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# COST AND BENEFIT ANALYSIS FOR CLIMATE-SMART AGRICULTURAL (CSA) PRACTICES IN THE COASTAL SAVANNAH AGRO-ECOLOGICAL ZONE (AEZ) OF GHANA

Working Paper

CIAT 1967-2017

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Working Paper

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# SUMMARY

Most countries in sub-Saharan Africa (SSA), including Ghana, rely on agriculture for their income and food security. Any initiative that might help to sustain and improve productivity in agriculture would be a crucial step in improving people's livelihoods. The adoption of climate-smart practices is a key step in reducing the threat to the sustainability of agricultural production in Ghana. Yet, despite the concern about the threat caused by climate variability and change, little empirical analysis has been carried out to date on how best to tackle it. However, recently many of the development and government programs are being designed in such a way that if adopted, can tackle the problems associated with climate variability and change. The majority of rural farmers have now adopted these practices. However, the cost effectiveness of adopting these practices – a key ingredient to the policy-making processes – is challenging. The results presented in this report attempt to bridge the knowledge gap between the cost and effectiveness, using ex-ante cost-benefit analysis to assess the cost effectiveness of some of the proposed climate-smart agricultural practices. This study examines the private and social benefits and the costs of selected climate-smart agricultural practices as a step towards understanding their private and potential social benefits and costs and their implication in terms of deterring their adoption from the farmers' viewpoint and any potential social benefits, if adopted.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AEZ | agro-ecological zone |
| BAU | business as usual |
| CBA | cost-benefit analysis |
| CCAFS | CGIAR Research Program on Climate Change, Agriculture and Food Security |
| CIA | Central Intelligence Agency |
| CIAT | International Center for Tropical Agriculture |
| $CO_2$ | carbon dioxide |
| CSA | climate-smart agriculture |
| CSA-PF | Climate-Smart Agricultural Practices Prioritization Framework |
| CSIR | Council for Scientific and Industrial Research |
| FAO | Food and Agricultural Organization of the United Nations |
| GH$ | Ghana Cedi |
| GHGs | greenhouse gases |
| IRR | internal rate of return |
| MoFA | Ministry of Food and Agriculture |
| NGO | nongovernmental organization |
| NPV | net present value |
| OECD | Organisation for Economic Co-operation and Development |
| SSA | sub-Saharan Africa |
| STEPRI | Science and Technology Policy Research Institute |
| UNFCC | United Nations Framework Convention on Climate Change |
| US | United States of America |
| USAID | United States Agency for International Development |

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NEIL PALMER/CIAT

# 1. INTRODUCTION

Sub-Saharan Africa (SSA) is particularly vulnerable to current and future climate variability and change (Conway and Schipper, 2011) and is more likely to suffer from the threats associated with it because the capacity to adapt and cope with the adverse effect of climate change is weak compared to Europe and North America for example (Kumssa and Jones, 2010a). The current and projected climate variability and change show the impacts on systems and sectors that are important for human livelihoods (UNFCC, 2011). Some of the adverse impacts of climate variability and change in agriculture include loss of crop and livestock production through a reduction in crop and livestock yield and productivity (Traore et al., 2013). As the majority of households in SSA rely on agriculture for their livelihoods, climate change and variability poses a major threat to human security and poverty (Fanzo and Pronyk, 2011; Kumssa and Jones, 2010b). Achieving food security in the face of changing climate thus represents a big challenge (Beddington et al., 2012).

Evidence from the literature shows that as well as climate variability and change effects, there are other challenges that households in SSA must contend with such as soil erosion, land degradation, and deforestation (Pimentel and Burgess, 2013). For example, land degradation in Ghana reduced agricultural income by approximately US$4.3 billion in the period 2006–1015, representing a 5% increase in poverty (Diao and Sarpong, 2007). The livelihood of the majority of people in Ghana is therefore under threat due to the negative effects of land degradation (Pimentel and Burgess, 2013; Yiran et al., 2012). This situation is further worsened by the increase in deforestation, increased incidence of soil erosion and frequent droughts (Diao and Sarpong, 2011; Pimentel and Burgess, 2013; Symeonakis and Drake, 2010; Yiran et al., 2012). An increase in deforestation, for example, has led to a decrease in rainfall and changes in climatic conditions (Badejo, 1998). The main effect of soil erosion is a reduction in crop yield because of its effects on the loss of fertile topsoil, crusting, soil compaction, reduced water-holding capacity and reduced rooting depth (Nearing, 2013; Symeonakis and Drake, 2010). These challenges can result in a serious decline in crop yield and livestock productivity and thus a challenge to achieving food security and the ability to adapt (Connolly-Boutin and Smit, 2015).

For agrarian households, the Coastal Savannah Agro-ecological Zone (AEZ) of Ghana is an important area because crop and livestock production is relatively high there (MoFA, 2013). The inability of farming systems in this area to support the production of crop and livestock due to the negative effects associated with soil erosion, land degradation, deforestation, and climate change can lower the households' potential of achieving food security and sustainable livelihoods. Therefore, policy makers and development practitioners must continually strive to find new technologies that will provide households with a greater resilience and the ability to adapt to changing climatic conditions (Tachie-Obeng et al., 2013). Nevertheless, appropriate policy prescriptions and recommendations are based on the evidence generated through research. It is against this background that nongovernmental organizations (NGOs) and the donor community is supporting efforts to identify effective adaptation and mitigation options. Assessing the cost and benefits of adaptation is an important part of this process because it assists the adaptation planners and development practitioners to focus on the most efficient strategies for reducing vulnerability (UNFCC, 2011).

Climate-smart agricultural (CSA) practices can strengthen the three CSA pillars – mitigation, resilience and food security (FAO, 2012, 2010; USAID, 2007) – because, if implemented, they can increase productivity, reduce agriculture greenhouse gas (GHG) emissions and increase carbon sequestration (Perrin, 2015). The CSA practices therefore can improve households' ability to adapt while delivering environmental benefits (Perrin, 2015; Scherr et al., 2012). However, as widespread adoption of CSA practices will depend in part on the ability to make a business case for their benefits to the farmers, a cost-benefit analysis of implementing CSA practices should be conducted. In the context of this study, CSA comprises technologies such as intercropping, crop rotation, use of improved seeds, integrated nutrient management, and improved water management (Perrin, 2015), that were identified by farmers and development practitioners as having the highest impact on food security, mitigation, and resilience. This study is supported by the United States Agency for International Development (USAID) program and led by CIAT to assess the cost and benefits of some selected CSA practices implemented within the agricultural systems in the Coastal Savannah AEZ of Ghana. As farmers are the principal actors in bearing the cost and enjoying the benefits associated with implementing CSA practices, the main focus of this report is on the costs and benefits of CSA practices from the farmers' point of view.

## 1.1. THE STUDY OBJECTIVE

The main objective of this study is to:

- Evaluate the main costs and benefits associated with implementing eight selected CSA practices in the Coastal Savannah AEZ of Ghana.
- Assess the value of externalities associated with implementing the CSA practices.
- Incorporate the estimated value of externalities in the cost and benefit analysis of the CSA practices.

## 1.2. JUSTIFICATION

One effective way of increasing farm returns is to adopt appropriate agricultural practices. According to Doss (2001), innovative tools and methods can be instrumental in providing insights into the main issues that households decisions revolves around and which have an important bearing in supporting the uptake of appropriate farm practices. Despite the considerable amount of research on the adoption of agricultural practices available, there is surprisingly little knowledge of the impact of implementing specific CSA practices on farm income and the trade-offs associated with them (Doss, 2001; Ghimire and Huang, 2016; Sunding and Zilberman, 2001). Evidence from the literature shows that a full system cost-benefit analysis for soil carbon sequestration from various agricultural practices has not been adequately carried out (Franzluebbers, 2005). Knowledge of the impact of adopting a particular practice is important, particularly where the costs (e.g. farm inputs) and benefits (e.g. yield and income) for practices implemented on farms are borne by the households (Dallinger et al., 2016; Sain et al., 2016; Tschakert, 2004). Knowledge of the benefits that are enjoyed by both farm households and society at large (Tschakert, 2004) would be useful to governments that are interested in sensitizing farm households about implementing specific practice(s).

This report attempts to address the existing knowledge gap by conducting a cost-benefit analysis for adopting and implementing selected CSA practices by farm households in rural areas in the Coastal Savannah AEZ in Ghana. This study aims to demonstrate to government and development practitioners if the implementation of the selected CSA practices is economically viable, and to examine their potential to enhance households' ability to adapt (by increasing income and improving food security).

The eight practices analyzed in this report were derived from the CSA prioritization framework (CSA-PF) (Corner-Dolloff et al., 2014). The CSA-PF examined a long list of CSA practices that have been implemented (e.g. on existing farms) and potential CSA practices for adoption in the Coastal Savannah AEZ (CIAT–CSIR, 2016). CIAT and the Ghana Science Policy Platform with the Council for Scientific and Industrial Research (CSIR) led the application of the CSA-PF process. The potential of each practice in terms of its productivity, adaptability, and resilience was assessed to generate a short list of eight CSA practices. These eight practices are evaluated in this report.

This report is organized as follows. The next section briefly reviews the theoretical basis of a cost-benefit analysis (CBA) for evaluating CSA practices. We then introduce the study area, explain how the CSA practices were selected, describe the data collection process and summarize how CBA analysis was implemented in Section 2. In Section 3, we summarize the CBA results. We then discuss the main results and conclude in Sections 4 and 5, respectively. Section 6 includes the Appendices and the References are listed in Section 7.

### 1.3 THEORETICAL BASIS OF CBA FOR EVALUATING CSA PRACTICES

Mainstream economics hypothesizes that economic trade-offs are inevitable when limited resources are assigned to specific uses. Private economic agents are therefore motivated to seek avenues – using different tools and methods – that can help them to allocate resources with the objective of achieving optimum benefits. In the case of private benefits, one needs to compare the net present value (NPV) of benefits and costs to decide whether or not to invest in a specific activity or a project. However, for decisions relating to public goods – such as the stock and flow of natural resources, and associated benefits such as carbon sequestration where farmers invest in agroforestry practice – CBA estimates the benefits and costs associated with the differences in stock flow before implementation of the practice and after. Therefore the allocation of resources to achieve optimal benefits for a resource that is considered more beneficial to the public is even more challenging. This is because economic decisions that impact on the public involve a series of externalities, whose social impacts need careful accounting. CBA is an economic tool used in guiding the economic agents to allocate resources and decisions relating to investment or evaluating policy options. It does so by summing up the NPV of future flows of costs and benefits associated with investing in a project to establish whether undertaking a specific activity or a project is worth it or not. CBA is thus useful in comparing two scenarios: business as usual (BAU) scenario – before implementing a practice – and the scenario after implementation of the practice. However, the application of CBA in CSA practices is challenging. This is because attaching the value of non-tradable services – such as those associated with environmental services – can be difficult. Nevertheless, CBA is an economic tool of choice for evaluating investment decisions (van Wee, 2012).

MAIZE (NEIL PALMER/CIAT)

# 2. MATERIALS AND METHODS

## 2.1. THE STUDY AREA

This study was conducted in the Coastal Savannah AEZ of Ghana. The Coastal Savannah AEZ is a narrow strip of grassy and scrubby coast, about 8 km in width at its western end, stretches eastward through the Accra plains, where it widens to more than 80 km, and terminates at the southern corner of Ghana at the lower end of Akwapim-Togo ranges (CIA World Factbook, 2013)(Figure 1). It lies between latitude 4° 44' N to 11° 11' and longitude 3° 11' to 1° 11' E and covers an area of approximately 4,500 $km^2$ and receives bimodal rainfall averaging 600–1,200 mm annually. The rainfall is evenly distributed all year round; with March and July receiving heavy rains while September and October receives light rains. The length of the major and minor growing season is 105 and 50 days, respectively. The temperature range is between 180 °C and 290 °C. The altitude ranges from 1,240 to 2,000 meters above sea level (masl). Most farmers grow maize (*Zea mays*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), cassava (*Manihot esculenta*), cowpea (*Vigna unguiculata*), tomato (*Solanum lycopersicum*), shallot (*Allium cepa*), millet (*Penisetum typhoides*), coconut (*Cocos nucifera*) and pineapple (*Ananas comosus*). Maize, mixed cereal, and vegetable crop systems occupy about 320, 68, and 50 ha, respectively. The main livestock in this area are cattle, goats, and sheep. The data used in this study was collected from Ada district in the Coastal Savannah AEZ, from the cereal-legume-small ruminant smallholder production systems whose farm household characteristics are: farms of 2 ha or less, growing mainly cereals (e.g. maize and sorghum), legumes (e.g. groundnut, bambara bean [*Vigna subterranea]*) and cowpea, and rearing small ruminants (e.g. sheep and goats).

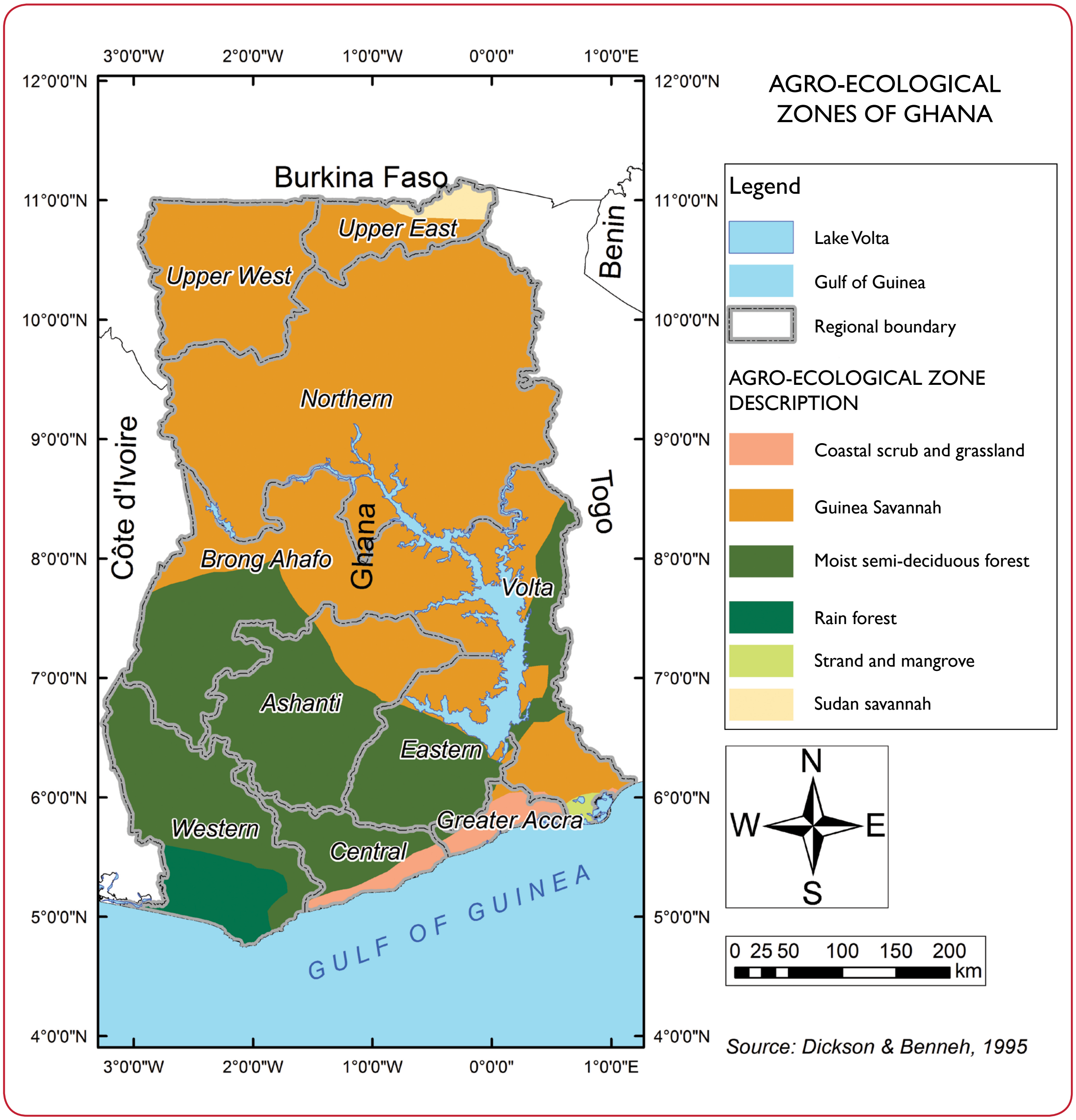


**FIGURE 1.** MAP OF GHANA, SHOWING THE COASTAL SAVANNAH AGRO-ECOLOGICAL ZONES (AEZ).

## 2.2. PRIORITIZATION PROCESS AND SELECTION OF CSA PRACTICES

The aim of the CSA-PF prioritization process was to identify Climate-Smart-Agricultural practices and investment portfolios that reflected the needs of a wide range of users, taking into account the investment costs, economic profitability, overall benefits and climate resilience outcomes to determine the feasibility of scaling-out CSA practices already implemented by farmers in the Coastal Savannah AEZ, and to identify potential practices that could be used in the Coastal Savannah AEZ. Consequently, a CSA stakeholder workshop was held at the Council for Scientific and Industrial Research-Science and Technology Policy Research Institute (CSIR–STEPRI) in Accra, Ghana with the aim of engaging stakeholders in the CSA-PF process. The CSIR–STEPRI workshop brought together 47 stakeholders[1] and experts drawn from: research institutes, NGOs, Ministry of Agriculture and academic institutes; farmers and members from various farmers associations; and communities (Appendix 1).

The CSA-PF process comprised: a validation of the study site and farm practices relevant in the context of cereal-legume ruminant smallholder farmers from Ada area of the Coastal Savannah AEZ (Appendix 2); an assessment of the farming practices based on their climate "smartness" for the selected region and production system based on 11 indicators of the CSA goals of productivity, adaptation and mitigation (Appendix 3); ranking and prioritizing the selected practices in order to generate a short list of 10 CSA practices (Appendix 4); and a CBA assessment of the selected eight CSA practices. This report focuses on the results from Step "e" (Table 1).

**TABLE I. A DESCRIPTION OF THE EIGHT CSA PRACTICES PRIORITIZED FOR CBA EVALUATION**

| CSA PRACTICE | DESCRIPTION OF THE CSA PRACTICE |
|---|---|
| Minimum/low tillage | • The decrease in tillage intensity that lowers practices that disturbs the soil and increase in surface residue. In the Coastal Savannah AEZ, it comprised a reduction of the use of mechanical ploughing and the use of oxen for ploughing. |
| Livestock prophylactic practices | • Some of the measures that are adopted by farmers to prevent the occurrence of the livestock diseases or their spreading. |
| Supplementary feeding with agro by-products | • The use of agro by-products and crop residues in the form of groundnut tops, maize cobs, silage, cut forage, by-products from grain winnowing, cowpea pods, peels of plantain and cassava, brewers grain and rice bran. These are supplemented with leaves from fodder plants and cut grass. |
| Crop rotation | • Continuous cropping without a fallow season. It entails growing of different crops in a well-defined sequence on the same piece of land. It may involve changing the type of crops grown on the farm each season or year. For example in the Coastal Savannah AEZ, a field could be planted to maize during the long rainy season (April–June) then after harvesting, the same field is planted to cowpea during the short rainy season (September–October). |
| Improved livestock housing | • An outdoor confinement area is used for enclosing livestock. The livestock housing has shade shelters that are under 20 $m^2$ and permanent or portable feeding and watering equipment. |
| Genetic resources | • The use of improved seed (e.g. hybrid seeds of maize) to improve yield without necessarily changing their production practices and without purchasing additional inputs. |
| Mixed cropping | • Growing more than one crop on the same field during the season. This technique makes efficient use of inputs such as soil, water and fertilizer. |
| Integrated nutrient management | • Practices that are performed to ensure improvement of soil health and environment, thereby increasing soil fertility. It aims to integrate the use of natural (e.g. organic fertilizers) and man-made (inorganic fertilizer) soil nutrients to increase crop productivity while preserving soil productivity for future generations. |

Source: Kombiok et al. (2012); Morris et al. (1999); Timpong-Jones et al. (2014).

[1] Survey participants were from different areas; 12, 15 and 20 of the participants were from Accra, Kumasi and Sege, respectively. Each participant assessed three CSA practices (3 complete surveys). The practices were then averaged and weighed using a computerized program.

## 2.3. DATA COLLECTION

The data on costs and benefits was derived from primary data collected from key resource farmer's households, from experts' opinions and from published work/reports. Household surveys were conducted between July and August 2016. A structured questionnaire was used to collect detailed primary data on the following issues related to CSA practices: general information of the study site; information on farming in the Coastal Savannah AEZ; anticipated costs and benefits of selected CSA practices relative to the BAU practices; changes on productivity associated with the CSA practices relative to the BAU practices; input and output market prices; cost of implementation, maintenance and operation; and on externalities (environmental and socioeconomic effects). Data from the literature review was used to fill in the data gaps generated by the primary data collection.

Before administering the questionnaire, six enumerators were trained in its use and they then pretested the survey tool by completing at least two surveys in full. The purpose of the pretest was to assess whether the enumerators understood the questions properly and if they could identify any problems with the translation of the questions. All unclear issues were highlighted and rectified before the final questionnaire was finalized for use. A total of 48 farm households were interviewed. These households were selected using a snowballing method (e.g. Christopoulos, 2009) in which key extension officers and/or agronomists who worked in the area were contacted. The extension officers and the agronomists called together a number of farmers that met the set criteria (such as living in the selected region, being smallholder farmers, and growing/ raising the indicated commodities specified for the study). Each farmer then contacted other eligible farmers in their network. Therefore the use of CSA practices was found in all the sampled households where each of the farmers was implementing at least one of the eight selected CSA practices in 2015. Because some of the CSA practices had a short implementation period (prior to the year of study – 2016), the survey data showed no significant differences in the yields, when we compared the business as usual and the CSA practices. So relying on information from recent years did not accurately capture the emerging field differences in impact of CSA on crop yields. Consequently, this study uses both the *ex-post* (because the practices had already been implemented by farmers) and *ex-ante* (because some of the impacts of CSA had not yet been realized) approaches. This required us to collect more evidence from the literature on the magnitude of introducing CSA practices on the various crop yields grown in the different systems.

Data on externalities associated with adoption and implementation of the eight selected CSA practice was gathered from 12 experts (or evaluators) using a semi-structured questionnaire. Key persons were selected based on their experience of the selected CSA practices on issues such as: soil hydrology, GHG emissions, changes in crop productivity, soil erosion, soil biodiversity and social capital. Each evaluator was asked for the maximum (or peak) and value (in GHC$) of each additional unit of external effects for at least three CSA practices. Information on external effects associated with implementing the eight CSA practices was gathered from the literature to fill in gaps where crucial information had been missing. The literature review comprised accessible government reports and peer-reviewed publications.

## 2.4. COST-BENEFIT ANALYSIS

The CBA tool was used in assessing profitability associated with different CSA practices. We implemented the probabilistic CBA by comparing the differences in the flow of net benefits (e.g. difference of flow of benefits and costs) over their life cycles. The life cycle period was the time when the farmers adopted a specific CSA practice up to the time when the farmers stopped using it – in order to start all over again or to adopt a different practice. There are two commonly used economic assessment indicators in CBA. They are the net present value (NPV) and the internal rate of return (IRR) (Juhász, 2011). The NPV represents the incremental flow of the differences of flow of benefits and costs generated by the different CSA practices compared over their life cycle periods. The NPV was determined by the least expected computed interest rate, and indicated how much wealth had been accumulated by the CSA practice during its entire life cycle period. NPV did not tell us about the real profitability of adopting and implementing any of the selected CSA practices. NPV was calculated as shown in Eq. 1.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{1 + r^t}$$

**where:** $B_t$ represents benefits at time t, $C_t$ represents investment and recurrent cost at time t, t represents time horizon, and r represents discount rate.

The IRR stands for the discount rate that equates to the present value of the flow of future net benefits to zero. The IRR did not specify the cost of capital (e.g. the interest rate), but it was compared with a range of possible values to assess how profitability varied across different scenarios. An investment was considered to be profitable if its IRR was higher than the cost (e.g. the discount rate). We computed IRR using average values obtained from the household survey. The IRR was determined as shown in Eq. 2

$$\sum_{t=1}^{n} \frac{B_t - C_t}{1 + r^t} = 0 \text{ when IRR} > \text{r: NPV} > 0$$

**where:** $B_t$ represents benefits at time t, $C_t$ represents investment and recurrent cost at time t, t represents time horizon, and r represents IRR.

The NPV and IRR were determined for each CSA practice. Each practice had its own adoption and operation functions that generated different streams of costs and benefits. The discount rate used in the study was derived from the interest rates payable by the farmers on their bank loans e.g. 25.51% (Bank of Ghana, 2016). The variability associated with the resulting IRR for each implemented practice was computed using the standard deviation of the values obtained from the household survey. All costs and benefits were converted to U.S. dollars.

In many instances, most CBA used a deterministic approach (Brent, 1996) where farm average or mode values of the survey variables were used in the calculation of the IRR (Sain et al., 2016). Following such an approach meant that no measurement of variability or uncertainty was considered in the computation of the IRR. Such an approach therefore could result in an underestimation of the risks taken by the farmers when adopting a practice. Using the probabilistic approach helps to overcome this limitation as it allows the analyst to consider not only a range of possible values of the variables under consideration, but also to attach to these values a measure of likelihood of their occurrence (Anderson and Dillon, 1992). The probabilistic approach can generate a cumulative distribution function of the IRR of the economic returns from the available alternatives. In this way, the cumulative distribution function of the IRR gives the probability that the IRR is less than or equal to a specified value. It provides the probability of the investment practices adopted by the farmers being profitable. In this study, the probabilistic CBA was carried out using Monte Carlo Simulation with @Risk software (Palisade Corporation, 2013). Using the probabilistic approach, the cumulative distribution function of the IRR was generated from the probability distribution of the random variables included in the analysis.

### 2.5. THE CBA MODEL AND VARIABLES USED

In this study, the CBA calculations for the NPV and the IRR associated with implementing the eight selected practices were carried out from a private investment point of view. The impact of the selected practices on the external (or social) effects such as soil erosion, soil biodiversity, social and political capital, water retention, carbon sequestration and biodiversity, were also estimated from a private point of view. In other words, the unit of analysis for this study was 1 ha. However, the value of externalities was computed separately from private profitability.

The flow of the net benefits of replacing BAU practice by CSA practice were estimated using (Eq. 3).

$$NPV_j^{csa-bau} = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[ \sum_{j=1}^{j} P_{jt} * \Delta Y_{Jt}^{csa-bau} - \sum_{j=1}^{j} \Delta C_{jt}^{csa-bau} \right]$$

where $P_{jt}$ represents the price of commodity "j" in time t;

$\Delta Y_{Jt}^{csa-bau}$ represents the annual change in yield for "j" for CSA compared to BAU practices;

$\Delta C_{jt}^{csa-bau}$ represents the annual change in cost of implementing the CSA compared to BAU practice;

*r* is the discount rate representing the opportunity costs; and
*T* represents the time horizon in the analysis (e.g. life cycle period).

Most CSA practices emphasize agricultural systems that use the ecosystems services in a way that promotes the sustainability of the systems over time. To estimate the effect of the CSA on crop yields, we assumed that the selected practices would have some positive impact on the ecosystems services through, for example, improving the soil fertility and quality, plant diversity, water infiltration and disease resistance. The implementation of some of the CSA practices related to livestock production could potentially reduce productivity losses such as those associated with exposing animal to cold weather or infestation by opportunistic pests and diseases (Lal, 2015). At the same time, the yield response from livestock related practices could take a substantial amount of time to be realized. Moreover, the time taken by crop or livestock yield to start responding due to the implementation of CSA practice varied by activity. This is because such a response might also have been affected by other biophysical aspects of the environment such as the frequency of drought and the extent of soil degradation.

Therefore, to model the effect of the crop or livestock yield associated with implementing a specific CSA practice, we assumed that the physical response function followed a shape characterized by: i) the time lag – the time between when CSA practice is implemented to when crop or livestock yield start to change due to implementation of the CSA practice (point [t0] to [t1]) in Figure 2), ii) the start of increase in physical response until it reaches maximum (point [t1] to [t2] in Figure 2), and iii) the period after which the physical response reached a linear plateau (point [t2] to [T] in Figure 2) (Beattie and Taylor, 1993). The difference between t1 and t0 is the response lag, while Yf is the maximum increase in yield associated with implementing a CSA practice, and T represent the entire life cycle period. This Liebig production function has been shown to have been used widely to estimate biological process corresponding to the law of minimum (Beattie and Taylor, 1993; Beattie et al., 1985).

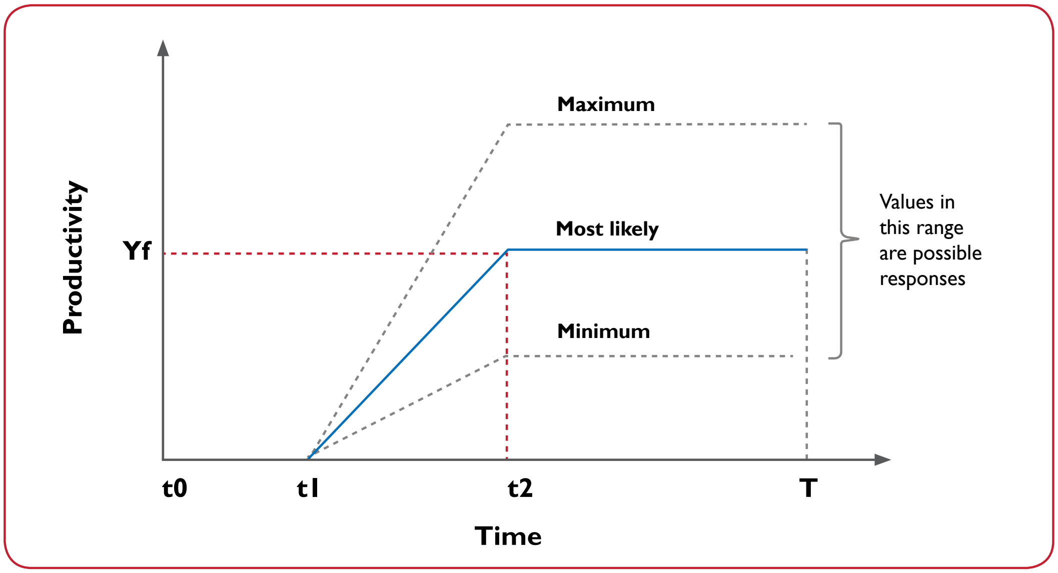


**FIGURE 2.** ASSUMED SHAPE OF THE PHYSICAL RESPONSE FUNCTION AND PARAMETERS CHARACTERIZING THE TRIANGULAR DISTRIBUTION. Source: Beattie and Taylor (1993).

## 2.6. THE MAIN VARIABLES

In the computation of CBA, three main types of cost were considered: installation, maintenance and operation costs. Installation costs represents costs that the farmer incurred during the adoption and implementation of the CSA practice. Maintenance costs are cost incurred by the farmer for sustaining the CSA practice during its life cycle period to ensure proper performance. Operation costs are those costs that were associated with introducing the CSA practices to outputs/ activities affected by the CSA such as (but not necessarily) harvesting. Both maintenance and installation costs were computed on a yearly basis. Operation costs were not necessarily incurred annually.

Other variables that were included in the CBA computation included: market prices for crop and livestock products, changes on crop production per hectare and livestock production per animal for both the BAU and CSA practice (e.g. yield response), the CSA life cycle period in years, and the time after adoption of the CSA practice when the yield response start to increase and when it reaches the maximum and the discount rate.

All these variables were categorized as either random or nonrandom. In probabilistic CBA, specifying whether the variables under consideration was random or nonrandom is important because nonrandom variables required evaluation at the average (mean) or mode value, while variables that are considered random were evaluated over the entire range of possible values through their association with cumulative distribution function (CDF).

In this study, random variables included installation cost, maintenance cost, operation costs and crop yield. The costs were considered random because they captured the variability in production technology across households in the study site. Crop yields response determined to a large extent the impact of implementing a CSA practice. Yields were considered random to reflect the degree of uncertainty about their true value.

Nonrandom variables were those that did not vary much across households, irrespective of CSA practice that the farm households implemented, for instance crops market prices, life cycle period, and discount rate. The prices of crops for example had minimal variation across farms based on the 2016 household survey data. Life cycle period and discount rate were considered nonrandom because their characteristics were largely determined by the nature of the implemented practice.

In estimating the uncertainty surrounding the response of crop yields as a result of using CSA practices, we assumed that the crop yield followed a triangular probability distribution characterized by three parameters: the minimum, the most likely and the maximum value (Figure 2). This kind of distributions was commonly used, especially in instances where there were issues of data limitation in terms of the true value of the parameters. In this study, in collecting data on these three parameters, we used data from the household survey, complemented by data from experts and the literature review. The variability of technology across farm households was therefore manifested through the triangular distribution. Similarly, for the cost structure, the shape of distribution function was determined by the best fit generated using @Risk software for the 2016 survey data for installation and maintenance costs collected from the 48 resource farmers.

### 2.6.1. PARAMETER VALUES USED IN ESTIMATING THE PRIVATE PROFITABILITY

To model the physical response curve after adoption and implementation of the CSA practices according to the linear model adopted for the crops under study, information from the survey was used to estimate the practice duration (Table 3). The survey data was used to estimate the initial yields ($Y_0$) without CSA practice (Appendix 5). Because of the short duration of time that it took to implement the CSA practice, the estimated value of the final yield ($Y_f$), the minimum ($Y_{min}$) and maximum ($Y_{max}$) parameters characterizing the triangular distribution used in the calculation of the variability in crop yield response due to implementing a CSA practice was computed according to the household survey data. The survey data showed that four CSA practices start showing yield responses in the third year. For the cost structure the @Risk software was used to establish best-fit distribution – thereby revealing what was known about the variability of CSA practices implemented across households – for the installation and maintenance cost data reported in 2016 (Table 2).

**TABLE 2. DISTRIBUTION OF COST STRUCTURES AND PARAMETER VALUES**

| | Incremental cost | |
|---|---|---|
| **CSA practices** | **Installation costs (US$/ha)** | **Maintenance costs (US$ha$^{-1}$year$^{-1}$)** |
| Crop rotation | Lognormal (595, 121) | Uniform (817,490) |
| Mixed cropping | Lognormal (143, 334) | Uniform (19, 117) |
| Minimum tillage | Lognormal (151, 285) | Uniform (77, 264) |
| Improved genetic resources | Lognormal (140, 319) | n/a |
| Improved Nutrient Management | Lognormal (102,22) | Uniform (49,299) |
| Livestock prophylactic practices | Lognormal (56,150) | Triangular (200, 200, 1334) |
| Supplementary feeding | Lognormal (39, 99) | Uniform (150, 1050) |
| Improved livestock housing | Lognormal (579, 524) | Lognormal (512, 643) |

NB: The distribution has been best fitted to the survey data.
n/a stands for not applicable.

### 2.7. EXTERNAL EFFECTS, THEIR VALUATION AND PARAMETER VALUES

The implementation of CSA practices was associated with more than direct benefits – in terms of improved productivity and income – but also a wide range of externalities such as ecosystem services and social benefits (Dale and Polasky, 2007). In Ghana, the externalities that resulted from the implementation of CSA practices were considered important factors in CBA. This is because they were not the underlying goal when developing CSA practices, yet they were crucial benefits. Evidence from the literature recognizes that some of the CSA practices generate many different external effects (Sain et al., 2016). The seven main external effects that were identified as relevant for and applicable in the study area and in line with the stakeholders' preferences included: carbon sequestration, biodiversity conservation, water availability, soil erosion, soil biodiversity, as well as social capital and structural social capital (Table 3).

We examined the externalities associated with all the eight CSA practices. Generally, one may examine these externalities in two levels: i) on-farm effects, and ii) off-farm effects on adjacent farms and in downstream location. The focus in this study was only on on-farm related externalities (Table 3). Analyzing the external effects, however, was a real challenge; it was complex and extensive because external effects are not typically traded in the market (Dale and Polasky, 2007). To overcome this challenge, we used experts from various disciplines of expertise and categories (Appendix 1) to contribute provide data to estimate the amount of change in externality as a result of the introduction of the CSA practices – thus ensuring the validity and reliability of the results. To estimate the shadow price of the external effects, we relied on the contingent valuation method to estimate the marginal value the households were willing-to-pay for the externalities. We chose the willingness-to-pay valuation method because it was the most appropriate when dealing with experts who were aware of all the local and regional implications of the externalities in question (Lera-López et al., 2014). When a high variation in the shadow prices for the externalities was encountered, it was considered a random variable and a simulation was done using @Risk software. Using this approach, the model was able to capture the large degree of uncertainty associated with the true value of the variables.

**TABLE 3. SOME OF THE EXTERNAL EFFECTS ASSOCIATED WITH THE SELECTED CSA PRACTICES**

| | Soil erosion | On-farm biodiversity | Carbon sequestration | Soil biodiversity | Water availability | Political and social capital[2] |
|---|---|---|---|---|---|---|
| Minimum tillage | Reduces soil erosion | Increases species of plants per unit area | Improves air quality by sequestering carbon | Increases soil fertility through increased decaying organic matter | Increases water infiltration by slowing flow of water | No significant effect |
| Genetic resources | No significant impact | No significant impact | No significant impact | No significant impact | No significant impact | Increases political and social capital |
| Improved livestock housing | Reduces soil erosion | No significant impact | Improve air quality through improving odor conditions and reduced dusts from livestock the air | Increases soil fertility through increased collection of manure | Enhances water collection | Increases political and reduces social capital (less demand for labor) |
| Mixed cropping | Reduces soil erosion | Increases species of plants per unit area | Enhances carbon sequestration[3] | Increases soil fertility (from crop residues) | Enhances water infiltration | Increases social and political capital |
| Integrated nutrient management | Reduces soil erosion | Increases species of organism per unit area | Improved air quality through reduced ammonia emission from manure storage facilities | Increases soil fertility through decaying biomass and carbon | Enhances infiltration because of improved soil structure | Increases political and social capital (technical expertise and decision making capacity) |
| Crop rotation | Reduces soil erosion | increases on-farm plant diversity (i.e. weeds) | improves air quality by sequestering carbon | Increases soil fertility through decaying biomass and carbon in the soil | Increases water infiltration by slowing flow of water | Increases social (through labor) and political capital |
| Livestock prophylactic practices | Difficult to determine | Difficult to determine | May be a source of bad odor | Increases soil fertility | No significant impact | Increases social and political capital |
| Supplementary feeding | Difficult to determine | No significant impact | Improved air quality through reduced ammonia emission from manure due to improved diet | Increases soil fertility | No significant impact | Increases social and political capital |

The units of measurement for the externalities are presented in Appendix 6.
Source: Berendse et al.(2015); Devereux (2014); Drinkwater et al. (1998); Gaudin et al. (2015); Havlin et al. (1990); Ilukor et al. (2015); Lal (2015, 2004); Locke et al. (2015a); Michigan State University (2016); Salado-Navarro and Sinclair (2009); Silva et al. (2013); TerAvest et al. (2015); Waha et al. (2013).

2 Increased social and political capital is through interaction with other farmers, extension agents, development partner and government agencies promoting specific CSA practices.
3 It is not yet clear which combinations of crops results in more biodiversity, biomass, organic matter and more water retention (Hoffland, 2015).

### 2.7.1 ON-FARM BIODIVERSITY

Evidence from the literature shows that the adoption of practices – such as crop rotation, mixed cropping, integrated nutrient management etc. – can increase below – and above- ground agro-ecosystem diversity (Carter et al., 2009; Munkholm et al., 2013; Tiemann et al., 2015). However, a standardized method for measuring on farm-biodiversity has not yet been developed (von Haaren et al., 2012). Based on the evidence from the literature, to quantify a change in on-farm biodiversity, a score was usually assigned based on support provided by different land use types. A land-use type where the main vegetation was forestry for instance was assigned the highest score because it provided more on-farm biodiversity compared to a food crop. A food crop was assigned a lower score because it provided less on-farm biodiversity benefits (Henry et al., 2009). For this study however, due to lack of data for on-farm biodiversity associated with the studied CSA practices, we estimated on-farm biodiversity associated with the BAU practices under study through the experts' interviews. We also assessed the relative increase of on-farm biodiversity after implementation of CSA relative to BAU. Through the interviews, we estimated the change in the number of species of plants and animals found on-farm, including cultivated crops, forages, and raised animals over the baseline. Then using the contingent valuation approach, we assessed the experts' willing to pay (in GHC$) for a unit change in on-farm biodiversity (e.g. the shadow price) due to adoption of the CSA practice. Multiplying the change in biodiversity score by the shadow price, we then derived the value of biodiversity associated with the land-use change at the farm level.

### 2.7.2 CARBON SEQUESTRATION

Carbon sequestration refers to the transfer of atmospheric $CO_2$ into other long-lived pools (Henry et al., 2009; Lal, 2008). Carbon sequestration is considered both a private and public good (Lal, 2008). This is because it leads to an increase in organic matter and raises carbon content in the soil. This in turn promotes better crop rooting, soil health and proper water drainage. Carbon sequestration also improves the air quality, by mitigating atmospheric greenhouse gas concentration – a public service (Farage et al., 2007; Lal, 1999; Tschakert, 2004). However, considering that for a given plant biomass, plants with more leaves than woody biomass store carbon for a short period of time (Nowak and Crane, 2002). It is a challenge to get accurate and reliable estimates from the literature on the amount of carbon sequestered by each of the studied CSA practices in the Coastal Savannah AEZ.

Therefore, to estimate the carbon sequestered in BAU practices and the associated change associated with implementing each of the eight CSA practices, experts' interviews were conducted. A contingent valuation method was then used to elicit the average value that the experts were willing to pay for 1 tonne of $CO_2$ sequestered per hectare per year. This value was around US$7, which compares well with the world carbon prices which is about US$6 $ha^{-1}$ $year^{-1}$ (Khatun, 2011). The value of carbon sequestered due to the implementation of the different CSA practices was therefore derived by multiplying the change in tonnes of $CO_2$ sequestered per hectare per year with the shadow price.

### 2.7.3 SOIL BIODIVERSITY

To capture the improvement in soil fertility due to the different CSA practices, we estimated the amount of nitrogen fixed per hectare by the different types of legumes that were present in the implemented CSA practices. The estimates on the amount of nitrogen fixed per hectare by legumes were gathered from the literature (Appendix 7). In addition to nitrogen fixation, decomposing organic matter associated with the different practices also contributed to the improvement of soil fertility. Our underlying assumption was that nitrogen was an indicator of soil health and quality. Therefore, we complemented the information from the literature with estimates from the experts' survey for the estimated change in soil nitrogen due to implementation of CSA practices relative to BAU. The expert survey thus enabled us to assess the amount of nitrogen fixed in 1 ha of soil per year or the percentage change over the baseline. Using contingent valuation we then estimated the shadow price of the amount of nitrogen fixed by the different CSA practices by assessing the value that the experts were willing to pay for the amount of nitrogen gained/fixed per hectare. We assumed that nitrogen fixed in the different CSA practices saved the households money that would have otherwise been used to purchase nitrogen. The value of a unit increase in soil nitrogen for each CSA practice was derived by multiplying the shadow price – which compares well with the price of a kilogram of nitrogen – provided by the experts with the change in nitrogen gained by the CSA practice over the BAU per hectare per year.

### 2.7.4 WATER AVAILABILITY

Like in other developing countries, in the Coastal Savannah AEZ, water is a major factor constraining agricultural output and income (Namara et al., 2010). The valuation of change in water availability associated with implementing the eight CSA practices was conducted by asking experts' interviews to estimate the amount of water (in $m^3$) that could be made available per hectare in a period of 1 year by the eight CSA practices over the BAU. The value of water was assessed using the contingent valuation method and was estimated to be US$0.8 $m^{-3}$. In computing water availability per practice, we assumed that the volume of water available/produced per hectare, as reported by the experts for the different CSA practices, was less than the amount of water lost through runoff. The value of water availability for each practice due to implementation of the different CSA practices was then derived by multiplying the change in water available per hectare per year by the shadow price and entered in the CBA computation.

### 2.7.5 SOCIAL AND POLITICAL CAPITAL

Social and political capital are important components of the social fabric when implementing CSA practices. This is because political capital is a resource that influence current and future activities that households might undertake (Stiglitz et al., 2009). Political factors at the national level policies, institutions and at the community level affect the fortunes of households and are potentially important capitals (Narayan and Pritchett, 1999). At a macro level, political interaction (e.g. higher level cooperation and frequent interaction with associations) is likely to increase the flow of new information (Putnam, 1993, 2001), thereby increasing ideas that could help in boosting the impact and implementation of practices. At the individual level, people with a wider social network are more likely to share ideas on how to overcome a specific constraint and/or to be employed (Aguilera, 2002), thereby easing labor constraints. According to the OECD, there are four different aspect of social capital: personal relationships, social network support, political engagement, and trust and cooperative norms (Scrivens and Smith, 2013). The aspect of social capital estimated in this study associated with implementation of CSA practices was the interaction aspect of social (e.g. participation in local groups of farmers, communities etc.) and political interaction (e.g. number of interaction with outside entities – agricultural association, institutions and policy makers). Social and political interactions were a relevant externality in the implementation of CSA practices because they help to capture the level of interaction through ideas or resource support that a households could draw on from their relationship with other households or external entities (Ng'ang'a et al., 2016; Scrivens and Smith, 2013).

The political interaction was estimated by first ensuring the experts understood what these two capitals referred to in terms of interactions with various associations or groups. With this understanding, and their knowledge relating to frequency of interaction, memberships of groups, characteristics of groups, the experts established the baseline social and political capital associated with BAU and estimated the change in both (as a percentage increase) due to implementing CSA practices. Then using the contingent valuation approach, the experts were assessed on their willing to pay (in GH$)[4] for a unit change in social and political capital. Multiplying the change in social and political capital with its shadow price, we then derived the value of political capital associated with the practice.

### 2.7.6 REDUCTION OF SOIL EROSION

One important role played by the implementing some of the CSA practices – such as minimum tillage and intercropping – was the reduction of soil erosion (Nearing, 2013; One Acre Fund, 2015; Sun et al., 2010). In CBA computation, the reduction in soil erosion was considered a positive externality because it preserved biodiversity and improved crop productivity (Marta-Pedroso et al., 2007). To monetize the benefit associated with soil erosion reduction, a team of soil experts in Ghana was asked to estimate the amount of soil erosion reduced per hectare of land in a 1-year period as a result of introducing the eight CSA practices compared to BAU practices. A replacement cost approach to assess the value of soil erosion reduction by estimating the amount of contaminants (in kilograms or percentage change over BAU) such as pesticides and inorganic fertilizer was used to address the negative effects associated with soil erosion. Using a price for the contaminants provided by the experts, the net value of benefits associated with soil reduction was then calculated and added as an external benefit in the CBA computation.

[4] This value provided by the expert during the survey was then converted into US$ during calculation.

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# 3. RESULTS

### 3.1 DESCRIPTIVE RESULTS

The life cycle period for the eight CSA practices ranged between 3 and 8 years (with a standard deviation of 2 years). Crop rotation, mixed cropping, minimum tillage and improved nutrient management had the shortest life cycle (3 years), while supplementary feeding had the longest life cycle (8 years) (Table 4). The average number of crops affected by crop rotation, mixed cropping, minimum tillage, improved genetic resources and improved nutrient management was six (Table 4). Improved livestock housing, supplementary feeding, improved genetic resources and livestock prophylactic practices affected four types of livestock: cattle, sheep, goats and chickens.

In the CBA calculation, the farm activities considered were those that farmers reported to have been affected by the CSA practices (Table 1). The cost of the BAU scenario comprised the expenses incurred by farmers in implementing and maintaining farm activities in 1 ha in 1 year. The costs of CSA scenario consisted of the costs associated with implementing and maintaining activities affected by the CSA practices on 1 ha for a period of 1 year. The costs of inputs and output prices for the affected farm activities were inputted into the CBA as constants. These values were derived from data collected from households who had implemented the CSA practices earlier. The NPV calculated for each CSA practice is estimated as the value of the enhanced yield and reduced production labor less the cost of implementation, maintenance and operation costs, while the social NPV is a summation of private NPV and externality benefits associated with adopting the CSA practices.

**TABLE 4. SUMMARY INFORMATION OF CROPS AND LIVESTOCK AFFECTED BY THE CSA PRACTICES, THEIR LIFE CYCLE AND AVERAGE FARM SIZES**

| CSA practices | Life cycle (years) | Crops affected by the CSA practices | Livestock types affected by the CSA practices | Farm size (ha) |
|---|---|---|---|---|
| Crop rotation | 3 | Maize, cassava, okra, tomatoes, pepper, beans and watermelon | | 9.6±6.22 |
| Mixed cropping | 3 | Maize, cassava, okra, tomatoes, pepper and watermelon | | 8.35±3.20 |
| Minimum tillage | 3 | Maize, cassava, okra, tomatoes, pepper and watermelon | | 5.08±3.64 |
| Improved genetic resources | 6 | Maize, okra, tomatoes, pepper and watermelon | Cattle and poultry | 7.74±4.86 |
| Improved nutrient management | 3 | Maize, cassava, okra, tomatoes, pepper and watermelon | | 4.31±1.99 |
| Livestock prophylactic practices | 5 | | Cattle, goats and poultry | 6.19±4.24 |
| Supplementary feeding | 8 | | Cattle, sheep, goats and poultry | 4.85±2.30 |
| Improved livestock housing | 6 | | Cattle, sheep, goats and poultry | n/a |

NB: n/a stands for not available.
Source: Authors survey (2016).

### 3.2 PRIVATE PROFITABILITY

The results showed that except for minimum tillage, all the CSA practices studied were profitable (Table 5). This is because all the CSA practices (except minimum tillage) had a positive NPV and an IRR greater than the discount rate. The IRR for crop rotation, improved genetic resources, improved nutrient management, livestock prophylactic practices, supplementary feeding and improved livestock housing ranged between 62 and 227%. Among the practices with positive NPV, mixed cropping had the lowest IRR (62%). The high IRR for the CSA practices, except for improved livestock housing, was attributed to the relatively low initial /installation costs (Table 6) and the short time lag for the impact – i.e. improved crop productivity and improved income – to be realized (Table 5). Minimum tillage had the lowest NPV. Minimum tillage had a very low impact in terms of productivity and income. The crops affected by minimum tillage were maize and watermelon and their impact combined was lower than that of BAU. Consequently, most farmers have not been practicing minimum tillage for more than 10 years (by the time of the survey – July 2016). Benefits were important factors influencing households decisions affecting the adoption of best-bet agricultural practices in Ghana (Akudugu et al., 2012). The consequence of positive impact was reflected in the time needed by the investment to repay in full and the cost used in its initial investment. Among the seven CSA practices with a positive NPV, three of them had a very short payback period (i.e. 1 year); two practices had a payback period of 2 years, while two practices had a payback period of 3 years (Table 5). In general therefore, with the exception of minimum tillage, all the CSA practices studied constituted a basket of promising investment options because they could yield positive benefits for farmers in a given year.

The probability distribution summary of the eight CSA practices studied is shown in Table 7 and Figure 3. The results shows the profitability risks associated with adopting each of the eight practices given the characteristics of the CDF of expressing the probability of IRR of being less or equal to a given value of the discount rate used in this study. On average, the results showed that of the seven practices that had a positive NPV (Table 5), only mixed cropping had a significant level of risk, of about 7%. All the other practices had minimal risk for farmers, implying that in any given year, the farmers who had implemented these practices were not likely to get an unprofitable result.

### 3.3 EXTERNALITIES

As expected, the implementation of CSA practices induced a flow of benefits associated with externalities such as improvement in water availability, reduction in soil erosion, increased soil biodiversity (i.e. improvement in soil fertility), increase in biodiversity (i.e. species of plants and animals), improvement in air quality (i.e. reduction of GHG emissions), and improved political and social capital (Table 3). The results of the Monte Carlo simulation (Table 8) showed that, on average, the benefit associated with improved water availability was higher, ranging between US$5 and 38 ha$^{-1}$ year$^{1}$ (Table 9) with an average of about US$22 ha$^{-1}$ year$^{1}$, compared to other CSA practices (Table 8). The benefits associated with increased biodiversity for the eight CSA practices ranged from US$8 to 41 ha$^{-1}$ year$^{1}$ (Table 9) with an average of about US$22 ha$^{-1}$ year$^{1}$ (Table 8). The estimated average value of improvement in air quality brought about by carbon sequestration as a result of implementing the CSA practices was about US$15 ha$^{-1}$ year$^{1}$ (Table 8). In the case of increase in soil biodiversity, which represented the value of soil fertility saved due to the implementation of the CSA practices, an average value of US$15 ha$^{-1}$ year$^{1}$ was estimated. The political and social capital gained due interactions associated or brought about by the adoption and implementation of the CSA practices was valued at an average value of US$14 and 19 ha$^{-1}$ year$^{1}$ respectively (Table 8). In this study, the analysis of labor and employment as social externalities were not performed because most of the farmers used their own labor, and in cases where hired labor was used, the farmers could not provide accurate estimate (in man-days) used per hectare for each practice. When the externalities benefit associated with CSA practices were taken into CBA calculations, the resulting social net private benefits ranged between US$1,705 and 7,699 ha$^{-1}$ year$^{1}$. The social IRR ranged between 76 and 300% (Table 10).

**TABLE 5. ESTIMATED NET PRESENT VALUE (NPV), INTERNAL RATE OF RETURN (IRR) AND THE PAYBACK PERIOD (PP)**

| CSA practice | Probability distribution average | | Payback period |
|---|---|---|---|
| | NPV (26%) in US$ | IRR (%) | (Years) |
| Crop rotation | 2,614 | 69 | 1 |
| Mixed cropping | 359.6 | 62 | 1 |
| Minimum tillage | -2,945 | (231) | - |
| Improved genetic resources | 1,348 | 107 | 2 |
| Improved nutrient management | 2,241 | 227 | 1 |
| Livestock prophylactic practices | 3,008 | 97 | 3 |
| Supplementary feeding | 3,933 | 100 | 3 |
| Improved housing | 5,197 | 77 | 2 |

NB: 26% is the rate at which the NPV has been discounted.

## TABLE 6. ESTIMATED IMPLEMENTATION, MAINTENANCE AND OPERATION COSTS

| CSA practice | Implementation cost (US$ $ha^{-1}$) | Maintenance cost (US$ $ha^{-1}$) | Operation cost (US$ $ha^{-1}$) |
|---|---|---|---|
| Crop rotation | 220 | 200 | 489 |
| Mixed cropping | 717 | 71.5 | 97 |
| Minimum tillage | 691 | 70 | 387 |
| Improved genetic resources | 689 | 63 | 0 |
| Improved nutrient management | 63 | 31 | 0 |
| Livestock prophylactic practices | 278 | 23 | 560 |
| Supplementary feeding | 157 | 16 | 900 |
| Improved livestock housing | 1,840 | 404 | 533 |

## TABLE 7. SUMMARY OF PROBABILITY DISTRIBUTION OF IRR RESULTS FOR THE EIGHT CSA PRACTICES

| | Summary of probability distribution of IRR results |
|---|---|
| Crop rotation | This practice is profitable to the farmer. On average, distribution of IRR is above 26.2% and there is 90% probability that the IRR will be between 26.2 and 111.8%. |
| Mixed cropping | The IRR is on average above the 26%. However, the results shows some degree of risks with about 7% probability of getting an IRR below the level considered profitable. |
| Minimum tillage | Very risky investment for the farmer since there is 100% likelihood of getting IRR less than 26%. The entire distribution of the IRR lies below 26% value. |
| Improved genetic resources | The distribution is above the estimated cost of capital (26%) with no likelihood of getting an IRR below 26%. Moreover, there is 5% probability the IRR will be larger than 150%. |
| Improved nutrient management | The distribution is above the estimated cost of capital (26%) with no likelihood of getting an IRR below 26%. There is 5% probability the IRR will be larger than 270%. |
| Livestock prophylactic practices | The result shows that this practice is profitable for the farmer with no risk of losing money. There is a 99% likelihood of getting an IRR greater than 26%. |
| Supplementary feeding | Highly profitable practice for the farmer as there exist no likelihood of getting IRR lower than 26%. |
| Improved housing | Profitable practice for the farmer as there exist just 3% likelihood of getting IRR lower than 26%. There is a 92% probability that the IRR distribution will lie between 27% and 118%. |

## TABLE 8. SUMMARY OF MONTE CARLO SIMULATION RESULTS OF THE BENEFITS ASSOCIATED WITH EXTERNALITIES

| Externalities | Mean (US$ $ha^{-1}$) | Minimum (US$ $ha^{-1}$) | Maximum (US$ $ha^{-1}$) | Standard deviation |
|---|---|---|---|---|
| Improved water availability | 22.1 | 5.8 | 33.7 | 5.3 |
| Reduction in soil erosion | 14.5 | 5.4 | 22.3 | 3.2 |
| Increased soil biodiversity | 15.2 | 5.4 | 24.7 | 3.8 |
| Increased biodiversity | 22.0 | 7.9 | 39.2 | 6.1 |
| Improved air quality | 14.9 | 2.8 | 29.3 | 5.2 |
| Increased social capital | 18.5 | 0.5 | 39.5 | 7.5 |
| Increased political capital | 14.2 | 0.9 | 24.7 | 4.7 |

NB: 1000 values were used in Monte Carlo simulation.

## TABLE 9. SUMMARY OF THE ESTIMATED CHANGES IN VALUE OF EXTERNALITIES FOR EACH CSA PRACTICE PER HECTARE PER YEAR

| Externalities | Crop rotation | Mixed cropping | Minimum tillage | Improved genetic resources | Improved nutrient management | Livestock prophylactic practices | Supplementary feeding | Improved livestock housing |
|---|---|---|---|---|---|---|---|---|
| | | | | Values in US$ | | | | |
| Improved water availability | 11.3 | 28.8 | 37.5 | 5.0 | 27.5 | n.a | 32.3 | 30.0 |
| Reduction in soil erosion | 8.7 | 33.8 | 21.9 | 4.5 | 16.3 | n.a | 15.0 | 19.5 |
| Increased soil biodiversity | 17.8 | 24.0 | 25.0 | 5.0 | 9.8 | n.a | 10.0 | 15.0 |
| Increased biodiversity | 7.8 | 15.0 | 10.6 | 7.5 | 29.3 | n.a | 40.5 | 37.5 |
| Improved air quality | 2.5 | 10.0 | 2.5 | 2.5 | 27.4 | n.a | 30.0 | 25.0 |
| Increased social capital | 13.1 | 14.0 | 12.0 | 0.0 | 19.9 | n.a | 49.8 | 25.0 |
| Increased political capital | 16.3 | 12.0 | 15.8 | 0.0 | 15.5 | n.a | 25.0 | 20.0 |

NB: US$ 1was equal to GHC$4 at the time of the survey (June–July 2016).

| TABLE 10. ESTIMATED NET PRESENT VALUE AND SOCIAL INTERNAL RATE OF RETURN | | |
|---|---|---|
| CSA practice | SNPV in US$ | SIRR (%) |
| Crop rotation | 3,055 | 76 |
| Mixed cropping | 1,143 | 137 |
| Minimum tillage | 753 | 293 |
| Improved genetic resources | 1,705 | 142 |
| Improved nutrient management | 2,814 | 300 |
| Livestock prophylactic practices | 4,361 | 165 |
| Supplementary feeding | 5,666 | 122 |
| Improved housing | 7,699 | 124 |

NB: 26% is the rate at which social net present value has been discounted.

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# 4. DISCUSSION

For the majority of policy makers and development practitioners, most actions/inactions around investing and promotion of most agricultural practices is based on two overarching issues: whether the agricultural practice to be promoted will be beneficial to farmers – as this largely determines its adoption and implementation potential; and whether society will benefit from adoption and implementation of such practices. Evidence from the literature shows that CBA is a useful tool that development practitioners use to evaluate investment options such as suitability of policies (van Wee, 2012; van Wee and Börjesson, 2015) government projects (e.g. tax, trade and income policies) and private projects (Boardman and Forbes, 2011; Cervone, 2010). CBA is thus a crucial tool in investment planning (Birol et al., 2010). The use of CBA in evaluating climate change related projects, models, and policies at different levels (e.g. plots, farms, watersheds, regions etc.) is also common (Dietz and Hepburn, 2013; Nassopoulos et al., 2012; Tol, 2003). The uncertainty about the margin costs of climate change is large, giving rise to a lot of debate on the uncertainties in the expected impacts of climate change and variability in the estimates and in ethical consideration (Randalls, 2011; Tol, 2012; van Wee, 2012). Despite these uncertainties and the ethical issues associated with the use of CBA, to make informed decisions, farmers, government and investors need to take action. Valid inputs are based on sound data analysis, and CBA is an appropriate tool that can provide the inputs required for urgent planning and investment decisions (Scrieciu et al., 2011; Turner, 2006). However, the use of CBA tool requires transparency and communication about the weakness and strengths of the choices made.

In the past, studies have used CBA to assess the ability of agricultural practices to thrive under climate change and variability (Daigneault et al., 2016; Mishra et al., 2013; Sain et al., 2016). Although this study also focuses on practices that farmers implement in order to adapt to climate change related effects, it is based on the studied eight CSA practices. These practices are the most prioritized CSA practices in Ada district in the Coastal Savannah AEZ and their evaluation may provide a timely support that is needed by the policy makers. This study is therefore an important step in overcoming barriers such as those that may hinder the implementation of appropriate adaptation options (e.g. Spires et al., 2014) All the CSA practices studied are considered to be 'no regret' options or 'early benefit' options (Dittrich et al., 2016; Fankhauser and Soare, 2013) because they comprise a basket of options that yield social and/or economic benefits irrespective of whether climate change occurs or not, delivering benefits now and building future resilience (Watkiss et al., 2015). Consequently, no assumptions were made about these practices in relation to climate change.

In CBA analysis, the time taken by the practice from its implementation to when impact on productivity and benefits was realized is very important. All the CSA practices analyzed, with the exception of minimum tillage, were profitable when all costs and benefits were considered. However, the result (Table 5) showed that some of the practices such as livestock prophylactic practices and supplementary feeding were characterized by a payback period (PP) of 3 years. As the majority of the sampled households were smallholder farmers, 3 years seems to be quite a long time. Therefore, practices with a PP of 3 years may be suitable for farmers that are supported with an appropriate enabling environment such as security of land tenure, low interest rate for credit and short-term livelihood options. Improved genetic resources and improved livestock housing had a PP of 2 years, while crop rotation, mixed cropping and improved nutrient management had a PP of 1 year. CSA practices with a short PP (e.g. 1–2 years) constituted a basket of strong choices for farmers in the Ada area. Of these, practices with the shortest PP (e.g. 1 year) may have been strongly preferred by a majority of the households because they reaped benefits only after a short period of time.

In their study, Ackerman and Heinzerling, (2002) note that the inability to account for externalities in CBA can result in findings that are not objective. For example, implementation of the eight CSA practices may, for instance, generate positive social and political benefits, thereby enabling improving knowledge diffusion. It is therefore important to consider the value of externalities associated with implemented practices when computing CBA. Such an approach is important because our aim is to promote CSA practices that yield desirable outcomes both on-farm and within agro-ecological systems. In addition, such an analysis can move valuation beyond financial aspects only (Chaudhury et al., 2016). Nevertheless, the valuation of nonmarket benefits is contentious because they are not traded in the market (Scrieciu et al., 2011). In this study, we valued externalities for inclusion in discussions with stakeholders in the broader CSA-PF process to identify externalities associated with the selected CSA practices, while changes in externalities and value were assessed through key experts' interviews. As valuation of NPV and IRR were in high demand among farmers, while SNPV and SIRR were in demand by government planners or policy makers, we computed them separately. The values associated with externalities for each CSA practice per hectare for 1 year was computed by considering a value derived from the key experts.

On average, all the CSA practices had positive values; they all improved water availability, reduced soil erosion, increased soil biodiversity, increased biodiversity and improved air quality (Table 8). Increased water availability was due to increased infiltration due to improved soil structure and improved water collection (Locke et al., 2015b). Increased biodiversity due to increased soil fertility – due to improved manure collection and decaying organic matter – was high for supplementary feeding (Table 9). Externality benefits associated with social and political capital was high for those practicing supplementary feeding – the only practice with the longest life cycle (e.g. 8 years) and PP (e.g. 3 years). A long payback period implies increased challenges for the uptake of a practice. Higher social capital due to supplementary feeding could be due to increased interactions between farmers – when seeking know-how on what to supplement their animals on. Higher political capital could be due to farmer's interaction with institutions when seeking long-term support in land-use (e.g. tenure security) and livelihood options. The use of supplementary feeding, improved nutrient management, and improved livestock housing had the highest impact in terms of improvement in air quality. This could be due to dietary manipulation through supplementary feeding which has been shown to have a reduce odor prior to excretion (Michigan State University, 2016). Livestock housing also reduced the dust particles from the animals and contributes to improved odor conditions (Michigan State University, 2016). Therefore supplementary feeding, improved nutrient management, and improved livestock housing could be considered worthy of investment if public goods such as mitigation was a priority. Given that CSA practices aims at increasing a household's ability to adapt, inclusion of the environmental benefits associated with these practices would strengthen the case for their adoption and implementation.

### 4.1 ADDRESSING THE DATA GAPS

The literature on CBA notes a number of concerns related to methodological issues such as uncertainty, valuation, and equity (UNFCC, 2011). In this study, the uncertainty as it relates to data/measurement was addressed through a representative sample size of farm households, cross-checking household survey data through focus group discussions and interviewing agricultural experts. For valuation, the BAU was well defined and discussed with the stakeholders (during CSA-PF) and experts. This ensured that the definition of what would happen to farming practices in the absence of CSA was well understood by farmers. The farmers were then able to use the BAU (as the baseline) when estimating the costs and benefits associated with the CSA practices. This ensured that the results are robust enough for use as a reference in decision making. Due to the sensitivity associated with the choice of discount rates, we applied a discount rate similar to the average interest rates charged by commercial banks in Ghana over the last 14 years (26%). Prices over the period of analysis were assumed to be constant; this is a limitation that can be addressed with an in-depth study focused on market dynamics. The CBA results in this study were also validated with the local stakeholders on January 2017 as a step towards including CBA in the broader participatory process for making decisions based on the new evidence produced in this report.

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# 5. CONCLUSION

To make the appropriate investment decisions about CSA priorities, there is a need for an in-depth understanding of trade-offs between the different CSA practices under investigation (one practice verses another), using the available data to make the best-bet decision. CBA is just one platform for assessing the economic profitability, risks and impacts associated with private benefits as well as externalities associated with the practice being studied. The economic assessment for the eight CSA practices related to cereal-legume-small ruminant production systems in the Coastal Savannah AEZ in Ghana provides critical information that that could be used to reassess existing practices or the practices being promoted by ongoing agricultural policies. The findings in this study also considered externalities benefits associated with the eight practices CSA practices, which could link well with government policies or farmers priorities, thereby affecting their adoption.

# 6. RECOMMENDATIONS

The findings of this study cannot be generalized for other agro-ecological zones (AEZs), particularly the Guinea Savannah (USAID's ZoI), because of the different contextual situations that the AEZs present. It would be advisable to replicate this study in the Guinea Savannah AEZ as the eight CSA practices prioritized for the study/report may differ and may provide some interesting insights to support the development of a CSA strategy for FtF 2.0.

According to the National Climate-Smart Agriculture and Food Security Action Plan for Ghana, water conservation and irrigation systems is the topmost priority for the savannah zone. Given that most intensive agricultural practices with potential for climate change mitigation uses some form of irrigation (although water management was not a prioritized CSA practice for the study), a CBA on integrated water management at all levels may present better opportunities to avoid stress at sensitive stages of crop production.

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# 8. APPENDICES

## APPENDIX 1. NUMBER OF STAKEHOLDER PARTICIPANTS, GENDER AND THEIR RESPECTIVE ORGANIZATION

| Number | Gender | Organization |
|---|---|---|
| 1 | M | CSIR-Animal Research Institute |
| 2 | M | MoFA Directorate of Crop Services |
| 3 | F | Ghana Farmers Wives Association |
| 4 | M | Farmer, Ada West |
| 5 | F | Farmer, Ada West |
| 6 | M | MoFA, Ada West |
| 7 | M | Climate Change Action Network-Ghana |
| 8 | F | Women in Agriculture Development (WIAD)/MoFA |
| 9 | M | Ghana CCAFS Platform |
| 10 | M | CSIR-Animal Research Institute |
| 11 | M | Department of Agriculture, Greater Accra Regional Coordinating Council |
| 12 | M | CSIR-Water Research Institute |
| 13 | M | FAO-GHANA |
| 14 | M | National Development Planning Commission |
| 15 | M | CSIR-Animal Research Institute |
| 16 | M | CSIR-Science Technology and Policy Research Institute |
| 17 | F | Animal Production Directorate-MoFA |
| 18 | M | Ghana National Association of Farmers and Fishermen |

## APPENDIX 2. LIST OF CSA PRACTICES SELECTED FOR THE STUDY

| | |
|---|---|
| 1. Mixed cropping | 2. Improved livestock housing |
| 3. Crop rotation | 4. Integrated nutrient management |
| 5. Mixed farming | 6. Integrated pest and disease management |
| 7. Agroforestry | 8. Genetic resources |
| 9. Water management | 10. Solar drying |
| 11. Minimum tillage | 12. Supplementary feeding |
| 13. Organic manure | 14. Semi-intensive livestock management |
| 15. Mineral fertilization | 16. Livestock prophylactic practices |
| 17. Irrigation | |

## APPENDIX 3. WEIGHTED ASSESSMENT RESULTS OF THE SELECTED CSA PRACTICES

| | Practice | Productivity | Adaptation | Mitigation | Total |
|---|---|---|---|---|---|
| 1 | Mixed cropping | 1.4 | 0.5 | 1.3 | 3.2 |
| 2 | Crop rotation | 1.6 | 0.6 | 1.3 | 3.6 |
| 3 | Mixed farming | 0.8 | 0.8 | 1.0 | 2.6 |
| 4 | Agroforestry | 1.0 | 0.6 | 1.1 | 2.7 |
| 5 | Water management | 1.3 | 0.2 | 0.9 | 2.4 |
| 6 | Rainwater harvesting and storage | 0.9 | 0.1 | 0.7 | 1.7 |
| 7 | Irrigation | 2.0 | 0.1 | 0.1 | 2.1 |
| 8 | Minimum/low tillage | 2.0 | 0.6 | 1.4 | 4.0 |
| 9 | Organic maturing | 1.4 | 0.5 | 0.8 | 2.6 |
| 10 | Mineral fertilization | 1.6 | 0.4 | 0.4 | 2.4 |
| 11 | Integrated nutrient management | 1.6 | 0.3 | 1.3 | 3.2 |
| 12 | Integrated pest and disease management | 0.9 | 0.1 | 0.2 | 1.2 |
| 13 | Genetic resources | 1.7 | 0.5 | 1.1 | 3.3 |
| 14 | Solar drying | 1.2 | 0.4 | 0.4 | 2.1 |
| 15 | Supplementary feeding with agro by-product | 2.3 | 0.5 | 0.8 | 3.6 |
| 16 | Improved livestock housing | 2.1 | 0.3 | 0.9 | 3.4 |
| 17 | Livestock prophylactic practices | 2.2 | 0.3 | 1.5 | 4.0 |

Source: Authors field data (2016).

## APPENDIX 4. FINAL RANKING OF THE SELECTED 10 CSA PRACTICES

| Rank | CSA Practice | Score |
|---|---|---|
| 1 | Minimum/low tillage | 4.0 |
| 2 | Livestock prophylactic practices | 4.0 |
| 3 | Supplementary feeding with agro by-products | 3.6 |
| 4 | Crop rotation | 3.6 |
| 5 | Improved livestock housing | 3.4 |
| 6 | Genetic resources | 3.3 |
| 7 | Mixed cropping | 3.2 |
| 8 | Integrated nutrient management | 3.2 |
| 9 | Agroforestry | 2.7 |
| 10 | Organic maturing | 2.6 |

Source: Authors field data (2016).

## APPENDIX 5. MEAN VALUE FOR THE BAU ($Y_0$) YIELD FOR DIFFERENT CROPS, AND THE FINAL YIELD ($Y_I$) UNDER THE CSA PRACTICES OBTAINED FROM THE SURVEY AND THE LITERATURE

| | $Y_0$(Kg ha$^{-1}$)[i] | $Y_f$ (kg ha$^{-1}$)[ii] | % Change (Ym) | $Y_{min}$(kg ha$^{-1}$) [iii] | $Y_{max}$ (kg ha$^{-1}$) [iii] | $Y_I$(kg ha$^{-1}$)[iii] e ha$^{-1}$) |
|---|---|---|---|---|---|---|
| **Crop rotation** | | | | | | |
| Maize | 511 | 1330 | 160 | 1520 | 3200 | 2250 |
| Cassava[5] | 5800 | 9625 | 66 | 6000 | 14000 | 10000 |
| Okra | 4312 | 9112 | 111 | 6000 | 12000 | 9000 |
| Tomato | 770 | 11816 | 1434 | 7500 | 15000 | 11250 |
| Pepper | 1112 | 4825 | 334 | 6500 | 22000 | 14250 |
| Watermelon | 1500 | 7600 | 406 | 25000 | 30000 | 22500 |
| Bean | 222 | 300 | 35 | 800 | 1200 | 1000 |
| **Mixed cropping** | | | | | | |
| Maize | 1389 | 1112 | –19 | 1520 | 2040 | 3400 |
| Cassava | 2468 | 3378 | 37 | 6000 | 12000 | 9000 |
| Okra | 1667 | 500 | –70 | 6000 | 9000 | 7500 |
| Tomato | 10634 | 11302 | 10 | 7500 | 15000 | 11250 |
| Pepper | 3667 | 6010 | 63 | 6500 | 22000 | 14250 |
| Watermelon | 6000 | 6000 | 0 | 25000 | 30000 | 27500 |
| **Minimum tillage** | | | | | | |
| Maize | 889.2 | 889.2 | 0 | 1520 | 2800 | 2160 |
| Cassava | 3852 | 3850 | 0 | 6000 | 8000 | 7000 |
| Okra | 1110 | 0 | N/A | 6000 | 8000 | 7000 |
| Pepper | 5201 | 0 | N/A | 6500 | 14000 | 10500 |
| Watermelon | 7410 | 29640 | 300 | 25000 | 30000 | 27500 |
| **Improved genetic varieties** | | | | | | |
| Maize | 534 | 1112 | 108 | 1520 | 3000 | 2260 |
| Okra | 962 | 1556 | 62 | 6000 | 12000 | 9000 |
| Tomato | 2300 | 2700 | 17 | 7500 | 15000 | 11250 |
| Pepper | 1711 | 2223 | 30 | 5000 | 11000 | 8000 |
| Watermelon | 19448 | 26225 | 35 | 25000 | 30000 | 27500 |
| Cowpea | 355 | 700 | 97 | 800 | 1825 | 1312 |
| Cattle | 0 | 8 | | | | |
| **Integrated nutrients** | | | | | | |
| Maize | 667 | 889 | 33 | 1520 | 2800 | 2160 |
| Okra | 0 | 1333 | – | 6000 | 12000 | 9000 |
| Tomato | 1541 | 2067 | 34 | 7500 | 15000 | 11250 |
| Pepper | 1556 | 2374 | 52 | 5000 | 9000 | 7000 |
| Watermelon | 0 | 22971 | - | 25000 | 30000 | 27500 |

NB: N/A stands for not applicable. Tomato boxes weigh about 52 kg. [i] Estimated average yield for the different crops on farms practicing BAU from the survey. [ii] Estimated average crop yields for the different CSA practices from the survey. [iii]Estimated average, minimum and maximum crop yields for the different CSA practices from the literature review. Improved maize variety involves both open pollinated varieties (OPVs) and hybrid and they range from early (80–85) maturing to late maturing (105–110days).

(continues)

5 When rotation is maize-beans-cassava-okra-tomatoes-pepper-watermelon.

(continued)

| | Improved livestock | | Livestock prophylactic | | Supplementary feeding | |
|---|---|---|---|---|---|---|
| | $Y_0$ | $Y_f$ | $Y_0$ | $Y_f$ | $Y_0$ | $Y_f$ |
| Eggs (units) | 0 | 365 | 0.4 | 0.6 | 5.5 | 2 |
| Cattle (units) | 0 | 5.5 | 34 | 40 | 1 | 1 |
| Sheep (units) | 0 | 8.5 | N/A | N/A | 30 | 38 |
| Chicken (units) | 0 | 120 | 22 | 32 | 39 | 46 |
| Cow's milk (liters) | 0 | 72 | N/A | N/A | 10 | 30 |
| Goat's milk (liters) (Units) | 2 | 102 | 10 | 14 | 7.4 | 10 |
| Guinea fowl (liters) (liter(Units) (Units) | N/A | N/A | 28 | 60 | 20 | 25 |

## APPENDIX 6. DISTRIBUTION OF PRICE STRUCTURES AND PARAMETER VALUES

| Commodities | Price per unit (GHc $kg^{-1}$) |
|---|---|
| Maize | Uniform (1.48, 3.36) |
| Cassava | Uniform (1.0, 3.4) |
| Okra | Normal (1.22, 1.38) |
| Tomatoes | Normal (2.59, 0.93) |
| Pepper | Uniform (4.22, 1.61) |
| Watermelon | Uniform (0.27, 1.17) |
| Bean | Uniform (3.12, 3.98) |
| Cowpea | Uniform (3.12, 3.98) |
| | **Price per unit (GHc $unit^{-1}$)** |
| Eggs | Uniform (0.52, 0.97) |
| Cattle | Uniform (1750, 3250) |
| Sheep meat | Normal (230, 57) |
| Chicken | Uniform (30, 90) |
| Cattle milk | Uniform (9.92, 4.37) |
| Goat meat | Normal (207, 41.77) |
| Guinea fowl | Normal (33.8, 5.44) |

NB: The distribution has been best fitted to the survey data.

## APPENDIX 7. A LIST OF EXTERNAL EFFECTS AND THEIR UNITS

| Number | External effects | Units |
|---|---|---|
| 1 | Water availability | $m^3$ water $ha^{-1}$ |
| 2 | Soil erosion | kg of contaminants $ha^{-1}$ |
| 3 | Soil biodiversity | $N_2$ fixed (Kg N $ha^{-1}yr^{-1}$) |
| 4 | On-farm biodiversity | # of species of plants $animals^{-1}$ $ha^{-1}$ |
| 5 | Political capital | # political interactions with external entities |
| 6 | Social capital | # social interactions with external entities |
| 7 | Air quality | $CO_2$ sequestered (t $CO_2$ $ha^{-1}$) |

## APPENDIX 8. ESTIMATED AMOUNT OF NITROGEN FIXED BY LEGUMES

| Grain legume | Scientific name | Intercropped | Nitrogen fixed (Kg N $ha^{-1}$ $yr^{-1}$) |
|---|---|---|---|
| Cowpea | *Vigna unguiculata* | Sole crop | 33 |
| Cowpea | *Vigna unguiculata* | Intercrop | 18-73 |
| Groundnut | *Arachis hypogea* | Sole crop | 55.8 |
| Pigeon pea | *Cajanus cajan* | Sole crop | 54.1 |
| Pigeon pea | *Cajanus cajan* | Intercrop | 12 |
| Soybean | *Glyxine max* (L.) | Sole crop | 35.8 |
| Soybean | *Glyxine max* (L.) | Intercrop | 2-60 |
| Common bean | *Phaseolus vulgaris* | Intercrop | 20-80 |
| Mung bean (green gram) | *Vigna radiata* | Sole | 12 |
| Pigeon pea / groundnut | *Vigna unguiculata / Arachis hypogea* | Intercrop | 45-83 |

Source: Njira et al. (2012); One Acre Fund (2015); Lindemann and Glover (2003).

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