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CONSERVATION AGRICULTURAL PRACTICES: DETERMINANTS AND EFFECTS ON SOIL HEALTH FOR SUSTAINABLE PRODUCTION IN NORTHERN GHANA

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ABSTRACT

Research background: The threat from climate change remains a major concern especially for developing economies like Ghana. Hence, agricultural practices that are environmentally friendly and improves soil health are very necessary for building resilience.
Purpose of the article: The present study investigated the determinants of conservation agricultural practices in northern Ghana as well as the effect of these practices on soil health for sustainable production.
Methods: Using cross-sectional data collected by the International food policy research institute from 1284 households, a multivariate probit model was first performed to identify the determinants of conservation agricultural practices while the inverse probability weighted regression adjustment was employed to establish the effect of conservation agricultural practices on soil health.
Findings & value added: Results from the multivariate probit model showed that socioeconomic and institutional factors as well as different household-specific factors, influence farmer's decisions to engage in various conservation agricultural practices. Crop rotation, fallowing, contour ploughing or pit planting and manure application were found to have a positive effect on soil health through improved resilience to soil erosion. The study concludes that conservation agricultural practices will be useful in Ghana's quest of achieving zero hunger since the conservation agricultural practices ensure that food is produced for the present generations without compromising the soil health for further productions. Hence, the current Ghanaian government's flagship programme dubbed 'planting for food and jobs' should include conservation agriculture as a priority module in its framework so that households could both increase their output while maintaining the quality of the soil.

Key words: conservation agriculture; inverse probability weighted regression adjustment; multivariate probit; soil health
JEL: Q00; Q01; Q12

INTRODUCTION

Conservation agriculture (CA) is defined as a series of sound land husbandry practices which minimize soil disturbance, improve organic matter and soil cover, and use of crop rotations and associations to reduce impact of pests and diseases (**Nyanga *et al.*, 2020; Kassam *et al.*, 2009**). The concept of conservation agriculture is hinged on three main practices which protect the productive base of agriculture. These include; minimum soil disturbance, perpetual organic cover (using crop residues or living cover crops) and crop rotation (**Michler *et al.*, 2019; Nyanga *et al.*, 2020).** According to **FAO (2010)**, conservation agricultural technology is a concept for resource-saving agricultural crop production that strives to attain acceptable and sustainable productivity and profits, as well as conserving the natural environment**.** Many empirical evidence suggest, that conservation agriculture is particularly important for most developing agrarian economies like Ghana where a significant proportion of the population depend on it for their livelihood. For instance, **Michler *et al.* (2019)** asserts, that agriculture and food security are threatened by climate change in Sub-Saharan Africa and hence, conservation agricultural practices which are also said to be climate smart helps to increase productivity, ensures resilience to climate shocks and reduces negative externalities. Climate smart agricultural practices simultaneously and sustainably increase productivity and resilience (adaptation), reduces or mitigates the emission of greenhouse gases as well as helps in achieving food security (**Nyanga *et al.*, 2020)**. Since conservation agriculture improves soil organic matter and improves the vegetation cover through planning of cover crops or planting trees, it lessens the impact of climate change while improving soil health (**Nyanga *et al.*, 2020)**. According to **Nyanga *et al.* (2020)**, conservation agricultural practices provide substantial ecosystem services that play a key role in sustaining the livelihoods of smallholder farmers, particularly in the rural communities. WHO (2005) defined ecosystem services as the conditions and processes through which natural ecosystems and the species that sustain them are maintained in order to benefit human life through one or more of provisioning (food, water, wood), maintenance (soil quality, air quality), regulatory (pest and disease control and pollination) as well as supportive services to the soil biodiversity. **Nyanga *et al.* (2020)** pointed out, that conservation agricultural practices are aimed at increasing crop yields while enhancing environmental sustainability by leveraging several ecosystem services such as supporting (soil formation, nutrient cycling, and primary production), regulating (climate and water regulation), and provisioning (food security) ecosystem services. Also, **Ikazaki *et al.* (2018)** investigated the role of conservation agricultural practices on soil conservation in the Sudan Savanna and found practices relating to minimum soil disturbance and vegetation cover to be of high relevance for soil and water conservation. They however failed to include crop rotation in their study with the reason that it was not practical in their study area, Burkina Faso.

Despite the enormous potential benefits of conservation agricultural practices as outlined in the literature, most conservation agricultural practices in Sub-Saharan Africa are driven by donors, civil society groups and Non-Governmental Organizations (NGOs) **(Nyanga *et al.*, 2020)**. **Steiner-Asiedu *et al.* (2017)** stressed that there are two basic ways to achieve sustainable farming systems; either by moving from Low External Input Agriculture (LEIA) to Low External Input and Sustainable Agriculture (LEISA) or by moving from High External Input Agriculture (HEIA) to High External Input and Sustainable Agriculture (HEISA). One inconsistent policy discourse in most developing countries are often attempts that seek to move from LEIA to HEIA through the use of chemical inputs to attain short term goals instead of plans to move from LEISA to HEISA (**Steiner-Asiedu *et al.*, 2017)**. Hence conservation agricultural practices are one of a typical LEISA and when combined with some level of chemical inputs will result in HEISA which will help in sustainable development. Thus, the emphasis should be to move from LEIA to LEISA and subsequently to HEISA where sustainability is given priority as compared to the later.

Also, one critical area of concern to farmers and agronomists is soil health. Soil health is simply the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. The idea of health is to highlight, that the soil is "living and not sick" (i.e. it is not eroded or degraded). The multi-purpose use of land and its maintenance usually disturb the soil, compromising its ability for sustain future production. Ploughing and disking as methods of tillage systems (so-called conventional tillage) in the humid regions reduce soil organic matter and upsurge the erosion process, leading to chemical, physical, and biological changes in the soil features that expand the reliance on external inputs and therefore increasing production costs, causing environmental effects (**Cardoso *et al.*, 2013**). In contrast, less soil-disturbance methods of production like minimum-tillage and organic farming are much more dependent on biological processes for sustainability (**Kaschuk *et al.*, 2010**). The definition of soil quality cannot be one for all types of soil and soil-use as opined by **Sojka and Upchurch (1999).** As a result, pointers of soil quality must be selected according to soil use and management, soil features and environmental conditions **(Cardoso *et al.*, 2013**). Hence given the potential for conservation agricultural practices, it is expedient to expect that CA practices will help to improve soil health which calls for a study such as this. The objective of this study is therefore to identify the determinants of conservation agricultural practices as well as estimate its effect on soil health in northern Ghana where the soils are relatively infertile compared to soils in the south. The results could inform agricultural development policies in the country towards the achievement of production systems that supports productivity of the present without compromising the potential of same soil to provide for the future generation.

Overview of some Conservation Agricultural Practices in northern Ghana

There are varying conservation agricultural practices at different parts of the world but irrespective of wherever it may be, it encompasses the three areas; minimum soil disturbance, soil cover and crop rotation **(Nyanga *et al.* 2020)**.

Crop rotation is the system of farming where by a farmer cultivates more than one type of crop on the same piece of land in a sequence. Hence, the farmer could grow legumes in parcel A, cereals in parcel B and roots and tubers in parcel C in the first farming season (i.e. legumes-cereals-roots and tubers sequence) but changes the sequence in the following season by farming cereals in parcel A, roots and tubers in parcel B and legumes in the parcel C (i.e. cereals-roots and tubers-legumes sequence). In this system, the integration of legumes will help to improve the nitrogen content of the soil for the cereal production in the subsequent season while the roots and tubers will help improve soil aeration for legumes also in the subsequent season. The practice also helps to ensure that not only one nutrient is continually used in the soil by varying the crop types on the piece of land. Crop rotation is also said to improve soil quality and farm output (**Chongtham *et al.* 2016; Donkoh, 2019**).

Fallowing is the practice by which farmer allows a piece of land to rest for a given period in order for it to regain its fertility. Fallowing enhances microbial activities in the soil such that the soil regains its fertility for increased productivity. Excessive cultivation on the same piece of land could be hazardous, as it could lead to leaching and degradation of the land. Fallowing also helps to improve the vegetation cover since all forms of shrubs and grasses could spring-up in the period for which the land is left fallow. **Liu *et al.* (2013)** indicated, that fallowing provides supportive ecosystem services such as biofuel supplies and microbial activities which are required for sustainable agro-ecosystem management.

Contour Ploughing or Pit planting is a sustainable water conservation technique used to conserve soil in most dryland areas like many parts of northern Ghana where the study was undertaken. Contour ploughing or pit planting is one in which ditches are dug along the contour to stop water from running down the slope and causing erosion along sloping land. Contours are constructed to shorten the slope length and change the direction of runoff flow for the purpose of storing water, preventing scouring and combating drought and soil erosion. When it is done by ploughing it is called contour ploughing but in most areas of Sub-Saharan Africa it is often planting pits. Pits or ditches of required sizes are excavated along contour (**Critchley, 1991**). The excavated top soil is disposed on the upper side of the slope and kept for refilling. A typical exam of pit planting is the Zai technology in which small planting pits of about 20-30cm in width, 10-20cm deep, and filled with manure. The pits are spaced 70-80cm apart resulting in about 10 000 holes per hectare. Hence, Zai technology refers to small planting pits in which organic matter (manure, compost, or dry biomass) is buried before planting the seed in those pits (**Danso-Abbeam *et al.*, 2019; Mottis *et al.* 2013**).

Manure Application is the art of applying manure (animal dung, droppings or compost) to the soil to increase the nutrient level of the soil for crop cultivation. **Sharma and Reynnells (2018)** stated, that manure application can provide nutrients to soils, improving soil fertility and crop production. Manure application could be applied either by broadcasting or side placement which does not disturb the soil, improves the structure of the soil, thereby conserving the soil.

Agroforestry is one of the major ways of improving the vegetation cover as well as a key option for sequestering carbon on agricultural lands which helps to mitigate the impact of climate change (**Schoeneberger, 2009**). It is the practice of growing trees or shrubs alongside crops. **Donkoh (2019)** opined, that the goal of agroforestry is to create diverse, ecologically sound and sustainable use of land and the benefits of agroforestry ranges from productivity, environmental to socioeconomic benefits. The environmental benefits can be classified into carbon sequestration, biodiversity conservation, soil enrichment and air and water quality improvement (**Jose, 2009).** Previous studies have confirmed that agroforestry has the potential to positively influence food security, adaptation and mitigation to climate (**Mbow *et al.*, 2013; Donkoh, 2019)**.

DATA AND METHODS

Data Source and Study Area

The study used secondary data obtained from the International Food Policy Research Institute (IFPRI) under the Ghana Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) 2015 baseline survey. The data was collected over 1284 households across the three northern regions (i.e. 222 households from the Upper East, 447 from the Upper West and 615 from the Northern region). The data from the Upper East Region was collected from the Bongo, Kassena Nankana East and Talensi-Nabdam disticts, that of the Upper West Region was collected from Wa West, Wa East and Nandowli districts while that of the Northern Region was taken from the Tolon/Kumbungu, Savelugu and West Mamprusi districts.

Northern Ghana account for about half the total land surface of Ghana but least developed. These regions lie roughly north of the Lower Black Volta River, which together with its tributaries, the White Volta, Red Volta, Oti river and Daka river, drain the area. Northern Ghana shares international boundaries with the Burkina Faso to the North, Togo to the east and Cote D'Ivoire to the lower southwest.

The climate in Northern Ghana is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. Agriculture is the mainstay of households and a majority of them engage in the cultivation of crops such as cereals, legumes, roots and tubers. Some households rear livestock and poultry while others engage in fishing especially those around the Volta basin.

Conceptual framework

The conceptual framework for this study is based on the system approach for building soil health and productivity by **Al-Kaisi (2015).** The system approach shows the mechanisms under which healthy soils are developed and maintained in order to ensure productive and sustainable agriculture (**Al-Kaisi, 2017**). As it is indicated in Figure 1, conservation agricultural practices are expected to offer a system service through increase in organic matter, which will also increase the aggregate stability of the soil and thus increase water storage. These services will independently help build a healthy soil which is resilient to land degradation or soil erosion.

Theoretical framework and estimation techniques

The study derived its theoretical underpinnings from the random utility theoretical framework. According to this theory, a system thinking rational farmer is expected to evaluate the net benefits that could be derived from a given conservation practice against his opportunity cost for not engaging in such practice. By "a system thinking rational farmer", we imply that farmers do not only decide on adopting to a given practice based on short term goals but also long-term sustainable benefits. Hence, a household will decide to engage in a given conservation agricultural practice if the perceived utility or net benefits are significantly greater. For instance, if we assume U_{i0} to denote the utility for not practicing CA and U_{i1} is the utility for practicing CA, then a farmer will practice CA if $U_{i1} - U_{i0} > 0$. The utility, though not directly observed can be expressed as a function of household characteristics, socio-economic activities and institutional factors expressed as Eq. 1.

$$U_i = \beta_i X_i + \varepsilon_i \quad (1)$$

Where: X_i is a vector explanatory variables, β_i is a vector of parameters to be estimated and ε_i is the error term assumed to have zero mean and constant variance.

The multivariate probit and the inverse probability weighted regression adjustment models were then applied to estimate the determinants of CA practices as well as the effect of these practices on soil health respectively.

The multivariate probit model was employed to identify the determinants of conservation agricultural practices in northern Ghana. The reason for the choice of model is because the various CA practices are correlated binary outcomes (**Greene, 2002**).

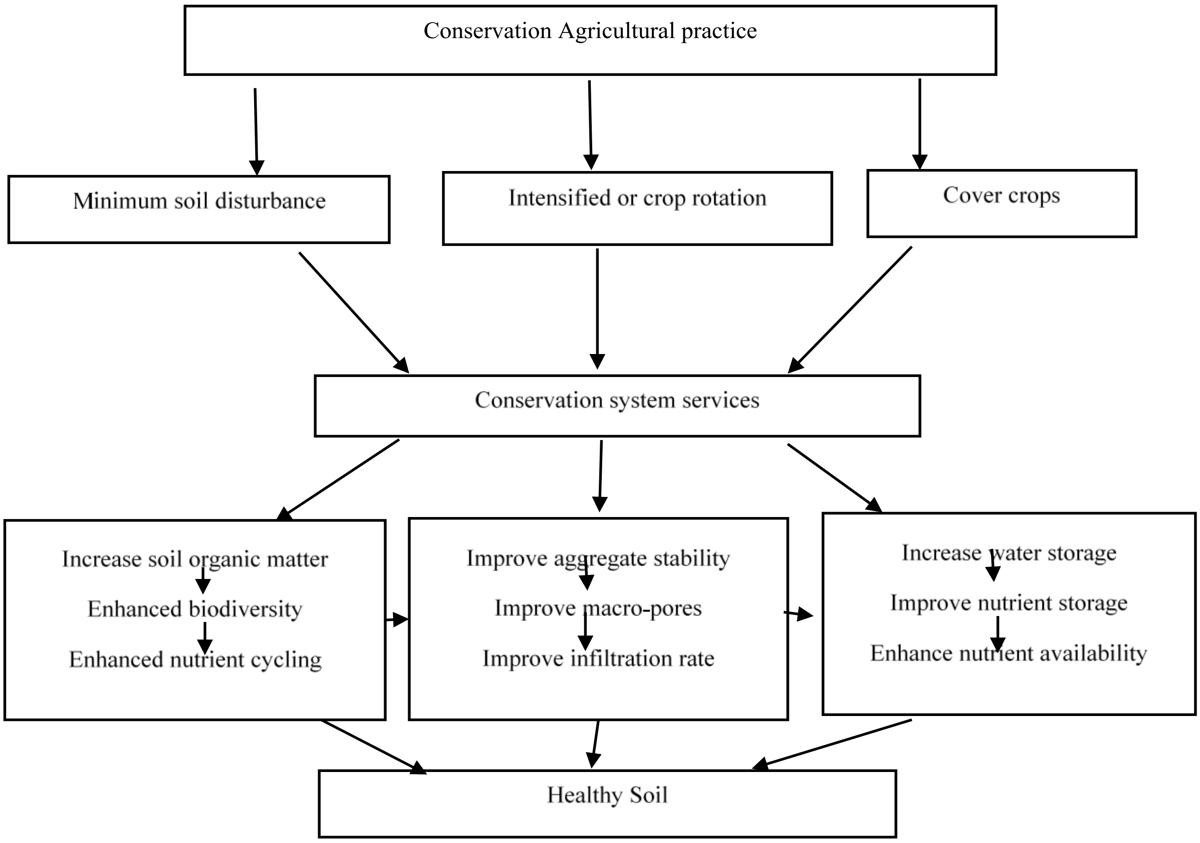

Figure 1: System approach for building soil health and productivity (Adapted from **Al-Kaisi, 2015**)

Following **Danso-Abbeam and Baiyegunhi (2017)** and **Donkoh *et al.* (2019)** a penta-variate probit model with five CA practices as dependent variables (Crop rotation, Fallowing, Contour ploughing or pit planting, manure application and agroforestry) could be expressed as Eq. 2.

$$y^*_{i,m} = X_{i,m}b_m + e_{i,m} \tag{2}$$

Where: $m = 1,2,\ldots 5$ (i.e. the five conservation practices considered in this study), y^* is the latent variable that drives household choice for a given CA practice, X is a vector of explanatory variables defined in Table 1 while e is the disturbance term.

$y^*_{i,m} = 1$ if $y^*_{i,m} > 0$ and 0, if otherwise. Since the conservation practices in this study is five, the tetra-choric correlation between the error terms could be expressed as Eq. 3.

$$\left(\begin{matrix} e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \end{matrix}\middle| x_1 + x_2 + \cdots x_{13}\right) \approx N\begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 \end{bmatrix} \tag{3}$$

Where: ρ is the pairwise correlation coefficient of the error terms with regards to any two of the estimated CA practices in the model. The correlation between the stochastic components of different CA practices are shown by the off-diagonal elements in the variance-covariance matrix (**Danso-Abbeam and Baiyegunhi, 2017**)

The effect of the various CA practices on soil health was estimated using the Inverse Probability Weighted Regression Adjustment (IPWRA). This is because, IPWRA has the ability to account for potentially biased estimates (ATT) that might emanate from propensity score models in the presence of misspecification (**Wooldridge, 2007**). Hence, IPWRA can ensure consistent results as it permits the treatment and the outcome model to account for misspecification due to its double-robust property. Here, soil health has been defined as 1 if the household agricultural soil is healthy (i.e. if their soils are not susceptible to erosion) and 0 if otherwise. **Imbens and Wooldridge (2009)** stated, that estimating the average treatment effect on the treated (ATT) involves a two-step process. Hence given the outcome equation (Eq.4).

$$Y_i = \alpha_i + \beta_i x_i + e_i \tag{4}$$

the propensity score is first generated from the selection equation as $ps = p(x; y)$ and in the second step, a linear regression is employed to estimate the propensity scores as $p(\alpha_0; \beta_0)$ and $p(\alpha_1; \beta_1)$ using inverse probability least squares on the binary outcome. The inverse probability least squares is expressed as Eq. 5-6.

$$\text{Min}_{\alpha_0,\beta_0} \sum_i^N (Y_i - \alpha_0 - \beta_0 x_i)/p(x,y) \quad (5)$$

if soil health is 0 for the ith household and

$$\text{Min}_{\alpha_1,\beta_1} \sum_i^N (Y_i - \alpha_1 - \beta_1 x_i)/p(x,y) \quad (6)$$

if soil health is 1 for the ith household.

Hence the ATT is then computed as the difference between Equation 5 and 6, expressed as Equation 7.

$$ATT = \frac{1}{N_w} \sum_i^{N_w} [(\hat{\alpha_1} - \hat{\alpha_0}) - (\hat{\beta_1} - \hat{\beta_0}) x_i] \quad (7)$$

Where: $(\hat{\alpha_1} - \hat{\alpha_0})$, are the estimated inverse probability weighted estimates for the treated group of the *i*th household and $(\hat{\beta_1} - \hat{\beta_0})$ are the estimated inverse probability weighted estimates for the control group. Finally, N_w is the total number of treated households.

RESULTS AND DISCUSSION

Summary statistics of Household socioeconomic and institutional variables

The results (Table 1) of the study showed that about 42% of the arable soils were reported by to be healthy (i.e. said to be resilient to soil erosion). With the household specific factors considered in this study, the average age of the household head in the study area was approximately 48 years which is well within the active labour force usually engaged in agricultural production. The respondents were made up of approximately 84% male headed households which indicates male dominance in the study area. About 95% of the household heads were married and about 99% of them indicating that agriculture was their main occupation. The average farm size that was recorded from the survey is approximately 4 acres (about 1.6 Ha) which implies that most of the respondents were smallholder farmers.

There was less participation in surface and ground water irrigation by the respondents in the study area. Only about 1% of the respondents supported their production with any form of irrigation (Table 1) which is an indication that the rain-fed farming is still the most dominant in the area. Access to credit is low in the area, only about 19% of the respondents reported having access to credit. Even those who had access to credit could only obtain an average of about hundred and twenty Ghana cedis (GHS 120) which is too small to support the production of the farmers. The average exchange rate at the time of data collection was 1 USD to GHS 3.82. Many financial institutions in the area demand collateral guarantee before advancing credit. The lack of collateral for accessing credit can affect the choice of farming practices. More than half (61%) of the respondents had access to extension services and this could be a source of knowledge and new methods of farming for their production. About 35% of the households belonged to farmer groups. Also, about 33% of households derived income from off-farm employment. On the average the total livestock owned by respondents in the study area is 4 which indicates that a farmer in the research area have at least a total of 4 livestock which could be a source of food, and income to cover some household expenses.

Farmer adaption to the various Conservation Agricultural (CA) practices in northern Ghana

Figure 2 presents the results of the various conservation agricultural practices and the proportion of households that engaged in them. The results showed, that majority of the households in northern Ghana practices Contour ploughing or pit planting (65.9%), followed by crop rotation (65.3%).

Table 1: Definition of variables, measurements and summary statistics

Variable	Measurement	Mean	Standard Deviation
Dependent Variable			
Soil Health	Dummy(1 if soil is resistant to erosion, otherwise 0)	0.42	0.28
Independent variables			
Household-Specific Factors			
Age of household head	Years	47.69	14.56
Sex of household head	Dummy(1 if male, otherwise 0)	0.841	0.365
Marital status of HH	Dummy(1 if married, otherwise 0)	0.946	0.225
Socioeconomic Factors			
Primary occupation of HH	Dummy(1 if agric., otherwise 0)	0.99	0.096
Farm size	Acres	3.917	4.037
Surface Irrigation	Dummy(1 if yes , otherwise 0)	0.06	0.055
Ground Irrigation	Dummy(1 if yes , otherwise 0)	0.07	0.141
Institutional Factors			
Credit Access	Dummy(1 if yes , otherwise 0)	0.189	0.285
Credit value	Amount in GH₵	120.33	166.41
Extension Service	Dummy(1 if yes , otherwise 0)	0.608	0.488
Farmer groups	Dummy(1 if yes , otherwise 0)	0.352	0.477
Off-farm Income	Dummy(1 if yes , otherwise 0)	0.333	0.471
Total livestock	Count(Number of livestock)	3.710	2.391

Agroforestry was the least practiced conservation agricultural technology in the study area. About 15% of households engaged in agroforestry while 19.6% engaged in fallowing. **Nkegbe and Shankar (2014)** found that adoption of agroforestry practices in northern Ghana was about 15.1%. This suggest, that agroforestry is not a pronounced CA practice in the area.

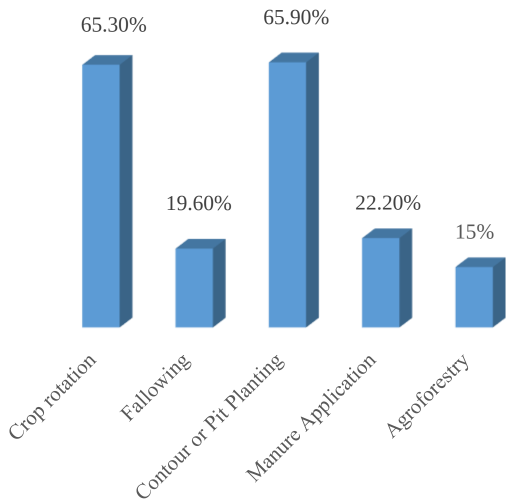

Figure 2: Farmer Adaption to the Various CA practices in northern Ghana

Determinants of Conservation Agricultural Practices in northern Ghana

Empirical estimates from the multivariate probit model showed, that the sex of the household head significantly influenced crop rotation and contour ploughing or pit planting. The marital status of the household head was also found to be significant for crop rotation and manure application, while household head's primary occupation significantly influenced manure application (Table 2 shows details of the determinants of CA practices).

The age of a household head negatively influenced fallowing and positively influenced contour ploughing or pit planting. This implies that older farmers are less likely to participate in fallowing but are more likely to participate in contour or pit planting. In order to preserve water throughout a production season, an experienced farmer more likely participates in contour ploughing or pit planting for water sustainability for his crops. The present results confirm that of **Chiputwa *et al.* (2010),** who identified that the age of the farmer positively affects the use of contour farming. It however, contradicts the findings of **Ngwira *et al.* (2014); Mlenga (2015),** that the age of the farmers does not influence the adoption decision of conservative agricultural practices.

The sex of the household head positively influenced both crop rotation and contour plouging or pit planting. The results showed, that male headed households are more likely to practice crop rotation and contour ploughing or pit planting as compared to their female counterparts. Because these conservation practices require more physical strength and the farmer needs to be very strong or should have more money to hire labour, the female household heads are at a disadvantage. Female farmers in the area are naturally less energy and tend to have less access to financial resources and farm lands. In a previous study, **Chiputwa *et al.* (2010)** also found out, that male farmers were more likely to adopt and increase the use of contour ridges compared to their female counterparts. However, **Ngwira *et al.* (2014)** also found out, that gender has no influence on conservative agricultural practices.

Table 2: Determinants of Conservation Agricultural Practices in northern Ghana

Variable	Coefficient (Std Error)				
	Crop Rotation	Fallowing	Contour Ploughing or Pit Planting	Manure Application	Agro-forestry
Household-Specific					
Age	0.004 (0.003)	-0.007 (0.003)**	0.005 (0.003)*	0.004 (0.003)	0.004 (0.003)
Sex	0.344 (0.104)***	0.174 (0.123)	0.191 (0.103)*	-0.061 (0.114)	0.009 (0.123)
Marital Status of HH	0.449 (0.167)**	-0.213 (0.185)	0.222 (0.166)	-0.302 (0.180)*	-0.165 (0.196)
Socioeconomic Factors					
Primary Occupation of HH	0.128 (0.380)	-0.242 (0.400)	-0.059 (0.378)	-0.783 (0.390)**	-0.145 (0.431)
Farm Size	0.045 (0.011)***	0.059 (0.010)**	0.007 (0.010)	-0.074 (0.015)***	0.007 (0.011)
Surface Irrigation	0.316 (0.284)	-0.124 (0.338)	0.894 (0.351)**	-0.148 (0.283)	-0.600 (0.384)
Groundwater Irrigation	5.050 (177.4)	0.094 (0.652)	4.908 (165.5)	-0.148 (0.283)	-4.337 (173.2)
Institutional Factors					
Credit Access	0.112 (0.153)	0.175 (0.172)	-0.022 (0.141)	-0.003 (0.171)	-0.088 (0.163)
Credit Value	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	0.000 (0.000)
Extension Service	0.009 (0.079)	0.077 (0.087)	-0.208 (0.078)**	0.094 (0.089)	-0.196 (0.092)**
Farmer Group	0.432 (0.084)***	-0.235 (0.093)**	0.312 (0.082)***	0.100 (0.089)	0.270 (0.094)**
Off-farm Income	0.193 (0.080)**	0.098 (0.087)	0.237 (0.079)**	0.201 (0.086)**	0.024 (0.092)
Total Livestock	-0.018 (0.027)	-0.024 (0.031)	0.026 (0.027)	0.276 (0.030)***	0.078 (0.031)**
Constant	0.974(0.422)**	-0.429(0.454)	-0.291(0.421)	-0.480(0.441)	-1.167(0.487)

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively

Marital status of household head positively influenced crop rotation but negatively influenced manure application. The positive effect of marital status on crop rotation was expected and suggest, that household heads that are married are more likely to practice crop rotation. This is because household heads who are married are likely to have advantage of family labour who could help when the household participates in crop rotation. The negative influence of marital status on manure application was not expected. However, it could imply that married households shift to inorganic fertilizer application other than manure. **Ali *et al.*** (2018) found marital status to have a positive significant influence on their adoption of inorganic fertilizers. and less likely to participate in manure application. Moreover, if married households do not keep animals and/or cannot afford manure, it may also result in their less probability of manure application.

Farm size was found to positively influence crop rotation and fallowing but with a negative influence on manure application. This implies, that households with larger farm sizes are more likely to practice crop rotation and fallowing but less likely to practice manure application. Such results indicate that farmers with access to more farmland can afford fallowing portions of their land. A previous study by **Ngwira *et al.* (2014)** also found that total land size cultivated positively influenced conservative agriculture. However, **Chippewa *et al.* (2010)** found, that total arable area did not influence any of the conservative agricultural practices.

The results also show that surface irrigation positively influenced contour ploughing or pit planting. This implies, that households that participated in surface irrigation for production are more likely to also participate in contour ploughing or pit planting suggesting that most of the surface irrigation farmers employ this CA practice to conserve the moisture content.

Surprisingly, the results show that access to extension services delivery negatively affects some CA practices such as contour Ploughing or pit planting and agroforestry. This result could be attributed to the reintroduction of fertilizer subsidies by the government of Ghana since 2008 till date which have influenced the direction of trainings by agricultural extension agents (**Ragasa and Chapoto, 2017**). It is evident in the current efforts by the government of Ghana through its flagship planting for food and jobs programme which is seeking to boost production with subsidised chemical fertilizers could mean that farmers that have access to extension services are also more likely to have access to the subsidised fertilizers. As a result, they may not see the immediate need to engage in the labour demanding CA practices.

Membership of farmer group positively affects the CA practices of crop rotation and agroforestry but negatively affects fallowing. This implies, that household heads that belong to farmer groups are more likely to engage in crop rotation and agroforestry but less likely to engage in fallowing of their farmland. Farmer groups could provide the financial and labour support during cultivation and tree planting but may have less land available to permit fallow periods since about 50% of Ghanaian smallholder farmers own less than 3ha **(Ngwira *et al.*, 2014)** also found out, that membership of farmer group positively influenced conservation agricultural practices.

Households that receive off-farm income are more likely to engage in crop rotation, contour ploughing or pit planting and manure application (Table 2). Such results could mean that the extra income earned off- farm makes it possible for such household to support their farming activities with these conservation agricultural practices since they require some level of capital to establish. **Chiputwa *et al.* (2010)** found out, that disposable income positively influenced contour ridging.

Livestock ownership was found to have a positive influence on manure application and agroforestry. This was expected since many households in the area are known to make use of animal droppings as manure on their farms. Such households will have access to large amount of animal droppings which will serve as manure for their farms and will also serve as a motivation to grow trees on the farm to provide shade and serve as resting places for the livestock. **Chiputwa *et al.* (2010)** also identified, that the number of cattle had positively influenced zero-tillage**.** **Ngwira *et al.*, (2014)** found out that tropical livestock unit index had no influence on conservative agriculture. But **Zulu-Mbata *et al.* (2016**) identified tropical livestock units to negatively affect households that participated in their full conservation agricultural practices (minimum tillage, crop rotation and residue retention).

Relationship between the various Conservation Agricultural Practices

The multivariate probit results (Table 3), show that the various combinations of the conservation agricultural practices are mostly complementary when applied on various farms. **Chiputwa *et al.* (2010)** reported complementarities among zero-tillage, contour ridging and crop rotation emphasizing that most conservative agricultural practices are practiced together.

Effect of conservation agricultural practices on soil health in northern Ghana

The effect of the various CA practices in northern Ghana is presented in Table 4. The results showed a positive effect of four CA practices on soil health namely; crop rotation, fallowing, contour ploughing or pit planting and manure application. Agroforestry was not significantly associated with soil health.

The positive effect of crop rotation on soil health is in synch with **Wang *et al.* (2020)** who found a positive potential for diversified crop rotations to influence soil health indicators in China. **Kugbe and Zakaria (2015)** also reported that CA practices such as crop rotation positively influenced soil conditions in northern Ghana. This was expected because, different crops will utilize different nutrients in the soil and so nutrients are not over mined. Also, the integration of legumes in the crop rotation system helps to improve the fertility of the soil as well as microbial activity. Hence, crop rotation is expected to improve the structure of the soil thereby decreasing its probability of being eroded either by rain or wind. Also, fallowing was also expected to have a positive effect on soil health.

Table 3: Relationship between the Conservative Agricultural Practices

CAPS	Coefficient (Std Errors)
Crop Rotation & Fallowing	0.262 (0.048)***
Crop Rotation & Contour Pit Ploughing	0.335 (0.041)***
Crop Rotation & Manure Application	0.016 (0.051)
Crop Rotation & Agroforestry	0.227 (0.052)***
Fallowing & Contour or Pit Planting	0.121 (0.048)**
Fallowing & Manure Application	0.114 (0.054)**
Fallowing & agroforestry	0.181 (0.055)***
Contour or Pit Planting & Manure Application	0.115 (0.050)**
Contour Pit Planting & Agroforestry	0.050 (0.054)
Manure Application & Agroforestry	0.058 (0.057)

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively

Table 4: IPWRA estimates of the effect of the various CA practices on soil health

Outcome Variable	TE	Crop rotation	Fallowing	Contour Ploughing or Pit Planting	Manure Application	Agroforestry
	ATT	0.02(0.023)***	0.053(0.031)*	0.166(0.022)***	0.173(0.031)***	-0.027(0.031)
Soil Health	POM	0.161(0.017)***	0.220(0.012)***	0.121(0.015)***	0.191(0.012)***	0.234(0.012)

Note: ***, ** and * represents 1% 5% and 10% significance level respectively

This is because, soils left on fallow improves on its vegetation cover since shrubs and all forms of grasses will grow on such uncultivated land. **Jalota *et al.* (2017)** also indicated that fallowing helps to protect the soil against soil erosion through improvement in the vegetation cover.

Contour ploughing or pit planting which showed the highest percentage of adaption by households in northern Ghana showed a positive effect on soil health. This is often done along contours to intercept run-offs thereby minimizing the incidence of soil erosion and hence the positive effect as revealed in the study. Finally, manure application also had a positive effect on soil health. Manure application improves the structure of the soil making it less susceptible to soil erosion. Agroforestry which was found to be the least practice CA was found not to be significant in influencing soil health.

CONCLUSION AND RECOMMENDATION

The purpose of the study was to investigate the determinants of Conservation Agricultural (CA) practices in northern Ghana as well as the effect of these practices on soil health. The results showed that different household-specific factors (Age, sex and marital status of household head), socioeconomic (the primary occupation of household head, farm size and surface irrigation), and institutional factors (Extension services, farmer groups, off-farm income and total livestock reared by the household) influence farmers' decision to engage in various CA practices. Crop rotation and fallowing were significant and positively correlated with all CA practices. Contour ploughing or pit planting was not significantly correlated with agroforestry and manure application. The effect of crop rotation, fallowing, contour ploughing or pit planting and manure application were found to have had a positive effect on soil health through improved resilience to soil erosion. It is recommended, that conservation agricultural practices should be encouraged as part of the soil improvement strategies to help Ghanaian farmers to produce sustainably. Also, the current government flagship planting for food and jobs programme should include conservation agricultural practices as a priority module so that farmers could increase their productivity without compromising the quality of the soil.

Due to limitation of the data, the study used resilience to soil erosion as a proxy for soil health which captures only the physical dimension. We therefore suggest, that future research expand the scope to include other components of a healthy soil.

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