Cost-Benefit Analysis of On-Farm Climate Change Adaptation Strategies in Ghana

Article · August 2020

DOI: 10.4314/gjg.v12i1.2.

4 authors:

Shaibu Baanni Azumah
Solidaridad Network, West Africa
49 PUBLICATIONS **652** CITATIONS
SEE PROFILE

William Adzawla
International Fertilizer Development Center (IFDC)
61 PUBLICATIONS **713** CITATIONS
SEE PROFILE

Aminu Osman
University of Cape Coast
8 PUBLICATIONS **25** CITATIONS
SEE PROFILE

Paul Yao Anani
University for Development Studies
6 PUBLICATIONS **108** CITATIONS
SEE PROFILE

Cost-Benefit Analysis of On-Farm Climate Change Adaptation Strategies in Ghana

Shaibu Baanni Azumah[1*]
William Adzawla[2]
Aminu Osman[3]
Paul Yao Anani[4]

Abstract

Climate change continues to hamper crop-based systems across sub-Sahara Africa. Adaptation strategies prove to be effective at improving production and enhancing livelihoods of farm households. This study employs Cost-Benefit Analysis (CBA) to assess the perceived economic profitability of adopting various on-farm climate change adaptation strategies among farmers in Zabzugu and South Tongu districts in the north and south of Ghana. A simple random sampling approach was used to select 300 farmers who had previously benefited from climate change projects. Major strategies adopted in both districts were: changing of planting dates, planting early maturing varieties, row planting, seed refilling and planting drought tolerant varieties. Adoption intensity was high in Zabzugu district compared to the South Tongu District. Generally, the adoption of each strategy was perceived to be profitable since the estimated average benefits outweighed the average costs. However, the most profitable strategies were strip cropping, repeated sowing, refilling, zero tillage and row planting. Less profitable strategies included land rotation, mixed farming, early planting, tractor ploughing and "A-frame" contour farming. Among others, drought tolerant varieties of rice, maize and soybeans, as well as zero tillage, repeated sowing and strip cropping, should be promoted and farmers encouraged to adopt these practices for enhanced benefits.

Keywords: Climate adaptation strategies; Climate change; Cost-Benefit Analysis; Farmers; Ghana

[1]Solidaridad Network, West Africa. Okine Street, East Legon, Accra [*]Corresponding author's email address: raszumah1983@gmail.com [2]International Fertilizer Development Centre (IFDC). 113A Mbabane Avenue, East Legon. Accra, Ghana. [3]School of Economics, College of Humanities and Legal Studies. University of Cape Coast. Cape Coast, Ghana. [4]Faculty of Agriculture. University for Development Studies

Ghana Journal of Geography Vol. 12(1), 2020 pages 29- 46

https://doi.org/10.4314/gjg.v12i1.2

Introduction

Achieving food security remains a global priority. In a recent report by the Food and Agriculture Organisation (FAO) and the Economic Commission of Africa (ECA) (2018), it is noted that about 821 million people are undernourished or short of food across the globe. Similarly, globally, about 45% of deaths in children under 5 years of age is a result of maternal and child undernutrition - the worst situation of this insecurity is more prevalent in Sub-Saharan Africa (FAO, IFAD, UNICEF, WFP, & WHO., 2019). The situation of food insecurity in Ghana is still dire as the country produces about 50% of its cereal needs, nearly two-thirds of its fish requirement, half of its meat requirement and less than one-third of raw materials needed for agro-based industries (Darfour & Rosentrater, 2016). Ghana has about 2.3 million people living in severe food insecurity and about 1.6 million people undernourished (FAO, IFAD, UNICEF, WFP, & WHO., 2019). The Government of Ghana (GoG), in line with global development goals and objectives, has prioritized food security and self-sufficiency in the production and supply of food in a bid to enhance availability and economic and physical access to individuals. The challenge, although global, to achieving food security is climate change and its associated impacts.

Climate change and its signs are widespread across Ghana. As Ghana is an agrarian economy with a high dependence on rainfed agriculture, climate change would affect crop production in the country, thereby affecting the entire economy and the drive towards food security (Armah et al., 2011). Already, drought, soil erosion and bush fires pose a threat to food production, especially in the northern part of the country (Armah et al., 2011). Similarly, due to the high subsistence nature of crop production in Ghana, farmers rely on traditional techniques that lead, not only to low yields, but also to a vicious poverty cycle and low adaptive capacities to climate change. Areas of Northern Ghana which hitherto had never experienced the double tragedy of drought and floods within and between seasons are now experiencing it (Akudugu, Dittoh & Mahama, 2012). Nevertheless, the structural transformation of Ghana's economy requires that agriculture remains robust to meet the increasing demand from the other areas such as the service and industrial sectors. As explained by Arndt, Asante, & Thurlow (2015), there is a negative spill-over effect from a decline in agricultural production on the productivity of nonagricultural sectors of the economy. There are also uneven effects of climate change on households in Ghana; often, the poor, rural households and those located in the northern part of the country are most affected by climate change. For Asante & Amuakwa-Mensah (2015), climate change and variability continue to worsen the plight of poor Ghanaians who are mostly women and children. Farmers use different adaptation strategies in order to reduce the impacts of climate change on farm outcomes and household livelihoods.

Climate adaptation requires adjustment in economic and social systems in response to actual or expected climate change and its impacts. By this explanation, which is adopted in this study, adaptation can be reactive or proactive (Burton et al., 2006). Climate adaptation is generally not new to humanity. Over the years, farmers continue to adopt adaptation strategies that can help overcome the direct effects of climate change. Climate adaptation has been proven to have enhanced yields and mitigated the challenges of low agricultural productivity, though this did not result in optimum production levels. Antwi-Agyei et al. (2014) explained that climate adaptation strategies by farmers in Ghana and sub-Saharan Africa are meant to spread climate risks and reduce climate impacts. Similarly, Nyantakyi-Frimpong & Bezner-Kerr (2015) revealed that farmers adapt to climate change in order to reduce adverse effects on farming. Therefore, climate adaptation has the potential of sustainably reducing the threats posed by climate variability, as well as vulnerability to climate change (Fentie & Beyene., 2019).

There are trade-offs associated with climate adaptation since this may require some resource investment. The high poverty among farmers means that cost constraints would severely limit climate adaptation, and hence, the benefits from climate adaptation. Ozor et al. (2010) for instance identified the high cost of adaptation strategies, lack of access to credit access, and low income among the topmost constraints to climate adaptation by households in southern Nigeria. Using data from surveyed households in Malawi, Mozambique, and Zambia, Mutenje et al. (2019) found that climate smart agricultural (CSA) practices that incorporate soil and water management practices based on the tenets of conservation agriculture (CA), improved plant varieties, and intercropping of cereal-legume plant species, are economically viable and should be implemented by risk-averse smallholder farmers. Mutenje et al. (2019) employed cost-benefit analysis (CBA) together with a mixed methodology approach (stochastic dominance) to determine the probability of investment in various CSA technology combinations.

Other studies that analyzed the profitability of various Climate Change Adaptation Strategies (CCAS) include Bimpeh (2012), Shongwe et al. (2014), Liu et al. (2016), Sain et al. (2017), Ng'ang'a et al. (2017), Martey (2018) and Mutenje et al. (2019). Sources on the adoption of adaptation strategies include Khatri-Chhetri et al.(2016), Mabuku et al. (2018) and Anuga et al. (2019). Considering the economic implications of climate adaptation, there is a need to understand the costs and benefits of climate adaptation strategies. This would help farmers to properly identify effective strategies and influence policy discussions on the choice of adaptation strategies from a pure revenue or output maximization perspective. Yet, none of these studies mentioned above dwelled on the climatic peculiarities in Ghana, and hence and the need for this study. Although there are empirical studies on the adoption of CSA practices and climate adaptation strategies (CAS) among farmers in Ghana, there few studies have conducted CBA of implementing on-farm climate change adaptation strategies in Ghana. Specifically, this study examines the adoption levels of on-farm CAS in Ghana and the profitability of adopting them by using CBA.

Methodology

Study locations

The study was conducted in two locations in Ghana – the South Tongu and Zabzugu districts. The South Tongu district (located in the south of Ghana) occupies a land area of 643.57 km^2, with Sogakope as its administrative capital. It is a coastal district with associated climate change impacts. Two rainy seasons persist in the district, a major and a minor one, which are characterized by different raining intensities. Agriculture is the primary employer of the indigenes of South Tongu district and farmers are mainly engaged in the production of maize, vegetables, and rice (Adzawla, Azumah, Anani, & Donkoh, 2019). The Zabzugu district (located in the north of Ghana) lies in the Guinea savannah zone. The district covers a total land area of 1,100.1 km^2. Zabzugu district experiences a unimodal rainfall pattern with mean annual rainfall of about 1,125mm. The people of Zabzugu district are mostly farmers and cultivate crops such as maize, rice, and groundnut. Livestock is also produced in large quantities in the district.

Sampling and data collection

Two locations (i.e. the Zabzugu and South Tongu districts) with distinct ecological characteristics where selected from the north and south of Ghana for this study. The choice of the districts was also based on the implementation of climate-related projects by GIZ Ghana and the Ministry of Food and Agriculture (MoFA). In all, ten (10) communities were selected for this study – five (5) in each district, via a simple random sampling approach. Random numbers were generated using MS excel. Communities with the highest random numbers per each district were selected for the study. The same process of simple random sampling was then applied in the final sampling stage to select 30 out of the list of farmer households that benefited from the project in each selected community. This meant a total sample size of 300 (150 for South Tongu and 150 for Zabzugu). Data was collected using a semi-structured questionnaire supported by expert interviews with MoFA staff in the two districts during the 2018 farming season.

Data analyses

The data were analyzed using a quantitative approach. Profitability of climate adaptation strategies was analyzed using the Benefit Cost Ratio (BCR). Tröltzsch et al. (2016) indicated that the choice of method for assessing climate adaptation strategies depends on the aim of the study. The authors outlined seven economic assessment models:

Multi-Criteria Analysis (MCA) is often used because adaptation approaches are often in areas that are difficult to assess and usually involve a lack of or inadequate quantitative data. Iterative Risk Management (IRM) is most relevant for long-term applications under conditions of adaptation deficit. Also, Real Options Analysis (ROA) is a potentially useful tool when investments are near term, where there is learning potential when new climate risk information becomes available, and where there is an adaptation deficit. The Robust Decision Making (RDM) approach is applied to evaluate adaptation in the face of uncertainty when there is a high risk of maladaptation. RDM applies widely to current and future time periods and focuses as a decision criterion on robustness rather than optimality. Conversely, Portfolio Analysis (PA) is a useful approach to analyze the potential complementary combinations of adaptation projects under high uncertainty. However, existing decision support methods, including CBA and Cost-Effectiveness Analysis (CEA), can be used for assessing current climate variability and adaptation deficit. CBA is commonly used, and specifically quantifies and monetizes all the costs and benefits of an action and promotes the rigorous analysis of the various factors affecting strategic choices (Boardman, 2004).

According to Tröltzsch et al. (2016), CBA estimates the economic efficiency of a policy or strategy by comparing the net present value of the planning, preparation and implementation costs to the benefits derived from implementing those actions. CBA aids socioeconomic decision-making and can be used to evaluate the desirability of a given intervention. The analysis of costs and benefits can significantly assist decision-makers in working out the best strategy for using scarce economic resources for more effective climate adaptation approaches and help prioritize resilient investments. Broadly, the benefit-cost ratio (BCR) for each adaptation strategy was determined through the following four major steps:

The sources of benefits and costs associated with each adaptation strategy were identified. Monetary values were assigned to each source of benefit and cost identified in stage one. For the costs, the farmers were asked to provide the cost of adopting each strategy. This cost includes both installation and operational costs of each strategy. For the benefits, the monetary values for adopting the various strategies were determined by estimating the value of the percentage increase in yield attributable to each adoption. The best approach was to rely on the respondents' perceived monetary values ascribed to the CAS. The study took careful note of the opportunity cost of identified sources of costs for implementing a strategy where the farmer seems not to be very much sure of how to assign monetary values to them.

The BCR for each adaptation strategy was subsequently computed following equation (1):

$$\sum BCR_i = \frac{\sum B_t/(1+r)^t}{\sum C_t/(1+r)^t} \qquad (1)$$

where:

BCR_i= Benefit Cost Ratio of the i^{th} strategy

B_t = Total benefits at year t,

C_t = Total costs at year t,

r = Discount rate

$(1+r)^t$= Discount factor at year t.

Since climate adaptation strategies that were practiced were records for one period, adoption with immediate costs and benefits, t, in this evaluation was assumed to be 1 while r was assumed to be the prevailing lending rate (30.5%) of the country (BoG, 2018).

A decision was made and conclusions drawn on each adaptation strategy. Generally, the higher the BCR, the better the strategy while the lower the BCR, the less economically viable the practice.

Results and Discussion

Adoption of CCAS by farmers

Following studies like Assan et al. (2018), the study identified 20 climate change adaptation strategies and presented them to the farmers who were asked to indicate those they adopted. The percentage distribution of climate adaptation by the respondents is presented in Table 1. From the results, majority of the farmers (99.7%) had changed their planting periods as a climate change adaptation strategy. Depending on the crop, the farmers said they would now plant late or early in the season. For instance, maize that used to be planted in early April in South Tongu district is now being planted from the middle to the end of April annually. The change in the planting period is mainly a reactive adaptation to the late onset of the rains. According to farmers in the north of Ghana (Zabzugu district to be precise), the planting period for maize has also been slightly adjusted to mid-June to early July annually. The farmers affirmed that the adjustments in planting period were largely due to the new breeds of improved seeds that respond to shorter raining periods due to climate change.

There is a gradual influx of early maturing varieties, especially maize, in the country. These varieties usually have a short production period. Therefore, the crops are able to mature before the cessation of the rains. There is a complete adoption rate of early maturing varieties in Zabzugu and a 92.7% rate in South Tongu . The difference in adoption levels between the two districts is largely due to the differences in ecological zones. Related to early maturing varieties is the adoption of drought-resistant varieties in the study areas (Adzawla et al., 2019). The adoption of drought-tolerant varieties was higher in Zabzugu (78.7%) than in South Tongu (64%). These figures are lower than those revealed by Awotide et al. (2016) who found a 90% adoption level of drought-tolerant varieties among farmers in Nigeria. Another prominent strategy adopted by farmers in both districts is row planting. Previously, farmers planted maize and other crops in nonlinear forms. The pattern has changed in recent times where farmers plant using lines with appropriate spacing between crops. More farmers in Zabzugu (92.7%) compared to those in the South Tongu (81.3%) had planted their crops in rows. This indicates an increase of 21.6% and 10.2% respectively for Zabzugu and South Tongu compared to the findings by Bimpeh (2012) who found that 71.1% of farmers adopted row planting. Planting in rows improves aeration and plant density as well as the performance of other agronomic activities such as weeding on the farm.

The adoption of rotation systems is on a lower scale in the South Tongu district than in the Zabzugu district. Only 6% and 2% of beneficiaries in South Tongu adopted crop rotation and land rotation strategies, respectively. For Zabzugu, 98% and 62.7% of the farmers adopted crop rotation and land rotation, respectively. Similarly, ploughing services were adopted more in Zabzugu district than in South Tongu district, while zero tillage practice is adopted more in South Tongu than in Zabzugu district. The adoption of organic manuring and green farming practices was low in both districts. For instance, only 13.7% and 30.3% of farmers in South Tongu and Zabzugu districts respectively adopted organic farming systems, which corroborates the findings of Martey (2018).

Adoption rates of A-frame contour farming, strip cropping, animal ploughing, and bunding were found to be the lowest in the two districts. Contour planting is a sustainable farming system in which farmers plant crops across or perpendicular to slopes to follow the contours of a field slope. Strip cropping involves the cultivation of a field divided into long, narrow strips alternating in a crop rotation process. It is used when a slope is too steep or when no alternative method is available to prevent soil erosion. The low adoption of strip cropping could be ascribed to the flat nature of the topography of the Zabzugu and South Tongu districts. Developments in technology and the mechanization of agriculture have also contributed to the low usage of animals for traction in both districts. According to the farmers, tractor ploughing is now the main source of tilling the land for cropping, since animal traction was costly and time-consuming. The lack of appropriate engineering capabilities and insufficient finance also limited the adoption of bunding of farmlands to conserve water and nutrients. Generally, there was a high adoption of climate change adaptation strategies (CCAS) in the north of Ghana (i.e. Zabzugu district) compared to the south of Ghana (i.e. South Tongu district). This was ascribed particularly to the severe impacts of climate change on crop-based systems in the north of Ghana which experiences a unimodal rainfall pattern.

Table 1: Percentage distribution of adoption of CCAS by district

Strategy	South Tongu		Zabzugu		Total	
	Adoption		Adoption		Adoption	
	Freq	%	Freq.	%	Freq.	%
Change planting date	150	100.0	149	99.3	299	99.7
Early maturing varieties	139	92.7	150	100.0	289	96.3
Row planting	122	81.3	139	92.7	261	87.0
Refilling	107	71.3	142	94.7	249	83.0
Drought tolerant varieties	96	64.0	118	78.7	214	71.3
Tractor ploughing	61	40.7	148	98.7	209	69.7
Intercropping	60	40.0	142	94.7	202	67.3
Mixed farming	50	33.3	147	98.0	197	65.7
Repeated sowing	30	20.0	130	86.7	160	53.3
Crop rotation	9	6.0	147	98.0	156	52.0
Zero tillage	114	76.0	42	28.0	156	52.0
Mulching	45	30.0	87	58.0	132	44.0
Green manuring	32	21.3	90	60.0	122	40.7
Cover cropping	13	8.7	88	58.7	101	33.7
Land rotation	3	2.0	94	62.7	97	32.3
Organic farming	20	13.3	46	30.7	66	22.0
Bunding	9	6.0	35	23.3	44	14.7
Animal ploughing	1	0.7	42	28.0	43	14.3
Strip cropping	6	4.0	35	23.3	41	13.7
A-frame contour farming	10	6.7	14	9.3	24	8.0
N	150		150		300	

Source: Field data, 2019

Figure 1 further presents the intensity of adoption of various CCAS by farmers in the two districts of Ghana. The range of adoption was found to be between 3 and 20 CCAS. The percentage distribution of the farmers increased steadily from three to seven strategies, that is, from 0.3% adopters of three strategies to 16.7% adopters of seven different strategies. However, from seven to twenty strategies, the percentage of adopters shows a general downward trend with some hikes. The distribution at the district level, however, differs slightly. For instance, while no farmer from Zabzugu district adopted less than 6 strategies, no farmer in the South Tongu district adopted more than fourteen strategies. While the adoption in South Tongu district increases sharply to a peak of about 31% and at seven strategies and declines thereafter, the adoption intensity peaked at 11 strategies in the Zabzugu district. It is therefore concluded that the adoption of CCAS was higher in Zabzugu district than in South Tongu district.

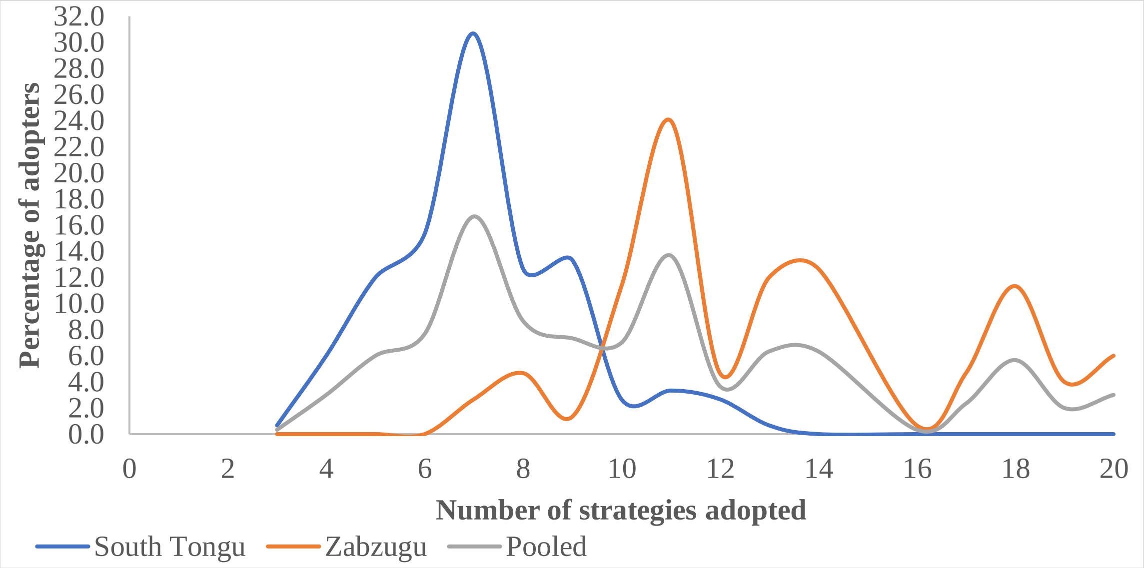

Figure 1: Adoption intensity by district
Source: Field data, 2019

Locational distribution of Benefit-Cost Analysis of climate change adaptation strategies (CCAS)

Recall, from the methodology, that a benefit-cost analysis was conducted using lending rate at 30.5% for the single year of adoption. The result is presented in Table 2. Generally, the results show that all adaptation strategies are economically viable since the estimated BCR are above 1.

Overall, the first five strategies with the highest BCR are strip cropping, repeated sowing, refilling, zero tillage and row planting, while the strategies with the lowest BCR are land rotation, mixed farming, early planting, tractor ploughing and a-frame contour farming. For South Tongu, strip cropping, refilling, row planting, zero tillage and crop rotation, in that order, recorded the highest BCR while cover cropping, animal ploughing, tractor ploughing, mixed farming and land rotation recorded the lowest BCR values. On the other hand, strip cropping, repeated sowing, zero tillage, row planting and green manuring recorded the highest BCR in Zabzugu while land rotation, a-frame contour ploughing, bunding, mixed farming and organic farming recorded the lowest BCR. To promote climate adaptation strategies and improve the economic returns from adoption, strategies with higher BCR should be encouraged. The study by Ng'ang'a et al. (2017) found that minimum tillage is not an economically viable climate adaptation strategy.

The average cost of adopting a strategy was found to be Fifty Ghana Cedis (GH¢50.00), the equivalent of US$ 9.14. The corresponding average benefit of adopting a CCAS was found to be about GH¢107.00 (about US$ 19.6) in the two districts. This led to a BCR of 2.4. Thus, the benefit of adopting an on-farm CCAS is 200 percent more than the cost of adopting it. At the district level, a cost of GH¢37.00 is required to adopt a strategy in South Tongu district to obtain a benefit of about GH¢73.00. This gives a BCR of 2.16. For Zabzugu district, a cost of about GH¢63.00 is required to obtain a benefit and a BCR of GH¢142.00 and 2.63, respectively.

Strip cropping which recorded the highest BCR in both districts involves the cultivation of different crops in alternative strips on the same piece of land at the same production time. Primarily, this strategy prevents soil erosion on the farms. Although it is less adopted (as in Table 2) in both districts, its economic viability remained significantly high for those farmers who adopted it. In fact, the strategy is a form of intercropping where mostly, farmers integrate maize production with leguminous crops. The advantage of this system is that it does not only lead to an increase in yield but also improves the fertility of the soil and enhances an effective utilization of fertilizer.

Repeated cropping which recorded the second highest BCR involves the cultivation of the same crop or different crops on the same piece of land continuously. The system is also known as continuous cropping. Common among farmers, especially in the South Tongu district, is the cultivation of the same crop on a piece of land over the years. Nonetheless, the cultivation of different crops is the most effective in controlling pests and diseases. Refilling involves the replanting or re-sowing of a plant due to low germination. Refilling ensures that there are the right plant populations on a farm to ensure an improvement in yield. The farmers explained that planted seeds may not germinate due to a number of factors including pest attacks, poor seed quality and environmental conditions. Although refilling is among the highest five economically viable CCAS in South Tongu, this is not so in Zabzugu. Observation has shown that timely refilling is needed to ensure a uniform growth in crops and increase farm output.

Zero tillage involves no disturbance of the soil before planting. The practice was common among maize farmers while all rice farmers indicated that they had tilled their lands. Zero tillage is a way of improving the moisture content of the soil and allowing maximum functioning of soil microorganisms. It is a major practice in South Tongu although the economic viability of the strategy is higher in the Zabzugu district. In the Zabzugu district, it is becoming virtually impossible to cultivate without tilling the land due to fast hardening of the soil in the area. Row planting has gained wide popularity among the farmers in the two project areas. The farmers explained that planting in rows allows them to perform other activities on the farm with ease. Planting in rows also ensures optimal plant population and spacing on the farm. Similarly, row planting allows the farmers to move freely on the farm. These could lead to higher outputs on the farms, thereby improving their economic performance.

Table 2: Locational distribution of Benefit-Cost Analysis of adopting CCAS

Strategy	South Tongu			Zabzugu			Total		
	Cost (GHC)	Benefit (GHC)	BCR	Cost (GHC)	Benefit (GHC)	BCR	Cost (GHC)	Benefit (GHC)	BCR
Change planting date	82.51	161.82	2.44	124.34	304.10	3.07	103.35	232.72	2.76
Early maturing variety	87.86	176.64	2.21	94.15	190.01	2.81	91.11	183.56	2.52
Drought tolerant variety	86.93	208.34	2.70	82.28	218.57	3.36	84.35	214.02	3.07
Crop rotation	76.67	150.78	2.81	95.63	234.05	2.80	94.54	229.24	2.80
Land rotation	96.67	128.00	1.80	139.97	217.79	2.21	138.63	215.01	2.20
Mixed farming	203.00	286.68	1.76	171.70	313.98	2.76	179.64	307.05	2.51
Row planting	105.12	263.03	2.84	70.31	189.12	3.90	86.58	223.67	3.40
Intercropping	117.92	221.53	2.22	76.58	194.77	3.71	86.08	200.92	3.37
Re-filling	63.36	177.67	3.23	64.42	158.40	3.70	63.98	166.30	3.51
Repeated sowing	89.67	217.90	2.94	64.52	186.00	4.15	67.41	189.67	4.01
Strip cropping	57.50	191.33	3.37	59.43	175.78	4.38	59.38	176.14	4.35
Zero tillage	84.37	182.59	2.83	69.05	176.70	4.10	75.74	179.27	3.54
Tractor ploughing	221.15	294.48	1.62	160.83	275.54	2.88	174.92	279.97	2.59
Animal ploughing	193.68	220.26	1.61	141.45	250.11	2.98	145.25	247.94	2.88
Cover cropping	98.46	125.62	1.37	145.13	246.06	2.90	142.80	240.07	2.82
Mulching	76.00	183.31	2.53	144.12	250.69	2.84	132.37	239.08	2.79
Bunding	219.00	295.10	2.11	142.93	240.22	2.73	145.84	242.33	2.71
A-frame contour farming	114.09	130.27	1.95	141.22	239.98	2.70	140.08	235.35	2.67
Organic farming	148.00	229.25	2.31	135.86	235.46	2.80	136.79	234.98	2.76
Green manuring	78.59	126.72	1.83	111.89	209.65	3.28	107.81	199.48	3.11
Total	736.27	1451.81	2.16	1255.03	2832.73	2.63	995.65	2142.27	2.40
Average	36.81			62.75			49.78		
Obs.	150	72.59	2.16	150	141.64	2.63	300	107.11	2.40

Source: Field data, 2019

Conclusions and Policy Implications

To make the appropriate investment decisions about prioritizing on-farm CAS, there is a need for an in-depth understanding of the trade-offs between the different CAS. This study presents the nexus between costs and benefits of adopting various on-farm CAS among farmers in the north and south of Ghana. Cost benefit analysis as an approach for assessing economic profitability, risks and impacts associated with benefit and associated externalities. The benefit cost analysis serves as an essential strategy for understanding the financial implications of various climate change adaptation strategies. The economic assessment for the CAS provides critical information that could be used to reassess existing practices being promoted by ongoing agricultural policies in Ghana, which could possibly affect adoption.

The major CAS adopted in both districts were changing of planting dates, planting of early maturing varieties, row planting, refilling and planting of drought tolerant varieties. The adoption intensity varied from district to district, with a higher adoption intensity in Zabzugu district than in South Tongu district. Generally, the adoption of each CAS was profitable since the estimated average benefits outweighed the average costs. However, the most profitable on-farm CAS were strip cropping, repeated sowing, refilling, zero tillage and row planting. On the other hand, the less profitable strategies included land rotation, mixed farming, early planting, tractor ploughing and a-frame contour farming.

Drought tolerant varieties of rice, maize and soybean should be promoted and farmers encouraged to adopt them. Beyond the training of farmers, stakeholders including the Ministry of Food and Agriculture (MoFA) and the Department of Agriculture of the Metropolitan, Municipal, District Assemblies should consider establishing demonstration farms to enhance the adoption and farmers' understanding of the various CCAS, especially zero tillage, repeated sowing and strip cropping which have been found to have the greatest benefits.

References

Adzawla, W., Azumah, S. B., Anani, P. Y., & Donkoh, S. A. (2019). Gender perspectives of climate change adaptation in two selected districts of Ghana. *Heliyon, 5*(11), 1-6. e02854. https://doi.org/10.1016/j.heliyon.2019.e02854.

Akudugu, M. A., Dittoh, S., & Mahama, M. S. (2012). The Implications of Climate Change on Food Security and Rural Livelihoods: Experiences from Northern Ghana. *Journal of Environment and Earth Science, 2*(3), 21-29. https://www.iiste.org/Journals/index.php/JEES/article/view/1626/1579.

Antwi-Agyei, P., Stringer, L. C., & Dougill, A. J. (2014). Livelihood adaptations to climate variability: insights from farming households in Ghana. *Regional Environmental Change, 14* (4), 1615–1626. https://doi.org/10.1007/s10113-014-0597-9.

Anuga, S. W., Gordon, C., Boon, E., & Surugu, J. M.-I. (2019). Determinants of Climate Smart Agriculture (CSA) Adoption among Smallholder Food Crop Farmers in the Techiman Municipality, Ghana. *Ghana Journal of Geography, 11*(1), 124 – 139 . https://dx.doi.org/10.4314/gjg.v11i1.8.

Armah, F. A., Odoi, J. O., Yengoh, G. T., Obiri, S., Yawson, D. O., & Afrifa, E. K. (2011). Food security and climate change in drought-sensitive savanna zones of Ghana. *Mitigation and Adaptation Strategies for Global Change, 16*(3), 291-306. https://doi.org/10.1007/s11027-010-9263-9.

Arndt, C., Asante, F., & Thurlow, J. (2015). Implications of climate change for Ghana's economy. *Sustainability, 7*(1), 7214–7231. https://doi.org/10.3390/su7067214.

Asante, F., & Amuakwa-Mensah, F. (2015). Climate change and variability in Ghana: Stocktaking. *Climate, 3*(1), 78–99. https://doi.org/10.3390/cli3010078.

Assan, E., Suvedi, M., Olabisi, L., & Allen, A. (2018). Coping with and adapting to climate change: A gender perspective from smallholder farming in Ghana. *Environments, 5*(86), 1–19. https://doi.org/10.3390/environments5080086.

Awotide, B. A., Abdoulaye, T., Alene, A., & Manyong, V. M. (2016). *Adoption of drought tolerance maize varieties for Africa, productivity, food security and welfare in Nigeria: An Ex-Post Impact Assessment.* PhD Thesis, University of Ibadan, Nigeria.

Bimpeh, E. (2012). *Effects of the MCA-Ghana Program Farmer Training on Productivity of Smallholder Maize Farmers in the Kwahu East District of Ghana.* Doctoral dissertation, Kwame Nkrumah University of Science and Technology. Kumasi, Ghana.

Boardman, E. A. (2004). *Cost-benefit Analysis: Concepts and Practice*. 2nd edition. Ed. ARC, Bucharest.

BoG. (2019). *Summary of Economic and Financial Data.* Bank of Ghana. Accra, Ghana.

Burton, I., Diringer, E., & Smith, J. (2006). *Adaptation to climate change. International policy options*. Arlington: Pew Center on Global Climate Change.

Darfour, B., & Rosentrater, K. A. (2016). *Agriculture and Food Security in Ghana.* 2016 ASABE Annual International Meeting Paper. Iowa State University, Digital repocitory. pp. 1-11.

FAO & ECA. (2018). *Regional Overview of Food Security and Nutrition. Addressing the threat from climate variability and extremes for food security and nutrition.* Food and Agriculture Organisation. Accra, Ghana.

FAO, IFAD, UNICEF, WFP, & WHO. (2019). T*he State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns.* FAO, Rome, Italy.

Fentie, A., & Beyene, A. D. (2019). Climate-smart agricultural practices and welfare of rural smallholders in Ethiopia: Does planting method matter?. *Land Use Policy, 85*(1), 387–396. https://doi.org/10.1016/j.landusepol.2019.04.020.

Khatri-Chhetri, A., Aggarwal, P. K., Joshi, P. K., & Vyas, S. (2016). Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural Systems, 151*(1), 184-191. https://doi.org/10.1016/j.agsy.2016.10.005.

Liu, S., Connor, J., Butler, J. A., Jaya, I. K., & Nikmatullah, A. (2016). Evaluating economic costs and benefits of climate resilient livelihood strategies. *Climate Risk Management, 12*(1) 115–129. https://doi.org/10.1016/j.crm.2015.11.005.

Mabuku, M. P., Senzanje, A., Mudhara, M., Jewitt, G. P., & Mulwafu, W. O. (2018). Strategies for coping and adapting to flooding and their determinants: A comparative study of cases from Namibia and Zambia. *Physics and Chemistry of the Earth, 111*(1), 20-34. https://doi.org/10.1016/j.pce.2018.12.009.

Martey, E. (2018). Welfare effects of organic fertilizer use in Ghana. *Heliyon 4*(10), 1-26. https://doi.org/10.1016/j.heliyon.2018.e00844.

Mutenje, M. J., Farnworth, C. R., Thierfeldera, C., Mupangwad, W., & Nyagumboa, I. (2019). A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics 163*(1), 126–137. https://doi.org/10.1016/j.ecolecon.2019.05.013.

Ng'ang'a, S. K., Miller, V., Essegbey, G., Karbo, N., Ansah, V., Nautsukpo, D., Kingsley, S., &

Nyantakyi-Frimpong, H., & Bezner-Kerr, R. (2015). The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. *Global Environmental Change, 32,* 40–56. https://doi.org/10.1016/j.gloenvcha.2015.03.003.

Ozor, N., Madukwe, M., Enete, A., & Amaechina, E. (2010). Barriers to Climate Change Adaptation Among Farming Households of Southern Nigeria. *Journal of Agricultural Extension, 14*(1), 114-124. https://doi.org/10.4314/jae.v14i1.64079.

Sain, G., Loboguerrero, A. M., Corner-Dolloff, C., Lizarazo, M., Nowak, A., Martínez-Barón, D., & Andrieu, N. (2017). Costs and benefits of climate-smart agriculture: The case of the Dry

Corridor in Guatemala. *Agricultural Systems, 151*(1), 163–173. https://doi.org/10.1016/j.agsy.2016.05.004.

Shongwe, P., Masuku, M. B., & Manyatsi, A. M. (2014). Cost Benefit Analysis of Climate Change Adaptation Strategies on Crop Production Systems: A Case of Mpolonjeni Area Development Programme (ADP) in Swaziland. S*ustainable Agriculture Research, 3*(1), 37-49. http://dx.doi.org/10.5539/sar.v3n1p37.

Tröltzsch, J., Rouillard, J., Tarpey, J., & Lago, M. (2016). *The economics of climate change adaptation: Insights into economic assessment methods.* ECONADARPT Deliverable 10.2.