpong 2008). The age of the cocoa tree is often considered a crucial factor of diminishing productivity. Given that yield rate increase has its peak at 18 years after planting (Binam et al. 2008), the consequence of too many over age trees is a drastic reduction of the potential yield of cocoa in many farms.

In the context of these challenges, research is needed to identify the most effective and sustainable ways to strengthen cocoa productivity, facilitate formulation of appropriate policies and incentive structures aimed at encouraging farmers to adopt integrated pests management, include multi-purpose trees along with cocoa trees (agroforestry), use of organic fertilizers or green manure such as intercropping with legumes. These practices may enhance productivity, improve livelihoods of farmers by increasing profitability as well as protect the environment, conserve biodiversity and ensure agro-ecological sustainability. Therefore, this paper analyzes the determinants of cocoa productivity and profitability in order to provide insights into challenges for future cocoa farming. This study focused on Ghana, the world's second largest cocoa producer after Côte d'Ivoire and a major exporter of high quality cocoa beans to the global market (Aithnard 2014; Boateng et al. 2014). With a potential yield of 1500–2000 kg ha^{-1} (Aneani and Ofori-Frimpong 2013), the current national average of 400 kg ha^{-1} is inadequate. Identifying key constraints may contribute to further close this yield gap.

Methodology

Sampling and data collection

The study was conducted from August to October 2014. A four-stage sampling technique was used to select a representative sample of cocoa farmers in Ghana (Table 1). All six cocoa growing regions in Ghana (Brong Ahafo, Western, Eastern, Ashanti, Central and Volta region) were considered at the first stage of sampling (region-level sampling). This allowed comparison of the regions as well as generalization of the country-wide results. At the second stage of sampling (district-level sampling), five cocoa growing districts were randomly selected from each region based on COCOBOD's categorization of cocoa growing areas (Fig. 1). Further, two communities were selected randomly from each district as the third stage of sampling (community-level sampling). The Central and Volta regions have only four and two cocoa growing districts, respectively. Thus, five communities were included from each of these two districts in the Volta region, while two communities were included from each of the four districts in the Central region. To summarize, a total of 731 cocoa farmers were randomly selected from the 58 communities in the 26 selected districts at the final stage of sampling.

Questionnaire

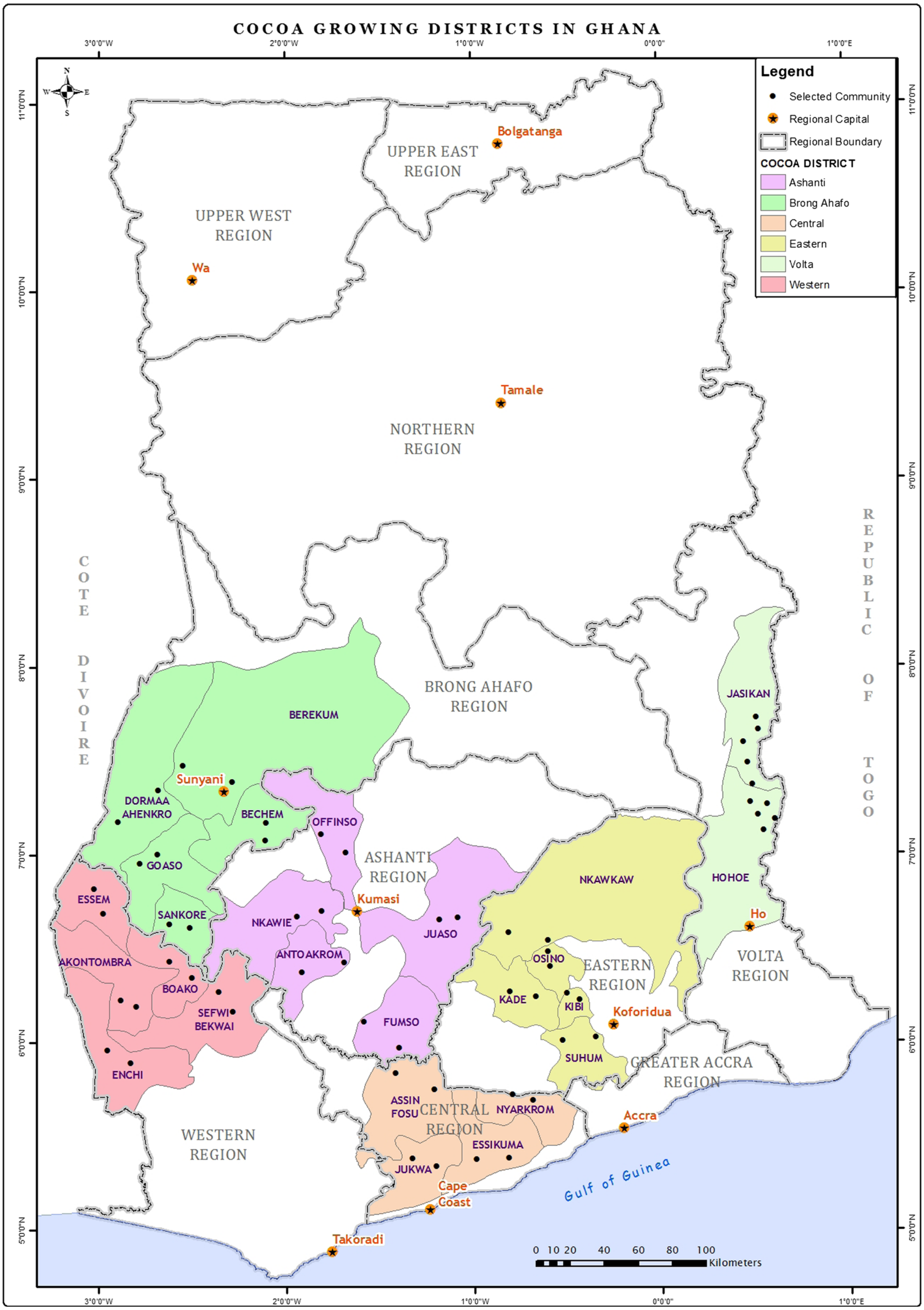
Face-to-face interviews were conducted with the selected farmers using a semi structured questionnaire covering six issues namely, demographic characteristics, farm characteristics, occurrence of pests and diseases, farm management practices, farm income and expenditure. Demographic characteristics of the farmers included their gender, age, educational level and number of years in cocoa cultivation (experience). Age of cocoa trees (in years), cocoa variety planted and size of cocoa farms (in hectares) constituted farm characteristics, while frequency of weed control, capsids control, black pod disease control, pruning and fertilizer application constituted farm management practices. Occurrence of major pests and diseases on the farms were enumerated. The amount of money made from selling dried fermented cocoa beans (i.e., a 64 kg bag of cocoa beans was Gh ¢212 or US$ 56.5 at the time of the survey) constituted the farm income, while the costs on the farm such as cost of labour, fertilizer, weedicides, pesticides and fungicides constituted the farm expenditure. Profitability was determined by comparing farm income with farm expenditure. The questionnaire was pre-tested with a group of 50 farmers (outside the selected districts), specifically to correct for difficulties in interpretation (question wording) and to provide order bias. Enumerators and supervisors were selected and trained on how to administer the questionnaires efficiently.

Data analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS), version 22.0. Descriptive statistics was done using cross tab to analyze the socio-economic characteristics of the farmers. Productivity (kg ha^{-1}) was calculated by dividing total quantity of dried fermented beans (kg) by total farm size (ha). Stepwise multiple regression was used to ascertain

Table 1 Multistage sampling procedure for selecting farmers for baseline survey

Sampling stage							Total
Region (non-random)	Brong Ahafo	Western	Eastern	Ashanti	Central	Volta	6
District (random)	5	5	5	5	4	2	26
Community (random)	10	10	10	10	8	10	58
Farmer (random)	158	110	126	115	112	110	731


COCOA GROWING DISTRICTS IN GHANA
Legend
Selected Community
Regional Capital
Regional Boundary
COCOA DISTRICT
Ashanti
Brong Ahafo
Central
Eastern
Volta
Western
3°0'0"W
2°0'0"W
1°0'0"W
0°0'0"
1°0'0"E
11°0'0"N
10°0'0"N
9°0'0"N
8°0'0"N
7°0'0"N
6°0'0"N
5°0'0"N
UPPER EAST REGION
Bolgatanga
UPPER WEST REGION
Wa
Tamale
NORTHERN REGION
COTE DIVOIRE
REPUBLIC OF TOGO
BRONG AHAFO REGION
BEREKUM
JASIKAN
Sunyani
DORMAA AHENKRO
BECHEM
OFFINSO
ASHANTI REGION
GOASO
NKAWKAW
HOHOE
ESSEM
Kumasi
SANKORE
NKAWIE
JUASO
Ho
AKONTOMBRA
ANTOAKROM
OSINO
EASTERN REGION
VOLTA REGION
BOAKO
KADE
KIBI
SEFWI BEKWAI
Koforidua
FUMSO
SUHUM
ENCHI
GREATER ACCRA REGION
ASSIN FOSU
CENTRAL REGION
NYARKROM
WESTERN REGION
Accra
ESSIKUMA
JUKWA
Gulf of Guinea
Cape Coast
Takoradi
0 10 20 40 60 80 100
Kilometers

◀**Fig. 1** Map of Ghana showing the communities in the selected cocoa growing districts where the baseline field survey was conducted

only the parameters that significantly influenced cocoa productivity. The empirical model for estimating parameters that significantly influenced cocoa productivity is specified as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e$$

where Y is the dependent variable (cocoa productivity); X_1 is the frequency of capsids control (per season); X_2 is the frequency of black pod disease control (per season); X_3 is the fertilizer application; X_4 is the pruning; X_5 is the farm age (yrs); X_6 is the farm size (ha); X_7 is the quantity of dried fermented beans per farm (kg); β_i is the standard coefficients to be estimated ($i = 1, 2, 3, \ldots, 7$); β_0 is the constant, and e is the error term.

Results

Profile of cocoa farmers and farm characteristics

The majority of cocoa farmers were male (76.6%) with women constituting the minority (23.4%) (Table 2). The male dominance in cocoa farming was observed in all regions. Results from the survey also revealed that the majority (58.0%) of farmers are between 41 and 60 years old (Table 2). Only 19.6% of the farmers are relatively young (20–40 years). Ashanti and the Central regions had the majority (62.6 and 62.5%, respectively) of farmers within 41–60 years, while the Western region had relatively more (28.2%) farmers within 20–40 years. About 85% of cocoa farmers have received some form of education while only 15% have not received any form of education (Table 2). The Volta region had the lowest number (6%) of farmers without education, while the Central region had the highest number (23.2%). The educational level of the cocoa farmers was, however, low as the majority (50.9%) had only middle/JHS school education. Only 9.6 and 4.0% of the farmers had secondary and tertiary education, respectively. In the Volta region, secondary (15.5%) and tertiary (10.0%) education was even more represented. In terms of the number of years active in cocoa farming, the majority of farmers (43.5%) had 11–20 years of experience (Table 2). A similar trend was observed in all six regions. Only 12.3% of the farmers had over 30 years of experience in cocoa farming.

The majority (33.0%) of the farmers cultivated cocoa on lands with a size ranging from 2.01 to 4.00 ha, with only 12.2% on lands above 8.00 ha (Table 3). However, most of the farmers in the Volta region (63.9%) cultivated cocoa on lands of less than 2.00 ha, with only 25.0% up to 4.00 ha. The Ashanti region had the highest average farm size of 5.7 ha, while the Volta region had the smallest size of 2.2 ha (Fig. 2). The majority (43.2%) of the cocoa trees were between 11 and 20 years, while 26.8% were between 1 and 10 years (Table 3). Only 8.5% of cocoa trees were over 30 years. The Eastern region had most (36.5%) of the young farms with trees younger than 10 years, while the Central region had no farms with trees over 30 years. The hybrid developed by the cocoa research institute of Ghana (CRIG) is the dominant (57.7%) cultivar planted (Table 3). The amazonica was, however, the most dominant cultivar in the Western (48.2%) and Ashanti (44.3%) regions.

Occurrence of pests and diseases

Black pod and the cocoa swollen shot virus disease were the major diseases reported in this study, with black pod disease being the dominant (86.9%) one (Table 4). The Western region recorded the highest (93.6%) occurrence of the black pod disease. The Ashanti and Volta regions also recorded a high occurrence (92.2 and 91.8%, respectively) of black pod disease, while the Eastern region had the least one (74.6%). Compared with the black pod disease, the cocoa swollen shoot virus disease was not widespread. Only 18.9% of farmers in all the six cocoa regions reported the occurrence of the viral disease on their farms. However, the Western (43.6%) and Eastern (34.1%) regions had the highest occurrence of the swollen shot virus, while the Volta region (3.6%) had the lowest one.

Major pests identified in this study were capsids (94.8%) and cocoa shield bugs (75.5%) (Table 4). Other pests such as the moth and mealy bugs were also reported to attack the cocoa trees as well as the pods. The Western (98.2%), Central (98.2%) and Ashanti (96.5%) regions reported a high occurrence of capsids. All farmers in the Western region reported the occurrence of cocoa shield bugs on their farms (Table 4). The Central region also reported a high

Table 2 Demographic characteristics in percent of cocoa farmers interviewed in six cocoa growing regions of Ghana and their significance level

Background characteristics	Region							*p* value
	National (n = 731)	Brong Ahafo (n = 158)	Western (n = 110)	Eastern (n = 126)	Ashanti (n = 115)	Central (n = 112)	Volta (n = 110)	
Gender								
Male	76.6	74.7	71.3	82.5	71.3	74.1	85.5	0.032
Female	23.4	25.3	28.2	17.5	28.7	25.9	14.5	
Age of farmers (years)								
21–40	19.6	23.4	28.2	16.7	13.0	17.0	18.2	0.021
41–60	58.0	53.8	58.2	55.6	62.6	62.5	57.3	
≥60	22.4	22.8	13.6	27.8	24.3	20.5	24.5	
Educational level								
None	15.5	17.7	16.4	11.1	17.4	23.2	6.4	<0.001
Primary	20.1	24.1	24.5	15.9	20.0	22.3	12.4	
Middle/JHS	50.9	48.1	49.1	59.5	51.3	42.0	55.5	
Secondary	9.6	6.3	6.4	9.5	10.4	10.7	15.5	
Tertiary	4.0	3.8	3.6	3.6	0.9	1.8	10.0	
Cocoa farming years								
1–10	23.2	30.4	12.8	23.8	17.4	22.4	30.0	<0.001
11–20	43.5	39.9	40.9	41.3	42.6	49.1	49.1	
21–30	20.9	16.5	31.9	21.4	23.5	21.5	12.7	
>30	12.3	13.3	14.5	13.6	16.5	7.1	8.1	

NB: Results are expressed as percentage of farmers; Significant at $p < 0.05$

(92.0%) incidence of cocoa shield bugs, as compared to the Volta region (14.5%).

Determinants of cocoa productivity

Cocoa productivity was generally very low in all six regions (Fig. 3). Average productivity was 234 kg ha^{-1} (Table 5). The Western region recorded the highest productivity with 381 kg ha^{-1}, while the Ashanti region had the lowest with 180 kg ha^{-1} (Fig. 3). Results also show that the productivity with 5% of the farmers was below 13 kg ha^{-1}, while 95% recorded a productivity below 617 kg ha^{-1} (Table 5). The outcomes of the regression analysis are presented in Table 6. The F-value of 212.798 was statistically significant ($p < 0.01$), indicating a combined influence of all significant variables on productivity. The adjusted R^2 is 0.670, suggesting that about 67.0% of the variability in cocoa productivity could be explained by the factors investigated. The Durbin-Watson value was 1.832, indicating that there was no autocorrelation.

Farm management practices, namely capsid control, black pod disease control, fertilizer application and pruning significantly influenced cocoa productivity positively (Table 6). Capsid control and fertilizer application, however, had the highest positive standard coefficient of 0.090 and 0.089, respectively. However, results from this study revealed that, on average, farmers are only able to spray against capsids ca. three times instead of the recommended four times (Table 5). Results also revealed that 5% of farmers do not spray at all against capsids, while 95% of farmers spray less than four times. Results showed that 61.4% of farmers applied fertilizers, while 38.6% do not apply any fertilizer (Table 4). More farmers (82.1%) of the Central region apply fertilizers, than farmers (45.3%) of the Eastern region. Results also revealed that the majority of farmers (86.5%) applied fertilizers during the rainy season, contrary to CRIG's recommendation of fertilizer application at the beginning of the rainy season.

Black pod disease control and pruning also had a positive, though smaller standard coefficient of 0.062 and 0.046, respectively. Results from the survey

Table 3 Determination of farm size (ha), farm age (years), cocoa variety planted in six cocoa growing regions of Ghana and their significance levels

Background characteristics	Region							*p* value
	National (n = 731)	Brong Ahafo (n = 158)	Western (n = 110)	Eastern (n = 126)	Ashanti (n = 115)	Central (n = 112)	Volta (n = 110)	
Farm size (ha)								
0.00–2.00	28.6	25.9	14.5	27.0	15.7	26.8	63.6	<0.001
2.01–4.00	33.0	26.6	35.5	44.4	31.3	35.7	25.5	
4.01–6.00	17.6	22.8	24.5	11.9	19.1	17.0	9.1	
6.01–8.00	8.6	11.4	10.9	6.3	13.0	7.1	1.8	
>8.00	12.2	13.3	14.5	10.3	20.9	13.4	0.0	
Age of farm (years)								
1–10	26.8	27.2	19.1	36.5	17.4	26.8	32.7	<0.001
11–20	43.2	40.5	52.7	37.3	35.7	50.9	44.5	
21–30	21.5	20.3	19.1	13.5	34.8	22.3	20.0	
>30	8.5	12.0	9.1	12.7	12.2	0.0	2.7	
Cocoa variety planted								
Amelonado	0.4	1.3	0.0	0.0	0.0	0.0	0.9	<0.001
Amazonica	24.5	8.2	48.2	14.3	44.3	28.6	10.9	
Hybrid	57.7	84.2	40.9	59.5	38.3	50.0	62.7	
Amazonica and hybrid	17.4	6.3	10.9	26.2	17.4	21.4	25.5	

NB: Results are expressed as percentage of farmers; Significant at $p < 0.05$

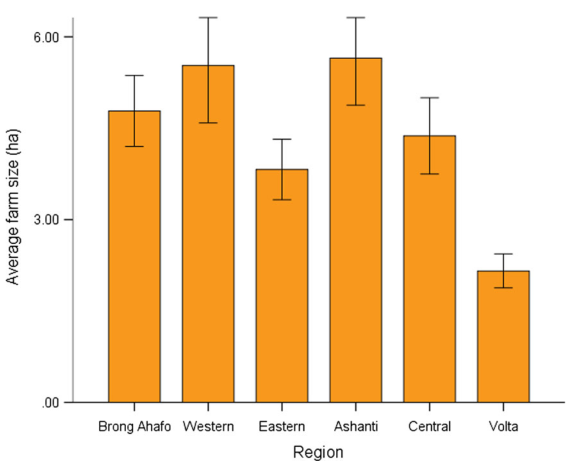


Fig. 2 Average farm size (ha) under cultivation in the six cocoa growing regions of Ghana

showed that, on average, farmers are able to spray ca. three times a year to control black pod disease (Table 5). Results also revealed that 5% of farmers do not spray at all against black pod disease, while 95% spray less than six times. The age of the cocoa farm and size of the farm in hectares also significantly ($p < 0.01$) influenced cocoa productivity (Table 6). However, the size of the cocoa farm in hectares recorded a strong negative standard coefficient of −0.665.

Profitability in cocoa production

Profitability was generally very low in all six regions (Fig. 4). The average annual profit margin per ha was Gh ¢568 (US$ 150) (Table 5). The Western region recorded the highest profit margin of Gh¢ 961 (US$ 256) per ha, while the Volta region had the lowest margin of Gh¢ 437 (US$ 117) per ha. Further analysis of the data revealed that 5% of farmers recorded profit margins of less than Gh¢ 87 (US$ 23) per ha, while 95% made profits less than Gh¢ 1778 (US$ 474) per ha (Table 5).

Discussion

Profile of cocoa farmers and farm characteristics

The dominance of male cocoa farmers is because in Ghana and especially in rural farming communities, males are often more resource endowed than females.

Table 4 Occurrence of major pests and diseases in cocoa farms, fertilizer application by cocoa farmers in Ghana and their significance level

Background characteristics	Region							*p* value
	National (n = 731)	Brong Ahafo (n = 158)	Western (n = 110)	Eastern (n = 126)	Ashanti (n = 115)	Central (n = 112)	Volta (n = 110)	
Diseases								
Black pod disease	86.9	88.0	93.6	74.6	92.2	82.1	91.8	<0.001
Swollen shoot virus	18.9	12.0	43.6	34.1	11.3	9.8	3.6	<0.001
Pests								
Capsids	94.8	92.4	98.2	93.7	96.5	98.2	90.9	<0.001
Cocoa shield bug	75.5	81.6	100.0	73.8	87.8	92.0	14.5	<0.001
Moth	4.0	7.6	0.0	13.5	0.0	0.0	0.0	<0.001
Mealy bug	5.9	1.3	4.5	22.2	0.0	3.6	3.6	<0.001
Fertilizer application								
Yes	61.4	65.2	59.1	45.3	65.2	82.1	51.8	<0.001
No	38.6	34.8	40.9	54.8	34.8	17.9	48.2	
Period for fertilizer application								
Beginning of the raining season	13.5	9.7	3.1	36.6	8.0	17.0	10.7	<0.001
During the raining season	86.5	90.3	96.9	63.8	92.0	83.0	89.3	
Type of fertilizer used								
Assasewura (NPK/10:10:10)	96.7	96.2	100.0	100.0	93.4	98.9	91.1	<0.001
Sedalco (NPK/6:0:20 + trace elements)	3.3	3.8	0.0	0.0	6.6	1.1	8.9	

NB: Results are expressed as percentage of farmers; Significant at $p < 0.05$

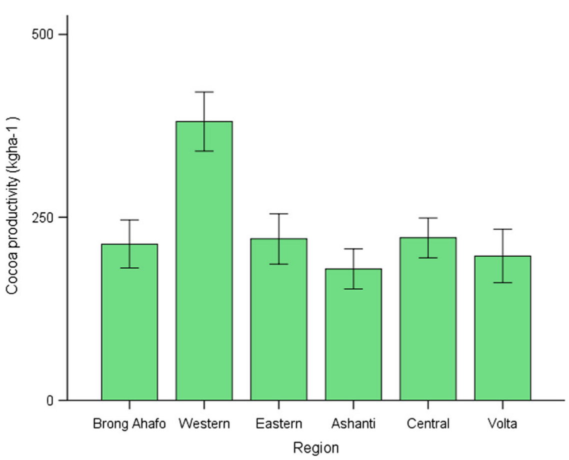


Fig. 3 Average cocoa productivity (kg ha^{-1}) of farmers per annum in the six cocoa growing regions of Ghana

Males are often endowed with resources such as land and other assets by virtue of the inheritance system (Baffoe-Asare et al. 2013). Also, in most agrarian societies of Africa, women are generally marginalized in terms of access to information, external inputs as well as income (Anang et al. 2011). It is therefore easier for men to engage in cocoa cultivation than women. Cocoa farming is a tedious job that requires physical strength. The relatively old age of cocoa farmers may influence physical strength and hence productivity. The high number of educated farmers reported in this study erases the general perception that most cocoa farmers are illiterate and have no form of education (Baah 2006). Education enhances farmers understanding technologies and helps to better appreciate, accept and implement innovations (Asamoah 2015). Also, the relatively long period of cocoa farming reported by the farmers is likely to enhance their knowledge of cocoa production and post-harvest management practices, which have implications on bean quality. The cocoa tree becomes productive after four years of planting with yield increasing annually until about 18 years of age; then yields start to decline (Binam et al. 2008). Findings from this study suggest that the majority of cocoa trees are within the prime stage and thus, with the right farm management care, should be more productive.

Table 5 Summary of cocoa profitability and the variables used in the stepwise regression analysis of productivity

Variable	Mean	SD	Median	Percentiles			
				5%	25%	75%	95%
Cocoa productivity (kg ha^{-1})	234	197	185	13	93	320	617
Frequency of capsids control (per season)	2.9	1.1	3.0	0.0	2.0	4.0	4.0
Frequency of black pod disease control (per season)	2.8	2.0	3.0	0.0	1.0	4.0	6.0
Frequency of pruning (per season)	1.6	0.6	2.0	0.0	1.0	2.0	2.0
Age of cocoa farm (years)	15.0	9.0	13.5	4.0	8.7	19.3	31.0
Size of cocoa farm (ha)	4.4	3.7	3.2	1.0	2.0	5.6	11.3
Quantity of dried fermented beans per farm (kg)	1006.8	978.9	597.0	32.6	245.0	1216.0	3242.0
Profitability per ha (Gh¢)	568	488	429	87	147	880	1778

Table 6 Results of stepwise regression analysis of cocoa productivity

Model	Standard coefficient (β)	t-value	p-value
(Constant)	–	5.919	0.000***
Capsids control	0.090	3.742	0.000***
Black pod disease control	0.062	2.726	0.007***
Fertilizer application	0.089	3.898	0.000***
Pruning	0.046	2.078	0.038**
Farm age (years)	0.122	5.507	0.000***
Farm size (ha)	−0.665	−24.402	0.000***
Quantity of dried fermented beans per farm (kg)	0.933	33.535	0.000***
F-value (10, 720) = 212.798			
$R^2 = 0.673$			
Adjusted $R^2 = 0.670$			
Durbin-Watson = 1.832			

** $p < 0.05$, *** $p < 0.01$

Occurrence of pests and diseases

Cocoa trees, like other crops, are susceptible to a number of diseases and pests that affect the yield of pods from the trees. Black pod disease, also known as pod rot, is a fungal disease caused by two *Phytophthora* species, *P. palmivora* and *P. megakarya* (Baah and Anchirinah 2011). It is characterized by browning, blackening and rotting of cocoa pods and beans. Work by Akrofi et al. (2015) also found the Western region to have the highest spread of the black pod disease, representing 34.1% of the total infested area surveyed. The high occurrence of black pod disease in the Western region might be due to the fact that it is the wettest part of Ghana with an average rainfall of 1600 mm per annum (Ministry of Food and Agriculture 2015) and thus, favourable for fungal growth. The CSSVD is caused by the cacao swollen shoot virus and is reported as a major constraint to cocoa production in West Africa (Ameyaw et al. 2014). Findings from this study reveal, however, that the CSSVD was less dominant compared with the black pod disease.

Capsids are reported to be the major insect pest in Ghana and West Africa (Boateng 2011; ICCO 2015). They use their needle-like mouth part to pierce the surface of cocoa stems, branches and pods, suck the sap of the cocoa tree, killing the penetrated host cells and producing unsightly necrotic lesions (Boateng 2011; ICCO 2015). Cocoa shield bugs, *Bathycoelia thalassina*, are large green insects, which feed on cocoa pods, pierce the pod husk with their mouth parts

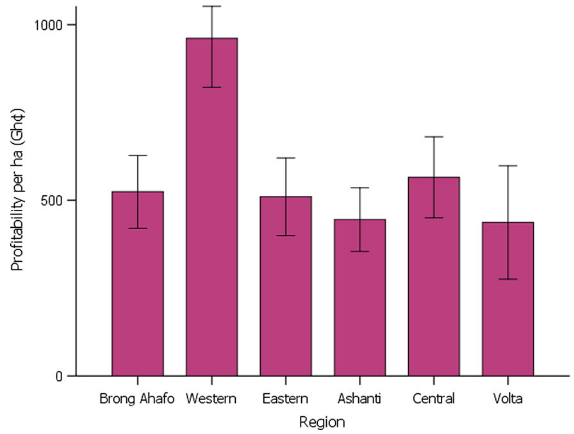


Fig. 4 Average profitability (Gh¢) per ha of cocoa production per annum in the six cocoa growing regions of Ghana

and suck out the content of the beans (Boateng 2011). As a result young pods stop growing, turn yellow and then black. Owusu-Manu (1976) estimated that 60% of immature pod ripening is caused by *B. thalassina* feeding and it is responsible for 18% loss of the annual national production in Ghana. Good farm management practices such as spraying with insecticides can be used to control these insect pests.

Determinants of cocoa productivity

The large, positive effect of capsid control and fertilizer application implies that both measures have a relatively higher impact on productivity than any other farm management practice. Research at CRIG indicated that capsids could reduce cocoa yields by 25% in 3 years in case of severe attacks (Owusu-Manu 1985). Thus, capsids are the main insect pest targeted for control by cocoa farmers in their bid to obtain a desirable yield (Antwi-Agyakwa et al. 2015). As a result, CRIG recommended farmers to spray against capsids with insecticides four times a year, in August, September, October and December to ensure effective control (Asamoah 2015). Farmers' inability to spray against capsids four times in a year might be due to availability and affordability of insecticides. Currently, Imidacloprid (Confidor®), Bifenthrin (Akatemaster®) and Thiamethoxam (Actara®) are the insecticides approved by COCOBOD for use by farmers to control capsids.

Prolonged cultivation of cocoa on a piece of land has been reported to reduce soil fertility due to soil nutrient mining (Appiah et al. 2000). Fertilizer application to soils can replenish the depleted soil nutrients and, hence increase productivity. To ensure sustainable production, CRIG has recommended farmers to apply fertilizers once a year to enrich the soil at the beginning of the rainy season (May/June). Fertilizers used by the farmers include Assasewura fertilizer (NPK/10:10:10), and Sedalco (NPK/6:0:20+ secondary nutrients). The secondary nutrients in Sedalco fertilizer include zinc, boron and manganese. Assasewura is a granular fertilizer and is applied at 375 kg ha^{-1}, while Sedalco, a liquid fertilizer, is applied at 75 ml ha^{-1} (10 ml is mixed with 11 l of water).

Black pod disease is an economically important disease of cocoa as it causes severe damage to both pods and beans leading to drastic reduction of yields. Findings from this study suggest that control of the disease has a positive impact on productivity. CRIG has recommended farmers to spray against black pod disease with approved fungicides at least six times a year at monthly intervals starting in May/June with the onset of the rainy season to ensure effective control of the disease and a sustainable production of the pods (Asamoah 2015). Approved fungicides used to control black pod disease include Ridomil (6% metalaxyl-M and 60% copper oxide), Nordox (Cuprous oxide), Champion (Cupric hydroxide), Funguran (Cupric hydroxide) and Kocide 101(Cupric hydroxide).

Farm age and pruning also recorded positive impact on productivity. Majority of the cocoa trees (43.2%) were within their prime productive stage (11–20 years) and this might have accounted for the positive impact on productivity. Pruning involves the removal of excessive and diseased branches for proper canopy management. It ensures adequate ventilation, maintain tree height which facilitate spraying and harvesting of pods. All these enhances productivity. The negative impact of farm size on productivity suggests that, if the size of cocoa farm increases, the productivity decreases. This could be due to the fact that the larger the farm, the more difficult it is for maintenance, thus resulting in low productivity. Multi-purpose (shade) trees should be planted on cocoa farms (agroforestry) to provide shade, mulch and improve soil fertility and plants that deter pests and support pests predators also intercropped with cocoa to aid reverse the current trend of low productivity, protect the environment and ensure agro-ecological sustainability.

Profitability in cocoa production

The extremely low profitability recorded in all six regions might be due to the low cocoa productivity. Western region recorded relatively high productivity and this might have accounted for the relatively high profit margin in that region. Again, high cost of farming especially with regards to cost of labour might account for the low profitability. Cocoa farming is a tedious job that requires much physical strength. Most of the cocoa farmers are above 40 years (Table 2). The relatively old age of farmers might increase labour cost as these farmers need to hire labour (for weeding, pruning, spraying against capsids and black pod disease, harvesting, etc.). The low profitability implies also that farmers are not able to invest in their farms in terms of adoption of more advanced farming practices to ensure sustainable production.

Cocoa farmers should be prudent and efficient in the use of farm inputs, reduce the use of pesticides and fungicides by using black ants, *Oecophylla longinoda* (van Wijngaarden et al. 2007) and beneficial endophytes, *Trichoderma spp* (Deberdt et al. 2008; Hanada et al. 2009) as biological agents to control cocoa capsids and black pod disease, respectively. Organic matter could be used to increase the nutrient content in the soil such as the use of cocoa pod husk to improve the K content in the soil. Nitrogen fixing legumes can be inter-cropped with the cocoa to improve the N content in soil. These intensification practices will increase productivity of the farmers, reduce cost associated with farming and thus, increase profit margins. Finally, managers of the cocoa sector in Ghana should create enabling environment by ensuring efficient, equitable and affordable access to farm inputs, improve road infrastructure that links farms to villages, improve access and affordability to healthcare and education, develop human capital through continuous training of farmers and extension workers and build social capital by encouraging formation of farmer group associations to advance the interest of farmers. These will enhance the socio-economic wellbeing of cocoa farmers and communities and improve productivity and increase profitability.

Conclusions

Cocoa production in Ghana is dominated by male cocoa farmers, with the majority of the farmers being older than 40 years. The relatively old age of the farmers would influence productivity and profitability. Cocoa farmers in Ghana are smallholder farmers with an average farm size of about 4.4 ha. Black pod disease and capsids were the dominant biotic stressors. Productivity was generally very low (<300 kg ha^{-1}), as well as profitability (Gh¢ 568 (US$ 150) per ha) in all six regions. The Western region showed the highest productivity (381 kg ha^{-1}) and profitability (Gh¢ 961 (US$ 256) per ha). Control of capsids and fertilizer application is suggested to have the greatest impact for increasing productivity. Farm size caused a decrease in productivity. This implies that good farm management practices such as spraying against black pod and capsids, pruning and the application of fertilizers would significantly increase cocoa productivity and thus profitability and ensure sustainable production rather than excessive land expansion which eventually leads to lower productivity.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest.

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