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The Economic Viability of Cocoa Crop Insurance in Ghana

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Abstract

This study was motivated by the fact that Ghanaian cocoa producers face lower yields than other main cocoa producing counties which in turn increases food insecurity for smallholder producers. In addition, low yields experienced by Ghanaian producers is a driving factor for forest degradation and deforestation as cocoa producers encroach further into previously undisturbed forests in efforts to increase their incomes. There are currently production methods to achieve higher yields readily available in Ghana; however, many producers choose not to adopt these methods because they are seen as too risky, or simply cannot adopt them due to financial/credit constraints. A common rationale for producers not adopting new technologies is that smallholder producers are risk averse and find it difficult to risk the little capital they may have. Smallholder producers frequently forego opportunities because they are vulnerable to adverse shocks such as crop failure that can move them into or deeper into poverty. Crop insurance could mitigate these risks but there is currently no crop insurance available for cocoa in Ghana. The Climate-Smart Cocoa (CSC) Working Group has proposed offering crop insurance for producers who follow the practices of CSC. This study estimated the average yields and yield variation (risk) between two groups of producers: (1) those who followed CSC practices: have training for efficient agrochemical input usage, used inorganic fertilizer, and practiced shade management (appendix 5) and (2) those who did not use CSC practices: no input-use training, no shade management, but did use inorganic fertilizer. The objectives of this study were: (1) to estimate yield differences among producers who follow CSC and non-CSC practices (2) estimate the impact of CSC practices on risk (i.e. yield variation) using percent chance of indemnity payments to producers and relative standard deviation of yield as measurements, and (3) estimate potential revenue gains through following CSC practices. To

investigate these objectives, a regression model was estimated to predict cocoa yields using historical yield for 19 districts in Ghana for the copping seasons of 2010-2011 and 2011-2012. Regression results were then used to identify average yields at the district level, yield variance, and fair-market premiums for producers who followed CSC practices and those who did not in 19 districts of Ghana. The results of the study show that producers who followed the CSC recommended practices had higher yields, less risk, and higher gross revenue in every district of the study. Meaning, producers can obtain higher incomes by following CSC on lands that are already under cocoa cultivation as well as income stability through crop insurance. By obtaining these benefits, producers are not allowed to encroach into undisturbed forests and remain in the CSC program. Therefore, CSC can not only increase farm income but also reduce deforestation.

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I. Introduction

Agriculture plays an important role in Ghana's economy, representing 21.5 percent of total GDP and 56 percent of the total labor force in 2013, including many smallholder farmers who are responsible for 80 percent of Ghana's agricultural production (CIA, 2014; Stutley, 2010). Approximately 54 percent of rural households in Ghana depend upon agriculture as their main livelihood (World Bank, 2008). Cocoa (*Theobroma Cacao*) is both the largest share of agricultural GDP and largest agricultural export in Ghana. Along with gold and remittances, cocoa is a top source of foreign exchange in Ghana (CIA, 2014). In 2011, Ghana exported a total of 697,236 tons of cocoa beans with a value of more than $2.2 billion USD, second only in the export of cocoa beans to Côte d'Ivoire on the international market (FAO, 2014a).

Ghana's large cocoa exports were obtained in spite of having one of the lowest yields per hectare in the world, less than 400 kg ha^{-1} (Dormon, Van Huis, Leeuwis, Obeng-Ofori, & Sakyi-Dawson, 2004; Ruf & Schroth, 2004; Stutley, 2010) as compared to neighboring Côte d'Ivoire where producers yield twice that amount; 800 kg ha^{-1} (Dormon et al., 2004). On-farm factors are responsible for low yields including the incidence of disease and pests; failure to adopt research recommendations such as adopting high-yielding hybrid varieties, control of capsids and insects with proper pesticide usage, shade management, and weed control; a low producer price, and an insufficient extension system (Dormon et al., 2004). Failure to adopt the recommended research procedures, such as inorganic fertilizer use, could be a result of limited access and or availability of fertilizer as well as producers not having access to credit. A study commissioned by Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Ghana Ministry of Food and Agriculture was conducted in Ghana in 2009 which showed that the majority of cocoa farmers did not have access to credit: seven percent had reported receiving a formal loan through a bank or credit union in the previous three years (2007-2009) and only 32.5 percent had received credit through informal sources. In total, credit was unavailable to more than 60 percent of cocoa farmers in Ghana during the three years of this study, 2007-2009 (Panin & Asante, 2009). However, even if credit was available, there are no guarantees that producers would take advantage of it as interest rates in low-income countries can be prohibitively high with large percentage of collateral needed as well. Poor landowners tend to be risk averse because they are the most vulnerable to adverse shocks (i.e. crop failure) that can move a household deeper into poverty from which they cannot easily escape from (IFAD, 2011a; Todaro & Smith, 2012; World Bank, 2014). The avoidance of adverse shocks typically equates to foregone opportunities (higher yields/incomes) for smallholder producers (Cole, Giné, & Vickery, 2013; Dercon & Christiaensen, 2011; Dercon, Gunning, & Zeitlin, 2011; IFAD, 2011a; Karlan, Osei, Osei-Akoto, & Udry, 2012; Morduch, 1995).

Historically, increased country cocoa production in Ghana had been the result of producers who had encroached further into virgin forests (Ruf & Schroth, 2004). Problems of encroachment have largely been driven by local land shortages as well as diminished productivity on cocoa farms as a result of diseases such as the fungal disease black pod (*Phytophthora megakarya*) and cocoa swollen shoot virus (CSSV) of the genus *badnavirus* (Berry, 1992). Moreover, producers opt to encroach into forests and make use of forest rent, the nutrient stock that has built up on the forest floor through time, rather than replant cocoa trees on existing farms (Ruf & Schroth, 2004; Ruf & Zadi, 1998). Cocoa is traditionally a shade crop, grown in the understory of a forest. Shade is important for cocoa trees because it helps to regulate solar radiation, air movement, and temperature. Cocoa trees are sensitive to all of these factors, especially at a young age (Wood & Lass, 1985). However, the introduction of new varieties in the 1950s that performed well in direct sunlight promoted the expansive practices of cocoa production in Ghana because the new varieties were not as sensitive to radiation, air movement, and temperature (Ruf & Schroth, 2004). This eliminated the need for shade trees and accelerated the problems facing Ghana's forests today of forest degradation and deforestation (Ruf & Konan, 2001; Ruf & Schroth, 2004; Ruf, 2011).

One way to mitigate forest degradation and deforestation is through the implementation of Climate-Smart Agriculture (CSA). The FAO (2013) defined climate-smart agriculture as, "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals." These practices have been adapted to cocoa, known as Climate-Smart Cocoa (CSC). The CSC approach to agriculture is endorsed by the Ghanaian Government and promoted by the Climate-Smart Cocoa Working Group which was established in 2011 (NCRC, 2012). CSC is a holistic approach to agriculture with four fundamental elements: (1) access to extension services and financial credit, (2) access to crop insurance with premiums that are paid through funds obtained through a carbon fund, (3) land use planning, and (4) data management and management, reporting, and verification (MRV). The first element of CSC, access to extension services and credit, is already available through other projects that exist in Ghana such as the Cocoa Abrabopa Association and Cocoa Livelihood Project (CLP) (R. A. Asare, 2014; WCF, 2014b). However, there is concern that only raising farm yields will not only fail to mitigate deforestation but could actually enhance it (R. A. Asare, 2014).

For this reason, the other elements are crucial in the success of CSC. All three remaining elements relate in some way to carbon funds such as the United Nation's Reducing Emissions from Deforestation and Forest Degradation (REDD+) collaborative initiative in low-income countries. REDD+ has a goal to significantly reduce emissions from deforestation and degradation (UN-REDD, 2011). Without proper land use planning and MRV, funds cannot be obtained through programs such as REDD+ as they require accurate accounting in carbon stocks. The funds that can potentially be obtained through a carbon stock could then be used to pay for crop insurance for the cocoa producers who follow CSC practices (R. A. Asare, 2014). It is through this holistic approach, including crop insurance, that deforestation can be mitigated while raising cocoa yields for Ghanaian producers through access to credit, access to inputs, and input use training.

One difficulty facing the holistic approach of CSC is that traditional crop insurance products can be expensive and many programs which are widely adopted, like those being offered in the United States, depend heavily upon subsidies from government (Barnett & Coble, 1999; USDA, 2011). In countries such as Ghana where a large portion of the population is still engaged in subsistence agriculture, subsidies are a problem for two main reasons: (1) it introduces inefficiencies in agricultural markets such as production of crops in ill-suited regions and (2) governments cannot consistently maintain the subsidies (Linnerooth-Bayer, Mechler, & Hochrainer-Stigler, 2011). Efforts have been made to develop new insurance products that are more affordable for low-income countries. One such product is weather-based index insurance (WII) that uses a proxy variable such as rainfall to determine when yields are low enough to initiate a payment from the insurer to the insured (IFAD, 2011b; Roberts, 2005; Stutley, 2010). This method reduces transaction costs compared to traditional insurance policies lime multiple-peril crop insurance (MPCI) because it does not require that an insurance adjuster from the insurance provider make any on-farm assessments (Stutley, 2010). As reduction in transaction costs are achieved the cost of an insurance premium (amount paid from the insured to the insurer to receive coverage from an insurance product) reduces and becomes closer to the cost of indemnity payments (amount paid from the insured to the insurer in the event of a loss). The situation where insurance premiums are equal to indemnity payments can be referred to as a fair-market premium.

This study identifies fair-market premiums at two different coverage levels for 19 districts in Ghana for two groups of cocoa producers: (1) those who followed CSC practices: have undergone input-use training, used inorganic fertilizer, and practiced shade management (appendix 5) and (2) those who did not use CSC practices: no input-use training, no shade management, but did use inorganic fertilizer. Regression analysis was performed using household-level data on input use, production, and farm characteristics provided from the World Cocoa Foundation (WCF) as part of their cocoa livelihood program (CLP). Data for cocoa in West Africa is scarce and the data used in this study are unique because it provides large spatial coverage with a sample size of 1,200 households in 108 villages, 19 districts, and five regions. The uniqueness of this study is further enhanced through the use of daily precipitation data provided by Awhere Incorporated. Precipitation data were available at a five arc-minute resolution; approximately equal to an on-the-ground weather station positioned every nine kilometers in Ghana. These unique data were then used to perform a regression analysis with cocoa yield (kg ha^{-1}) as the dependent variable. Regression results were used to simulate yields in @RISK (Palisade Corporation, 2014) for Ghanaian cocoa producers at the district level. The objectives of this study were: (1) to investigate yield differences among producers who follow CSC and non-CSC practices (2) investigate the impact of CSC practices on risk using percent chance of indemnity payments to producers and relative standard deviation as measurements, and (3) investigate potential revenue gains through following CSC practices.

II. Literature Review

A. Cocoa in Africa

Successful Cocoa (*Theobroma Cacao*) cultivation first occurred in West Africa in 1822 when production was introduced to the small island of Príncipe. From there, cultivation spread to other islands in the archipelago: São Tomé in 1830 and Bioko in 1854 (Nava, 1953). Cocoa cultivation in São Tomé depended heavily on labor from Angola and Nigeria. As such, Fernando Po eventually introduced cocoa cultivation to Nigeria in 1874 (Ayorinde, 1966). While widespread cocoa cultivation failed to develop in Nigeria, cultivation was more widely accepted when the amazon-basin originating *amelonado* cocoa bean was introduced to Ghana in 1879 (Ayorinde, 1966). Although cocoa cultivation had been previously introduced to Ghana by Basel missionaries as early as 1815 (Cocobod, 2014), it was met with little success (Wanner, 1962). Much of Ghana's success in cocoa was a result of its ambitious farmers who were already well versed in the ways of commercial markets and trade through their experience with palm oil, oil palm kernels, and rubber (Berry, 1992). With their experience, farmers quickly accepted and expanded the cultivation of cocoa and developed cocoa trade (Hill, 1963).

West Africa was responsible for approximately 63 percent of cocoa production in the world in 2012, representing four of the top five largest cocoa-producing countries: (1) Côte d'Ivoire, approximately 33 percent of global production; (3) Ghana, approximately 18 percent of global production; (4) Nigeria, approximately eight percent of global production; and (5) Cameroon; approximately five percent of global production (FAO, 2014b). A map of African cocoa-producing countries in 2012 can be seen in figure 1.

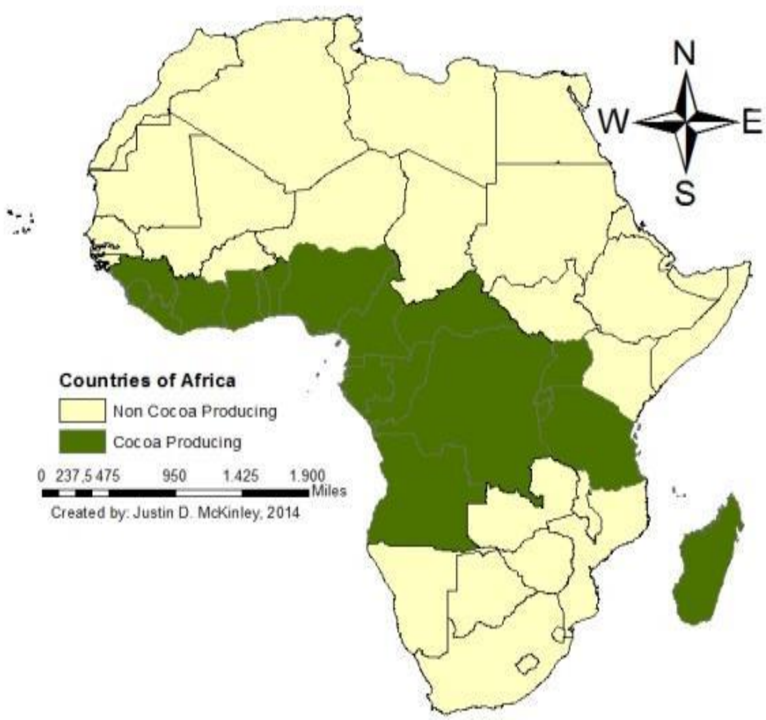

Figure 1. Cocoa-growing regions of Africa (FAO, 2014b)

B. Cocoa in Ghana

Cocoa was originally cultivated in Ghana, named the Gold Coast at the time, in the Akwapim Mountains located in the Eastern Region. From there cultivation began a westward migration in 1892 and by 1910 was widely adopted throughout the southern tropical portion of Ghana (Hill, 1963). Adoption and expansion was so successful that for a time, Ghana was the world's largest exporter of cocoa (Berry, 1992). In the 1920s there was an endemic outbreak of cocoa swollen shoot virus (CSSV) of the genus *badnavirus* in the Eastern Region. The outbreak in Ghana in 1936 was the first instance of CSSV ever reported and the disease is still endemic to Ghana and Nigeria (Wood & Lass, 1985). CSSV is spread by mealy bugs, *Planococcus citri* (Wood & Lass, 1985) and can kill the amazon-basin originating variety *Amelonado* seedling within a few months of infection (Wilson, 1999). There is no cure for the virus and the disease can only be managed through the destruction of virus sources (infected trees) although some attempts have been made to control the disease vector (mealy bugs) with no success (Wood & Lass, 1985). The CSSV outbreak reduced production in the Eastern Region and promoted the westward expansion of cocoa cultivation in Ghana (Berry, 1992). The spread of cultivation followed the moist semi-deciduous forest of the Brong-Ahafo and Ashanti Regions as the climate, particularly precipitation, were optimal for cocoa production (Berry, 1992). The importance of precipitation on cocoa farms is of special importance in Ghana, and globally, because most farms do not have irrigation systems. A recent study conducted in Ghana that spanned 2,810 households, 335 villages, and all five regions that were used in this study found that 94 percent of all cocoa farms surveyed did not have irrigation (Hainmueller, Hiscox, & Tampe, 2011). Furthermore there are only 30,000 ha of irrigated croplands in Ghana; which represents one half of one percent of total cropland (Stutley, 2010). A map of cocoa-producing regions of Ghana is presented in figure 2.

Figure 2. Political boundaries of cocoa-growing regions of Ghana
Note: cocoa is not produced in all areas of each region

Cocoa Seasons in Ghana

Before a cocoa tree can produce a pod (which contains the cocoa beans), the cocoa flower must first be pollinated and the pod must mature (D R Glendinning, 1972; Wood & Lass, 1985). In Ghana, the flowering period occurs roughly from early January to late May and the pod maturation period occurs roughly from early June to late October. The main harvest period for cocoa generally occurs from early September to late February of the following year. In addition to the main cocoa harvest, a minor or light harvest also occurs from mid-May to mid-July (*personal communication Dr. S.T. Ampofo, Cocoa Abrabopa Association*). Cocoa pods require approximately five months to mature for harvest (D R Glendinning, 1972). As such, the main harvest period corresponds with the rainy season of southern Ghana which typically begins in April. Preferred cocoa-growing precipitation is between 1,500 mm and 2,000 mm per annum (ICCO, 2013). Annual precipitation below 1,250 mm is unfavorable because the tropical temperatures (also required for cocoa production) cause evaporation from the tree to be greater than the precipitation received in this environment (Wood & Lass, 1985). Additionally, annual precipitation above 2,500 mm greatly increases the incidence of fungal diseases such as black pod, *Phytophthora megakarya,* and witches' broom, *Crinipellis pernicosa* formerly known as *Marasmius pernicosa* (Wood & Lass, 1985). From a physiology standpoint, cocoa also requires minimum temperatures of between 18^{o}-21^{o} Celsius and maximum temperatures of between 30^{o}-32^{o} Celsius (ICCO, 2013).

Cocoa Production Trends in Ghana

After more than a half-century of production, Ghana reached a production peak of 580,000 tons in 1965, but by 1977, production had fallen to a low of 324,000 tons (FAO, 2014b). A major reason noted for the decline was that many trees had been planted 30-40 years previously and were past their most productive stages (Amanor, 1996). Cocoa is most productive (from a yield standpoint) between 15 and 25 years after planting, although cocoa may have a profitable lifespan of 50 years, yield declines and production cost increases are both realized in the 26th year (Montgomery, 1981). The World Bank (1975) cited five primary reasons for Ghanaian producers' unwillingness to invest in cocoa at the time of their study: (1) low producer price set by the government, (2) lack of technical assistance to producers, (3) inadequacy of input distribution system for agro-chemical inputs, (4) excessive amount of over-aged trees, and (5) the lack of a comprehensive development plan for the cocoa sector.

The declining cocoa production in Ghana was recognized by the Ghanaian government when in 1970 the government was issued an $8.5 million USD loan from the World Bank to inject capital in to a diminishing cocoa sector. From 1970 to 1975 money was used to replant and rehabilitate 35,207 hectares of cocoa in Suhum that had been neglected or abandoned after the CSSV endemic (World Bank, 1975).

After the rehabilitation efforts were complete in the Suhum region, a similar project was initiated in the Ashanti Region. In 1975, a total of 12,140 hectares of cocoa farms were replanted at a cost of $14 million USD which was again acquired through a World Bank loan (World Bank, 1975). The report that was constructed at the conclusion of the Ashanti project cited many troubles that are still facing the cocoa industry today. These troubles include extension systems with low saturation, low yield, aged trees, and minimal input usage for items such as fertilizer.

Despite the difficulties facing the Ghanaian cocoa industry, Ghana was still the third largest producer of cocoa in the world in 2012 (FAO, 2014b). This production level was achieved in Ghana with a yield of less than half that of neighboring Côte d'Ivoire: less than 400 kg ha $^{-1}$ and 800 kg ha $^{-1}$, respectively (Dormon et al., 2004). Dorman et al. (2004) attributed the low yields to incidence of disease and pests, failure to adopt research recommendations, a low producer price, and an insufficient extension system. The responses from government and non-governmental agencies (NGOs) to address these deficiencies in the cocoa sector include improving access to high-yielding hybrid cocoa varieties, providing trainings and information to farmers, and providing farmers with access to credit for inputs (R. A. Asare, 2014).

C. World Cocoa Foundation Cocoa Livelihoods Program

One existing program that attempts to address these deficiencies is the Cocoa Livelihoods Program (CLP) from the World Cocoa Foundation (WCF). The program provides training and information to farmers as well as providing them with access to credit. WCF is an NGO based out of Washington DC, with financial support from its cocoa industry members. WCF has programs in Central and South America, Southeast Asia, and West Africa (Norton, Nalley, Dixon, & Popp, 2014). WCF was founded in 2000 with a commitment to creating a sustainable cocoa economy by putting farmers first, promoting agricultural and environmental stewardship, and strengthening development in communities that produce cocoa (WCF, 2014a). One way in which WCF has worked towards these commitments is through the implementation of the CLP program in 2009 (WCF, 2014b). Since 2009, the CLP has operated in five West African countries: (1) Cameroon, (2) Côte d'Ivoire, (3), Ghana, (4) Liberia, and (5) Nigeria (WCF, 2014b). The program has three main objectives: (1) Improve marketing efficiency in the cocoa sector; (2) improve on-farm cocoa production, efficiency, and quality; and (3) improve the competitiveness of farmers on diversified cocoa farms (WCF, 2014b).

An integral part of CLP's efforts to meet these objectives has been to offer training programs to farmers. Three such programs were offered: (1) farmer field school (FFS), (2) farmer business school (FBS), and (3) input promoter (IP) (Norton et al., 2014) . In Ghana, these training programs were taught by different CLP-partner organizations. Two of the three programs focus on agronomics while the other focuses on the business aspects of cocoa production. FBS was taught by Gesellschaft für Internationale Zusammenarbeit (GIZ) and has a primary goal of changing the producer's perception from farming as a lifestyle to farming as a business. They provided the financial tools necessary to balance a budget as well as providing an understanding of financial services available (Norton et al., 2014). The other two training programs were taught by the Ghana Cocoa Board (Cocobod). Cocobod is the sole exporter of cocoa in Ghana and is also responsible for subsidies (agro-inputs: fertilizer, pesticide, fungicide) and cocoa extension services to Ghanaian cocoa producers (Kolavalli & Vigneri, 2011).The first training program of CLP, FFS, focused on improving basic agronomic skills to better manage the health of cocoa trees. The training program provides information on pest and disease management, replanting, estimating farm size, safety practices, pruning techniques, fermentation methods, and fertilizer use (Norton et al., 2014). The third and final training program, IP, is also taught by Cocobod. During this capstone course, producers use the skills that they have gained from FFS and FBS and proceed with IP to learn more about efficient and effective agro-chemical input use. Upon completion of the IP training, farmers should know proper farm management techniques, how to budget properly and coordinate financial resources, and how to safely use chemical inputs. Furthermore, upon successful completion producers qualify for credit through the CLP program (Norton et al., 2014). Results of Norton et al. (2014) show that the CLP, and in particular IP training had been successful in increasing yields for targeted cocoa producers in Ghana by 75.24 percent. By the end of phase one of the CLP program, a total of 106,000 farmers have been trained throughout participating West African nations: Cameroon, Côte d'Ivoire, Ghana, Liberia, and Nigeria (WCF, 2014b). Although CLP addresses many of the problems facing cocoa producers today it fails to address one of the largest environmental problems facing the cocoa industry today, deforestation.

D. Deforestation in Ghana

Agroforesty, a system in which trees and shrubs remain alongside agricultural crops can be useful in managing climate and pests when applied to cocoa production (R. Asare & David, 2011). For example, shade trees on a cocoa farm can support up to 180 different bird species that can help to control insects that spread disease (R. Asare & David, 2011). The effect of shade on cocoa is extremely complex as it affects several important factors in cocoa production: solar radiation, air movement, temperature, relative humidly, and soil moisture (Wood & Lass, 1985). A study conducted in Ghana by Murray (1954) found that cocoa yields without nitrogen fertilizer had increased when light levels were decreased up to 50 percent. However, after 50 percent cocoa yields declined. This same study found that when nitrogen fertilizer was used that cocoa yields increased until the 75 percent light level where yields plateaued and then slightly decreased until full sun exposure (Murray, 1954). Subsequent studies also found that shade reduction increases yields when nitrogen fertilizer is applied (Ahenkorah, Akorifi, & Adri, 1974; Gockowski & Sonwa, 2008, 2011). Shade reduction increases cocoa yields because more leaves are produced higher sunlight which significantly stimulates flowering of the cocoa tree and results in more cocoa pods and thus more cocoa beans (Asomanin, Kwakwa, & Hutcheon, 1971;

Boyer, 1974; Cunningham, Smith, & Hurd, 1961). Producers' yield gain from reduced shade is a driver of forest degradation and deforestation. Another driver is that producers encroach into forests in order use the nutrient stock that has built up on the forest floor through time, known as forest rent (Ruf and Schroth 2004; Ruf and Zadi 1998).

Land tenure can also play a role in deforestation. In much of West Africa, including Ghana, a customary means of claiming land has been the *doit d'hache*, or, "right of the axe" (R. A. Asare, 2010). Through this customary means, land and user rights to a bundle of resources can be obtained on lands through the act of clearing vegetation that currently resides on the lands and then planting trees or crops in place of the recently cleared vegetation (R. A. Asare, 2010). However, custom dictates that land cannot be claimed without proper authorization. For instance in share cropping, if lands are not cleared within a given time period the sharecropper's right to the land is nullified (R. A. Asare, 2010). Besley (1995) argues that more secure land tenures should have a positive effect on tree planting. However, data from Ghana suggest that the security of land tenure does not play a significant role in willingness to plant tree crops (Otsuka, Quisumbing, Payongayong, & Aidoo, 2003). Meaning, even producers with less secure land tenure are willing clear lands and plant new trees such as cocoa.

Links between deforestation and cocoa were seen as early as the 1920s when farmers in São Tomé attempted to increase yields by reducing shade cover (Navel, 1921). The first substantial expansion of cocoa cultivation – and concurrently deforestation – in Ghana occurred in the 1930s and 1940s as farmers afflicted with CSSV abandoned their failing farms in the Eastern Region to move westward. From the Eastern Region, farmers followed the semi-deciduous forests – which were ideal for cocoa production – into the Ashanti Region and then the Brong-Ahafo Region. During the expansion of the 1930s and 1940s, production in the Eastern Region fell by 60 percent but those losses were largely offset by the new production in Ashanti and Brong-Ahafo (Berry, 1992).

From the 1940s to the 1980s, the preferred means of cocoa production is what can be referred to as a ‘complex cocoa agroforest,’ meaning, cocoa is planted in the understory of a forest and then the canopy is thinned around the cocoa as it ages (Ruf, 2011). This practice is integrated with the forest system and likely prevailed because technologies, such as chainsaws, which made the removal of large trees much easier, were not yet available in Ghana. Until the 1950s, *Amelonado* and *Trinitario* cocoa were the only available varieties in Ghana. These varieties were prone to disease, took as long as eight years to bear fruit, and were resistant to few pests (Edwin & Masters, 2005). New Amazonian varieties from Peru arrived in Ghana in the 1950s and outperformed locally-used varieties in time to bear fruit and disease resistance. Furthermore, the new varieties had the advantage of bearing fruit two times per year, provided overall higher yields, and performed very well in no-shade environments (Ruf & Schroth, 2004). By 1961, an estimated 60,000 ha had already been planted to the recently introduced Amazonian varieties (Edwin & Masters, 2005; D. R. Glendinning & Edwards, 1962).

Through the 1950s and 1960s, cocoa rose in popularity to become the most important cash crop in the agroforest system in Ghana. The movement of the farmers also brought about changes in economic, social, and environmental landscapes. In particular, increased competition among cocoa producers, localized land shortages, cocoa diseases, and fluctuations in the cocoa market drove farmers further and further into previously undisturbed remote forest landscapes to cultivate cocoa (Okali, 1983).

Attempts to reduce pressures on forest landscapes occurred in the 1970s with World Bank projects to rehabilitate the depleted and mostly abandoned cocoa regions of Suhum and Ashanti.

By the start of the Ashanti project in 1975, cocoa cultivation was believed to occupy between 1.2 – 1.8 million hectares and was responsible for employing around 2.5 million people; 25 percent of Ghana's population (World Bank, 1975). Until this rehabilitation project, farmers' responses to disease, land shortages, and other market factors was to encroach further into virgin forests (Ruf & Schroth, 2004).

In the early 1980s, a series of subsequent drought years led to large-scale fires in 1983 throughout forest reserves of the transitional zone of Ghana as well as cocoa-producing regions, commonly referred to as "bush fires". These fires affected thousands of hectares of cocoa in the prime semi-deciduous forest belt (Edwin & Masters, 2005), decreasing the area of land planted to cocoa in Ghana (figure 3). Amidst the environmental challenges being faced by cocoa producers, they were also faced with political challenges. During the same year as the bush fires, Ghana was also adopting an IMF structural adjustment program. As part of the program requirements, subsidies for fertilizers and pesticides were ended and cocoa extension services were eliminated for farmers (Edwin & Masters, 2005). In the absence of government assistance, cocoa farming became less profitable for many farmers, particularly those with older farms and as a result cocoa expansion declined (Benhin & Barbier, 2004). Many farms during this time diversified their agricultural production. Some farmers even opted to completely abandon cocoa and removed their trees. Others still moved in to growing other crops such as pineapple, banana, coconut, and oil palm (Amanor, 1996). During this period, production of cocoa fell to 158,000 tons (FAO, 2014b).

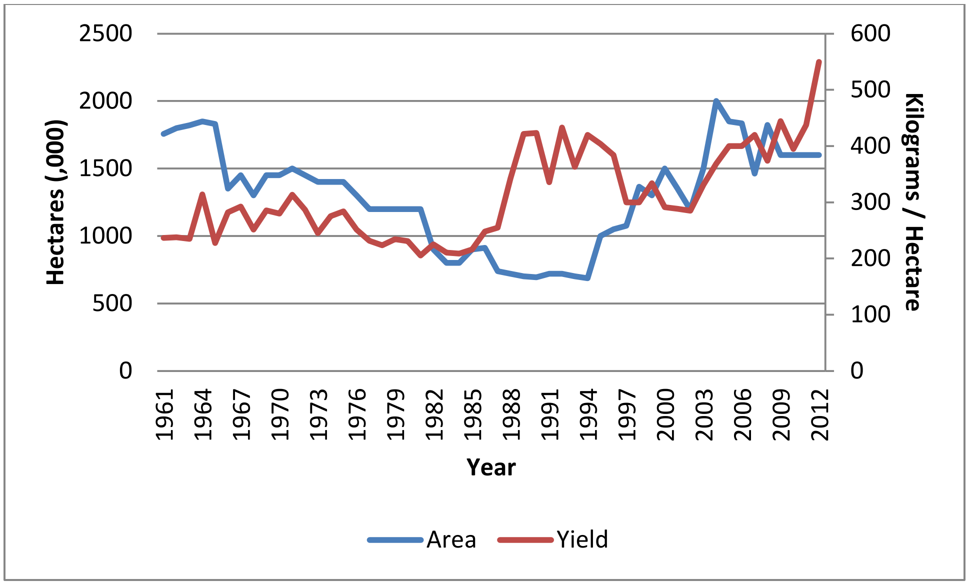

Figure 3. Cocoa yield and area harvested in Ghana (1961-2012) (FAO, 2014b)

The waning of the cocoa industry leading up to the 1990s was met with intervention through the availability of new cocoa varieties and higher farm gate prices. With these interventions came a sharp increase in expansion (figure 3) particularly in the western portion of the country, including expansion in to moist evergreen forests that were not as well suited for cocoa production as the semi deciduous forests. Cocoa production saw increases of four percent per annum from the late 1980s to the early 2000s (Abenyega & Gockowski, 2003).

Since 2000, production of cocoa has consistently increased in Ghana (FAO, 2014b). These increases in production are a combination of further expansion and higher yields (figure 3). However, the sharp increase in yields (calculated as country production divided by country area harvested) starting in 2010 could possibly have been attributed to smuggling of cocoa from neighboring Côte d'Ivoire. The New York-based firm Commodities Risk Analysis estimated that between 75,000 and 100,000 metric tons of cocoa beans were smuggled into Ghana from Côte d'Ivoire during the 2010 – 2011 harvest season (McLure, 2010). Historically, cocoa smuggling has occurred in the opposite direction, Ghana to Côte d'Ivoire with an estimated peak of approximately 20 percent of Ghana's cocoa production being smuggled into Côte d'Ivoire in the 1980s (Kolavalli & Vigneri, 2011). More recently, a higher producer price in Ghana and political unrest in Côte d'Ivoire has caused the flow of smuggled cocoa beans to be reversed (McLure, 2010). Meaning, the yield increases shown in figure 3 are dubious. The area harvested for cocoa however is not. The expansion from the year 2000 onward has resulted in further forest degradation and deforestation and intrusion into forest reserves (R. A. Asare, 2014). Visual representation of deforestation in the west of Ghana, including parts of Western, Brong-Ahafo, and Ashanti Regions can be seen in figure 4. Major deforestation has occurred from 1986 to 2011 (4.3 percent per annum), making this region a major focus for environmental ecosystem services (FCPF, 2014).

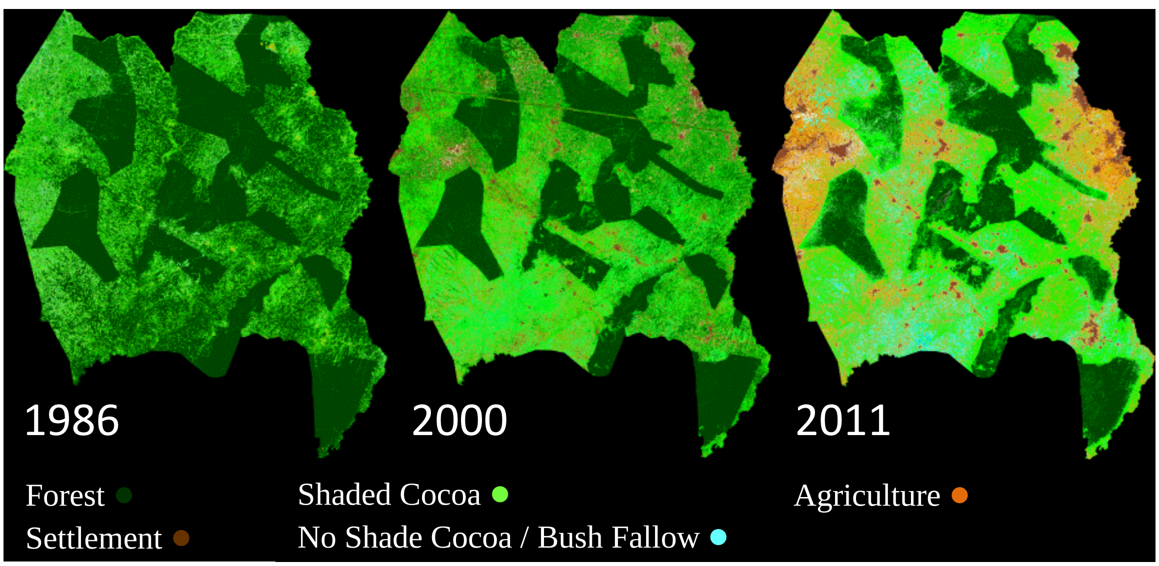

Figure 4. Deforestation maps in Ghana 1986-2011 (FCPF, 2014)

Opportunities exist to reduce forest degradation and deforestation in Ghana. One such example is the United Nation's Reducing Emissions from Deforestation and Forest Degradation (REDD+) collaborative initiative in low-income countries. REDD+ has a goal to significantly reduce emissions from deforestation and degradation (UN-REDD, 2011). Early in the stages of REDD+ readiness process, agriculture, and specifically cocoa production, had been found to be a significant factor in the growth of forest degradation and deforestation in Ghana (R. A. Asare, 2014). While agriculture's role in deforestation was recognized in Ghana, so too was the importance of agricultural income to smallholder farmers. The link with these two concepts as well as the realization of the role that smallholder agroforestry producers could play in carbon sequestration and abatement of deforestation/ degradation in the face of global climate change led to the creation of the Climate-Smart Cocoa Working Group (R. A. Asare, 2014).

E. Climate-Smart Cocoa

Climate-smart cocoa (CSC) is an extension of climate-smart agriculture (CSA). The FAO (2013) defined climate-smart agriculture as, "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals." The pillars of climate-smart agriculture are presented in figure 5. CSA practices have economic and environmental benefits encompassed in a forward-looking approach in order to not only achieve gains, but also stability in food production and prices (FAO, 2013). Although the five pillars shown in figure 5 are crucial in the success of CSA, Asare (2014) argues that in the case of CSC, CSA initiatives also need to be linked by a network that provides access to financial, human, and social capital. Furthermore, for the recommended procedures of CSA to be adapted to CSC, risk mitigation must also be offered to cocoa producers (R. A. Asare, 2014; NCRC, 2012).

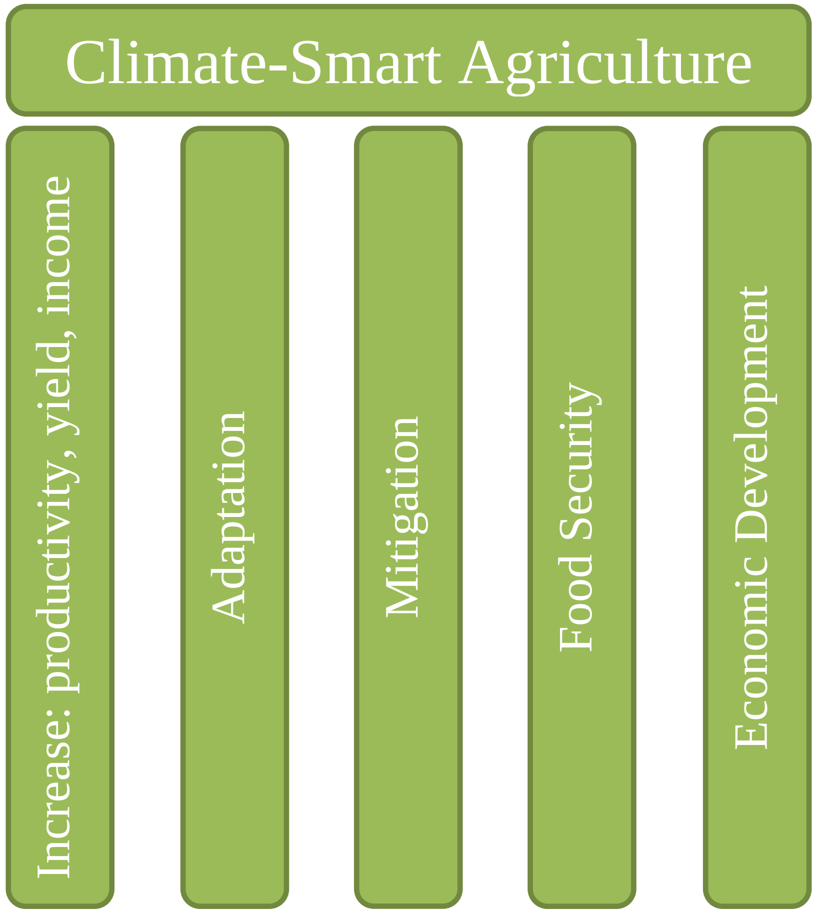

Figure 5. Pillars of climate-smart agriculture (R. A. Asare, 2014).

As the concept of CSA was gaining global recognition in 2010 and 2011, the Climate-Smart Cocoa Working Group was established to explore the application of climate-smart agriculture in Cocoa. The CSC working group was initiated by Forest Trends and their local partner in Ghana, the Nature Conservation Research Centre (NCRC), with a goal to define strategies to reduce the illegal entry of cocoa farms into forest reserves (R. A. Asare, 2014). Over the next year, NCRC worked with partners from the private sector (cocoa buying companies, insurance companies, and banks) and the public sector to think critically about how to combat the problems of deforestation in cocoa farming (R. A. Asare, 2014). The initial output of the CSC working group was a report entitled, "The Case and Pathway toward a Climate-Smart Future for Ghana" (NCRC, 2012).

The CSC Working Group report concluded that cocoa production in Ghana was not on a sustainable course due to three primary factors: (1) changes in temperature and rainfall patterns due to climate change, (2) primary emphasis on intensification without thought of how production increases could further promote expansion and deforestation, and (3) a total lack of land use planning (NCRC, 2012). In addition, the report made recommendations towards a "desired future state" of cocoa production and forest systems: (1) reduce the greenhouse gas emissions resulting from cocoa expansion into forests as well as the conversion of other lands with high to medium carbon stocks, (2) increase carbon stocks in low-shade cocoa production systems, (3) improve cocoa producer livelihoods by increasing cocoa yields and access to mitigation and adaptation benefits, (4) demonstrate the importance of land-use planning for CSC production at the community level, and (5) promote biodiversity and ecological resilience within cocoa-farming landscapes (NCRC, 2012).

NCRC (2012) identified a holistic approach of five key areas of improvement that need to be implemented together in order to reach the desired future state of cocoa production in Ghana as, "(1) extension: enhance productivity and economic returns in CSA manner – inputs, extension services, best practices, and financial products, (2) credit: de-risk cocoa farming activities linked to CSA strategies through increased access to credit, (3) yield insurance: de-risk cocoa farming activities linked to CSA strategies through development of specialized cocoa farm insurance products, (4) landscape planning: reduce cocoa expansion into high carbon landscapes and increase carbon values on farm landscapes- test solution for land tenure and benefit sharing, and (5) measuring, reporting and verification (MRV): manage and link data related to CSA approaches." The first two elements of CSC, access to extension services and credit, are currently available through existing projects in Ghana such as the Cocoa Abrabopa Association and Cocoa Livelihood Project (CLP) (R. A. Asare, 2014; WCF, 2014b). However, the CSC Working Group is concerned that only raising yields will not only fail to decrease deforestation and forest degradation but could even enhance it (R. A. Asare, 2014).

The approach of CSC in Ghana varies slightly from the recommended CSA pillars in figure 5. Specifically, the CSC approach focuses just on three of the five pillars: (1) mitigation combined with data management and MRV; (2) increased yield based upon accessible extension services, inputs, and risk-mitigation services as well as focus on growing cocoa in appropriate soil types; and (3) economic development that centers upon land-use planning (R. A. Asare, 2014). In the case of CSC in Ghana, the remaining two pillars – food security and adaptation – are believed to result from the successful implementation of the other three pillars.

Adaptation and mitigation strategies are of particular importance for a crop with such finite physiological constraints as cocoa. With the variability of rainfall and temperatures both likely to increase as a result of climate change, the need for the adaptation and mitigation techniques presented in CSC are becoming more urgent (R. A. Asare, 2014). Cocoa production systems that have little to no shade are more susceptible to reductions in rainfall and increases in temperature than complex agroforests (Anim-Kwapong & Fimpong, 2008). Furthermore, complex agroforests are diminishing in West Africa (Ruf & Schroth, 2004; Ruf, 2011) and forest degradation and deforestation persists throughout the high forest zone of Ghana as low- or no-shade production systems are favored over complex agroforest (R. A. Asare, 2014). Shade-grown cocoa can reduce the encroachment of cocoa farming into forests and other protected lands (R. Asare & David, 2011). Concurrently, demand for socially responsible cocoa, such as fair-trade cocoa is increasing (FAO, 2009). In the USA, demand for socially-responsible cocoa caused imports of fair trade certified products to increase by 67% from 2009 to 2010 bringing the total imports of fair trade certified products from 2002 to 2010 to over 16 million pounds (Fair Trade USA, 2011).

The demand for socially-responsible cocoa combined with the need to protect the forest landscapes of Ghana provides a unique opportunity for the Ghanaian cocoa industry to proceed with CSC. Implementation and adoption of CSC management practices need to occur at the farm level. For this adoption to take place, farm-level resources need to be available (R. A. Asare, 2014). These productivity increases of existing cocoa farms, coupled with community-based, landscape level land-use planning, can help to abate the expansive practices of converting forest landscapes to cocoa farms. The focus of this strategy is to provide producers with physical (distribution) and financial (credit) access to farm inputs such as chemical fertilizer, hybrid germplasms, and agro-chemicals in order to increase yields. Concurrently, as a way to provide incentives to follow these practices by mitigating the financial risks that producers may bear as a result of taking credit to purchase inputs, crop insurance needs to be provided to producers.

Many of the recommended practices for CSC have been available to producers in Ghana for over 30 years (R. A. Asare, 2014). Although the practices have been available, the adoption has been low. Asare (2014) suggests three factors limiting adoption: (1) limited or absent extension and training opportunities, (2) costs and risks associated with the adoption of capital and labor intensive recommended practices with no yield guarantee, and (3) persistent lack of access to essential economic and agronomic resources. Therefore, to enable large-scale adoption, CSC recommended practices need to be supported by access to credit, to afford inputs; training, to use inputs effectively and efficiently; and insurance, to mitigate risks associated with increased expenditures on farm inputs (R. A. Asare, 2014). Most elements of the enabling recommendations are already available in Ghana, albeit on a limited scale and in isolation. The exception however is the absence of crop insurance for cocoa which is not currently available (R. A. Asare, 2014), and the absence of publically available, sector-wide data, hence a recommendation for improved data management and MRV. Data management and MRV are also important to access funds from REDD+ or ER-PIN as these programs require accurate carbon accounting to receive payment. The payments obtained through carbon funds are also important for crop insurance in CSC because the CSC Working Group suggests paying for insurance premiums for producers following CSC practices with the payments obtained from the carbon funds (NCRC, 2012). The CSC Working Group believes that by incentivizing producers to follow CSC practices with crop insurance, reduction in forest degradation and deforestation can be obtained (R. A. Asare, 2014). It is through this holistic approach to cocoa production in Ghana that deforestation can be mitigated while raising cocoa yields for Ghanaian producers through access to credit, access to inputs, access to crop insurance, and input use training.

F. Crop Insurance

Overview

Crop insurance is a mechanism in which agricultural producers can attempt to mitigate risk. A consolidated glossary of risk management terms from the United States Department of Agriculture (USDA) Risk Management Agency (RMA) can be found in appendix 4.

Generally, crop insurance can be divided into two main categories: crop yield insurance and crop revenue insurance (Barnett & Coble, 1999). In crop yield insurance, indemnities are paid to producers when crop yield falls below the insured yield level that is based upon actual production history (APH) (USDA, 2011). APH is used to determine the expected yield of the producer by taking an average of at least four years of actual verifiable production records (Barnett & Coble, 1999). In the United States, when the producers' own yields are not available an average of yields from neighboring areas are used (USDA, 2011). Crop revenue insurance is very similar to crop yield insurance but it also provides revenue protection by guaranteeing commodity prices (Barnett & Coble, 1999; USDA, 2011).

In the United States, crop insurance is subsidized for coverage at the catastrophic level, known as CAT coverage (Barnett & Coble, 1999). Producers must pay an administrative fee to participate in CAT coverage but the government pays the entire premium (USDA, 2011). Producers have the option to purchase additional coverage beyond CAT coverage, which only guarantees 50 percent of average yield (Barnett & Coble, 1999). The premium on additional coverage - known as buy-up coverage – is partially paid by the producer but is still 50 percent subsidized by the government for most coverage levels in excess of 50 percent (USDA, 2011).

Insurance products allow insured individuals to share risk with a large pool of other policy holders (Barnett & Coble, 1999). Risk can be either idiosyncratic or systemic (World Bank, 2014). In agriculture, an idiosyncratic risk is an isolated weather event such as hail damage. If one farmer experiences losses as a result of hail it is highly unlikely than this weather event will be shared by many farmers in a region (Barnett & Coble, 1999). Systemic risk however is experienced by many farmers in a region. Systemic risks are weather events such as drought that affects entire regions rather than individual farmers (Barnett & Coble, 1999). Difficulties arise in crop insurance because many risks in agriculture are systemic (Barnett & Coble, 1999).

The heterogeneous nature of risk (i.e idiosyncratic and systemic) means that not all risks are insurable. Rejda (1995) reports six conditions that experts have identified over time that make risk insurable: (1) Risk must have determinable and measurable loss. It must be possible to determine the time and magnitude of a loss. (2) Risk must be pooled among a large, roughly homogenous group of individual exposure units. A large pool allows for more accurate prediction of expected losses through the statistical law of large numbers. (3) Only seemingly random occurrences of accidental and unintentional loss should be insured. (4) Risk should not have positive correlation across exposure units as it has the potential of catastrophic loss to the insurer. When positive correlation exists among exposure units the statistical law of large numbers does not hold because convergence does not occur to the expected sample mean when sequences of variables are not random. (5) The frequency and severity of a loss must be calculable to establish a premium rate. (6) The premium must be economically feasible so purchasers can afford the insurance product. In reality, insurance products deviate from these ideal conditions. For example, the systemic risk of weather events such as drought associated with crop insurance violates condition four (Barnett & Coble, 1999).

To protect themselves against catastrophic losses, private insurance companies will typically load premium rates (i.e. charge in excess of costs) in order to build reserves to use in the event of indemnity payments exceeding premiums collected in a given year (Barnett & Coble, 1999). Other precautions are taken to ensure that the ideal conditions to insure risk hold. Moral hazard violates condition three. Moral hazard occurs when policyholders decisions become more risky and cause the chances of losses to increase as a result of purchasing insurance (Barnett & Coble, 1999; IFAD, 2011b; Laffont, 1995; Roberts, 2005; World Bank, 2014). Deductibles and co-payments are used to mitigate moral hazard (Barnett & Coble, 1999). A deductible is either set as a percentage of the insured sum or a set monetary amount. This is the first part of a claim for an indemnity payment and is paid by the policyholder (Roberts, 2005). A co-payment can be used in addition to a deductible and represents a percentage of a claim that the insured individual is responsible for paying (Barnett & Coble, 1999). A more recent method for reducing moral hazard is the use of index-based insurance (IFAD, 2011b; Mobarak & Rosenzweig, 2013; Smith & Watts, 2009). Index insurance is a more recent type of insurance product that has indemnity payments based off of certifiable occurrences such as rainfall or other weather events (Roberts, 2005).

Multiple-Peril Crop Insurance

Multiple-peril crop insurance (MPCI) has been available in the United States since the 1930s (USDA, 2011). This insurance type provides coverage against a variety of natural occurrences such as hail or fire damage (Barnett & Coble, 1999). Policy holders will pay for additional coverage for different perils. Although available since the 1930s, MPCI was operated on a limited basis until public / private partnerships in the 1980s provided subsidies to the MPCI packages (USDA, 2011). MPCI became more popular after regular disaster payments were ended in 1981 (USDA, 2011) The introduction of fully subsidized CAT coverage in 1994 increased MPCI coverage to over 200 million acres in the United States (USDA, 2011).

MPCI products guarantee a level of expected yield rather than measure the damage caused by a loss event and typically insured yields are in the range of 50 to 70 percent of historical average yields (Roberts, 2005). MPCI is advantageous in that it provides coverage for more perils than a typical index-based insurance product (IFAD, 2011b). In addition, MPCI is also well-suited for perils in which crop loss is difficult to measure (Roberts, 2005). An example of this in cocoa production would be an instance of black pod fungus, *Phytophthora megakarya*. The prevalence of the fungus is not known on a farm. A black pod infection could be affecting as few as one tree or as many as all of the trees on the farm. MPCI is also well-suited for perils that have an impact over time (Roberts, 2005). An example of this in cocoa would be CSSV which kills the tree and requires indemnity payments for losses in the initial year as well as payments for future years until the replacement tree can bear fruit. MPCI is however expensive to operate and not suitable for smallholder agriculture in low-income countries (IFAD, 2011b). Much of the expense in MPCI comes from high transaction costs. Usually, it is necessary to complete pre-inspections on each insured farm as well as in-field measurements to assess yield loss (Stutley, 2010). Further exasperating the problem is that transaction costs increase in low-income countries where information is highly imperfect (Todaro & Smith, 2012). Premium are typically high in MPCI because of high losses (with high moral hazard) and administrative costs that are often exceeding 10 to 15 percent of premiums (Stutley, 2010). Most MPCI programs operate at a loss and are dependent upon government subsidy (Roberts, 2005; Stutley, 2010).

<u>Weather-Based Index Crop Insurance</u>

Index-based insurance is used to avoid the high transaction costs associated with indemnity-based systems such as MPCI (Linnerooth-Bayer et al., 2011). Index-based insurance programs use a proxy variable for a region rather than indemnifying losses at an individual level (Stutley, 2010). In crop insurance, these proxies are typically weather variables such as rainfall (IFAD, 2011b; Roberts, 2005; Stutley, 2010). Weather-based index insurance (WII) reduce transaction costs by eliminating on-farm assessments (Stutley, 2010). Insurance adjusters do not physically view losses on the farm and therefore the costs associated with sending an adjuster to each farm is removed. WII also reduces costs because there is a lack of adverse selection (insured have hidden information about their risk exposure) and a lack of moral hazard (IFAD, 2011b). Both are eliminated because WII-indemnities are paid only when the proxy variable – such as rainfall – falls below a trigger point (Roberts, 2005). Because producers have no control over weather, they do not have control over indemnity payments. Another advantage of WII in agriculture is that it works well with correlated risks such as drought (IFAD, 2011b). This is counter intuitive as an ideal condition for insuring risk is that it should not have a positive correlation because it can result in a catastrophic loss to the insurer (Rejda, 1995). WII is not well-suited for idiosyncratic risks such as hail damage but works well with systemic risks such as drought because the impact is over a wide area (Roberts, 2005).

WII is not without disadvantages. WII experiences basis risk, meaning that there are times that a producer may experience a loss that they are not compensated for (IFAD, 2011b). This is a spatial basis risk and is the result of a variation in the peril occurrence within a region; WII works best in a homogenous region (IFAD, 2011b). In addition, WII can only cover limited (typically one to two) perils which may not satisfy risk-management needs of the producers (IFAD, 2011b). Lastly, WII is still a relatively new product and requires development in the technical capacity and expertise in agro-meteorology (IFAD, 2011b).

To date there have been several applications of WII piloted (IFAD, 2011b). Variations of WII have been available in India since the late 1970s, the United States and Canada since the early 1990s, and more recently available in Morocco, Mexico, Sudan, and Brazil (Stutley, 2010). India is the only country to undergo a market-based scale-up of WII (IFAD, 2011b). The largest WII program is in India where in the 2010-2011 agricultural year more than nine million farmers held policies, premium volume were over $ 258 million USD, and the total sum insured was over $3.17 billion USD (Clarke, Mahul, Rao, & Verma, 2012). In the same season, $125 million USD – approximately 48 percent – was paid in indemnities through the program (Clarke et al., 2012). The program has been successful in India where it is highly subsidized by the government and farmers' premium rate is capped at 1.5 percent of insured value for wheat and two percent for other crops (Clarke et al., 2012).

Crop Insurance in Low-Income Countries

Ghana is considered a middle-income country (MIC) based on the World Bank's development indicators (World Bank, 2013). MICs represent just less than half of the world's population and account for one-third of the population living on less than $ 2 USD per day (World Bank, 2011). The income range of MICs varies as the highest income MIC has per capita income ten times larger than the lowest MIC (World Bank, 2011). Although Ghana is considered a MIC it still faces many of the same challenges in agriculture as a low-income country (LIC). Specifically, agriculture is still predominantly at the subsistence level with some cash crops (Stutley, 2010). This broad stage of agriculture is still prevalent throughout Africa and is typically defined by low productivity (Todaro & Smith, 2012). A reason for this low productivity is that smallholder farmers are less likely to adopt new technologies (Todaro & Smith, 2012). Part of this unwillingness to adopt new technologies is that yield losses related to weather shocks can trap smallholder households in poverty (IFAD, 2011b). Crop insurance could help guard smallholder households from shocks.

The availability of formal crop insurance programs is limited in low-income countries despite the same areas being highly susceptible to fluctuations in weather (Mobarak & Rosenzweig, 2013). Most households low-income countries have historically mitigated risk through informal risk-sharing schemes, examples from India include diversified lands, migration, and marrying a spouse from another village that faces different risks (Rosenzweig & Stark, 1987; Townsend, 1994). The previously-mentioned informal mechanism likely exist partially because traditional insurance (MPCI) is costly to operate as it requires on-farm assessment (IFAD, 2011b). Formal insurance programs are also less feasible in LICs where there are a large number of farmers and insurance markets are underdeveloped (IFAD, 2011b). These high-cost formal insurance programs are highly subsidized by governments to be economically feasible to producers (Barnett & Coble, 1999; Clarke et al., 2012; USDA, 2011). In order for crop insurance to become economically viable in LICs the costs of operating the programs must be kept low.

The interest in cost reduction has led to increased focus on WII program in LICs. WII programs are much cheaper to operate than MPCI programs (Linnerooth-Bayer et al., 2011). Reasons for this are that WII requires limited individual underwriting, it does not require on-farm loss adjustment, it does not have problems of adverse selection, it does not have problems of moral hazard, and claims can be settled with lower costs than MPCI (IFAD, 2011b). The success of the MPCI program in the United States comes as a result of high subsidies (Barnett & Coble, 1999; USDA, 2011). However, subsidies are a concern for crop insurance programs in LICs because the inefficiencies of the subsidies lead to market distortion as farmers may take unnecessary risks and also because governments cannot afford to facilitate the programs; especially if a large section of the population is engaged in agriculture (Linnerooth-Bayer et al., 2011). An example of market distortion from the United States occurs from producers not having the incentive to produce more robust crops and producers farming in areas that are high risk for drought or floods (Linnerooth-Bayer et al., 2011). Crop insurance in developing countries cannot depend upon subsidies and thus must reduce costs by reducing moral hazard, adverse selection, and administrative costs in order to be economically viable; all of which are incentives of WII.

Crop Insurance in Ghana

In December of 2009, a project called Innovative Insurance Products for the Adaptation to Climate Change (IIPACC) was initiated with funding from the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (Stutley, 2010). This project was jointly implemented by the National Insurance Commission of Ghana (NIC) and Gesellschaft für Internationale Zusammenarbeit (GIZ) (Stutley, 2010). The stated objective of IIPACC is, “to support the development of a sustainable agricultural insurance system and to introduce innovative and demand-oriented crop insurance products to protect against financial risks caused by extreme weather events and other forms of climate change” (Gille, 2013).

The Ghana Agricultural Insurance Programme (GAIP) is funded through the IIPACC (GAIP, 2013). The steering committee of GAIP was established in September of 2010 (GAIP, 2013). This committee was comprised of eleven GAIP-member institutions: (1) National Insurance Commission (chair), (2) Ministry of Finance & Economic Planning, (3) Ministry of Food & Agriculture, (4) Ghana Meteorological Agency, (5) Ghana Insurers Association, (6) Ghana Re, (7) Ghanaian farmer representatives, (8) Stanbic Bank, (9) Agricultural Development Bank, (10) Gesellschaft für Internationale Zusammenarbeit (GIZ) (secretariat), and (11) the World Bank (GAIP, 2013). The first insurance product that became available from GAIP was a WII product released in 2011 that covered over 3,000 smallholder farmers (GAIP, 2013). The coverage was available in three different regions and only covered maize (Gille, 2013). In 2011, the WII was extended to three additional regions, six in total, and also began to cover soya in addition to maize (Gille, 2013). By 2012, MPCI and a pilot for Area-yield index insurance (AYII), which is much like WII but relies on observed yields over an area rather than a weather index, were added to the available insurance products from GAIP as well as one additional region and coverage now extended to include maize, soya, and sorghum (Gille, 2013). Since the start of GAIP in December of 2009, the program has had success in creating dialogue between the public and private sector, capacity building the supply side of available insurance products, creating a regulatory framework, diversifying risk through reinsurance policies, and creating awareness of the program (Gille, 2013). However, GAIP has struggled to create cost-effective distribution channels, provide affordable premiums (or adequate risk coverage), minimize basis risk, or actively engage the government (Gille, 2013). Government involvement is lacking in part because crop insurance is largely viewed as a commercial initiative rather than a public initiative. Crop insurance should be viewed as an instrument to manage agricultural and climate risks by the government to ensure successful scale-up and use of insurance in Ghana. This involvement can contribute to the affordability and comprehensive coverage of crop insurance in Ghana, more producers being covered by insurance, and the sustainability of a crop insurance program in Ghana (Gille, 2013). Although crop insurance has become more available in recent years in Ghana, there is currently still no crop insurance product available for cocoa.

Crop Insurance for Cocoa

Cocoa crop insurance was offered for two to three years in Jamaica in the early 1980s (Mahul & Stutley, 2008). The product offered was an MPCI product that was discontinued because of underwriting costs and an inability to properly define losses due to drought (Mahul & Stutley, 2008). The inabilities to properly define losses from drought were likely due to insufficient historical data. In Ghana, agricultural statistics are managed by the Ghana statistics, research, and information department (SRID). However, SRID has not maintained any time-series production and yield databases for plantation tree crops, including cocoa (Stutley, 2010). In Ghana, the Ghana Cocoa Board and its affiliate, Cocoa Research Institute of Ghana (CRIG), are responsible for all aspects of research and development for the sector. However, collecting and maintaining reliable yield data has not been a priority, and to date, the Cocoa Board does not have accurate data on the number of cocoa farmers in the country or the total area under production, much less farm by farm yield data (*personal communication Mr. E.T. Quartey, Director of Research, Monitoring and Evaluation, Cocobod*).The absence of these data are not ideal in conducting formal risk assessment for those crops (Stutley, 2010). Data are a fundamental need for proper risk assessment. Another risk-assessment challenge facing cocoa is the production cycle of perennial crops. Vilsack (2009) describes this production cycle in four stages: (1) establishment: zero yield, (2) development: exponential yield growth, (3) maintenance: relatively constant yields, and (4) decline: reduction in yields. Mahrizal et al.

(2014), using data from Afari-Sefa et al. (2009), show that the yield of a cocoa tree depends heavily on the age of the tree (figure 6). The inverted-U pattern seen in figure 6 was found for four different production scenarios: (1) low input landrace cocoa (LILC), (2) high input no shade amazon cocoa (HINSC), (3) high input medium shade cocoa (HIMSC), and (4) organic systems (Mahrizal et al., 2014). The difficulty that this presents for crop insurance is that a tree can have the same yield at two different points in its lifecycle but at the first point the yield is increasing while at the second point yield is decreasing. For example, HINSC is shown in figure 6 as the top curve. Yield for HINSC is approximately 800 kg ha^{-1} around year seven and again around year 20. However, HINSC reaches maximum yield around year 14 and then yields begin to decline. If the underwriter for an insurance program did not know the age of the tree they would not be able to assess if expected yields the following year would be more or less than present year. Because this study does not have any information about the age of the trees, an optimal tree replacement rate is assumed so farm production will be in steady state. The issue of tree age is of greater importance for a MPCI policy than a WII policy because MPCI is farm specific and WII covers a region, using the statistical law of large numbers to create an average age of tree.

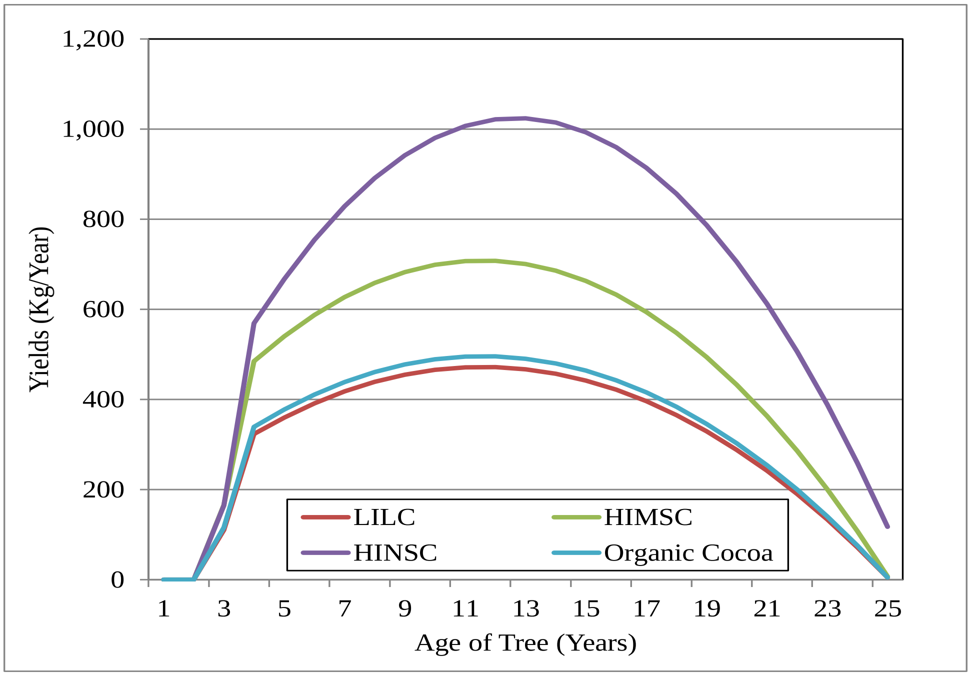

Figure 6. Estimated yield and age of tree for LILC, HINSC, HIMSC, and organic cocoa in Ghana (Mahrizal et al., 2014)

In the United States, perennial crop insurance is available through the United States Department of Agriculture's Risk Management Agency. Crops covered under MPCI include: almonds, apples, apricots, avocados, citrus, bananas, blueberries, cranberries, coffee, figs, grapes, macadamia nuts, nectarines, papaya , peaches , pears, plums, prunes, table grapes, and walnuts (Vilsack, 2009) . Policyholders can select coverage levels between 50 and 75 percent for most crops based on APH (Vilsack, 2009). In 2009, the United States provided $5.4 billion USD in insurance premium subsidies, nearly $500 million USD went towards specialty crops in the fruit, vegetable, tree nuts, and nursery category (Shields, 2013). The high costs of MPCI policies and lack of historical data to establish APH make this policy ill-suited for cocoa in Ghana (Stutley, 2010). WII is more practical for a non-irrigated perennial crop (World Bank, 2009).

Recently, studies were commissioned to investigate the feasibility of crop insurance for cocoa in Ghana. Two of the studies – one commissioned by NCRC and administered by Price

Waterhouse Cooper (PWC) (2014) and another commissioned by the IIPACC group and administered by Charles Stutley (2010) – both studies emphasized protection against disease and pests rather than weather events. According to Stutley (2010), drought was not reported by producers as a serious concern currently on their established cocoa plantations at the time of the study. Rather, producer more frequently cited on-farm problems with pest and disease. However, this study was not concerned with future scenarios when climate change is likely to cause more sporadic weather. The same study also found that farmers were interested in insuring against climatic risks, but the emphasis from cocoa producers was still on insurance for pest and disease. Five potential insurance products were created from this study, one of which was for cocoa. Stutley (2010) proposed a CAT coverage policy to protect cocoa producers against CSSV infection. The catastrophic coverage would be provided by the government and would pay out in the event of tree loss due to CSSV (Stutley, 2010).

A third study, commissioned by Gesellschaft für Internationale Zusammenarbeit (GIZ) and administered by Jan Jozwik (2013), looked specifically at agricultural index insurance for cocoa. The study cautions against using historical weather data in a time of more variable weather. Over 50 percent of the surveyed producers in the GIZ study reported a perceived general decline in rainfall, 33 percent cited an increase in rainfall and 16 percent stated that rainfall had become more erratic (Jozwik, 2013). Although the results are based upon qualitative data of the farmers' perceptions of rainfall, they could indicate that weather was quite variable in a small region or possibly that producers' perceptions were quite variable in a small region. All 114 producers surveyed for this study were from the Ashanti region; spatial basis risk is a potential issue for index insurance in Ghana (Jozwik, 2013). Jozwik (2013) suggests training farmers on collecting weather data to reduce basis risk. The Jozwik study also found farmers to be particularly interested in insurance against black pod and CSSV. It is important to note that in the case of CSC producers', access to crop insurance is coupled with training programs that teach producers how to mitigate risks of disease such as black pod and CSSV. Therefore limiting risk exposure to these disease through proper management practices. For this reason, WII seems to be a more appropriate insurance product for CSC because it trains producers on best management practices and guards them from losses in the event that the producer does everything right but poor weather conditions reduce cocoa yields. There is a large potential benefit of providing index insurance but care must be taken in order to provide insurance that benefits the producers (Clarke, 2011).

G. Risk

The World Bank (2014) states that taking on risk is needed to pursue opportunities for development and warns that the risk of inaction may be the worst option of all in achieving their development goals for the poor. The poor tend to be the most vulnerable to risks because adverse shocks such as crop failure are a major cause of moving households deeper into poverty from which they cannot easily escape (IFAD, 2011a; Todaro & Smith, 2012; World Bank, 2014). Adverse shocks (i.e. crop failure) can prevent smallholder farmers from realizing opportunities (i.e. higher yields) (Cole et al., 2013; Dercon & Christiaensen, 2011; Dercon et al., 2011; IFAD, 2011a; Karlan et al., 2012; Morduch, 1995). For example, farmers in Ethiopia choose not to use inorganic fertilizer out of fear of droughts and other shocks and prefer to keep their savings to cushion potential shocks (Dercon & Christiaensen, 2011) Conversely, farmers in Ghana and India have been more willing to take on risks by increasing their investments in new seeds, inorganic fertilizer, and other agro-chemicals because they insulated from shocks through rainfall insurance (WII) (Cole et al., 2013; Karlan et al., 2012).

The 2014 WDR cites four components of risk management: (1) knowledge: to understand shocks, internal and external conditions, and potential outcomes; (2) protection: reduce the probability and size of losses and increase benefits; (3) insurance: transfer resources across people and time from good to bad states of nature; and (4) coping: to recover from losses and make the best of benefits (World Bank, 2014). The first three components are preparations for risk that should compare the cost of preparation (insurance premium) and probable benefit (indemnity payment) (Ehrlich & Becker, 1972). Todaro and Smith (2012) cite a sequenced response in coping strategies used by households: (1) diversification of income sources, (2) help from community (social capital), (3) reduction of household size through migration, (4) sale of movable assets such as cattle and farm implements, and (5) sale or abandonment of fixed assets such as land, house, or grain stores. These coping strategies are more difficult for poor smallholders because they have fewer assets to cushion shocks (Todaro & Smith, 2012). As such, preparations for risk become more important for poor smallholders. CSC proposes to reduce risk by training producers on best management practices, providing access to inputs and credit, and providing access to insurance for producers who follow the practices of CSC. The incidence of yield loss to has the potential to decrease if producers have access to the information and materials necessary to control disease and pests. Furthermore, losses due to weather can be mitigated for CSC producers through crop insurance. These CSC practices can be an integral part of risk preparedness strategies for smallholder farmers.

III. Data and Methodology

A. Description of Data

Yield and Farm Characteristics

The total sample of 1,200 households used in this study covered a total of five regions, 19 districts, and 109 villages in Ghana. This study used total yearly yields, inclusive of both cocoa harvests from the main and light cocoa season, measured in kg ha^{-1}. In addition, household farm characteristic data were used in this study which included the variables: input-promoter training for producers who had received training on efficient agrochemical input usage, a binary variable for fertilizer use, gender, a binary variable for shade management (appendix 5), and farm size in hectares. The surveys used in this study are: (1) the baseline survey, conducted by Mathematica, completed in February 2011; (2) survey one, conducted by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), International Institute of Tropical Agriculture (IITA), TechnoServe, and Socodevi, completed in August 2011; (3) survey two, conducted by the same CLP partners as survey one, completed in February 2012; and (4) survey three, conducted by Dalberg Global Development Advisors, completed in August 2012. These surveys were conducted across Cameroon, Nigeria, Côte d'Ivoire, and Ghana. However, this study restricts data to Ghana because that is the focus area for NCRC's climate-smart cocoa initiative. Furthermore, these four surveys only cover the main cropping seasons for 2010-2011 and 2011-2012.

After the data were cleaned by removing observations outside of two standard deviations from the mean for land size and yield (appendix 3), there were a total of 1,200 households (the observational unit) across the four surveys. The distributions of sample sizes across region and district are presented in table 1.

Table 1. Distribution of survey observations by region and district

Location	n
Ashanti	194
Adansi South	44
Ahafo Ano South	36
Atwima Nwabiagya	61
Bosome Freho	53
Brong-Ahafo	124
Asunafo North	40
Asunafo South	42
Asutifi	42
Central	115
Asin North	60
Upper Denkyira West	55
Eastern	267
Akyemansa	54
Birim North	45
Birim South	168
Western	500
Aowin Suaman	55
Bia	52
Bibiani Awiaso Bekwia	49
Juaboso	138
Sefwi Akontombra	44
Sefwi Wiawso	112
Wassa Amenfi West	50
All Regions	1,200

Note: Regions are in bold font with districts contained within region following and indented

Weather

Daily weather observations for 2008-2013 were obtained from Awhere Incorporated's online weather platform (accessed March 31, 2014). Awhere provides daily weather observations on weather variables including, but not limited to: precipitation (mm), minimum and maximum temperatures (^{o}C), and growing degree days with a flexible threshold that can be adjusted online. This study only uses daily precipitation data. These data were available at a five arc-minute resolution, or about nine kilometer square grid cells. The weather data were collected by a combination of global meteorological on-the-ground stations and orbiting weather satellites.

These data were the approximate equivalent of having a ground station every nine kilometers. The advantage of using data at this resolution for this study was that individual villages had unique weather data unless multiple villages were contained within the same 9^2 km grid cell.

This study used daily weather observations from January 1, 2008 to December 31, 2013. The primary focus of the weather data was on observations during the pod maturation stage; June 1 through October 31. Although there were a total of four surveys conducted, yield data were only available for two main cropping seasons, 2010-2011 and 2011-12, in which all appropriate weather data were matched with yield data by village location of the cocoa farms. Additional years of precipitation data were used to simulate precipitation data. Because these data only covered five years, robust precipitation distributions could not be obtained. To create precipitation distributions, all daily precipitation observations from the pod maturation stage were pooled for the five years of available data. Then, days from the pool were randomly selected with replacement 153 times (duration of pod maturation stage). This process was repeated 1,000 times for each district to create a robust precipitation distribution.

B. Methodology

Yield Model

Traditionally a crop insurance program is written based upon historical yield data of the farm or region, also called actual production history (APH). Because data on yield and production are scarce for cocoa in Ghana, APH is not available so a distribution of possible yields must be estimated so that the likelihoods of various thresholds can be estimated. These estimations can then be used to compute a fair market value for crop insurance. A previous yield model was estimated by Norton et al. (2014) using CLP data has the specification:

$$logY_i = \alpha + \beta_1 FFS_i + \beta_2 FBS_i + \beta_3 IP_i + \beta_4 Gender_i + \beta_5 FarmSize_i + \beta_6 FBO_i + \beta_7 Fert_i + \beta_8 Fung_i + \beta_9 Insect_i + \beta_{10} Herb_i + \beta_{11} lmprVar_i + \boldsymbol{\varphi_1} SeedSource_i + \boldsymbol{\varphi_2} Location_i + \varepsilon_i \quad (1)$$

Where $logY_i$ is the natural log of cocoa yield (kg ha^{-1}) for the i^{th} farmer, FFS_i, FBS_i, and IP_i are binary variables indicating the completion of the CLP farmer field school (FFS), farmer business school (FBS) and input promoter (IP), respectively for the i^{th} farmer, $Gender_i$ is a binary variable with a value of one indicating the i^{th} farmer is male, $FarmSize_i$ is the natural log of cocoa farm size measured in hectares for the i^{th} farmer, $Fert_i$, $Fung_i$, $Insect_i$, $Herb_i$, $ImprVar_i$, and FBO_i are binary variables having a value of one if the participant used inorganic fertilizer, fungicide, insecticide, herbicide, improved cocoa varieties, or was a member of an farmer-based organization, respectively for the i^{th} farmer, $SeedSource_i$ is a vector for source of seed (seeds from own farm, friend's farm, or government-certified seed which was included in the constant term) for the i^{th} farmer, $Location_i$ is a vector for location (Atwima Nwabiagya, Juaboso, and Sefwi Wiawso, with Birim South included in the constant term) for the i^{th} farmer, and ε_i is the error term for the i^{th} farmer.

While Norton's model was also specified to estimate yield, the purpose of the specification was different than this study. Norton investigated benefits of farmer training schools in Ghana. This study is also interested in the effect that training has on yield but furthermore, this study is interested in the impact of precipitation on yield. This study is restricted in what variables can be used because the regression will later be used to simulate yields. Therefore, variables that can be simulated are preferred and other variables included that cannot be simulated should have good justification for remaining in the model. Several alternative models were tested for this study, four of which are presented in table 2.

Table 2. Alternative regressions for yield model

	Model 1	Model 2	Model 3	Model 4	Final
Intercept	227.78***	-283.86***	-374.33***	-292.64***	-277.37***
Adansi South	81.58*	147.95***		145.87***	145.45***
Ahafo Ano South	2.96	35.88		34.02	33.74
Akyemansa	14.84	178.39***		176.34***	175.51***
Aowin Suaman	143.61***	86.47**		86.75**	86.99**
Asin North	5.21	106.32***		105.19**	104.82**
Asunafo North	84.14**	99.34**		97.77**	97.53**
Asunafo South	71.83*	107.11**		105.3**	104.91**
Asutifi	50.54	98.95**		96.84**	96.36**
Atwima Nwabiagya	-33.61	80.09*	-57.04	91.65*	83.43*
Bia	147.00***	147.93***		147.87***	147.79***
Bibiani Awiaso Bekwa	107.34***	178.49***		177.2***	176.88***
Birim North	54.82	158.61***		156.67***	156.04***
Birim South	64.40*	223.65***	49.6	225.07***	220.32***
Bosome Freho	4.67	83.74**		81.00*	80.46*
Juaboso	64.73*	53.36	-218.82***	56.52	53.07
Sefwi Akontombra	139.98***	132.35***		132.06***	132.14***
Sefwi Wiawso	116.42***	174.22***		176.34***	172.32***
Upper Denkyira West	83.86**	138.41***		137.5***	137.16***
IP	91.43***	44.41**	49.60*	19.69	15.71
Fertilizer	119.27***	122.94***	183.44***		
TF				157.31***	156.48***
NTF				118.47***	118.07***
Gndr	37.92***	34.85***	93.19***	35.64***	35.47***
lnSize	-73.02***	-63.78***	-95.92***	-64.20***	-63.85***
lnPrecip		370.44***	560.25***	369.55***	367.94***
Shade	-1.45	43.25**	60.89**	48.30*	42.5**
Non-response shade				13.07	
survey 1	94.77**				
survey 2	-123.15***				
survey 3	27.43				
R-Square	0.25	0.24	0.33	0.24	0.24
Adj R-Square	0.23	0.23	0.31	0.23	0.23
Root MSE	200.96	201.41	220.13	201.48	201.41
n	1,200	1,200	338	1,200	1,200

The first model investigated did not include a variable for precipitation; rather, the changes in precipitation were captured by the survey effect (*survey 1, survey 2*, *survey 3*, and the baseline in the constant term). Model one also investigated total inorganic fertilizer use (*fertilizer*) rather than dividing fertilizer use into fertilizer use with training (*TF*) and fertilizer use without training (*NTF*). The results of model one indicate that shade management (*shade*) is potentially a survey effect because *shade* is not significant when the fixed-effect for survey is included in the regression. Meaning, the positive outcome associated with *shade* that was observed in all other models could be explained by differences in the sampling instrument between surveys. This model was rejected primarily because survey effect cannot be easily simulated. Rather, by excluding it, the model captures the average effect of the survey. Otherwise, the survey instrument used would need to be assumed.

Several changes were made from model one to model two. The survey effect was replaced with a variable for the natural log of precipitation (*lnprecip*) during the pod maturation period. The variable *lnprecip* is highly significant when introduced in the model and remains highly significant in all subsequent models. The variable *shade* became significant when the survey effect was removed from the model. Model two was primarily rejected because this study was interested in investigating the impact of training on fertilizer use by removing the variable *fertilizer* and replacing it with fertilizer use with training (*TF*) and fertilizer use without training (*NTF*). Model two only captures the total effect of using fertilizer with no distinction to whether or not the producer had used fertilizer.

Model three was investigated over concerns of non-responses for the variable *shade*. Model three excludes the baseline survey because respondents were not asked if they practiced shade management on the baseline survey. When the baseline was excluded, shade not only remained positive and significant, the coefficient increased from 42.5 kg ha^{-1} to 60.89 kg ha^{-1}. Excluding the baseline survey reduced the sample size from 1,200 to 338. Model three was rejected primarily because of large the large loss of temporal observations (1,200 to 338) including a reduction in districts from 19 to four. Spatial observations are critical to observe variation in the variable *lnprecip* across space.

Model four was also investigated over concern of non-responses for the *shade* variable. In model four, all samples were included and an additional variable was included for a non-response for shade management (*Non-response shade*). This variable was not significant and did cause any large changes in any of the other coefficients that were used in the final model. Model four was rejected because the non-response variable for shade management (*Non-response shade*) was not significant and therefore did not add any explanatory power to the model. Furthermore, the non-responses for shade management do not appear to be a problem in this model because not only is *Non-response shade* not significant in model four, *shade* remains positive and significant in model three when the baseline is excluded.

IV. Results and Discussion

Summary Statistics

The majority (59.33%) of producers surveyed in this study were male, only 17.5 percent of all producers surveyed had undergone input promoter (IP) training through the CLP, 52.33 percent of all producers used inorganic fertilizer, and 20.25 percent practiced shade management. In total, 12.9% of the surveyed producer bad both undergone input training and were practicing shade management. The percentage of respondents who had undergone IP training was low because the majority (71%) of the sample was collected during the baseline survey at which time no producer had completed IP training. Similarly, the survey conducted during the baseline did not ask respondents if they practiced shade management. Alternate regressions (table 2) were investigated over concerns in the missing data for shade management. The final regression form (equation 2) was deemed robust because shade remained positive and significant when the baseline data was excluded from the regression (i.e. non-responses were excluded) and shade remained positive and significant when a non-response variable was included in the regression. The average farm size for the sample was 3.06 hectares, average daily precipitation during the pod maturation period was 3.35 mm, and average yield for the sample was 325.71 kg ha^{-1}. The district with the highest average yield was Sefwi Wiawso in the Western Region with 416.63 kg ha^{-1} and the district with the lowest average yield was Bosome Freho in the Ashanti Region with 200.71 kg ha^{-1}. A complete summary of descriptive statistics can be seen in table 3.

Table 3. Descriptive statistics by region and district

	Male (%)	Training[B] (%)	Farm Size (ha)	Fertilizer (%)	Shade Grown[C] (%)	Total Precipitation (mm/day)	Total Yield (kg/ha)
Ashanti[A]	60.31%	12.89%	2.88	27.84%	20.62%	3.07	232.64
			(2.02)			(0.42)	(181.03)
Adansi South	68.18%	0.00%	2.96	29.55%	0.00%	3.28	304.39
			(1.93)			(0.46)	(219.36)
Ahafo Ano South	61.11%	0.00%	3.23	30.56%	0.00%	3.56	217.74
			(2.11)			(0.47)	(152.50)
Atwima Nwabiagya	55.74%	40.98%	2.35	37.70%	65.57%	2.56	217.41
			(1.72)			(0.42)	(159.94)
Bosome Freho	58.49%	0.00%	3.18	13.21%	0.00%	3.17	200.71
			(2.27)			(0.30)	(175.63)
Brong-Ahafo[A]	46.77%	0.00%	3.67	27.42%	0.00%	3.56	263.18
			(2.10)			(0.49)	(157.86)
Asunafo North	42.50%	0.00%	3.30	32.50%	0.00%	3.75	290.38
			(1.94)			(0.50)	(180.84)
Asunafo South	52.38%	0.00%	3.88	28.57%	0.00%	3.53	265.58
			(2.21)			(0.48)	(152.31)
Asutifi	45.24%	0.00%	3.81	21.43%	0.00%	3.42	234.87
			(2.14)			(0.49)	(137.49)
Central[A]	57.39%	0.00%	2.84	52.17%	0.00%	3.16	290.36
			(1.87)			(0.41)	(218.26)
Asin North	61.67%	0.00%	2.26	53.33%	0.00%	2.99	268.56
			(1.21)			(0.39)	(187.17)
Upper Denkyira W.	52.73%	0.00%	3.48	50.91%	0.00%	3.35	314.14
			(2.22)			(0.43)	(247.37)
Eastern[A]	58.43%	32.58%	2.82	53.56%	30.34%	2.69	339.37
			(1.84)			(0.38)	(251.04)

Akyemansa	59.26%	0.00%	3.17	33.33%	0.00%	2.51	233.83
			(1.97)			(0.36)	(180.65)
Birim North	57.78%	0.00%	3.55	31.11%	0.00%	2.94	261.26
			(2.17)			(0.37)	(184.62)
Birim South	58.33%	51.79%	2.52	66.07%	48.21%	2.68	394.22
			(1.63)			(0.39)	(269.76)
Western[A]	63.00%	19.60%	3.16	67.40%	24.40%	3.80	378.17
			(2.15)			(0.36)	(234.99)
Aowin Suaman	74.55%	0.00%	3.78	74.55%	0.00%	4.50	403.42
			(2.21)			(0.36)	(241.28)
Bia	61.54%	0.00%	4.08	67.31%	0.00%	3.89	389.96
			(2.60)			(0.24)	(243.47)
Bib. Awiaso Bekwia	44.90%	0.00%	2.38	44.90%	0.00%	3.24	351.97
			(1.38)			(0.37)	(169.10)
Juaboso	60.14%	39.86%	3.08	70.29%	55.80%	4.03	376.72
			(2.17)			(0.35)	(221.69)
Sefwi Akontombra	70.45%	0.00%	3.05	65.91%	0.00%	3.97	404.42
			(1.93)			(0.35)	(246.95)
Sefwi Wiawso	67.86%	38.39%	2.76	69.64%	40.18%	3.25	416.63
			(1.88)			(0.41)	(256.48)
Wassa Amenfi West	60.00%	0.00%	3.45	70.00%	0.00%	3.90	258.58
			(2.40)			(0.37)	(219.93)
All Regions	59.33%	17.50%	3.06	52.33%	20.25%	3.35	325.71
			(2.04)			(0.66)	(228.99)

Note: All values in parentheses are standard errors. '[A]': denotes a region while all others are districts '[B]': No farmers had received training prior to the baseline survey '[C]': Some zero results are because shade management was not asked on the baseline survey.

Regression Results

After alternative specifications for the estimated regression model of this study were investigated (table 2), a final estimated regression model was determined. The estimated regression model for this study is estimated as:

$$Y_i = \beta_0 + \beta_1 \boldsymbol{Dist_i} + \beta_2 IP_i + \beta_3 TF_i + \beta_4 NTF_i + \beta_5 Gndr_i + \beta_6 Shade_i + \beta_7 lnSize_i + \beta_8 lnPrecip_i + \varepsilon_i \quad (2)$$

Where Y_i is observed annual yield (kg ha^{-1}) for the i^{th} farmer, $\boldsymbol{Dist_i}$ is a vector of binary variables representing individual districts (locations) for the i^{th} farmer with the district Wassa Amenfi West included in the intercept, IP_i is a binary variable taking a value of one for farmers who have completed IP training for the i^{th} farmer, TF_i is a binary variable taking a value of one for farmers who has received both IP training and also used inorganic fertilizer for the i^{th} farmer, NTF_i is a binary variable taking a value of one for a farmer who has not received training but had used inorganic fertilizer for the i^{th} farmer, $Gndr_i$ is a binary variable taking a value of one when the household head is male) for the i^{th} farmer, $Shade_i$ is a binary variable taking a value of one if the farm uses shade management for the i^{th} farmer, $lnSize_i$ is the natural logarithm of farm size in hectares for the i^{th} farmer, and $lnPrecip_i$ is the natural logarithm of average precipitation mm per day for the i^{th} farmer during the pod maturation period of the main crop such that:

$$Precip_{\lambda ti} = \sum_{d=1}^{153} P_{di} \Big/ 153. \quad (3)$$

Where $Precip_{\lambda ti}$ is average daily precipitation in mm for the i^{th} farmer in the λ^{th} location in the t^{th} time period, Pd_i is daily precipitation in millimeters for the i^{th} farmer and 153 is the duration in days of the pod maturation period for the main crop; from June 1 to October 31. Jozwik (2013) reports that 73 percent of farmers surveyed cited precipitation during this period as a major driver of yield. Any farms within a five arc-minute resolution have identical precipitation observations because this is the level at which weather data are aggregated. A complete list of independent variables with definitions and responses is shown in table 4.

Table 4. Definition of regression variables

Variable	Definition	Response
$\boldsymbol{Dist_i}$	District where respondents farm is located	district name
IP_i	Respondent completed IP training	1=yes, 0=no
TF_i	Respondent completed IP training and used inorganic fertilizer	1=yes, 0=no
NTF_i	Respondent did not complete IP training but used inorganic fertilizer	1=yes, 0=no
$Gndr_i$	Gender of household head	1=male, 0=female
$Shade_i$	Respondent practiced shade management (appendix 5)	1=yes, 0=no
$lnSize_i$	Natural logarithm of respondents reported farm size	hectares
$lnPrecip_i$	Natural logarithm of precipitation in pod maturation period	mm day^{-1}

Several variables that were not significant in the Norton et al. (2014) model (Equation 1) were also tested in this study but were excluded in the present model (Equation 2) because they were again found to not be significant. These variables are: (1) FFS, (2) FBS, (3) FBO, (4) fungicide, (5) herbicide, and (6) seed source. Insecticide use was found to be significant in Norton et al. (2014) but was excluded from this study because it was not found to be statistically significant. The two models also differ in how fertilizer use was analyzed. Norton et al. (2014) only indicates if fertilizer was used not if a producer was trained on how to use it. This study breaks inorganic fertilizer use in to two categories to determine the impact of training on the effectiveness of fertilizer use. As such, fertilizer use was classified into two categorical variables. The first variable (*NTF*) is fertilizer use with no input training and the second variable (*TF*) is an interaction variable (*fertilizer***IP*) for a producer who uses fertilizer and has undergone input-use training. Also, Norton et al. (2014) used the natural logarithm of yield as the dependent variable. This study found a linear relationship to be a better fit to the data. This is plausible because yields are sufficiently low in Ghana (<400 kg ha^{-1}) that they have not yet reached the point of diminishing marginal returns that would be realized when yields are. The most notable difference between the two models is the inclusion of mean daily precipitation (mm) during the cocoa pod maturation period in this model. Precipitation during this period was included in this model because it is a determining agro-meteorological factor in cocoa production. Previous studies find precipitation to have varying effects – both positive and negative – depending on the amount of precipitation (Ajayi, Afolabi, Ogunbodede, & Sunday, 2010; Ojo & Sadiq, 2010; Oyekale, 2012). Yield reductions occur because pods cannot mature with too little rain and too much rain increases the prevalence of disease such as black pod (Wood & Lass, 1985). Although the natural log was determined to be the most appropriate fit for this study, intuition dictates that too much precipitation would cause reductions in yield, requiring a quadratic function. However, there are not enough observations in this study to observe this relationship and therefore the natural log was used. Lastly, a binary variable for shade was added in the present model because of the importance of shade in CSC practices as well as cocoa production in general.

Regression results are reported in table 5. Wassa Amenfi West was defined as the constant and all other locations were compared to this district. All location coefficients were found to be positive compared to Wassa Amenfi West and all but Ahafo Ano South and Juaboso were found to be statistically different. Although *IP* training alone was not found to be statistically significant, the interaction between fertilizer use and *IP* training (*TF*) was found to be significant. This indicates that many of the advantages of the IP training program come from the understanding of how to properly use fertilizer. Fertilizer use without training (*NTF*) was also found to be significant; however, the coefficient for *TF* was higher at 156.48 kg ha^{-1} as compared to 118.07 kg ha^{-1} for *NTF*. *TF* was expected to have a higher coefficient than NTF because IP training teaches producers about efficient and effective input usage. Slightly larger yields were also realized when the household head was male rather than female, with a coefficient of 35.47 kg ha^{-1}. As farm size increases, the effect on yield was negative. However, this effect was diminishing so the natural log of farm size in hectares was used. Meaning, as a farm increases in size, yields decrease as a lower rate. The average hectare on a small farm often receives more attention from the producers than larger farms, resulting in higher yields for small farms. Precipitation was also found to have diminishing return on yield so the natural log of this variable was specified. As expected, the log of precipitation during the pod maturation period had a large coefficient of 367.94 kg ha^{-1} and was highly significant but with as a natural log, returns from precipitation are eventually diminishing. Meaning, the first millimeter of precipitation received on the farm is more important for cocoa yields than the 100^{th} millimeter of precipitation. As an example from this study, the district with the lowest average daily precipitation was Birim South (2.29 mm day^{-1}) and the district with the highest daily precipitation was BIA (3.72 mm day^{-1}). If Birim South, the district with the lowest average precipitation, were to receive an additional one centimeter (10mm) of precipitation for the entire season, cocoa producers there would receive an additional 10.32 kg ha^{-1} of cocoa. If BIA, the district with the highest average precipitation, were to receive an additional one centimeter (10mm) of precipitation for the entire season, cocoa producers there would only receive an additional 6.4 kg ha^{-1} of cocoa. As precipitation increases the benefit of each additional unit decreases. Lastly, shade was found to be significant with a coefficient of 42.51 kg ha^{-1}. The positive coefficient result of the shade management variable is contrary to some literature (Ahenkorah et al., 1974; Gockowski & Sonwa, 2008, 2011; Murray, 1954). It is possible that the positive coefficient for shade management was the result of a survey effect in the regression as *shade* was not found to be significant in model one of table 2. However, there are reasons that increased shade management would result in higher cocoa yields. Most notable are the reduction of pest and disease damage (Campbell, 1984) and decreased weed growth in shaded production systems (Ahenkorah et al., 1974). Furthermore, a forthcoming study on the effect of shade on cocoa yields over a four-year period in two locations of Ghana also found shade to have both a positive and significant effect on cocoa yields (R. Asare, Asare, Ræbild, & Anim-Kwapong, n.d.). The relationship between shade and cocoa yields is complex and still not completely understood. However, the Cocoa Research Institute of Ghana (CRIG) recommends that cocoa be grown under approximately 30-40 percent canopy cover.

Table 5. Regression results for yield ha^{-1}

Variable	Coefficient	Standard Error
Constant[A]	-277.37***	(74.94)
Adansi South	145.49***	(42.90)
Ahafo Ano South	33.74	(44.55)
Akyemansa	175.51***	(45.50)
Aowin Suaman	86.99**	(40.13)
Asin North	104.82**	(40.94)
Asunafo North	97.53**	(43.12)
Asunafo South	104.91**	(42.87)
Asutifi	96.36**	(43.25)
Atwima Nwabiagya	83.43*	(46.07)
Bia	147.79***	(39.94)
Bibiani Awiaso Bekwia	176.88***	(41.74)
Birim North	156.04***	(44.03)
Birim South	220.32***	(39.72)
Bosome Freho	80.46*	(41.76)
Juaboso	53.07	(35.15)
Sefwi Akontombra	132.14***	(41.69)
Sefwi Wiawso	172.32***	(36.62)
Upper Denkyira West	137.16***	(40.14)
IP	15.71	(35.20)
TF	156.48***	(35.61)
NTF	118.07***	(13.78)
Gndr	35.47***	(12.23)
lnSize	-63.85***	(9.91)
lnPrecip	367.94***	(50.48)
Shade	42.51**	(20.58)

Note: '***', '**', and '*' are significant at the 1, 5, and 10 percent levels, respectively.
'A' Wassa Amenfi West in included in the constant.
R^2=0.24 RMSE=201.4 N=1,200

The majority of variables in the regression presented in table 5 were binary variables. Only farm size and precipitation have associated continuous distributions. However, when simulating results, the average farm size, as shown in table 3, was used for each district. This was done to hold the effect of farm size on yield constant because farm size is not a prerequisite of CSC. Therefore, precipitation was the only variable with a distribution in the simulations. This regression has an R^2 value of 0.24 and a root mean square error (RMSE) of 201.4. The low R^2 value and high RMSE indicate that much of the yield variance is not explained by this model. Both R^2 and RMSE could be improved with more precise data. Some factors that can explain yield variation that this study does not have data for are: age of tree, tree density, soil type, soil fertility, percent shade cover, amount (kg) of inputs used, and date of input application. The high value for RMSE means that one standard deviation of yield variation is equal to 201.4 kg ha^{-1} from the conditional mean. Because the error term was assumed to have a normal distribution with mean zero, 95 percent (i.e. approximately two standard deviations) of observations in the simulated error term can be found between -402.8 and 402.8 kg ha^{-1}. Yield variations in the simulations were greatly increased as a result of the variation from the error term.

Yield Simulations

Using the previously described yield-prediction model (equation 2), Monte Carlo simulations were conducted based upon specific farm characteristics for two groups of cocoa producers: (1) those who followed CSC practices: have undergone input-use training, used inorganic fertilizer, and practiced shade management (appendix 5) and (2) those who did not use CSC practices: no input-use training, no shade management, but did use inorganic fertilizer. Each scenario was simulated 1,000 times to estimate mean indemnity payments for each district. Three sources of uncertainty (each with a distribution) exist. Potential precipitation distributions were investigated using the software package @RISK from the Palisade Corporation (Palisade Corporation, 2014). Observed data were fitted to various distributions and ranked based on Akaike Information Criterion. The lognormal distribution was determined to be the most appropriate distribution for precipitation. The distributions of the estimated betas and the error term were each assumed to be normally distributed consistent with conventional regression theory and the empirical evidence of the distribution of the residuals. Formally, the three sources of uncertainty in this model are:

1. Uncertainty in precipitation, distributed such that:

$$precip_i \sim LN\left(\overline{precip}, \sigma^2_{precip}\right) \tag{4}$$

The precipitation random draw for an individual farmer, i, has a log normal distribution with a mean of observed precipitation mean, $\overline{precip}$ and standard deviation of observed precipitation standard deviation, σ^2_{precip}.

2. Uncertainty in the beta coefficients where **b** is the full vector of estimated coefficients, distributed such that:

$$\boldsymbol{b_1} - \boldsymbol{b_k} \sim N(\boldsymbol{\beta_1} - \boldsymbol{\beta_k}, Cov(\boldsymbol{b_1} - \boldsymbol{b_k})) \tag{5}$$

The estimated betas, $\boldsymbol{b_1}$-$\boldsymbol{b_k}$, are normally distributed with means equal to the beta coefficients, $\boldsymbol{\beta_1}$- $\boldsymbol{\beta_k}$, and standard deviations of the covariance of the beta estimates. In the simulations $\boldsymbol{\beta_1}$- $\boldsymbol{\beta_k}$ representing the means are replaced by their estimates $\boldsymbol{b_1}$-$\boldsymbol{b_k}$.

3. Uncertainty in the error term is distributed such that:

$$\varepsilon_i \sim N(0, \sigma^2) \tag{6}$$

The error, ε_i, *is* normally distributed with mean of zero and standard deviation of σ.

All of these sources of uncertainties were included in the simulations. In all cases the population moments of the distributions were replaced by their sample, point estimates. The simulations ran concurrently with precipitation and model uncertainties being simulated 1,000 times each. After the uncertainties resulting from the beta coefficients and error terms were simulated as a function of appropriate covariances, the simulated regression coefficients were multiplied by the selected values of independent variables. In the case of precipitation, a Monte Carlo draw for precipitation was multiplied by the precipitation coefficient. All other regression coefficients were multiplied by fixed values of the independent variables, in most instances these were binary variables except for farm size which was held constant as the average from each district. Negative yield observations were removed entirely before computing the yield distribution rather than truncated at zero because: (1) there were no instances of zero yields in the observed data set and (2) truncating at zero would have resulted in lower simulated yields than removing those observations entirely and the simulated mean yields with this adjustment are less than observed mean yields. On average, 12.77 percent of simulated observations were removed: 9 percent of the CSC simulations and 17 percent of the non-CSC simulations.

Using the above-mentioned simulation results, the fair-market premium for crop insurance – where premium cost is equal to average indemnity payment – was established. The results of the Monte Carlo simulation were used because APH – which insurance policies are typically written from – were not available for this study. To determine the fair market value of crop insurance the mean values of simulations were used in place of APH. These values differ among locations as well as across the characteristics of the farm. The equation for fair market crop insurance can be shown as:

$$Premium = \%\ chance\ of\ loss * avg\ loss\ below\ stated\ threshold * price_{cocoa} \quad (7)$$

$$Premium = {}^{j}/_{n} * \sum\left((\bar{x} * c) - m_{1-j}\right)/j * P_{cocoa} \quad (8)$$

Where j is the total number of simulations with yield below the defined coverage level of the insurance (50% and 70% in this study), n is the total number of simulations, $(\bar{x} * c)$ is the crop coverage level with $\bar{x}$ as the average of the simulated yields estimated in the model and c is the coverage level of insurance, m_{1-j} are simulated values below the coverage level such that $m < (\bar{x} * c)$, and P_{cocoa} is the producer price set by the Ghanaian Cocoa Board. Price was converted to USD by taking the average of daily exchange rates from the main cocoa harvest for the 2012-2013 season, resulting in a producer price of \$1.77 USD kg^{-1} for this study. Two coverage levels were used in this study. CAT coverage of 50 percent was used a minimum with a buy-up options to 70 percent. This range was considered reasonable of cocoa producers because 50 percent CAT coverage is the minimum commercially-available option and coverage levels in excess of 70 percent were considered too expensive to maintain. The true costs of operating an insurance program are understated by using Equation 8 because it does not incorporate administrative and operational costs which accounts for 20 percent of insurance premium for maize in the USA by a conservative estimate (Babcock & Cox, 2012).

Yield simulations were conducted based upon specific farm characteristics for two groups of cocoa producers: (1) those who followed CSC practices: have undergone input-use training, used inorganic fertilizer, and practiced shade management (appendix 5) and (2) those who did not use CSC practices: no input-use training, no shade management, but did use inorganic fertilizer. The two groups, CSC and non-CSC can be shown as:

$$\widehat{CSC} = IP + TF + Shade \tag{9}$$

$$\widehat{non - CSC} = NTF \tag{10}$$

All else was held constant for the analysis including farm size, gender, and fertilizer use. Both climate-smart and non-climate-smart producers were assumed to have used inorganic fertilizer. Although only 52.33 percent of all respondents used fertilizer (table 3), it was held constant because there are instances of fertilizer use without training. Results from the regression parameters show a yield difference favoring CSC producers by 96.68 kg ha^{-1}. This value was obtained by subtracting equation 10 from equation 9. However, when simulations for CSC and non-CSC were conducted for each district with 1,000 iterations, the yield difference favoring CSC producers was reduced to 67.24 kg ha^{-1} on average. The change in yield difference between CSC and non-CSC producers from the regression parameters (96.68 kg ha^{-1}) and the simulated yields (67.24 kg ha^{-1}) is a result of how negative values were managed during simulations. Negative values were removed disproportionately for CSC (9% of samples) and non-CSC (17% of samples) producers in the simulation results. This dichotomy existed because non-CSC producers had a lower yield on average, meaning negative higher probability of simulating a negative value. By removing more left-side observations for non-CSC producers than CSC producers, the yield difference between the two groups reduces. This adds some positive bias to the yields of non-CSC producers. Average simulated yield results are presented in table 6. Climate-smart producers were found to have higher yields than non-climate-smart producers at the one-percent level in every district. The largest difference in average yield was found in Juaboso where CSC producers had an average of 77.31 kg ha^{-1} more than non-CSC producers and the smallest difference in average yield was found in Atwima Nwabiagya where CSC producers had an average of 52.26 kg ha^{-1} more than non-CSC producers. The yield differences viewed in the simulated results for Juaboso and Atwima Nwabiagya are likely the result of the standard errors of the regression. Juaboso had the largest yield difference and the smallest standard error from the regression results. Similarly, Atwima Nwabiagya had the smallest yield difference and the highest standard error in the regression results. The wider the variability in yield was for the two groups, the smaller the overall yield difference was between them. The results of yield differences indicated that by adopting CSC practices farmers would see higher average yields with only slight increases in the standard deviation of yield. This means that the gains in average yield do not come with higher yield risks.

Table 6. Simulated yield (kg ha^{-1}) comparison between CSC and non-CSC

	Non-CSC	CSC
Adansi South	275.17	341.84
	(167.99)	(189.53)
Ahafo Ano South	286.29	356.31
	(171.49)	(187.85)
Akyemansa	248.97	310.78
	(162.03)	(185.13)
Aowin Suaman	310.07	384.97
	(178.09)	(197.49)
Asin North	271.17	335.37
	(171.46)	(188.78)
Asunafo North	313.12	389.65
	(182.43)	(193.78)
Asunafo South	296.07	371.52
	(174.44)	(192.17)
Asutifi	297.51	366.88
	(171.69)	(186.45)
Atwima Nwabiagya	271.57	323.83
	(188.90)	(207.85)
Bia	310.81	385.85
	(182.63)	(191.37)
Bibiani Awiaso Bekwia	298.40	367.08
	(177.14)	(187.49)
Birim North	243.16	304.59
	(165.90)	(181.79)
Birim South	227.40	282.70
	(158.25)	(179.03)
Bosome Freho	239.31	292.64
	(154.84)	(177.95)
Juaboso	312.74	390.05
	(184.22)	(192.51)
Sefwi Akontombra	303.05	373.66
	(183.05)	(196.59)
Sefwi Wiawso	300.57	369.47
	(177.75)	(196.41)
Upper Denkyira West	267.42	333.95
	(167.43)	(188.23)
Wassa Amenfi West	298.01	367.25
	(176.14)	(193.89)

Note: All yield differences are significant at the one-percent level across rows
All values in parentheses are standard errors

The simulated average yields from table 6 were then used to compute the amount of total yield (kg ha^{-1}) that insurance would cover for producers at different coverage levels for both CSC and non-CSC producers. Insured yield is computed as:

$$Yield_{ins} = Yield_{sim} * Coverage \qquad (11)$$

Where $Yield_{ins}$ is the insured yield that the farmer is guaranteed to receive in the event of a loss, $Yield_{sim}$ is the simulated average yield values from table 6 and *Coverage* is the percentage of expected yield that is guaranteed to the producer in the event of a loss. For this study, coverage levels were investigated at the 50-percent and 70-percent levels. The insured yield differs across districts, coverage level, and production system (CSC or non-CSC). The lowest insured yield in this study was for a non-CSC producer in Birim South with a 50-percent coverage level. The insured yield in this instance was only 113.70 kg ha^{-1}. Conversely, a CSC producer in Asunafo North with a 70-percent coverage level will have an insured yield of 272.75 kg ha^{-1}. The differences for insured yields were a result of the differences in expected yields for non-CSC and CSC producers as well as the coverage level being investigated. Table 7 presents the insured yield (i.e. yield amount that is guaranteed by the insurance policy) for 50 and 70 percent coverage. The results of table 7 were calculated using the simulated yield values in table 6.

Table 7. Insured yield (kg ha^{-1}) amounts for CSC and non-CSC by district

	50 Percent		70 Percent	
	Non-CSC	CSC	Non-CSC	CSC
Adansi South	137.58	170.92	192.62	239.29
Ahafo Ano South	143.15	178.15	200.41	249.41
Akyemansa	124.48	155.39	174.28	217.55
Aowin Suaman	155.04	192.49	217.05	269.48
Asin North	135.59	167.69	189.82	234.76
Asunafo North	156.56	194.82	219.18	272.75
Asunafo South	148.04	185.76	207.25	260.06
Asutifi	148.75	183.44	208.25	256.81
Atwima Nwabiagya	135.78	161.91	190.10	226.68
Bia	155.41	192.92	217.57	270.09
Bibiani Awiaso Bekwia	149.20	183.54	208.88	256.96
Birim North	121.58	152.29	170.21	213.21
Birim South	113.70	141.35	159.18	197.89
Bosome Freho	119.66	146.32	167.52	204.85
Juaboso	156.37	195.02	218.92	273.03
Sefwi Akontombra	151.53	186.83	212.14	261.56
Sefwi Wiawso	150.28	184.74	210.40	258.63
Upper Denkyira West	133.71	166.98	187.19	233.77
Wassa Amenfi West	149.01	183.63	208.61	257.08

Any time the simulated yield amount was less than the insured amounts presented in table 7, an indemnity was triggered. The difference in the amount of simulated yield and insured yield what will henceforth be known as yield gap. An average was taken for all instances in which simulated yields were less than insured yield. These average yield gaps are presented in table 8 for each district at 50 and 70 percent coverage levels. The yield gap for CSC was larger than non-CSC. However, it is important to remember that the average yields for CSC producers were significantly higher than non-CSC producers with an average yield difference of 67.24 kg ha^{-1} (table 6) and yield variance (standard deviation) is only slightly higher for CSC producers. Meaning that in absolute terms, CSC cocoa is slightly riskier. However, when yield is normalized, CSC is less risky. The larger yield gap values for CSC were expected as their average and insured yields were also higher than non-CSC with only minimal increases in variance.

Table 8. Average yield (kg ha^{-1}) gap for CSC and non-CSC by district

	50 Percent		70 Percent	
	Non-CSC	CSC	Non-CSC	CSC
Adansi South	65.47	72.12	89.60	101.54
Ahafo Ano South	64.94	78.67	88.37	105.75
Akyemansa	63.38	72.15	85.80	99.61
Aowin Suaman	68.82	81.24	95.20	112.92
Asin North	64.29	73.32	86.96	104.65
Asunafo North	67.89	81.96	94.88	109.99
Asunafo South	62.14	82.26	91.91	108.14
Asutifi	68.27	75.78	88.24	101.19
Atwima Nwabiagya	66.99	71.81	93.96	102.52
Bia	71.23	73.13	100.36	106.56
Bibiani Awiaso Bekwia	63.80	71.09	89.37	97.63
Birim North	59.54	68.66	82.98	97.66
Birim South	53.93	68.13	78.83	92.14
Bosome Freho	54.31	64.03	75.53	88.97
Juaboso	67.04	81.58	97.74	104.37
Sefwi Akontombra	72.76	76.46	96.96	109.83
Sefwi Wiawso	67.01	82.33	89.84	112.21
Upper Denkyira West	64.62	73.79	87.53	99.87
Wassa Amenfi West	64.55	73.67	87.28	111.55

Yield Gap = difference of insured yield minus simulated yield (when simulated yield < insured yield)
0

The probability of receiving an indemnity payment is presented in table 9 for the 50 and 70 percent coverage levels for each district surveyed. The probability of receiving an indemnity payment is defined as:

$$\%\ chance\ indemity = \frac{observation\ below\ trigger\ yield}{all\ observations} \tag{12}$$

The trigger yield is the trigger amount at which a farmer will receive an indemnity payment (USDA, 2011). In this study, the trigger yields are the insured yields (table 7) that are computed by taking the average of simulated yields multiplied by the coverage rate (50% and 70%). When a simulated yield was less than the insured yield, an indemnity payment was made for the difference (kg) times the price of cocoa. In each instance, the probability of receiving an indemnity payment was greater for non-CSC producers despite having lower yield gaps. Again, this was dependent upon the difference in average and insured yields for CSC and non-CSC producers. Table 9 shows that there were fewer indemnity payments (i.e. less yield risk) for CSC than non-CSC producers in every district surveyed in this study. The reduction in risk can likely be attributed to the increased yields associated with following CSC practices. Namely, yield increases are realized primarily through training, especially in unison with inorganic fertilizer use, and the practice of shade management.

Table 9. Percent chance of indemnity payment at the district level

	50 Percent		70 Percent	
	Non-CSC	CSC	Non-CSC	CSC
Adansi South	23.6%	21.0%	35.3%	32.9%
Ahafo Ano South	23.0%	18.9%	35.8%	30.8%
Akyemansa	25.3%	23.3%	37.1%	34.8%
Aowin Suaman	21.7%	18.5%	34.1%	29.4%
Asin North	25.0%	21.8%	37.7%	32.5%
Asunafo North	22.2%	17.0%	34.9%	28.6%
Asunafo South	23.5%	17.7%	34.4%	29.7%
Asutifi	20.3%	17.4%	34.0%	29.9%
Atwima Nwabiagya	28.5%	25.1%	40.0%	37.3%
Bia	22.9%	18.0%	34.1%	28.6%
Bibiani Awiaso Bekwia	22.4%	17.9%	35.3%	31.1%
Birim North	25.9%	23.5%	37.0%	35.2%
Birim South	28.8%	24.9%	39.6%	36.9%
Bosome Freho	24.5%	23.4%	37.7%	36.4%
Juaboso	22.9%	15.9%	34.2%	29.1%
Sefwi Akontombra	22.9%	19.6%	35.6%	30.5%
Sefwi Wiawso	22.2%	19.0%	35.5%	30.1%
Upper Denkyira West	24.2%	20.8%	37.1%	33.4%
Wassa Amenfi West	21.7%	20.4%	35.5%	29.9%

Results of indemnity payments at the village level for coverage at the 50 and 70 percent levels are presented in table 10. In this example for fair-market premiums, the average indemnity payment was equal to the premium paid by the farmers. This study uses an exchange rate of $1 USD = 1.89 GHC. This value was computed by taking the average daily exchange rate from September 1, 2012 to February 28, 2013. This timeframe was used because it was the harvest period for the main crop. This study assumed that 64 kg bags of cocoa beans were purchased for 2012-2013 producer price of 212 GHC, resulting in a value of $1.77 USD kg^{-1} at the farm gate. In most instances, non-CSC producers were paying higher premiums than CSC producers. CSC producers paid higher premiums than non-CSC producers in seven of the 19 districts: (1) Akyemansa, (2) Aowin Suaman, (3) Birim North, (4) Birim South, (5) Bosome Freho, (6) Upper

Denkyira West, and (7) Wassa Amenfi West. However, these higher premiums purchased higher insured yields. Because the insured yields of CSC and non-CSC producers differ, it is difficult to compare them directly. For instance for Catastrophic (50%) coverage in Akyemansa, the average indemnity payment for non-CSC producers was less than CSC producers at $28.42 USD and $29.77 USD, respectively. However, the value of the insured yield for non-CSC producers was $220.33 USD (124.48 kg * $1.77) and $275.04 USD (155.39 kg * $1.77) for CSC producers. A normalized value can be obtained by dividing indemnity payment by insured value. This normalized value, expressed as indemnity as a percent of insured yield is 12.90 percent and 10.82 percent for non-CSC and CSC producers, respectively. The normalization showed that even when CSC producers had higher indemnity payments than non-CSC producers, they still had less yield risk.

Table 10. Average indemnity payments per hectare at the district level

	50 Percent		70 Percent	
	Non-CSC	CSC	Non-CSC	CSC
Adansi South	$27.29	$26.79	$55.93	$59.13
Ahafo Ano South	$26.46	$26.36	$56.02	$57.65
Akyemansa	$28.42	$29.77	$56.29	$61.44
Aowin Suaman	$26.42	$26.66	$57.54	$58.71
Asin North	$28.41	$28.35	$58.02	$60.20
Asunafo North	$26.72	$24.69	$58.54	$55.62
Asunafo South	$25.81	$25.77	$55.95	$56.93
Asutifi	$24.59	$23.35	$53.14	$53.47
Atwima Nwabiagya	$33.80	$31.86	$66.57	$67.65
Bia	$28.87	$23.27	$60.61	$53.95
Bibiani Awiaso Bekwia	$25.31	$22.54	$55.82	$53.72
Birim North	$27.30	$28.61	$54.32	$60.84
Birim South	$27.51	$30.00	$55.24	$60.25
Bosome Freho	$23.57	$26.49	$50.45	$57.31
Juaboso	$27.12	$23.03	$59.21	$53.69
Sefwi Akontombra	$29.53	$26.56	$61.17	$59.36
Sefwi Wiawso	$26.31	$27.74	$56.45	$59.73
Upper Denkyira West	$27.70	$27.23	$57.40	$59.12
Wassa Amenfi West	$24.81	$26.63	$54.91	$59.03

Note: Indemnity payments in USD ha^{-1}

An alternative way to compare premiums is to look at the cost of the fair-market premium (table 10) in comparison to the average revenue of cocoa produced. For this study, CSC and non-CSC producers are assumed to have equal costs. The average revenue of cocoa was the average yield (table 6) multiplied by the producer price of cocoa ($1.77 USD). The results of the premium as a percent of average cocoa value are presented in table 11. In all cases, premiums paid for CSC producers were a smaller percent of cocoa revenue than non-CSC producers. For catastrophic coverage of 50 percent, a farmer in Juaboso was estimated to pay 3.3 percent of average cocoa value to obtain coverage. A non-CSC producer in the same district would pay 4.9 percent of expected cocoa value for the same coverage. The highest percentage that any CSC producer would pay for basic (50 percent) coverage was 6 percent in Birim South. These percentages are very low because: (1) the fair-market premium being used did not take administrative and operational costs of the insurance program into consideration which conservatively accounts for 20 percent of insurance premium for maize in the USA (Babcock & Cox, 2012) and (2) the estimation is based on revenues rather than profit. However, this study assumes that input costs are equal between CSC and non-CSC producers because each group uses inorganic fertilizer.

Table 11. Premium as percent of average cocoa revenue

	50 Percent		70 Percent	
	Non-CSC	CSC	Non-CSC	CSC
Adansi South	5.6%	4.4%	11.5%	9.8%
Ahafo Ano South	5.2%	4.2%	11.1%	9.1%
Akyemansa	6.4%	5.4%	12.8%	11.2%
Aowin Suaman	4.8%	3.9%	10.5%	8.6%
Asin North	5.9%	4.8%	12.1%	10.1%
Asunafo North	4.8%	3.6%	10.6%	8.1%
Asunafo South	4.9%	3.9%	10.7%	8.7%
Asutifi	4.7%	3.6%	10.1%	8.2%
Atwima Nwabiagya	7.0%	5.6%	13.8%	11.8%
Bia	5.2%	3.4%	11.0%	7.9%
Bibiani Awiaso Bekwia	4.8%	3.5%	10.6%	8.3%
Birim North	6.3%	5.3%	12.6%	11.3%
Birim South	6.8%	6.0%	13.7%	12.0%
Bosome Freho	5.6%	5.1%	11.9%	11.1%
Juaboso	4.9%	3.3%	10.7%	7.8%
Sefwi Akontombra	5.5%	4.0%	11.4%	9.0%
Sefwi Wiawso	4.9%	4.2%	10.6%	9.1%
Upper Denkyira West	5.9%	4.6%	12.1%	10.0%
Wassa Amenfi West	4.7%	4.1%	10.4%	9.1%

Another way to compare CSC and non-CSC producers is to consider risk. In this model the risk was the dispersion of the simulated yield ha^{-1}, or the standard deviation of the results. However, because the mean yield of the two groups – CSC and non-CSC – was not equal the regression error term must be normalized to have a fair comparison of risk. This normalization was accomplished with the coefficient of variation expressed as:

$$CV_\lambda = {}^{\sigma_\lambda}/_{\mu_\lambda} \tag{13}$$

Where the coefficient of variation, ($C_{v\lambda}$) is equal to the ratio of the standard deviation (σ_λ) – yield per hectare – to the mean (μ_λ) – yield per hectare – for the λ^{th} location. Relative standard deviation (RSD) is the absolute value of the coefficient of variation multiplied by 100 to be expressed as a percentage. Lower percentages equate to lower yield risk. Table 12 shows the results of RSD values for CSC and non-CSC producers. In every district, CSC producers have lower RSD (less risk) than non-CSC. The difference between non-CSC and CSC ranges from four percent in Bosome Freho to ten percent in Juaboso with an average difference of seven percent. These results indicate that CSC practices reduce risk in cocoa production in the observed locations. The primary reason for the observed decrease in yield risk is a result of the higher yields obtained through CSC practices. In addition, the standard deviations for yield shown in table 6 were not substantially different for non-CSC and CSC producers which also influence RSD. However, the largest driver of RSD reduction for CSC producers were the higher yields obtained by CSC producers.

Table 12. Relative standard deviation for CSC and non-CSC

	Non-CSC	CSC
Adansi South	61%	55%
Ahafo Ano South	60%	53%
Akyemansa	65%	60%
Aowin Suaman	57%	51%
Asin North	63%	56%
Asunafo North	58%	50%
Asunafo South	59%	52%
Asutifi	58%	51%
Atwima Nwabiagya	70%	64%
Bia	59%	50%
Bibiani Awiaso Bekwia	59%	51%
Birim North	68%	60%
Birim South	70%	63%
Bosome Freho	65%	61%
Juaboso	59%	49%
Sefwi Akontombra	60%	53%
Sefwi Wiawso	59%	53%
Upper Denkyira West	63%	56%
Wassa Amenfi West	59%	53%

Although this study has been analyzing the costs of insuring non-CSC compared with CSC, it was not the intent to insure farmers who do not participate in the CSC practices. Rather, insurance was to be used to help mitigate the perceived risks of following CSC practices such as additional expenses of farm inputs such as inorganic fertilizer. As such, a better comparison is to look at the expected gross revenue of non-CSC producers who do not have crop insurance as compared to CSC producers who do have crop insurance. Because both CSC and non-CSC producers are using inorganic fertilizer, costs are assumed to be equal between the two groups. The expected gross revenue of non-CSC producers was:

$$\widehat{revenue}_{non-CSC} = yield * price_{prod} , \tag{14}$$

and the expected gross revenue of CSC producers was:

$$\widehat{revenue}_{CSC} = \left(yield * price_{prod}\right) + (price_{prod} * gap_{yield}) - premium_{fair\ mkt} \quad (15)$$

The difference between the gross revenue of the two groups was that CSC producers paid premiums for insurance and any CSC producer who had a yield below the insured yield received an indemnity payment to compensate for the loss. The results of this analysis are presented in table 13. The results were based on the simulated yields for each district.

Table 13. Gross Revenue per hectare of insurance for CSC and non-CSC producers

	Non-CSC	CSC	CSC Gain
Adansi South	\$487.05	\$605.05	\$118.00
Ahafo Ano South	\$506.74	\$630.66	\$123.92
Akyemansa	\$440.68	\$550.08	\$109.40
Aowin Suaman	\$548.82	\$681.40	\$132.58
Asin North	\$479.98	\$593.61	\$113.63
Asunafo North	\$554.21	\$689.67	\$135.46
Asunafo South	\$524.05	\$657.59	\$133.54
Asutifi	\$526.59	\$649.37	\$122.78
Atwima Nwabiagya	\$480.68	\$573.17	\$92.49
Bia	\$550.13	\$682.95	\$132.82
Bibiani Awiaso Bekwia	\$528.16	\$649.73	\$121.57
Birim North	\$430.39	\$539.12	\$108.73
Birim South	\$402.49	\$500.37	\$97.88
Bosome Freho	\$423.58	\$517.97	\$94.39
Juaboso	\$553.55	\$690.38	\$136.83
Sefwi Akontombra	\$536.40	\$661.38	\$124.98
Sefwi Wiawso	\$532.00	\$653.97	\$121.97
Upper Denkyira West	\$473.33	\$591.10	\$117.77
Wassa Amenfi West	\$527.48	\$650.03	\$122.55

In every instance, crop insurance under CSC production has higher revenue gains than non-CSC production. CSC producers have expected returns of at least $92.50 USD ha^{-1} (Atwima Nwabiagya) more than non-CSC producers. On average, CSC producer will have higher returns of $119.02 USD ha^{-1} and as much as $136.83 USD ha^{-1} (Juaboso). Given that the average income revenue of a non-CSC producer was $ 500.33 USD, the average gain of $119.02 USD represents a gain of 23.79 percent of the non-CSC producers' simulated revenue. The returns for CSC producers were equal at both coverage levels – 50, and 70 percent – because in this example we use a fair-market premium where premium equals average indemnity payment with no transaction or overhead costs figured into the premium. These results show that even if the CSC producers were to pay for the crop insurance they would have higher returns than non-CSC producers based on the assumption of a fair-market premium (premium = indemnity).

V. Summary and Conclusions

A. Summary

The objectives of this study were: (1) to estimate yield differences among cocoa producers who follow CSC and non-CSC practices in Ghana (2) estimate the impact of CSC practices on risk using percent chance of indemnity payments to producers and relative standard deviation as measurements, and (3) investigate potential revenue gains through following CSC practices. This investigation was done through regression analysis and simulations of regression results for individual districts in Ghana. This study looked specifically at the differences in cocoa yield, insured yield, yield gaps, probability of indemnity payment, price of average indemnity, premium payment as a percent of expected revenue, relative standard deviation, and revenue gains for purchasing insurance for CSC producers and non-CSC producers. Simulations were generated using an estimated yield regression model for cocoa that was estimated using a sample of 1,200 Ghanaian farmers over two main harvest seasons.

B. Results and Recommendations

Producers who followed CSC practices were estimated to have higher yields in each district than those producers who did not follow CSC practices. On average results indicated higher yields of 96.68 kg ha^{-1} for producers who follow CSC practices. Results of simulations also show higher yields for producers who follow CSC practices although this result is less at 67.24 kg ha^{-1}. CSC practices reduced yield risk for producers in every district. The largest contributor to this was the statistically significant yield gains obtained by following CSC practices. Producer training resulted in yield gains in this study. The largest increase in yield from training was a result of increased yield from inorganic fertilizer use. Most likely this gain is a result of better timing and more precise application amounts of inorganic fertilizer as a result of training.

However, data on dates applied and amounts applied for fertilizer were not available in this study to know for certain. In addition, producers who have undergone training may have better access (financial and physical) to agronomic inputs than producers who have not undergone any training. Better physical access is the result of the network of the training program making the agronomic inputs available and better financial access is the result of producers who have completed training being given access to credit when needed. The training that was used for this study was the inupt promoter (IP) training program from the WCF's CLP. This training is similar to the proposed training for CSC because it trains farmers on input use and provides financial credit to those who have completed training. In addition, CSC aims to provide crop insurance for producers who follow CSC practices. Because the training proposed for CSC involves pest and disease management while also providing access to agronomic inputs, it is likely that the training proposed by CSC will further reduce yield risk for producers.

To further guarantee reductions in yield risk, a WII policy should be offered rather than a MPCI policy. By offering a WII policy, adverse selection and moral hazard are eliminated. Because indemnities would only be paid in the event of unfavorable weather, producers would have incentives to continue with best practices on their farms. Conversely, if a producer had a MPCI policy they would not have incentive to manage diseases and pests with best management practices because the MPCI policy would cover their losses. This reduces yields and makes the insurance program more expensive to operate. The models used for this study were more suitable to WII because they did not assume any of the additional risk associated with MPCI policies resulting from adverse selection and moral hazard. Although some of the perils that are of great concern to Ghanaian producers (black pod and CSSV) would not be covered by a WII product, the training associated with complying with CSC practices will enhance prevention and management techniques of the producers to these perils. Furthermore, the effectiveness of the training could be reduced by moral hazard if those perils were covered by the insurance product. The most important reason for recommending WII over MPCI is the substantial cost savings through the reduction of operational and transaction costs and the elimination of adverse selection and moral hazard.

Shade management was included in CSC practices for this study. Shade management is an important aspect of CSC because carbon transactions such as those offered in REDD+, can be acquired by using shade management and could offset the cost of insurance premiums for producers. In addition to carbon transactions, the crop insurance premium for CSC producers could be offset by private-sector funding. This study found that producers who practiced shade management had higher yields of 42.51 kg ha^{-1}. Although these results opposite of some previous literature (Ahenkorah et al., 1974; Gockowski & Sonwa, 2008, 2011; Murray, 1954) it has the same results as a forthcoming publication in Ghana (R. Asare et al., n.d.). The conflicting results of previous and present studies warrants more investigation into the relationship between shade management and cocoa yields.

Finally, CSC producers were found to have higher gross revenue than non-CSC producers. On average, CSC producer had higher gross returns of $119.02 USD ha^{-1}. The largest difference in gross returns between CSC and non-CSC producers was in Juaboso where there was a total difference of $136.83 USD ha^{-1}. Along with having the highest gain in gross revenue, Juaboso also had the highest simulated yield (390.05 kg ha^{-1}), the highest yield difference to non-CSC (77.31 kg ha^{-1}), and the lowest standard error (lowest yield risk) from the regression (35.15 kg ha^{-1}). Crop insurance appeared to be an economically viable option for CSC producers. The normalized yield distribution and the percent chance of an indemnity payment being distributed were reduced for the producers who followed the recommended practices of CSC while concurrently raising average yields. The holistic approach of CSC can mitigate forest degradation and deforestation. Giving producers access to credit and inputs to increase yields alone does not guarantee that producers will reduce expansive practices. The additional benefit of crop insurance as part of CSC practices should play a vital role in decreasing forest degradation and deforestation.

C. Limitations

The amount of data collected and analyzed in this study makes it distinctive. Previous studies investigating cocoa yields at the household level used smaller samples. A study conducted by Edwin and Masters (2005) which investigated genetic improvements and yield gains in Ghana had a sample size of 192 and another study conducted by Norton et al. (2014) which investigated the impact of farmer training schools had a sample size of 183. The CLP data in this study are temporally limited (only two years), however, the countrywide breadth (location) of the observations makes it one of the most extensive datasets for studying West African cocoa.

Although the data of this study were extensive, the yield model – with an R^2 value of 0.24 – developed from the data did not have enough explanatory power to confidently write insurance policies. With a root mean square error of 201.4 kg ha^{-1}, much of the variation in the simulated yields came from the error term of the model. More accurate data are needed to increase the R^2 and consequently the explanatory power of the model. Some key areas of improvement would be: (1) GPS-measured farm size instead of self-reported farm size, (2) quantities of agro-chemical use rather than binary (yes/no) variables, (3) specific measurement of canopy cover for shade management rather than producers' response, and (4) more temporal observations. Lastly, the two variables that were most important in defining CSC practices, IP training and shade management, were not present or not completed for the baseline survey. The question for hade management was not included in the survey and there were no producers who had completed training during the baseline study. The quality of the study would be enhanced if more temporal observations that included these two variables were available.

D. Future Research

Writing accurate insurance policies requires an immense amount of data. Accurate daily weather data are already available in Ghana as 9^2 km grid cells and if cocoa crop insurance were to be offered in the future, the accuracy of yield data would be certain to increase. The data were limiting in this study but the initial findings were very promising in regards to economic viability of cocoa crop insurance at the farm level in Ghana. This topic should be revisited in the future as new temporal observations become available. In addition, future studies should investigate funding mechanisms and allocation of resources for CSC, Ghana-specific transaction and operational costs of managing a WII product, and lastly the economic sustainability of an insurance market for CSC should be investigated under different climate change scenarios.

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VII. Appendix

A. Permissions to use figures

Appendix 1. Email from Dr. Rebecca Asare

Rebecca Asare — Sep 25 (4 days ago)

to me

Dear Justin,

Thank you for your email and your request to use the figures noted above. By this email I grant you permission to use and alter the figures as needed.

Kind regards,
Rebecca

Rebecca Ashley Asare (Ph.D.)
Nature Conservation Research Centre
Forest Trends Incubator for Ecosystem Services
Accra, Ghana | [redacted]

On Wednesday, September 24, 2014 9:21 PM, Justin McKinley [redacted] wrote:

> Dear Dr. Asare:
>
> I am currently a graduate student at the University of Arkansas studying the feasibility of crop insurance for cocoa in Ghana. I am writing you today because the university requires written permission from original authors to reproduce figures, tables, etc. in a thesis.
>
> With your permission, I would like to use an altered version of the figure in section 2.1 - The main pillars of a climate-smart agriculture approach - from your report entitled, "Understanding and Defining Climate-Smart Cocoa: Extension, Inputs, Yields, and Farming Practices" in my Master's thesis.
>
> In addition, I would like to use an altered version of Figure 6 - Land Use Change in Dominant Cocoa Cultivation Landscape Within Program Area - from the FCPF report entitled, "Emission Reductions Program Idea Note (ER-PIN)" in my Master's thesis.
>
> Thank you for your time. I hope to hear from you soon.
>
> Best Regards,
>
> Justin McKinley

Appendix 2. Email from Dr. L. Lanier Nalley

Lawton Lanier Nalley
to me

3:45 PM (41 minutes ago)

Justin:

You have my permission to use the figure

Best of luck
Lanier Nalley

Sent from my iPhone

...

On Sep 24, 2014, at 3:42 PM, "Justin McKinley [redacted] wrote:

> Dear Dr. Nalley:
>
> I am currently a graduate student at the University of Arkansas studying the feasibility of crop insurance for cocoa in Ghana. I am writing you today because the university requires written permission from original authors to reproduce figures, tables, etc. in a thesis.
>
> With your permission, I would like to use Figure 1 - Cocoa yield curves over one production cycle (25 years) in Ghana for three predominant production systems: LILC, HINSC, and MIMSC - from your journal publication entitled, "An optimal phased replanting approach for cocoa trees with application to Ghana" in my Master's thesis.
>
> Thank you for your time. I hope to hear from you soon.
>
> Best Regards,
>
> Justin McKinley

C. Data Cleaning Procedure

Appendix 3. Data cleaning procedure

Created By: Justin D. McKinley
Date: April 21, 2014
This document outlines the procedure in which yield data – obtained from the World Cocoa Foundation's Cocoa Livelihood Program – was cleaned prior to analysis. The cleaning was conducted in three major parts: CLP input errors, land size outliers, and finally yield outliers. The procedures are outlined in detail in the following sections.

CLP Input Errors

There are three different training programs that a farmer can attend through the CLP. These programs are Farmer Field School (FFS), Farmer Business School, (FBS), and Input Training (IP). When a farmer finishes IP training they are then qualified to receive inputs from the CLP program. There were some discrepancies in the original data to be controlled for; five in total. To fix these issues, five new variables were created using SAS and the values were adjusted according. A table of how the data was handled is shown below:

```
*************************************************
* NewVar    FFS   FBS   IP    CLP   ASSUME      *
* fix1      0     0     0     1     CLP=0       *
* fix2      1     0     0     1     CLP=0       *
* fix3      0     1     0     1     CLP=0       *
* fix4      1     1     0     1     IP=1        *
* fix5      0     1     1     1     FFS=0       *
*************************************************
```

In the above table, 0=no and 1=yes. FFS, FBS, and IP are as previously defined and CLP is a binary variable for whether or not the farmer received inputs from the CLP program. The last column is the assumption that was made based off of the five problem scenarios that were identified. For example, the variable fix1 corrects the error in which a farmer claims CLP inputs but has not conducted any of the training. This is impossible because a farmer is required to attend IP training prior to obtaining CLP inputs. We assume in this case that there was an entry error and that CLP should not be equal to one (yes) but rather CLP should be equal to zero (no). Other assumptions are shown in the table above.

Farm Size Outliers

Next, outliers were identified based upon farm size. An initial box plot identified an extreme outlier at more than 2,000 hectares. To correct for this the observations with extreme outliers were removed directly with 50 hectares as the cutoff point. After all farmers with farm size greater than 50 hectares removed, descriptive statistics were to determine the mean and standard deviation of farm size.

Yield Outliers

Working with observations that had already been corrected for CLP-input errors and farm size, attention focused on outliers based on yield. Extreme outliers were also identified in this data set with some farmers claiming yields well beyond the feasible range for cocoa, even in research settings. To remove these observations (likely an error that occurred from farm size being understated) observations were deleted that had yield in excess of 2,000 kg/ha for the main yield and 2,500 kg/ha for total yield. Observations were removed for both scenarios. These yields are considered a maximum feasible in most any part of the world and represent the physical constraints of the cocoa tree.

With the sample restricted to observations with main yield < 2,000 kg/ha and total yield < 2,500 kg/ha, descriptive statistics were calculated. Yield differences are expected between location (by country) and whether the farmer uses chemical fertilizer. By analyzing statistics with both chemical fertilizer use and country as class variables, it was decided to set upper limits on yield constraints for four different scenarios: Ghana with fertilizer and Ghana with no fertilizer. As such, these two groups were created and each was restricted individually by again taking two standard deviations above the mean of each group. Finally, the four groups were merged in to one data set.

Results

The final sample for yield modeling has a 1,143 observations in Côte d'Ivoire and 1,211 in Ghana with maximum yields of 1,007 kg/ha in Côte d'Ivoire and 1,186 kg/ha in Ghana. These values are in line with expected feasible maximum yields for Ghana and Cote d'Ivoire where average yields are 400 kg ha $^{-1}$ and 800 kg ha $^{-1}$, respectively (Dormon et al., 2004). .

D. USDA Glossary

Appendix 4. Glossary of Relevant Risk Management Terms (USDA, 2011)

Actual Production History (APH). Actual Production History is the most common plan of insurance under the Multiple Peril Crop Insurance, or MPCI, umbrella. It is the basis for determining your guarantee under either multi-peril crop insurance or revenue insurance policies. The APH is calculated as a 4- to 10-year simple average of your actual yield on the insured land. If you do not have records of actual yields, a "transitional yield" based on average yields in your county is used.

Buy-up coverage. This refers to crop insurance coverage that exceeds the CAT (catastrophic) level. Coverage is available up to 75 percent of your expected yield or expected revenue (which is yield times price). In some areas, coverage up to 85 percent is available for some crops. You pay part of the premium, but government premium subsidy rates are now over 50 percent for most levels of coverage.

CAT coverage. CAT is short for "catastrophic," and refers to crop insurance coverage at the lowest, or catastrophic level. CAT coverage is set at the 50/55 level, which means that your yield must fall below 50 percent of your average yield before a loss is paid. These losses are paid at a rate of 55 percent of the highest price election. You must pay an administrative fee to become eligible to receive CAT coverage, but the government pays the entire premium.
Crop Revenue Coverage (CRC). CRC is the most widely available revenue protection policy. This policy guarantees an amount of revenue (based on your actual production history (APH) x commodity price), called the final guarantee. Crop revenue insurance. Crop revenue insurance pays you indemnities based on gross revenue shortfalls instead of just yield or price shortfalls. Types of crop revenue insurance includes Crop Revenue Coverage (CRC), Revenue Assurance (RA) and Income Protection (IP). These programs are subsidized and reinsured by the USDA's Risk Management Agency.

Crop yield insurance. Also known as Actual Production History (APH) yield, crop yield insurance pays indemnities to producers when yields fall below the producer's insured yield level due to most natural causes. Crop yield insurance is subsidized by the USDA's Risk Management Agency.

Disaster payments. These are direct payments to farmers on an emergency basis when crop yields are abnormally low due to adverse growing conditions. During the 1970s, there was a "standing" disaster payments program, with payments made without declaration of a disaster area. Regular payments ceased after 1981, but since then ad hoc disaster payments have been specially approved by the U.S. Congress on a number of occasions.

Multiple Peril Crop Insurance (MPCI). MPCI was established in the 1930s to cover yield losses from most natural causes. MPCI operated on a somewhat limited basis up through the early 1980s, when a private/public partnership was established. At that point, insurance availability was greatly expanded and premium subsidies increased in hopes of replacing the disaster payment program. Major reforms legislated in 1994—introduction of a low-cost CAT (catastrophic) coverage level, increased premium subsidies, and a requirement that participants in other farm programs obtain crop insurance—increased participation to over 200 million acres, covering the majority of acres of major field crops planted in the United States.

Premium. The amount of money you pay for risk protection. Option buyers pay a premium to option sellers for an options contract. Similarly, the person who buys an insurance policy pays a premium in order to obtain coverage.

Revenue Assurance (RA). Revenue Assurance provides coverage to protect you against loss of revenue caused by low prices, low yields, or a combination of both.
Reinsurance. A method of transferring some of an insurer's risk to other parties. In the case of Federal crop insurance, USDA's Risk Management Agency shares the risk of loss with private insurance companies that deliver policies to producers. Private reinsurance also exists. In this case, a private reinsurer assumes responsibility for a share of the risk, in return for a share of the premiums.

Revenue insurance. Revenue insurance, a cousin to MPCI, was introduced after the 1994 reforms and has become the most popular form of insurance in some areas. Whereas crop insurance covers only yield losses, revenue insurance pays when gross revenue (yield times price) falls below a specified level. These programs are subsidized and reinsured by the Risk Management Agency.

Risk. Uncertainty about outcomes that are not equally desirable. Risk is an important aspect of the farming business. The uncertainties of weather, yields, prices, government policies, global markets, and other factors can cause wide swings in farm income. Risk management involves choosing among alternatives that reduce the financial effects of such uncertainties.

Subsidy. Money given by the government to help producers function.

Trigger yield. Under GRP, farmers receive payments any time the actual county yield drops below the trigger yield that the farmer chooses. The trigger yield can be 90, 85, 80, 75, or 70 percent of the expected county yield, which is based on the county's yield history since 1962. Expected county yields are adjusted for upward trends.

Uncertainty. Lack of sure knowledge or predictability.

Yield. The amount of something, especially a crop, produced by cultivation or labor.

United States Department of Agriculture
Risk Management Agency

E. Clarification of shade management

Appendix 5 Shade Clarification: Personal Correspondence with Edwin Afari, WCF

Shade management depends on the age of cocoa trees. For productive trees we are looking at the number of mature forest trees with height above 12m and dbh of >30cm that provide adequate canopy cover for cocoa trees. And for young cocoa trees we are looking at using plantain/banana and other crops to provide shade cover. 1. Number of trees per ha matters – Shade tree count (12-16 per ha) 2. Species of Trees 3. Pruning of trees 4. Amount of Shade cover 5. Canopy Cover 6. Placement of trees 7. Removal if there [is] excess shade. Cutting and ringing