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CHAPTER 5

Household Economics of Cocoa Agroforestry: Costs and Benefits

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Abstract Current research suggests that cocoa agroforestry systems could offer stable yields, additional benefits and income from shade trees, despite potential added costs, such as from the purchase of insecticides. There is a paucity of profitability studies of different cocoa agroforestry systems. Only few of them go beyond a narrow focus on cocoa yields to model the entire agroforestry system and thus do not advance our understanding of the socio-economic value of other ecosystem goods. Based on

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survey data covering a thousand cocoa plots and group interviews with cocoa farmers, we explore the costs and benefits at the household level of including trees in cocoa systems. Comparing low and medium tree diversity systems, we find that income from cocoa beans, timber and fruit trees are higher and labour costs are lower in plots with medium diversity, while insecticide costs are lower on low-diversity plots. Overall, net benefits were higher on cocoa plots with higher tree diversity. Thus, cocoa agroforestry systems offer cost-reduction and income-improving advantages. Since cocoa systems vary among different agro-ecological zones in Ghana, we recommend that interventions aimed at increasing tree diversity consider the specific management practices of each farming household and the location in question.

Keywords Cocoa agroforestry · Tree diversity · Household economics · Profitability · Cost reduction · Income diversification

5.1 Introduction

Approximately two million households depend on cocoa farming as their primary source of livelihood income in West Africa (World Cocoa Foundation, 2022). For these farmers, cocoa field productivity is of utmost importance. Traditional pathways to increasing cocoa yields across the West African cocoa belt have involved the expansion of farms into forest areas and the cultivation of hybrid seeds mostly under full-sun systems, i.e. in monocrop systems with little to no shade. Since 1950, Côte d'Ivoire

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and Ghana have lost, respectively, 90 and 65% of their forest areas, mainly due to agricultural expansion with cocoa as the dominant crop (Kalischek et al., 2022). Deforestation driven by cocoa continues (Barima et al., 2016; Nunoo et al., 2015; Ongolo et al., 2018), including in forest reserves and national parks, where small-scale farming of cocoa is among the leading causes of deforestation and forest degradation (Acheampong et al., 2019; Kalischek et al., 2022). This strategy for cocoa expansion is unsustainable and there is an urgent need to identify ways to increase production without compromising environmental sustainability. Environmental sustainability is high on the agenda among major cocoa-buying companies (Carodenuto & Buluran, 2021), if not for the sake of the forest, then for the sake of market access, as the world's major chocolate consuming regions, the EU and the United States, are developing new regulations that are expected to hinder cocoa imports unless documented as deforestation-free. Cocoa agroforestry has been presented by researchers and farmers as a more sustainable and climate-resilient pathway for maintaining and even increasing cocoa farm outputs (Daghela Bisseleua, 2019).

As discussed in more detail in the previous chapters, cocoa agroforestry involves planting, or managing the regeneration of companion trees and/or crops with cocoa for agronomic, environmental and economic benefits (Asare, 2006; Asare & Asare, 2008). Cocoa agroforestry has been shown to enhance soil health, improve climate resilience, sequester carbon, increase farmer income, secure household food and nutrition needs, reduce pest and disease outbreaks (by acting as barriers) and improve biodiversity (Blaser et al., 2017; Nair & Nair, 2014). Yet, as this chapter will show, the types and extent of benefits to specific farms vary depending on the particular farming systems employed, including how much labour and inputs are used, but also tree species diversity. Thus, while the trade-off and cost aspects of managing cocoa agroforestry systems are different from full-sun systems, they also vary between different cocoa agroforestry arrangements (Asare et al., 2014; Nunoo & Owusu, 2017; Obiri et al., 2007).

Historically, West African cocoa farmers increased cocoa bean production by shifting to new cultivation frontiers, which had several advantages compared to other methods. Cocoa-cultivation frontiers are geographical regions of abundant unoccupied land resources (often forest land) that did not previously include cocoa cultivation. As a result of the introduction of cocoa cultivation, these regions have experienced substantial flows of people (migration) and capital (Knudsen & Agergaard, 2015). The expansion into new frontiers was mostly a cost-saving strategy, e.g. to resolve ecological instability in current production areas, such as helping manage pest and disease infestations and declining soil fertility (Kolavalli & Vigneri, 2011). This practice predominated because of the availability of large expanses of forest land in cocoa-cultivation belts (Asare, 2005; Kolavalli & Vigneri, 2011). Across the two leading cocoa-producing countries, Côte d'Ivoire and Ghana, land has become scarce, and farmlands fragmented. In Ghana, there are no major cultivation frontiers left (Amanor et al., 2021; Asare & Ræbild, 2016). As a result, farmers turned to intensive full-sun cultivation, which allows for increasing productivity through appropriate agricultural practices and the rational application of agrochemicals (fungicides and insecticides) and fertilizers. However, as the climate changes and becomes warmer or wetter, the pressure of diseases and pests on cocoa trees in full-sun cultivation may increase, leading to higher costs of production and lower income (Asare et al., 2014; Schroth et al., 2000). In contrast, several of the potential benefits of cocoa agroforestry practices, such as improving soil fertility, reducing pest infestations, reducing weed growth and moderating the impacts of dry spells and drought on yields (Abou Rajab et al., 2016; Bos et al., 2007; Tscharntke et al., 2011), all mitigate the impacts of climate change while reducing costs for farmers (Cerda et al., 2014).

In Ghana, cocoa farming serves as the main livelihood option for about 550,000 smallholder households (Ghana Statistical Service, 2019), whose livelihoods depend directly on cocoa farm yields. In such households, earnings from cocoa bean sales are a key component of total household incomes and critical to meeting household needs related to food, health, education and other necessities. However, cocoa farming is an input-intensive activity whose benefits mostly depend on how much labour, agrochemicals and fertilizer producers apply (Asare et al., 2019). Prior to the individualization of labour due to increasing urbanization and commercialization across the West African cocoa-growing belt, family, neighbours and community members were a key source of unpaid labour for cocoa cultivation that kept costs down. However, with increasing out-migration of labour from the cocoa areas and the proliferation of other competing economic activities in the cocoa-growing areas, such as small-scale and large-scale mining and sand winning, labour for cocoa farming has become scarce, increasing its cost (Ministry of Manpower Youth & Employment, 2007). This shortage of labour has furthermore been cited as a factor in the problem of child labour in cocoa cultivation in Ghana and across West Africa (Sadhu et al., 2020). The rising costs of labour also reduce the amount of money farmers can spend on fertilizers and agrochemicals such as herbicides, fungicides and insecticides. As a result, the inputs farmers use decrease, and by extension the outputs and cocoa farm incomes. The cost-reduction advantages hypothesized for cocoa agroforestry systems could therefore be helpful to farmers, especially if these were also associated with increases in farm outputs and benefits.

Based on a cost–benefit analysis, this chapter explores whether smallholder cocoa farmers increase their incomes and improve their livelihoods when implementing tree diverse cocoa-cultivation systems focusing on the effect of the level of tree species diversity. Specifically, the chapter asks the following questions: (i) how does the level of tree species diversity affect the costs and benefits of cocoa agroforestry? And (ii) what are the household economic implications of managing cocoa agroforestry systems across different climate gradients in Ghana? These questions are important in an era when sustainable production has become more important for conserving resources, improving the climate resilience of agricultural systems and enhancing livelihoods.

The chapter is organized into four sections. Following the introduction, Sect. 5.2 provides a review of the larger literature on cocoa farmers' livelihoods and the role of agroforestry in safeguarding livelihoods, while Sects. 5.3 and 5.4 detail the conceptual framework and methodology. Section 5.5 presents the results and discusses policy implications based on the findings, while Sect. 5.6 provides a conclusion.

5.2 Literature Review: Cocoa Farmers' Livelihoods and the Role of Agroforestry

The integration of trees into cropping systems provides smallholders with alternative livelihoods and income besides earnings from the sale of cocoa beans (Atangana et al., 2014; Cerda et al., 2014; Graefe et al., 2017; Ruf & Schroth, 2004). For example, it provides farmers additional income through the sale of firewood, fruits and, in some instances, timber (Asare et al., 2014; Graefe et al., 2017). The integration of trees into cocoa farms and landscapes is also important because trees help moderate the impact of climatic stress (from higher temperatures and droughts), provide shade for the cocoa trees, serve as barriers to the spreading of pests and diseases, and sequester/store carbon (Abou Rajab et al., 2016; Asare et al., 2014;

Bos et al., 2007; Daghela Bisseleua et al., 2013; Graefe et al., 2017; Smith Dumont et al., 2014; Tscharntke et al., 2011). On the other hand, cocoa agroforestry systems also introduce new costs. For example, shade trees may cause competition for root space and nutrients in young plantations (Smith Dumont et al., 2014; see also Chapter 2 in this volume), while excessive shade may increase pest and disease pressures (Graefe et al., 2017; see also Chapter 3 this volume). Cocoa agroforestry is also associated with a reduction in yields compared to intensified full-sun systems, assuming farmers apply the required inputs, and not considering the impacts of climate change on full-sun systems (Nunoo & Owusu, 2017). However, the actual and potential costs and benefits that smallholders derive from these cocoa agroforestry systems are influenced by institutional, technical, marketing and legal arrangements (Mugure et al., 2013; Roth et al., 2018). In Ghana and Côte d'Ivoire, for example, factors such as land and tree tenure arrangements; whether farmers originate from forest zones or savannah zones; and social networks; largely determine whether farmers integrate trees into their cocoa systems and affect the benefits farmers derive from such cocoa systems (Gyau et al., 2015; Roth et al., 2018; Ruf & Schroth, 2004; see also Chapter 4).

Household socio-economic characteristics, including resource endowments and household assets, are also important in determining the costs and benefits farmers derive from their cocoa systems. Based on socio-economic characteristics, cocoa farmers in Ghana could be grouped into aged and young, rich and poor, educated and illiterate, well-diversified and less-diversified farms, male and female, and indigenes and migrant farmers, among others. Each of these farmer types has different capacities to adopt cocoa agroforestry practices, based on their household socio-economic characteristics and tenure arrangements. For instance, the average age of cocoa farmers in Ghana currently is above fifty (Asamoah et al., 2015), which impacts willingness and ability to adopt innovative and improved cultivation practices, such as cocoa agroforestry (Barrientos et al., 2008; Boadi et al., 2022; Djokoto et al., 2016). Some of these socio-economic dynamics influencing the costs and benefits associated with cocoa agroforestry systems are modulated by prevailing state policies on access to inputs and producer prices.

Several state policies and programmes have been introduced in Ghana over the years to improve cocoa farmers' cultivation practices, leading to potential cost-saving advantages for cocoa farmers as well. The most relevant of these policies for cocoa agroforestry practices are the

Cocoa Mass Spraying Programme introduced in 2001, the Cocoa Hi-Tech Programme introduced in 2002/2003 and the Hand Pollination Programme introduced in 2017 (COCOBOD, 2018; Kolavalli & Vigneri, 2017). The Mass Spraying Programme, which increased the application of insecticides for effective pest and disease control, helped farmers control black pod infestations, which have been linked to the introduction of shade trees on cocoa farms—especially when the shade canopies are not managed well (Bos et al., 2007; Schroth et al., 2000; Tscharntke et al., 2011). The Cocoa Hi-Tech Programme, which involved the distribution of subsidized and/or free fertilizers to farmers (Kolavalli & Vigneri, 2017), increased yields, alleviating farmers' fears of reduced yields from adopting cocoa agroforestry systems. The Hand Pollination Programme has a similar potential to increase yields.

Increases in the cocoa producer price are also important to increase farmers' economic room for improvement in farm management, such as affording to purchase inputs, including planting materials for shade trees. A noteworthy development with significant implications for producer prices in Ghana is the "Living Income Differential Policy" (LID), which aims to reduce the differential between current incomes and the income needed for farmers to live a decent life. In 2019, the governments of Côte d'Ivoire and Ghana formed an alliance to demand that large trading companies and other sector players in Europe and North America pay a LID premium of USD 400 per tonne of cocoa purchased. While not yet implemented fully in price-setting policies, the LID policy has led to increments in purchasing prices in Ghana for a 64-kilogramme (kg) bag of cocoa from Ghana Cedis (GHS) 515 in the 2019/2020 cocoa season, i.e. 87.5 USD per bag (USD 1400 per tonne), to GHS 660 in the 2020/2021 cocoa season, i.e. 102 USD per bag (USD 1632 per tonne). The policy has also led to the International Cocoa Agreement, signed by producing and consuming member countries, which includes "a reference to remunerative prices to reach economic sustainability" and achieve a living income (ICCO, 2022). The international trading companies have supported the LID policy in their communications, but some push-back on the price increases has been seen in the sector, such as buyers' lowering the origin or quality differentials to off-set some of the LID-related price increment. Historically, favourable producer prices have been associated with improved investments in cocoa farms in Ghana (Kolavalli & Vigneri, 2011), and it is therefore likely that increased purchasing prices could have positive implications for farmers' adoption of improved cultivation practices such as cocoa agroforestry practices.

5.3 Conceptual Framework: Agroforestry, Farmer Income and Cost–Benefit Analysis

This chapter adopts a definition of cocoa agroforestry systems that includes the stage of the cocoa system and the associated species diversity and distribution. This takes into account the dynamic and constantly changing nature of cocoa systems over the life cycle of the cocoa crop in terms of the crops/trees included and their arrangement in the system. Cocoa agroforestry systems are thus defined as a form of tree diversification, which draws agronomic, environmental and economic benefits from strategically integrating suitable and valuable non-cocoa tree species and other plants in time and space (Asare, 2006). The cocoa plots in the survey were therefore classified into different cocoa systems based on the level of tree diversity on the plots. This classification of plots allows for the inclusion and focus on the total benefits of the cocoa agroforestry system, rather than a narrow focus on shade, which is just one of the characteristics or benefits of integrating trees into cocoa plots.

Using the Shannon–Wiener Diversity Index (H′), the plots were classified as either low-diversity plots or medium-diversity plots. No plot had a sufficiently high diversity to meet the threshold to be classified as a high-diversity plot. The low-diversity plots included cocoa plots close to mono-cropping systems, while medium-diversity plots all fall under agroforestry systems. The Shannon–Wiener Diversity index (H′) is recommended for studies where rare and abundant species are expected to be equally important (Morris et al., 2014). This means that plots classified as having greater diversity in this study had a greater number of rare and abundant species and vice versa.

The chapter's empirical analysis uses the cost–benefit analysis model, which has its roots in utilitarianism (Van Wee & Roeser, 2013). Utilitarianism as a decision-making theory is about maximizing the expected utility of a good, project or policy (Eggleston, 2012). This means that cocoa farmers' decisions on what cultivation systems to adopt are influenced by the expected benefits associated with different practices and systems. Within the context of the current study, cocoa farmers make their final decisions on whether to adopt cocoa agroforestry or full-sun cocoa systems by considering the resultant benefit cost ratios, the difference between benefits and costs, and the return on investments. In the current study, the cost dimensions associated with managing cocoa farms in Ghana were split into costs incurred at the household level by the farmer (private costs) and costs incurred by the state in supporting the cocoa sector (social costs). Private costs include farmers' costs for labour, fertilizer, insecticides, etc., for managing the cocoa farm. Social costs include the costs incurred by the state through its free inputs supply and input subsidy programmes. Private benefits include revenue from cocoa bean sales, food crops and ecosystem goods harvested from the cocoa farm. Social benefits cover revenue the state earns from selling Ghana's cocoa on the international market, etc. See Boadi (2021) for more details on the cost–benefit analysis.

5.4 Methods

Based on household surveys (n = 402) and focus-group discussions (n = 20) in three different climate impact zones, this chapter assesses the costs and benefits of cocoa agroforestry systems and the contributions of these systems to smallholders' livelihoods. Data were collected from cocoa farmers in twelve cocoa communities in seven administrative districts across Ghana's Ashanti, Ahafo, Western North and Western regions, corresponding to three climate zones along a gradient of increasing dryness and higher maximum temperatures from south to north, as well as greater vulnerability to expected climate change (Bunn et al., 2019). These are known as the Cope Zone (most favourable current climate in relation to cocoa and lowest climate vulnerability), Adjust Zone (moderately favourable current climate and moderate climate vulnerability) and Transform Zone (least favourable current climate and highest climate vulnerability) (see Fig. 5.1). Data was collected for two cocoa seasons: the 2015/2016 season, which was affected by a national drought, and the 2017/2018 season, which was characterized as a "normal" season in terms of seasonal weather patterns.

A total of 1040 cocoa plots belonging to 402 smallholder households in Ghana were surveyed, of which 884 were classified into different cocoa agroforestry systems based on the level of diversity on the plots using the Shannon–Wiener Diversity Index (H′). The remaining 156 plots did not have the required details on the species of integrated trees to be classifiable. The data collected through the household surveys include the

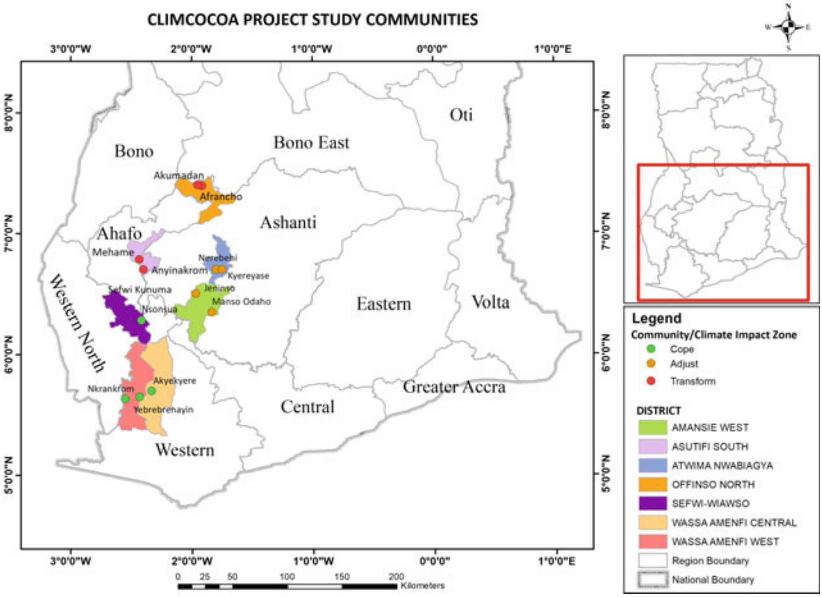

Fig. 5.1 A map of the twelve study communities in cocoa districts in the three climate impact zones (*Source* CLIMCOCOA project)

types, quantities and costs of inputs applied by farmers (land, labour, agrochemicals, capital), cocoa yields, timber and ecosystem goods, such as fruits, firewood and honey harvested from cocoa farms. Using the Shannon–Wiener Diversity Index, 681 cocoa plots were classified as low tree diversity plots and 203 as medium tree diversity plots. The plots were compared using the cost and benefit variables across the different cocoa systems. Cost and benefit parameters for the classified plots were computed using the cost and benefit analysis model described earlier (see Sect. 5.3). The costs of the cocoa systems were derived by calculating all production costs, averaged per hectare, in a complete farming season. This was done for the two seasons of interest. These costs included the cost of labour for weeding, pruning, applying inputs such as fertilizers, insecticides, fungicides, herbicides, harvesting, gathering and breaking pods, fermenting, transporting and drying cocoa beans, cost of inputs and fuel for their application, annual rents on lands where applicable, etc. The cost parameters have been computed in GHS/ha based on the farmers' and state's respective management costs. The benefits of cocoa systems were derived by calculating all the benefits, averaged per hectare, in a complete season. This was also done for the two seasons of interest. The benefits included revenue from cocoa bean sales, including any premiums from certification, food crops, fruits, timber, firewood, honey, mushrooms, bushmeat, snails, fodder/medicinal plants, etc. Similarly, the benefit parameters have been computed in GHS/ha for the farmer and for benefits accruing to the state. The private price for calculating revenue from cocoa beans is derived from the producer prices paid to farmers in the two seasons of interest, while the social price is derived from the FOB price Ghana receives from forward-selling cocoa in the two seasons under consideration. This was derived by converting the FOB price per tonne of cocoa beans to its kg equivalent. These costs and benefits were computed for the low and medium tree diversity cocoa plots for the two seasons and used to derive profitability on a per hectare basis.

5.5 Results and Discussion

The first results section presents findings pertaining to yields (which are linked to benefits) and dominant management practices (which are linked to costs) in low-diversity vs. medium-diversity cocoa plots, as well as in the three different climate zones. These management practices include use of fertilizer, fungicide, insecticide, herbicide and labour. The second section presents cost–benefit analyses of low- versus medium-diversity cocoa plots.

5.5.1 Yields and Household Management Practices

The study found that there were no significant differences in dry cocoa bean yields per hectare between plots of different tree diversity levels. The cocoa bean yield on low-diversity plots was 351.6 kg/ha compared to 358.5 kg/ha on medium-diversity plots (Table 5.1). This finding differs from earlier studies that have found somewhat negative correlations between high levels of shade and yield. This may be due to none of the plots in this study having a high level of tree diversity, thus indicating medium levels of shade. Another reason for this difference is that previous studies, such as that by Nunoo and Owusu (2017), classified cocoa plots using differences in shade levels rather than tree diversity. Nunoo and Owusu (2017) found significant differences in yields of dry cocoa beans per hectare between different levels of shade and reported yields of 516, 588 and 559 kg/ha for plots with no shade, low shade and medium shade (up to 15 shade trees and 85% shade canopy cover) and just 380 kg/ha for high shade cocoa systems (more than 15 trees/ha, with greater than 85% shade canopy cover). These differences illustrate the importance of looking not just at shade levels, but also at cocoa plot tree composition and diversity. Aside from the differences in systems compared and levels of analysis, other studies have attributed yield variations at the plot and farm levels to differences in productive efficiency and in farmers' adoption and use of innovation and technology (Armengot et al., 2020; Meijer et al., 2015).

The results from the analyses of the survey data show that medium tree diversity cocoa plots were significantly larger than low tree diversity plots, indicating that farmers with more resources are more likely to implement agroforestry systems (Table 5.1). Again, this diverges from the findings of Nunoo and Owusu (2017), who found no significant differences in

Table 5.1 Summary statistics associated with surveyed households and cocoa plots

Characteristics	*Low diversity*	*Medium diversity*	*Mean difference (Low − Medium)*
Cocoa plot size (hectares)	1.833	2.412	−0.579*
Yield (kg/ha)	351.576	358.475	−6.899
Total household cocoa landholding (hectares)	6.419	7.236	−0.817
Age of household head (years)	53.562	52.951	0.611
Farming experience of household head (years)	24.179	24.685	−0.506
Household size	5.249	5.532	−0.283
Granular fertilizer (kg/ha)	49.279	46.860	2.419
Foliar fertilizer (litres/ha)	0.731	0.993	−0.262
Fungicide 1 (grams/ha)	759.927	969.867	−209.94
Fungicide 2 (litres/ha)	0.148	0.066	0.082
Insecticide (litres/ha)	2.835	4.510	−1.675*
Herbicide (litres/ha)	1.251	1.418	−0.167
Labour (hours/ha)	770.038	745.954	24.084

*Significant at 5%

Source Survey data from fieldwork in all three climate zones combined farm sizes when focusing on shade levels rather than tree species diversity. There were no significant differences in total cocoa landholdings for households, the age of household heads, their farming experience, or household size for plots of different tree diversity levels (Table 5.1). Use of insecticides was significantly higher on plots with medium diversity, indicating either that more insecticides were needed or that the farmers with more tree diversity on their plots, which were also significantly larger, had more resources to purchase and apply insecticides. Sellare et al. (2020) also found significantly higher insecticide application on Fairtrade certified cocoa plots compared to uncertified plots in Côte d'Ivoire, attributing the higher use to farmers' extra income from premiums and related services offered by certified cooperatives, allowing them to buy and/or access additional inputs.

The application of fertilizer and agrochemical inputs between low tree diversity and medium tree diversity plots was found not to be significantly different (Table 5.1). A higher fertilizer use was expected on low-diversity plots, which had fewer trees improving the soil fertility. However, across all plots fertilization was well below national recommended levels, which explains the lack of difference. Labour hours per hectare per year, which included both hired and unpaid labour sources (family labour, communal pooled labour and all other unpaid labour used on cocoa plots), was slightly higher on low tree diverse plots than more tree diverse plots, although the differences were not statistically significant.

As shown in Table 5.2, cocoa bean yield per hectare was significantly higher in the Cope zone (423.0 kg/ha) compared to the Adjust (343.04 kg/ha) and Transform (317.87 kg/ha) zones, illustrating the different suitability of the three climate zones for cocoa farming. The national average yield of dry cocoa beans per hectare in the 2017/2018 cocoa season was about 500 kg/ha according to FAOSTAT data. Total cocoa landholding and household size differed significantly across the three climate impact zones (Table 5.2). The smaller landholdings in the Cope zone compared to the Transform and Adjust zones are due to the scarcity and traditionally high demand for land in Ghana's main cocoa-cultivation zone and the traditional inheritance practice of dividing cocoa plantations among the owner's children (Löwe, 2017). The smaller household sizes in the Adjust Zone may be due to the closer proximity to urban areas, as rural–urban influences on household size tend to result in larger households in rural areas, as shown by national statistics (Ghana Statistical Service, 2019).

Table 5.2 Summary statistics for households associated with surveyed households and cocoa plots in the different climate impact zones

Characteristics	*Transform*	*Adjust*	*Cope*	*Mean differences*		
				Adjust and transform	*Cope and transform*	*Cope and adjust*
Cocoa plot size (hectares)	2.66	2.08	1.55	−0.58*	−1.12*	−0.54*
Yield (kg/ha)	317.87	343.04	422.97	25.17	105.12*	79.95*
Total HH cocoa landholding (hectares)	9.17	6.68	4.87	−2.49*	−4.29*	−1.81*
Age of household head (years)	56.50	56.10	49.50	−0.40	−7.00*	−6.60*
Farming experience of household head (years)	25.87	25.09	22.41	−0.78	−3.46*	−2.68*
Household size	5.34	4.81	5.93	−0.53*	0.60*	1.13*
Granular fertilizer (kg/ha)	100.79	35.93	20.52	−64.87*	−80.27*	−15.40
Foliar fertilizer (litres/ha)	0.90	0.55	0.77	−0.35*	−0.13	0.22
Fungicide 1 (grams/ha)	937.73	641.81	825.35	−295.92*	−112.38	183.54
Fungicide 2 (litres/ha)	0.09	0.07	0.17	−0.02	0.08	0.10
Insecticide (litres/ha)	2.31	4.72	2.19	2.40*	−0.12	−2.53*
Herbicide (litres/ha)	0.41	1.28	2.26	0.87*	1.85*	0.98*
Labour (hours/ha)	546.90	605.85	953.50	58.95	406.6*	347.65*

*Significant at 5% using a t-test
Source Survey data from fieldwork combining both levels of tree diversity

The application of insecticides in their recommended quantities is key to preventing and/or reducing yield losses from insects like mirids, and the recommendation is for farmers to apply insecticides four times a year, in August, September, October and December (Asare, 2014). The application of insecticide is significantly higher in the Adjust zone compared to the Cope and Transform zones (Table 5.2). Cocoa farmers with sufficient financial capacity therefore tend to apply higher amounts of insecticides, even if not up to the required and recommended amounts. This, coupled with the current finding that higher tree diversity plots were associated with significantly higher plot sizes (land resources), suggests that the observed differences in insecticide application are explained by differences in household financial resources. With land becoming increasingly scarce and fragmented across Ghana's cocoa belts (Bymolt et al., 2018), the differences in plot sizes show that medium-diversity plots are managed by better resourced farmers than low-diversity plots. Well-resourced farmers may be able to purchase and apply significantly more insecticide on their plots than farmers whose cocoa plots have low tree diversity.

5.5.2 *Farm Costs and Benefits, and Their Economic Implications*

Cost and benefit components are key to estimating and comparing the profitability of cocoa systems. However, other factors such as farmer skills and training, access to inputs and good soils, age of cocoa farmers and plots, among a host of other factors, also influence the cost and benefits associated with specific cocoa farms. For cocoa agroforestry systems, tree diversification generally provides additional benefits through, for example, timber, fruits and other products for subsistence use.

Table 5.3 presents the summary statistics for the cost and benefit categories associated with the low- and medium-diversity cocoa systems. The private costs and benefits are those faced by the farmer, while the social costs and benefits (shown in parenthesis in the table) are those experienced by society or the state. For example, the private cost of fertilizer is based on farmers' purchase prices, while the social cost includes state subsidies, which is why social costs are always higher. Fertilizer, insecticide and herbicide expenditures all increase with increasing tree diversity in both cocoa seasons. The differences are largest in the private costs in both relative and absolute terms.

The higher expenditure on insecticides corresponds to the significantly higher insecticide use in the more diversified plots, as described earlier. Insecticide use is naturally related to the presence of insects, which may be higher in more shaded environments (Graefe et al., 2017; Schroth et al., 2000), though this may not be the case if proper agricultural practices are focused on insect prevention (Armengot et al., 2020). Other studies have mentioned higher applications of agrochemicals, and by extension higher input costs, in full-sun or low-shade cocoa systems than on highly shaded systems (Asare et al., 2014, 2019; Obiri et al., 2007). Such high inputs are mainly due to the higher short-term cocoa yields and the need

Table 5.3 Summary statistics of costs and benefits associated with the different cocoa systems (in GHS/ha). Social costs and benefits shown in parenthesis, where relevant

C/B categories	*Diversity level*	*2015/2016*		*2017/2018*	
Private price 64 kg cocoa bag		425		475	
Social price 64 kg cocoa bag		578		535	
		Mean	*N*	*Mean*	*N*
Cost categories					
Fertilizer	Low diversity	14.19* (30.64)	665	36.67 (74.96)	665
	Medium diversity	46.48* (56.61)	202	60.21 (82.91)	202
Fungicide	Low diversity	19.43 (34.97)	533	22.48 (41.88)	533
	Medium diversity	23.11 (37.81)	176	30.08 (50.93)	176
Insecticide	Low diversity	111.83 (100.49)	657	136.49 (154.43)	657
	Medium diversity	190.24 (167.47)	201	221.33 (252.04)	201
Herbicide	Low diversity	41.45 (36.37)	266	57.31 (57.07)	266
	Medium diversity	39.73 (36.82)	102	52.98 (52.48)	102
Fuel	Low diversity	55.62	486	55.17	555
	Medium diversity	62.09	161	61.49	174
Labour (hired)	Low diversity	1177.81	451	1122.74	530
	Medium diversity	896.91	169	935.89	184
Land	Low diversity	31.38	128	31.25	160
	Medium diversity	29.11	73	29.93	78
Benefit categories					
Cocoa bean income	Low diversity	2278.09 (3098.21)	556	2460.99 (2771.85)	598
	Medium diversity	2503.67 (3404.99)	183	2620.04 (2950.99)	197
Food crop income	Low diversity	138.81	556	160.24	598
	Medium diversity	129.62	183	191.22	197
Certification	Low diversity	–	–	80.47	9
Premium	Medium diversity	–	–	91.85	17
Ecosystem products	Low diversity	–	–	112.73	77
	Medium diversity	–	–	6.89	35
Timber and Fruits	Low diversity	–	–	14.79	662

(continued)

Table 5.3 (continued)

C/B categories	*Diversity level*	*2015/2016*		*2017/2018*	
	Medium diversity	–	–	45.99	197
Profitability category					
Private profitability	Low diversity	1187**		1382**	
	Medium diversity	1526		1658	
Social profitability	Low diversity	2028**		1639**	
	Medium diversity	2454**		1923**	

NB: Ecosystem products include firewood, honey, mushrooms, bushmeat, snails, fodder and medicinal plants

*Significant at 5% between tree diversity levels; **Significant at 5% between years (within tree diversity levels)

Source Survey data from fieldwork

for input intensification in low-shade cocoa systems as a requirement for sustaining yields and managing pests.

Hired labour costs were higher for low tree diversity plots compared to medium tree diversity plots (Table 5.3). The labour was mostly used for manual weeding, which indicates that weeds are a major issue in less diverse and less shaded environments. Regarding the benefit categories, cocoa bean income per hectare increases with increasing tree diversity for both 2015/2016 and 2017/2018 cocoa seasons. Incomes from ecosystem products (i.e. firewood, honey, mushrooms, bushmeat, snails, fodder and medicinal plants) were higher among farmers with low tree diverse cocoa plots, as these products are often collected outside the cocoa farm as well. More than twice the number of farmers with low-diversity plots (77) had income from ecosystem products than farmers with medium-diversity plots (35). Cerda et al. (2014) used cocoa typologies classified according to the size of integrated trees, their densities in the shade canopy and the yields of the agroforestry products, and found cocoa yields made higher contributions to farmer net incomes, with very little contribution from agroforestry products. However, the overall and major contribution of agroforestry products was to household consumption and food security (Cerda et al., 2014). In the current study, medium-diversity plots accrued more incomes from timber and fruits than low-diversity plots. This was expected, as this income category is associated with tree integration, which means that higher tree diversity plots are more likely to contribute higher quantities of these marketable products compared to low tree diverse cocoa systems.

Cocoa bean income per hectare was higher on medium-diversity plots (GHS 2620/ha in the 2017/18 season and GHS 2503/ha in the 2015/2016 season) compared to low-diversity plots (GHS 2460/ha in the 2017/2018 season and 2278/ha in the 2015/2016 season). While average private costs did not differ greatly between low- and medium-diversity cocoa plots, the average benefits per hectare were markedly different in both cocoa seasons. In contrast, in their cost–benefit study in Ghana, Nunoo and Owusu (2017) found marked differences in the cost of production between full-sun and cocoa agroforestry systems, with higher total production costs for low-shade cocoa systems and the lowest total production costs for their heavy shade cocoa systems. In Nunoo and Owusu's (2017) study, the difference in cost was because full-sun systems were managed using a high level of inputs.

In sum, this current study found that a greater diversity of tree species could be more profitable than a lower diversity of tree species, despite the higher expenditure on insecticides.

5.5.3 *Policy Implications*

The findings of this study show that tree integration should be encouraged, especially in cocoa-growing areas, where climate conditions are already dry or projected to become dry, as tree diversity overall increases the profitability and competitiveness of cocoa farms. Yet, it also shows that tree species diversity is important and not just levels of shade. In particular, agroforestry farms with fruit trees are more profitable and more competitive.

One key finding from the chapter is that hired labour costs were higher for low tree diversity cocoa plots compared to medium tree diversity plots. The implication is that cocoa agroforestry systems provide cocoa farmers with an avenue for reducing labour inputs and corresponding costs, e.g. related to manual weeding. Reducing hired labour means that saved costs may be used elsewhere, including to improve cocoa farming. Reduced household labour means more time for other activities, e.g. on-farm or off-farm diversification. The reduced labour demands of agroforestry systems are even more important given recent labour shortages resulting from the proliferation of competing economic activities in cocoa communities, e.g. small-scale illegal mining. As labour costs constitute the greatest percentage of cocoa farmers' total costs, labour-saving practices, associated with higher tree diversity plots in this study, provide avenues for both improving farmers' household incomes and reinvesting the savings from the avoided labour costs back into their farms.

Additionally, the integration of trees and crops that provide marketable products, such as timber and fruit trees, is important for incomes accruing from the agroforestry component of cocoa systems. This requires that the government and other stakeholders in Ghana's cocoa sector take a closer look at the challenges confronting cocoa farmers on restrictions limiting access to relevant tree seedlings and the use of timber trees planted and/or managed on their farms. On the other hand, low-diversity plots were associated with higher values of so-called environmental incomes, e.g. mushrooms, snails and honey, mainly for subsistence use. This is unexpected and may be due to low-diversity plots belonging more often to smaller farmers with a greater need for the collection of environmental products. Research and policy recommendations on cocoa farmers' choice of cultivation and management practices should thus bear in mind the kinds of benefits different farmers depend on.

Finally, due to variations in levels of resources and social networks, as mentioned above, cocoa farmers' access to and use of inputs such as land, fertilizer and agrochemicals differ. In addition, farmers' use of inputs varies based on differences in access and in how production is managed on plots. These factors will lead to disparate costs and benefits. The findings indicate that farmers who have more resources and better networks, leading to increased access to knowledge of better management practices and ability to afford inputs, choose to implement agroforestry systems. To encourage farmers who do not have these resources or networks to implement agroforestry, it is necessary to provide them with easier access to knowledge of good agricultural management practices, resources and inputs. Importantly, this needs to be tailored to match the specifics of the climate zone and the social position of the farmer.

5.6 Conclusion

The costs and benefits associated with different cocoa agroforestry systems compared to full-sun cocoa systems are important for household economic dynamics in cocoa farming communities. This chapter has explored these dynamics of household economies in Ghana across two broadly defined cocoa farming systems: those with low and high tree diversities respectively. It did so using cost and benefit parameters associated with the cost of inputs at market prices, the corresponding benefits to farmers, the cost of inputs to the economy and the corresponding revenues accruing to the state.

As this study has found, farmers who managed higher tree diversity on plots had correspondingly larger plots than those who managed low-diversity plots. This finding suggests that cocoa farmers' land resources could either directly or indirectly influence the degree and extent of on-farm tree diversification implemented. While certain input costs, such as insecticides, were higher in medium-diversity plots, the labour costs were substantially lower. Gross cocoa bean income per hectare was higher in plots with higher tree diversity, as was the income from timber and fruit trees. Combined, the net benefits favoured cocoa plots with a higher diversity of trees. The major conclusions from the chapter are that cocoa agroforestry systems offer cost-reductions and income-improving advantages and can help cocoa households free up labour for both on-farm and off-farm diversification activities.

Finally, to maximize benefits, recommendations and interventions must be tailored to take into account the specific management practices of each farming household, as well as the climate zone in which the location in question is situated. Additionally, incomes from agroforestry cocoa farms can be improved if restrictions concerning trees planted and managed on farms are addressed.

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