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Measuring sustainability of conservation and conventional practices in maize production in Ghana

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Abstract: Scientists and researchers worldwide have recommended Conservation Agriculture as one that has the potential to promote sustainability in agriculture. This paper attempts to measure and compare the economic, social, and environmental sustainability of both conservation and conventional practices used for maize production in the northern region of Ghana employing the Multi-Attribute Value Theory (MAVT) approach. Based on the three pillars of sustainability (economic, social, and environmental), adopters of minimum tillage practice (scoring 0.5, 0.6, 0.82) and the combined adoption of minimum tillage and integrated organic-inorganic fertilizer application (scoring 0.53, 0.5, 0.88) emerged as sustainable practices. Despite these scores, the z-test of difference in means of the conservation practices and conventional ones were all insignificant, indicating that the conservation practices in use were not different from the conventional ones in terms of their contribution to sustainable maize production. Technical assistance and training that aids in ensuring the appropriate application of conservation practices should be ensured if the goal of sustainability is to be realized.

Keywords: sustainability, conservation practices, Multi Attribute Value Theory, Ghana, Northern region.

Introduction

The development of agricultural production towards the attainment of the Sustainable Development Goals (SDGs) is gaining much attention worldwide (Yiu & Saner, 2014) due to the fact that agriculture is directly related to poverty, food security, natural resource use, the environment, health, and climate change (Tscharntke et al., 2012; Fess & Benedito, 2018). The term sustainability, which gained popularity after the release of the Brundtland Commission's report, *Our Common Future* in 1987, is defined as "one that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Based on the definition by the Brundtland Commission, Becker (1997) identified three important interrelated pillars linked to the scientific operationalization of sustainability from ecological, economic, and social viewpoints. In literature, different definitions of sustainability exist because the term means different things to different people (Hansen, 1996; Rigby et al., 2001). Nevertheless, the most common and holistic definition of the concepts of sustainability and of sustainable development considers simultaneously economic, ecological (environmental), and social sustainability aspects (Becker, 1997; Yiu & Saner, 2014). According to Yiu and Saner (2014), sustainable development is one that focuses on the integration and balance of these three pillars in decision-making.

Hansen (1996), after an extensive review of literature, defines a sustainable agricultural system as "one that fulfils a balance of several goals through time". These goals include meeting the food needs of people, ensuring economic viability of agricultural systems and social welfare, while maintaining or improving upon the natural state of the environment (Hansen, 1996). Following the definition of sustainable agriculture, Francis et al. (2008) defines a sustainable farming strategy or practice as one that includes a concern for environmental soundness, a farmer's social responsibility to the local community, and also profitable in current economic terms.

Researchers and scientists worldwide are promoting Conservation Agriculture (CA) as a means to attaining economic, social, and environmental sustainability in production (Sommer et al., 2014; Vanlauwe[a] et al., 2014; FAO, 2014; FAO, 2010). This move is based on CA's principles of minimum physical soil disturbance by tillage practices; permanent soil cover with plant materials; crop diversification in space and time; and the integration of organic and inorganic fertilizers. In general, CA is defined as a management system that excludes the degradative components existing in conventional management systems (FAO, 2014; Wall et al., 2013; FAO, 2010). CA includes the practices of minimum tillage, improved crop varieties, intercropping, rotations, and the use of cover crops that helps to mitigate soil nutrient depletion and land degradation, hence resulting in increased yields (Hobbs, Sayre, & Gupta, 2007). Vanlauwe[b] et al. (2014) propose a fourth principle: the proper management of soil fertility and the balancing of nutrient flows, including the integration of organic and inorganic fertilizers[1].

While this suggestion may be in the right direction towards achieving sustainability in production, little evidence of studies measuring sustainability of CA considering the three pillars (e.g. Silici, 2010) exists in literature to support this claim. A review of 104 publications on sustainability of CA practices by Smith et al. (2017) shows authors dwelling on indicators from either one or two of the three pillars of sustainability. In this regard, this paper aims to contribute to the understanding of the role of CA in sustainable production by estimating and comparing the sustainability of both conservation and conventional practices, focusing on maize production in the northern region of Ghana.

Indicators for measuring sustainability: a review

The choice of indicators in sustainability analysis according to Farrell & Hart (1998) depends on two main considerations: (1) what the analyst wishes to know and (2) how the information will be used. Farrell & Hart (1998) further notes that irrespective of the choice of indicators, of most importance is for indicators to reveal the links between economic, social and environmental objectives. Use of different indicators thus provides different

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[1] *Though the goals of both organic farming and CA are to reduce pollution and promote natural soil processes, the two concepts are not the same (Gowing and Palmer, 2008). CA allows the use of agrochemicals (e.g. fertilizers, herbicides), while organic farming prohibits their use.*

evidence (FAO, 2014). In the Sustainability Assessment of Food and Agricultural Systems (SAFA), the FAO (2014) classifies indicators into three main groups. The first one is the *Performance-based/result-oriented/outcome indicators* group which focuses on the results of compliance with an objective and are able to measure the performance of an operation, identify trends and communicate results. The second group is the *practice-based/prescriptive/process indicators*. This group of indicators require that the necessary tools and systems are in place to ensure best practices. These indicators are process rather than outcome-oriented. The third group in the SAFA classification is referred to as *target-based indicators* and focuses on whether the operation has plans, policies or monitoring, with targets and ratings based on steps towards implementing them. This notwithstanding, the target-oriented indicators do not prescribe certain practices but rather focus on effective delivery of sustainability which is noted as having both scientific and economic limitations in particular for small-scale producers. The SAFA (FAO, 2014) therefore proposes practice-based indicators associated with performance outcomes such as best management practices for assessing the sustainability of smallholder producers.

Besides the FAO's classifications and recommendations, researchers worldwide have and continue to express divergent views on the indicators to include in sustainability analysis (Lampridi, Sørensen, & Bochtis, 2019; Rasmussen et al., 2017; Smith et al., 2017; Moldan, Janoušková, & Hák, 2012; Dillon, Hennessy, & Hynes, 2010). Rigby et al. (2001) for example propose regional characteristics, management practices, and types of technologies specific to each region as catalysts that should influence the choice of indicators. Meanwhile, Dillon et al. (2016) suggest that choice of indicators in sustainability analysis should depend on their overall suitability to the socio-economic context of a nation, a region, or the area of study. Rasmussen et al. (2017) on the other hand, advocate for researchers to consider (i) key sustainability aspects (ii) indicators that are easy to operationalize, and (iii) relevancy and context-specificity of indicators, as the most important factors informing the choice of indicators. A review of indicators for measuring the three pillars of sustainability by different authors is presented in Table 1.

Materials and Methods

Method of estimation

The stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) dominates methods in literature for analysing sustainability in agriculture via efficiency estimates. Though widely used, they are unable to estimate social indicators such as access to resources, and food security (e.g. de Koeijer et al., 2002 ; Labuschagne et al., 2005; Cooper et al., 2007; Van Passel et al., 2009; Van Meensel et al., 2010; and Dong et al., 2015). Another problem with the DEA is its inability to rank decision units (Reig-Martínez, Gómez-Limón, & Picazo-Tadeo, 2011). Another approach to measuring sustainability is the use of the Multi Attribute Value Theory (MAVT) method. It is a Multi Criteria Decision Analysis (MCDA) method used to rank decision units by estimating a composite indicator of a group of attributes. This method according to Loken, (2007) and Gómez-Limón & Riesgo (2009) is more appropriate for agricultural policy analysis because of its ability to rank and compare management practices.

Table 1: Indicator choice for measuring the three pillars of agricultural sustainability

AUTHORS	INDICATORS		
	ENVIRONMENTAL	ECONOMIC	SOCIAL
Rasul & Thapa (2004)	1.Land use pattern 2.Cropping pattern 3.Soil fertility management 4.Pest and disease management 5.Soil fertility level	1. Land productivity 2.Yield stability 3.Profitability	1.Input self-sufficiency 2.Equity 3.Food security 4.Risk and uncertainties involved in crop cultivation
Gómez-Limón & Riesgo (2009)	1.Agro-diversity 2.Soil cover 3.Water use 4.Nitrogen balance 5. Energy balance 6.Pesticide risk	1.Total Gross Margin (TGM) 2.Profit 3.GDP contribution 4.Public subsidies	1.Total labour 2.Seasonal labour employment
(Gómez-Limón & Sanchez-Fernandez, 2010)	1.Specialisation 2.Mean area per plot 3.Soil cover 4.Nitrogen balance 5.Phosphorus balance 6.Pesticide risk 7.Use of irrigation water 8.Energy balance 9.Agro-environmental subsidy areas	1.Income of agricultural producer 2.Contribution of agriculture to GDP 3.Insured area	1.Agricultural employment 2.Stability of workforce 3.Risk of abandonment of agricultural activity 4.Economic dependence on agricultural activity
Dantsis et al., (2010)	1.Use of fertilizers 2.Use of pesticides 3.Irrigated water consumption 4.farm management practices: a. Agro-ecological management practices b. Farm machinery operation 5.Type of farming Systems	1.Farm financial resources: a. Gross agricultural value b. Gross agricultural margin 2. Farm structure: a. Crop diversity b. Holding size c. Plot number per farm d. Agricultural machinery	1.Age of farmer 2.Level of education 3.Pluriactivity (off-farm activities 4.Family size 5.Agricultural employment
Dillon et al. (2010)	1.Methane emissions 2.Organic nitrogen 3.Organic phosphorous	1.Viability 2.Direct payment as a % of Gross Output 3.Market return	1.Demographic viability 2.Isolation
Reig-Martínez et al. (2011)	1. Soil cover 2.Nitrogen balance 3.Pesticide risk 4.Energy balance 5.Environmental subsidy areas	1.Income of farmers 2.contribution of agriculture to GDP 3.Insured area	1.Agricultural employment 2.Work-force stability 3.Risk of abandoning agricultural activity 4.Economic dependence on agric. Activity
Dillon et al. (2016)	1.GHG emissions per farm 2.GHG emissions per kilogram of output 3.Emissions from fuel and electricity 4.Nitrogen balance per hectare 5.Nitrogen use efficiency per farm	1. Productivity of labour 2.Productivity of land 3.Profitability 4.Viability of investment 5.Market orientation	1.Household vulnerability 2.Level of agricultural education 3.Isolation risk 4.High age profile 5.Work-life balance

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Table 2: Description of sustainability indicators

PILLAR	INDICATOR	DEFINITION
Economic	Profit	A farmer's net income, estimated using the gross profit made from maize (i.e. revenue less total variable costs in production) measured in Gh¢/ha.
	Yield	Maize output per hectare measured in Mt/ha
	Yield stability	An index based on farmers' responses to a question on the trend of yield from 2013 to 2015 farming seasons
Social	Food security	Proportion of farm households rated as secure based on a set of 8 questions from FAOs Food Insecurity Experience Scale (FIES) by Ballard, Kepple, and Cafiero (2013)
	Farm Employment	An indicator of social implications of farming in the distribution of income in the farming community taking hired labour into consideration and measured in total hired labour/ha
	Environmental Awareness Index (EAI)	An index constructed from a set of questions on the awareness of the possible impact of excessive use of detrimental inputs and conventional practices on the environment
	Environmental Concern Index (ECI)	An index constructed from a set of questions on the concern for the environment i.e. farmers consciousness in preventing environmental damage or pollution
Environmental	Inorganic fertilizer	An input in production whose excessive use is detrimental to the environment and to consumers, measured in Kg/ha
	Pesticide	An input in production whose excessive use is toxic to the environment, measured in Lit/ha
	Herbicide	An input in production whose excessive use is toxic to the environment, measured in Lit/ha

Note : indicators have different units of measurement, a normalization procedure suggested by Nardo et al. (2008) was used to rescale the indicators in a range of 0 to 1, where values close to one denotes most sustainable and values far from 1 were considered not sustainable.

Sustainability indicators

The choice of indicators for measuring sustainability in this study was based on common practices in maize production in the region (Table 2). The analysis focused on maize yield, profitability, and yield stability as the economic indicators for measuring sustainability. Total hired labour employed on the farm, environmental awareness, environmental concern, and food security status of farm households were considered for the social pillar, while the rates of inorganic fertilizers, Herbicides, and pesticides applied on the farm measure environmental sustainability.

Constructing a composite indicator of sustainability for the adopted practices

A composite indicator of sustainability was calculated following Diaz-Balteiro and Romero (2004). The composite economic, social, and environmental indicator of sustainability (CIS) for each farm practice was calculated as the weighted sum of the normalized indicators: expressed as follows:

$$CIS_i = \sum_{i=1}^{h} w_i\,(x_i), \quad where\ i = 1, \dots, n \qquad (1)$$

Where w_i is the weight of indicator *i*, x_i is the normalized value of indicator *i* achieved by each farm.

From equation (1), the practice with the highest value score is considered most sustainable amongst the practices. The values range from ‘0’ to ‘1’. The ‘minimum level of sustainability’ is ‘0.5’. The most sustainable practice is thus the one with a composite score closest to 1(the ideal score). The weights *w*, assigned represent the partial contribution to the overall score, based on how important the criterion is for the decision makers (Loken, 2007). Under the sustainable development concept, the three pillars – economic, social, and environment, are equally viewed as important in attaining sustainability (Hansen, 1996; World Bank, 2002). An objective weighting is rather used by dividing the aggregated indicator scores by the number of indicators

used in the analysis

$$CIS = \left[\sum_{i=1}^{h} x_i\right]/n \qquad (2)$$

Where *n* denote the sample size for each practice.

The *CIS* was calculated for the economic, social, and environmental pillars separately. The economic, social, and environmental scores for both the conventional and conservation practices were compared to the most sustainable score (1.0). Separate statistical tests (z-test) were performed to test the hypothesis that conservation practices are more sustainable in comparison with conventional practices.

Normalization of indicators used in estimating sustainability

Because the variables used in estimating the composite indicator of sustainability have different measurement units; normalization to an appropriate scale is necessary.

Following the re-scaling or ranging normalization procedure by Nardo et al. (2008), all the indicators used were normalized using the following expressions;

$$x_i = \frac{(C_i - C_{imin})}{(C_{imax} - C_{imin})} \qquad (3)$$

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$$x_i = \frac{(C_{imax} - C_i)}{(C_{imax} - C_{imin})} \quad (4)$$

Where x is the normalized value of indicator i, c_i is the crude value of indicator i, for each farm, c_{imin} and c_{imax} represents the minimum and maximum crude values of indicator i in the sample. Equation (3) was used to normalize indicators that had increasing values denoting sustainability (e.g. net profit, yield), while equation (4) was used where decreasing values indicated sustainability (e.g. conventional fertilizer application rate). This procedure according to Nardo et al. (2008) gives a precise scale measurement between 0 and 1 for each attribute, where 1, is the most sustainable practice. The ideal vector is thus $x^* = (1, \dots, 1)$.

Data and sampling

The study employed both cross-sectional and panel data collected from the Northern Region of Ghana, the largest of the ten regions and located in the north of the country.

Agriculture provides a livelihood for over 70% of the inhabitants in this region. Howbeit, the region experiences very high levels of fluctuations in the annual rainfall pattern, varying between 700 and 1100 mm (Van der Geest, 2011). A relatively drier climate exists in the north than the southern parts of the country, because of its closeness to the Sahel, and the Sahara. Also, a single rainy season prevails, beginning in May and ending in October resulting in high incidences of drought, especially from intra-seasonal rainfall variability (Van der Geest, 2011). Crop production is hence very vulnerable to drought due to the over reliance on the natural climate and to the low adaptive capacity attributed to both the geographic and socioeconomic features of the region (Antwi-Agyei et al., 2012). Maize and yam are the major crops produced in the region, in addition to millet, sorghum, rice, groundnut, cowpea, and soybean.

The cross-sectional data collection involved one-on-one interviews with farmers using a structured questionnaire while interview guides were used to interview researchers, extension service providers and other stakeholders. A multi-stage sampling procedure was employed in the data collection process. The first stage involved a purposive selection of three districts; Kumbungu, West Mamprusi, and Yendi, because programmes and projects on conservation agriculture have taken place, while other programmes are still ongoing in these districts. In the second stage of the sampling procedure, five farming communities from each of the three districts were randomly selected. The third and final stage involved a random selection of maize farmers in the selected communities. In all 411 farmers were interviewed following the sample size estimation procedure by Bartlett, Kotrlik, & Higgins, (2001) based on the 2010 population and housing census data. Secondary data for the analysis were collected from the Ministry of Food and Agriculture (MoFA), farmers, and from Agro-input dealers in the study areas and included prices of inputs such as seeds, agrochemicals, labour, and prices of maize grain.

Seven possibilities exist for the adoption of the three CA practices – minimum tillage, maize-legume rotation, and integrated organic-inorganic fertilizer practices (Table 3).

Table 3: Conservation practices used by maize farmers

PRACTICE CHOICE	MINIMUM TILLAGE (M1)	MAIZE-LEGUME ROTATION (R1)	ORGANIC-INORGANIC FERTILIZER INTEGRATION (F1)
$M_0R_0F_0$			
$M_1R_0F_0$	✓		
$M_0R_1F_0$		✓	
$M_0R_0F_1$			✓
$M_1R_1F_0$	✓	✓	
$M_1R_0F_1$	✓		✓
$M_0R_1F_1$		✓	✓
$M_1R_1F_1$	✓	✓	✓

Note: adoption of conservation practices is denoted by M_1 (minimum tillage), R_1 (maize-legume rotation, and F_1 (organic-inorganic fertilizer). Non-adoption of the three conservation practices is denoted by $M_0R_0F_0$.

Results and Discussion

Socio-demographic and farming characteristics

Maize production in the Northern region of Ghana is generally male dominated, with women focusing more on vegetables and legume production. Out of the total sample of farmers interviewed, 49 were females representing 11.9 percent, and the remaining 362 males representing 88.1 percent (Table 4). Female farmers generally prefer to grow other cereals such as cowpea, pigeon pea, and vegetables compared to maize in the study areas. The average age of the respondents is 40.56 with a standard deviation of 13.338.

Most of the respondents in the three districts are married (89.8%), have no formal education (68.9%), and also do not belong to any Farmer Based Organisation (FBO) (71.5%). Farming is the main occupation for most of the respondents (82.7%), while a minor of these farmers are civil servants, artisans, petty traders, and labourers. The sample shows that farmers using the three conservation practices ($M_1R_1F_1$) form the majority (28%). Being; (i) married, (ii) a household head, and (iii) a decision maker of the farm, significantly influenced adoption of the various conservation practices (Table 5). Nevertheless, involvement in other income generating activities, negatively influenced the use of conservation practices.

Table 4: Socio-demographic and farming information

	All farmers				Kumbungu		Yendi		West Mamprusi	
	Freq.	(%)	Mean	Std. dev.	Freq.	(%)	Freq.	(%)	Freq.	(%)
Total no. of respondents	411	100			135	32.8	135	32.8	141	34.4
Gender:										
0 = female	49	11.9	0.88	0.324	1	0.7	4	3.0	44	31.2
1 = male	362	88.1			134	99.3	131	97.0	97	68.8
Age of farmer			40.56	13.338						
Years of farming experience			20.14	13.415						
Marital status:										
1 = single	38	9.2			5	3.7	12	8.9	21	14.9
2 = married	369	89.8	1.92	0.309	129	95.6	123	91.1	117	83.0
3 = divorced	4	1.0			1	0.7	0.0	0.0	3	2.1
4 = widowed	0	0.0			0	0.0	0	0.0	0	0.0
Level of formal education:										
0 = None	283	68.9			96	71.1	91	67.4	96	68.1
1 = Primary/middle	56	13.6			21	15.6	18	13.3	17	12.1
2 = JHS	37	9.0	0.59	1.019	6	4.4	13	9.6	18	12.8
3 = Secondary	28	6.8			10	7.4	11	8.1	7	5.0
4 = Tertiary	7	1.7			2	1.5	2	1.5	3	2.1
Farming as main occupation:										
0 = No	71	17.3	0.83	0.378	17	12.6	28	20.7	26	18.4
1 = Yes	340	82.7			118	87.4	107	79.3	115	81.6
Member of FBO:										
0 = No	294	71.5	0.28	0.452	97	71.9	80	59.3	117	82.9
1 = Yes	117	28.5			38	28.1	55	40.7	24	17.1
Decision maker of farm:										
0 = No	38	9.2	0.91	0.290	10	7.4	3	2.2	25	17.7
1 = Yes	373	90.8			125	92.6	132	97.8	116	82.3
Involvement in an off-farm activity:										
0 = No	295	71.8	0.28	0.451	91	67.4	98	72.6	106	75.2
1 = Yes	116	28.2			44	32.6	37	27.4	35	24.8
Off-farm employment:										
Artisan	30	25.4			19	43.2	5	13.2	6	16.7
Civil Servant	17	14.4			4	9.1	5	13.2	8	22.2
Petty trading	42	35.6			18	40.9	12	31.5	12	33.3
Labourer	29	24.6			3	6.8	16	42.1	10	27.8
Practices:										
$M_0R_0F_0$	22	5.4			5	3.7	9	6.7	8	5.7
$M_1R_0F_0$	31	7.5			23	17.0	2	1.5	6	4.3
$M_0R_1F_0$	70	17.0			9	6.7	29	21.5	32	22.7
$M_0R_0F_1$	37	9.0			12	8.9	1	0.7	24	17.0
$M_1R_1F_0$	42	10.2			2	1.5	18	13.3	22	15.6
$M_1R_0F_1$	40	9.7			24	17.8	1	0.7	15	10.6
$M_0R_1F_1$	54	13.1			16	11.9	18	13.3	20	14.2
$M_1R_1F_1$	115	28.0			44	32.6	57	42.2	14	9.9

Note: adoption of conservation practices is denoted by M_1 (minimum tillage), R_1 (maize-legume rotation, and F_1 (organic-inorganic fertilizer).

Table 5: Parameter estimates of variables influencing adoption-Linear regression results

VARIABLES	STD. ERROR	STANDARDIZED COEFF. BETA	T	SIGNIFICANCE LEVEL
Constant	0.177		5.299	0.000***
Gender	0.066	-0.075	-1.285	0.200
Marital status	0.064	0.123	2.267	0.024*
Household head	0.049	-0.126	1.932	0.054*
Age of farmer	0.003	-0.088	-0.936	0.350
Experience in farming	0.002	-0.003	-0.037	0.970
Education	0.020	0.050	0.902	0.368
Decision Maker	0.065	-0.138	2.667	0.008**
Engagement in off-farm activity	0.040	-0.090	-1.809	0.071*
FBO membership	0.040	0.008	0.171	0.864

*Note: Dependent variable Adoption of conservation practices. *** denotes statistical significance at 1%, **5%, and * 10% levels*

Conservation Practices in use by farmers in the study area

The minimum tillage practices in use by farmers in the three districts are planting on old ridges, use of bullocks for tilling, and the use of hand hoes for tillage (Table 6). Hand hoe use dominates the other minimum tillage practices with 52.4% of farmers. Cowpea, soybean, groundnut, and pigeon pea are the legumes used in rotation with maize, but soybean and groundnut use dominate with 44.64% and 44.3% of farmers respectively, mainly because these legumes have relatively high demand on the market. Animal manure and compost are the two organic fertilizer inputs combined by farmers with chemical fertilizers for the Integrated Fertilizer Management Practice.

Economic, Social, and Environmental Sustainability

A high index of yield stability was scored by both adopters of all the conservation practices and non-adopters because most farmers experienced slight increases in yields from one season of production to the other (i.e. 2013 to 2015) (Table 7). However, yield increases were minimal and also far below the average national estimated achievable yield of about 6Mt/ha according to the MoFA (2013). These low yields in addition to high costs of production translated into low profits for both adopters of CA practices and conventional maize farmers.

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Table 6: Conservation practices in use

CONSERVATION PRACTICES	NO. OF FARMERS	PROPORTION (%) OF FARMERS USING EACH CONSERVATION PRACTICE
Minimum tillage		
1. Planting on old ridges	20	23.8
2. Use of bullock for ploughing	20	23.8
3. Hand hoe for ploughing	44	52.4
Maize-legume rotation		
1.Cowpea	16	7.14
2. Soy bean	100	44.64
3. Groundnut	97	43.30
4. Pigeon pea	11	4.91
Organic-inorganic fertilizer		
1. Manure	57	48.72
2. Compost	60	51.28

Table 7: Scores of economic indicators (1 = ideal)

PRACTICE	SCORES OF ECONOMIC INDICATORS		
	YIELD	PROFITABILITY	INDEX OF YIELD STABILITY
$M_0R_0F_0$	0.30	0.29	0.76
$M_1R_0F_0$	0.21	0.32	0.93
$M_0R_1F_0$	0.23	0.24	0.66
$M_0R_0F_1$	0.29	0.18	0.81
$M_1R_1F_0$	0.23	0.23	0.68
$M_1R_0F_1$	0.34	0.26	1.00
$M_0R_1F_1$	0.28	0.33	0.76
$M_1R_1F_1$	0.24	0.25	0.64

Adopters of both minimum tillage and integrated organic-inorganic fertilizer practices ($M_1R_0F_1$) recorded a yield stability index of 1.0, meaning that all the adopters of these practices witnessed yield increases from 2013 to 2015. The lowest yield stability index of 0.64 was recorded for adopters of the three conservation practices ($M_1R_1F_1$) and this implies that most farmers experienced either declines or stagnant yields over the period 2013 to 2015. Most adopters of minimum tillage practice ($M_1R_0F_0$) also observed positive trends in yield, resulting in a high stability index of 0.93. Minimum tillage has the ability to minimize soil erosion, increase soil organic carbon (C) and nitrogen (N) (Carter et al., 2009), which may have accounted for the increases in yield.

The environmental performance of all the indicators for both conventional practices and conservation practices are generally high (Table 8). The highest inorganic fertilizer score of 0.93 was recorded for adopters of both minimum tillage and integrated organic-inorganic fertilizer practice ($M_0R_1F_1$), while the lowest inorganic fertilizer score of 0.69 was recorded for adopters of minimum tillage practice ($M_1R_0F_0$) (Table 8).

Table 8: Scores of environmental indicators (1 = ideal)

Practice	Scores of environmental indicators		
	Inorganic fertilizer rate	Pesticide rate	Herbicide rate
$M_0R_0F_0$	0.83	0.95	0.79
$M_1R_0F_0$	0.69	0.99	0.79
$M_0R_1F_0$	0.88	1.00	0.80
$M_0R_0F_1$	0.79	0.97	0.73
$M_1R_1F_0$	0.83	0.99	0.82
$M_1R_0F_1$	0.85	0.96	0.84
$M_0R_1F_1$	0.93	1.00	0.88
$M_1R_1F_1$	0.82	0.89	0.80

Pesticide use in maize production in the Northern region of Ghana is very low resulting in high scores for both adopters of conservation practices and users of conventional practices (Table 8). Adopters of maize-legume rotation practice ($M_0R_1F_0$) had the highest and ideal score of 1.0 because they did not apply any kind of pesticides. Maize-legume rotations have the potential of breaking pest cycles; possibly the reason why users of this practice recorded the highest pesticide performance. Some conventional farmers and adopters of integrated fertilizers on the other hand experienced incidences of pest attacks and so used pesticides. Despite this, pesticide use was generally low in maize production in the study area. The use of herbicides is also very low among farmers resulting in high scores for both the conservation and conventional practice users.

Even though labour demand is higher with the adoption of conservation practices, the proportion of hired labour[2] in total labour use is very low with all the practices (Table 9).

Table 9: Scores of social indicators

Practice	Scores of social indicators			
	Prop. of food secured	EAI	ECI	Farm employment
$M_0R_0F_0$	0.05	0.85	0.83	0.21
$M_1R_0F_0$	0.26	0.96	0.95	0.22
$M_0R_1F_0$	0.11	0.87	0.86	0.10
$M_0R_0F_1$	0.11	0.73	0.75	0.31
$M_1R_1F_0$	0.05	0.76	0.76	0.10
$M_1R_0F_1$	0.13	0.76	0.76	0.20
$M_0R_1F_1$	0.04	1.00	0.72	0.17
$M_1R_1F_1$	0.25	0.90	0.91	0.14

Adopters of maize-legume rotation practice ($M_0R_1F_0$) and both minimum tillage and maize-legume rotation practices ($M_1R_1F_0$) have the lowest farm employment index of 0.1, while adopters of integrated organic-inorganic fertilizer practice ($M_0R_0F_1$) have the highest score of 0.31. Though minimum tillage practice, especially that done manually with hoes,

[2] The proportion of hired labour in total labour used per hectare of farmland cultivated using a conservation practice(s) denotes the practice(s) contribution to employment in the society

require more labour for its operations, results indicate that adopters of this practice rely more on their own labour, thus with the lowest index of farm employment.

According to Zhen and Routray (2003), farmers' awareness (knowledge) of the negative impacts of conventional agriculture is an important social indicator of agricultural sustainability. The index of environmental concern assesses further farmers' attitude towards environmental conservation. The index of environmental awareness, index of environmental concern, the proportion of food secured households, as well as labour employed on the farm, measure social sustainability. Combined adopters of maize-legume rotation and integrated organic-inorganic fertilizer practices ($M_0R_1F_1$) scored the highest environmental awareness index (EAI), but the environmental concern (ECI) score of 0.72 show that this group of adopters are the least concerned (Table 9). Farmers' using all three conservation practices, $M_1R_1F_1$ obtained an EAI score of 0.90 and an ECI of 0.91, implying that they are both aware and concerned about environmental conservation, which is translated in the adoption of the three conservation practices.

Composite indices of economic, social, and environmental sustainability

Table 10 presents results of the composite indices of the three pillars of sustainability. Even though the indices of yield stability are high, maize yield and profits are very low, resulting in low economic sustainability scores for all the different sets of farm practices.

Table 10: Composite indices of economic, social, and environmental Sustainability (1 = ideal)

Practice	Economic sustainability	Social sustainability	Environmental sustainability
$M_0R_0F_0$	0.45	0.50	0.86
$M_1R_0F_0$	0.50	0.60	0.82
$M_0R_1F_0$	0.38	0.50	0.89
$M_0R_0F_1$	0.43	0.50	0.83
$M_1R_1F_0$	0.38	0.42	0.88
$M_1R_0F_1$	0.53	0.50	0.88
$M_0R_1F_1$	0.46	0.50	0.94
$M_1R_1F_1$	0.38	0.56	0.84

The highest composite economic sustainability score of 0.53 was obtained by adopters of $M_1R_0F_1$ practice (Table 10) while the lowest score of 0.38 by adopters of $M_0R_1F_0$, $M_1R_1F_0$, and $M_1R_1F_1$ respectively. A sustainable practice is one that scores between a minimum composite index of 0.5 and 1.0 (the ideal score). Economically, only minimum tillage practice ($M_1R_0F_0$), and both minimum tillage and integrated organic-inorganic fertilizer practices ($M_1R_0F_1$) are sustainable (Table 10).

Though food security and farm employment scores are very low for all the practices, they are all socially sustainable, except for combined adopters of minimum tillage and maize-legume rotation practices ($M_1R_1F_0$) (Table 10). The highest composite social sustainability score of 0.6 was obtained by adopters of minimum tillage practice ($M_1R_0F_0$).

Because of high environmental indicator scores for all the practices, composite environmental sustainability scores are high for both conventional and conservation practices. Adopters of maize-legume rotation practice ($M_0R_1F_0$), and combined adoption of maize-legume rotation and integrated organic-inorganic fertilizer practices ($M_0R_1F_1$) obtained the highest composite environmental sustainability scores of 0.89 and 0.94 respectively (Table 10). Though literature points to conservation practices as more sustainable environmentally compared to conventional practices (Wall et al., 2013), results of the study show conventional practice users scoring a high index of 0.86. This score is higher than that of adopters of minimum tillage practice ($M_1R_0F_0$) (0.82), and the score of adopters of integrated organic-inorganic fertilizer practice ($M_0R_0F_1$) (0.83).

A sustainable farming practice is one that includes a concern for environmental soundness, farmer's social responsibility to the local community, and also profitable in current economic terms (Francis et al., 2008). Based on the economic, social, and environmental scores, the use of minimum tillage practice ($M_1R_0F_0$), and combined use of minimum tillage and integrated organic-inorganic fertilizer ($M_1R_0F_1$) emerge as sustainable practices in maize production in the northern region of Ghana (Table 10).

Comparison of sustainability scores between conventional and conservation practices

The z-test of difference in the sustainability scores of the conventional and conservation practices are presented in Tables 11a to 11c. Conservation agriculture is thought of as one that leads to a reduction in the use of inputs such as inorganic fertilizers which translates into a reduction in overall cost of production leading to higher profits. Nevertheless, the *p*-values in Table 11a show that there is no difference in the economic sustainability scores of the conventional practices and the conservation ones. This indifference is a reflection of inefficiency in use of resources such as inorganic fertilizers by adopters of conservation practices as the study finds.

Table 11a: Z-test for equality of means: economic sustainability

<table>
<tr><th rowspan="2">Practice comparisons</th><th colspan="3">Group statistics</th><th colspan="3">z-test</th></tr>
<tr><th>N</th><th>Mean</th><th>Std. error</th><th>Diff. in Mean</th><th>Z</th><th>P>|z|</th></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>-0.05</td><td>-0.36</td><td>0.720</td></tr>
<tr><td>$M_1R_0F_0$</td><td>31</td><td>0.50</td><td>.0898027</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>0.07</td><td>0.59</td><td>0.558</td></tr>
<tr><td>$M_0R_1F_0$</td><td>70</td><td>0.38</td><td>.0580148</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td>37</td><td></td><td></td><td>0.02</td><td>0.15</td><td>0.881</td></tr>
<tr><td>$M_0R_0F_1$</td><td></td><td>0.43</td><td>.08139</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>0.07</td><td>0.54</td><td>0.588</td></tr>
<tr><td>$M_1R_1F_0$</td><td>42</td><td>0.38</td><td>.0748968</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>-0.08</td><td>-0.60</td><td>0.547</td></tr>
<tr><td>$M_1R_0F_1$</td><td>40</td><td>0.53</td><td>.0789145</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>-0.01</td><td>-0.08</td><td>0.937</td></tr>
<tr><td>$M_0R_1F_1$</td><td>54</td><td>0.46</td><td>.0678233</td><td></td><td></td><td></td></tr>
<tr><td>$M_0R_0F_0$</td><td>22</td><td>0.45</td><td>.106066</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>0.07</td><td>0.62</td><td>0.538</td></tr>
<tr><td>$M_1R_1F_1$</td><td>115</td><td>0.38</td><td>.0452625</td><td></td><td></td><td></td></tr>
</table>

Note: assuming a 95% confidence interval

The test of difference in the social sustainability scores of the conventional and conservation practices (Table 11b) were all insignificant, suggesting that the conservation practices used in maize production are not socially more sustainable compared with conventional practices.

Table 11b: Z-test for equality of means: social sustainability

Practice Comparisons	Group statistics			Z-test		
	N	Mean	Std. error	Diff. in mean	Z	P>|z|
$M_0R_0F_0$	22	0.50	0.1066004	-0.10	-0.72	0.470
$M_1R_0F_0$	31	0.60	0.0879883			
$M_0R_0F_0$	22	0.50	0.1066004	0.0	0.00	1.000
$M_0R_1F_0$	70	0.50	0.0597614			
$M_0R_0F_0$	22	0.50	0.1066004	0.0	0.00	1.000
$M_0R_0F_1$	37	0.50	0.0821995			
$M_0R_0F_0$	22	0.50	0.1066004	0.08	0.61	0.541
$M_1R_1F_0$	42	0.42	0.0761577			
$M_0R_0F_0$	22	0.50	0.1066004	0.0	0.00	1.000
$M_1R_0F_1$	40	0.50	0.0790569			
$M_0R_0F_0$	22	0.50	0.1066004	0.0	0.00	1.000
$M_0R_1F_1$	54	0.50	0.0680414			
$M_0R_0F_0$	22	0.50	0.1066004	-0.06	-0.52	0.604
$M_1R_1F_1$	115	0.56	0.0462883			

Note: assuming a 95% confidence interval

Table 11c: Z-test for equality of means: environmental sustainability

Practice Comparisons	Group statistics			Z-test for equality of means		
	N	Mean	Std. error	Diff. in Mean	Z	P>|z|
$M_0R_0F_0$	22	0.86	.0739779	0.04	0.39	0.698
$M_1R_0F_0$	31	0.82	.0690021			
$M_0R_0F_0$	22	0.86	.0739779	-0.03	-0.38	0.703
$M_0R_1F_0$	70	0.89	.0373975			
$M_0R_0F_0$	22	0.86	.0739779	0.03	0.30	0.760
$M_0R_0F_1$	37	0.83	.0617537			
$M_0R_0F_0$	22	0.86	.0739779	-0.02	-0.23	0.819
$M_1R_1F_0$	42	0.88	.0501427			
$M_0R_0F_0$	22	0.86	.0739779	-0.02	-0.23	0.821
$M_1R_0F_1$	40	0.88	.0513809			
$M_0R_0F_0$	22	0.86	.0739779	-0.08	-1.15	0.252
$M_0R_1F_1$	54	0.94	.0323179			
$M_0R_0F_0$	22	0.86	.0739779	0.02	0.24	0.813
$M_1R_1F_1$	115	0.84	.0341862			

Note: assuming a 95% confidence interval

According to literature (e.g. Erenstein 2003; Gowing and Palmer, 2008; Sommer et al., 2014; Vanlauwe[a] et al., 2014 conservation practices are more sustainable in comparison with conventional practices. The results of the z-test in Table 11c on the other hand show that conservation practices are not environmentally more sustainable compared with the conventional ones.

The hypothesis that conservation practice(s) use in maize production in the northern region of Ghana is/are more sustainable compared with the use of conventional practices is rejected, as results indicate in Table 11 a, b, and c.

Conclusion

Sustainable agricultural production is a daunting task and a worldwide necessity for all mankind due to its important role in ensuring food security, biodiversity conservation and environmental protection. To this effect, farm management practices and technologies towards sustainable production are currently at the forefront of agricultural research. The study compared the level of sustainability of both conventional and conservation practices mainly used in maize production in the Northern region of Ghana. Results of the study show that conservation practices are generally not economically sustainable, are poorly socially sustainable, but adequately sustainable environmentally. The scores based on the three pillars of sustainability show that use of minimum tillage practice, and the joint use of minimum tillage and integrated organic-inorganic fertilizer practices contribute to farm sustainability. Results suggest that CA adopters seem to miss out on sustainability apart from the environmental dimension. Poor implementation/management practices were observed where CA practices are adopted. Meanwhile, as literature suggests, CA has the potential of contributing to farm sustainability. There is a need for further education of farmers on the appropriate usage of inputs particularly fertilizers. Technical assistance and training should be provided to farmers to ensure the appropriate application of conservation practices in order to; minimize costs of production, increase productivity, raise profits of adopters, while at the same time reduce environmental pollution.

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