Original Research Article

CONSERVATION AGRICULTURE (C.A): AREAS OF IMPROVEMENT IN THE ADOPTION OF C.A PRACTICES IN EASTERN KENYA

ABSTRACT

Conservation agriculture (CA) is defined as a practice that aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture. Majority of Kenyan farmers lack awareness of the benefits of CA thus influencing their commitment to this relatively new practice. Of particular concern is the fact that CA has been marketed in Kenya for over a decade and ground tilling methods in most parts of the country have not yet evolved to CA standards. Uptake of CA technologies is highest amongst wealthier farmers and commercially oriented producers. This is because of stronger risk aversion on the part of the small holder farmer. The number of crops at a given time on a farm was between 4-6 percent for 47% of respondents and 7-10 for 33% of respondents. Only 12.1% of respondents recorded crop diversification of 1-3 comprising planned biodiversity on farm. The role of Conservation agriculture in promoting soil health is tested. 82.3% of respondents credited the reduced erosion on their farms to conservation agriculture. This combined with other benefits of Conservation Agriculture has motivated farmers to integrate conservation agriculture to the management of their farms. Out of the 24 indicators selected for this study, 10 indicators scored best performances. The study was done in Eastern Part of Kenya that fall between 50 to 100% arid and semi-arid areas (ASAL) categories. The counties in the study included Kitui, Machakos, Tharaka Ninti and Makueni counties which are home to 14 million residents (GoK, 2019). The objective of this research was to assess Conservation Agriculture (C.A): areas of improvement in the adoption of C.A practices in eastern Kenya. In conclusion, 14 out of 24 indicators show good to best performance while six indicators show moderate performance. There are areas that need urgent attention to improve the sustainability of CA agro-ecosystems. An overall score of 3(indicating moderate performance) was awarded to the agro-ecosystems under CA. The Social dimension and the diversity property of the ecosystem scored the highest performance. The least performance was recorded in the Environmental dimension and the functional properties of the agro-ecosystem. It was therefore recommended that the government through the ministry of agriculture should investing in promoting improvement in the adoption of Conservation Agriculture practices especially in arid areas such as that of eastern Kenya.

Key word: CONSERVATION AGRICULTURE (C.A), crop diversification, FARMER ORGANIZATION, agro-ecosystem

INTRODUCTION

Conservation Agriculture is a toolkit of agricultural practices that combines, in a locally adapted sequence, the simultaneous principles of reduced tillage or no-till; soil surface cover and crop rotations and/or associations, where farmers choose what is best for them. The Conservation Agriculture (CA) adoption varies across Europe, depending on the continent's ecological zones. Although Europe lags behind other countries in terms of CA adoption, the signs for future improvement are promising(Kertész & Madarász, 2014). In addition, due to increased environmental consciousness, particularly soil protection, and the desire to lower manufacturing costs, the area where CA is used is quickly expanding. In essence, CA is an approach that advocates the concept of sustainable intensification of production by picking the best possible options that farmers can tailor to their conditions. Kertész & Madarász (2014), argues that climate change has been anticipated to be one of the primary determining factors in the direction and expansion of CA in Europe. Conservation Agriculture fits within other resource management approaches such as sustainable land management; organic farming and agroforestry (FAO, 2009).

It is necessary to implement procedures that will improve the productivity, profitability, and feasibility of CA systems. In this sense, addressing these issues in Africa such as in southern Africa is projected to encourage smallholders to adopt CA, with favourable consequences for health of soils and as well as resilience to climate change and arid climate conditions(Thierfelder *et al.,* 2018). As a result of this realization, conservation agriculture as a concept for natural resource conservation is a viable alternative to traditional farming practices, as it aims to produce acceptable earnings with high and stable output levels while also safeguarding the environment (Lee & Thierfelder,2017). It has proven to be a promising alternative farm management system of attaining sustainable agricultural production. (FAO, 2009).

In a report to assess the level of Conservation Agriculture adoption in Kenya, (K'Owino, 2010), reiterates the findings of (Ekboir, 2003) and (Derpsch, 2005) that full conservation agriculture is today rarely practiced, and is indeed difficult to achieve right from the onset.

Policy coherence and the elaboration of the contribution of Conservation Agriculture to achieving the goals of the Country presents an initial challenge to CA implementation and up scaling. An analysis of The Kenyan Vision 2030 by (K'Owino, 2010), concludes that although agriculture has been identified as one of the key sectors to deliver the 10 per cent annual economic growth rate as envisaged under the economic pillar, Conservation Agriculture is not mentioned as part of the key strategies and action plans and is not given priority but elements of CA are dotted across the documents.

The objective of this research was to assess Conservation Agriculture (C.A): areas of improvement in the adoption of C.A practices in eastern Kenya. The hypothesis was that Conservation Agriculture (C.A) of improvement shows great adopted practices in eastern Kenya.

The study was done in Eastern Part of Kenya that fall between 50 to 100% arid and semi-arid areas (ASAL) categories. The counties in the study included Kitui, Machakos, Tharaka Ninti and Makueni counties which are home to 14 million residents (GoK, 2019). The researcher was able to come up with a sample size of 129 respondents using random sampling and stratified random sampling. The questionnaires that had been produced had been validated to ensure that they were accurate. The questionnaires, which were equal in quantity to the number of respondents, were then given to each respondent to complete.

RESULTS

The following Table shows the respondents who answered the questions for the study of which 29.3% were male and 67.7% male.

Table:1 Gender of respondents.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	39	29.3	30.1	30.1
	Female	90	67.7	69.9	100,0

	Total	129	97,0	100,0	
Missing	System	4	3,0		
Total		133	100,0		

Crop and Produce Diversification

This is a measure of farm resilience and economic sustainability. Mixed households are perceived as being more resilient than either purely crop or livestock farmers. For this study Farmers who kept livestock while practising conservation agriculture comprised 95.3% of the respondents. The number of crops at a given time on a farm was between 4-6 percent for 47% of respondents and 7-10 for 33% of respondents. Only 12.1% of respondents recorded crop diversification of 1-3 comprising planned biodiversity on farm. The Table below shows the respondents with or without livestock in the farms where they practice conservation agriculture.

Table:2 Livestock on farm

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes	123	92,5	95,3	95,3
	No	6	4,5	4,7	100,0
	Total	129	97,0	100,0	
Missing	System	4	3,0		
Total		133	100,0		

Table:3 crop diversification within their farms

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-3	16	12.0	12.1	12.1
	4-6	62	46.6	47.0	59.1
	7-10	44	33.1	33.3	92.4

	>10	10	7.5	7.6	100.0
		132	99.2	100.0	
Missing	System	1	0.8		
Total		133	100.0		

Food security is a measure of economic viability and social sustainability. Food is a basic human right and a measure of the days with food deficiency in household reflects the current status of hunger in relation to the sustainable development goal 2 of attaining zero hunger by 2030. A comparison of the number of food deficient days in a year in CA and non-CA systems is shown below. Under CA systems CA the number of days with food deficiency has been reduced by between 8 and 19 days in the counties of Kitui (8), Makueni (9), Tharaka Nithi (19) and Machakos (11). The Table below show the number of food deficiency days per year the households that practice C.A in the study area.

Table:4 FOOD SECURITY

County	**number of days with food deficiency**	**Proportion of the year**	**number of days with food deficiency (non CA)**	**Proportion of the year**
Kitui	52-112	14-31%	60-120	16-33%
Makueni	61-118	18-32%	72-125	20-34%
Tharaka nithi	65-120	18-33%	83-140	23-38%
Machakos	50-111	14-30%	60-124	16-34%

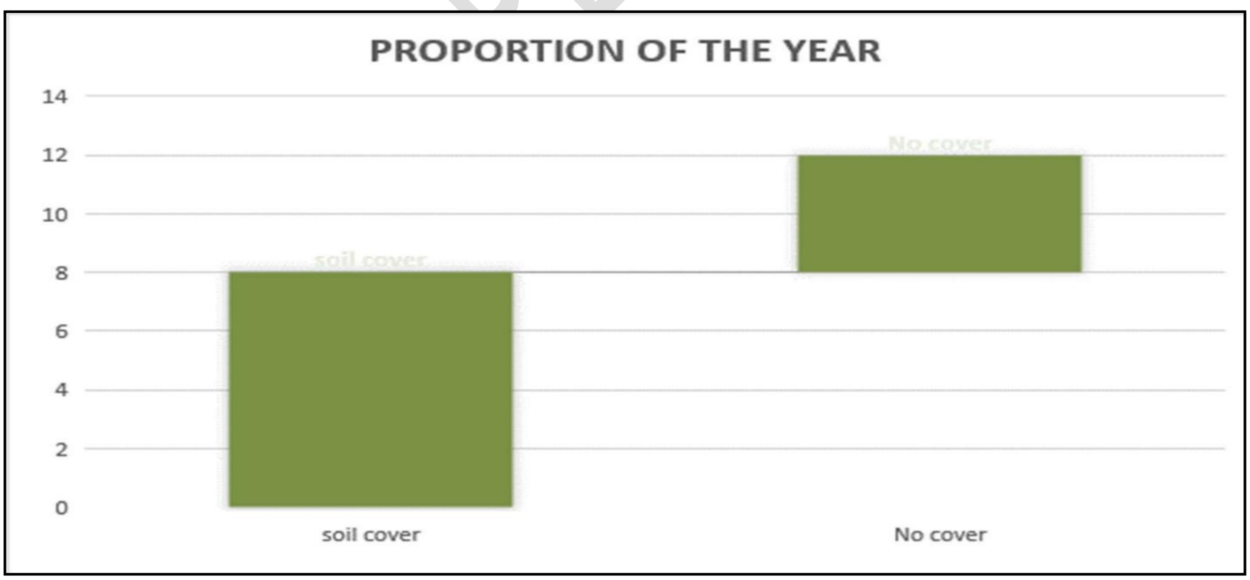
DISCUSSION

CROP YIELD

Crop yield and particularly yield increase is a measure of economic sustainability with an increase in yield being the ultimate production/economic sustainability indicator. According to Kassim *et al.*, 2019, based on primary FAO data, in the past five seasons of CA practice, yields have increased by 100% on average for cereals and by 240% for pulses with the highest increase being recorded in Tharaka Nithi county, followed by Machakos, Makueni and Kitui counties in that order .

SOIL HEALTH

This is a measure of environmental sustainability. It is represented by the Share of the year when arable land is covered by plant or plant residues. This describes the percentage of the year when crop is protected from erosive agents, has better infiltration and actively suppresses weeds aiding in aid control. The soil cover index is measured by the proportion of the year covered by plant residues and/or live cover. The table below visualizes the number of days in a year when soil is covered by mulch or live crops.



Graph 1

POTENTIAL EVAPOTRANSPIRATION

Potential evapotranspiration is a measure of environmental sustainability as well as production viability since water is a critical component of agro-ecosystems. Potential evapotranspiration is a measure of water use efficiency and thus is considered in this study under the environmental dimension. This was modelled in aqua-crop using soil, climate and crop data for maize (the common crop grown in all the four counties). The crop's stomata conductance, canopy senescence, leaf growth, and yield response to water stress are modelled using four stress coefficients (stomata closure, leaf expansion, canopy senescence, and change in harvest index (HI). The model subsequently estimates yield from the daily crop transpiration values. (Jin *et al*., 2014). Evapotranspiration (ET_o), following calculation of BY (its harvestable portion), and the grain yield (GY) is determined via harvest index (HI). The harvest index was considered as a measure of potential evapotranspiration in this study.

Modelling under two different scenarios in AquaCrop: Field Management under CA & Field Management under Conservation Agriculture as shown in the figures below;

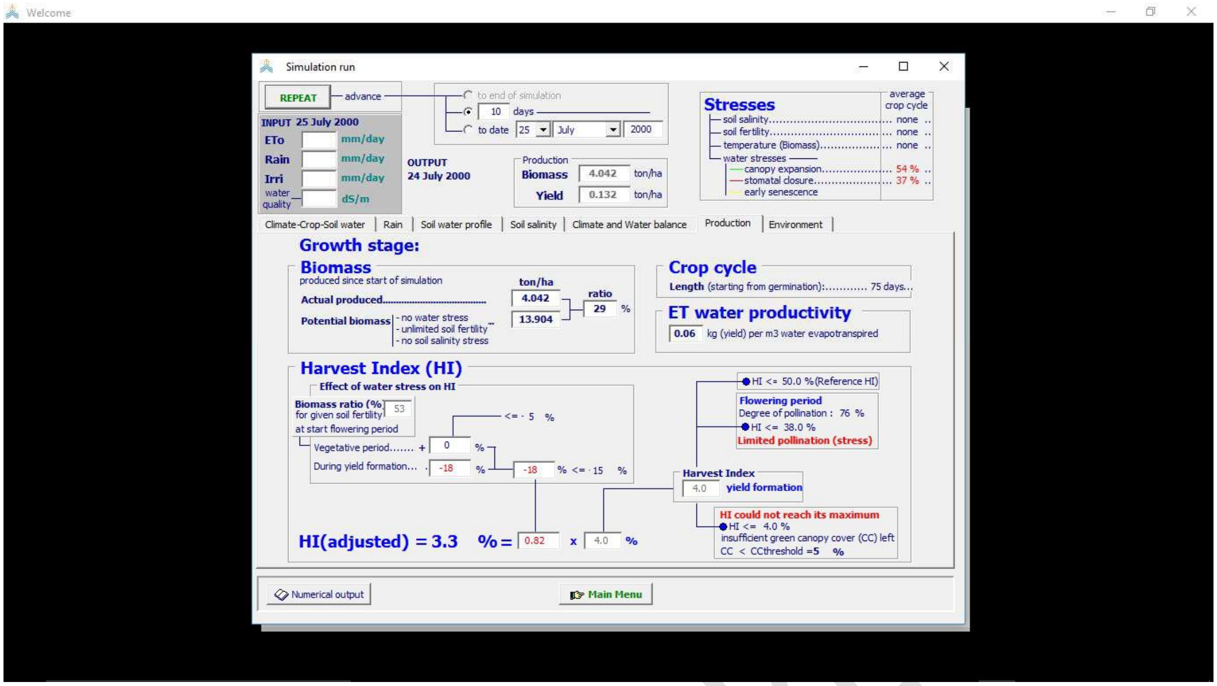


Figure 1: Field Management under CA Harvest Index = 3.3%

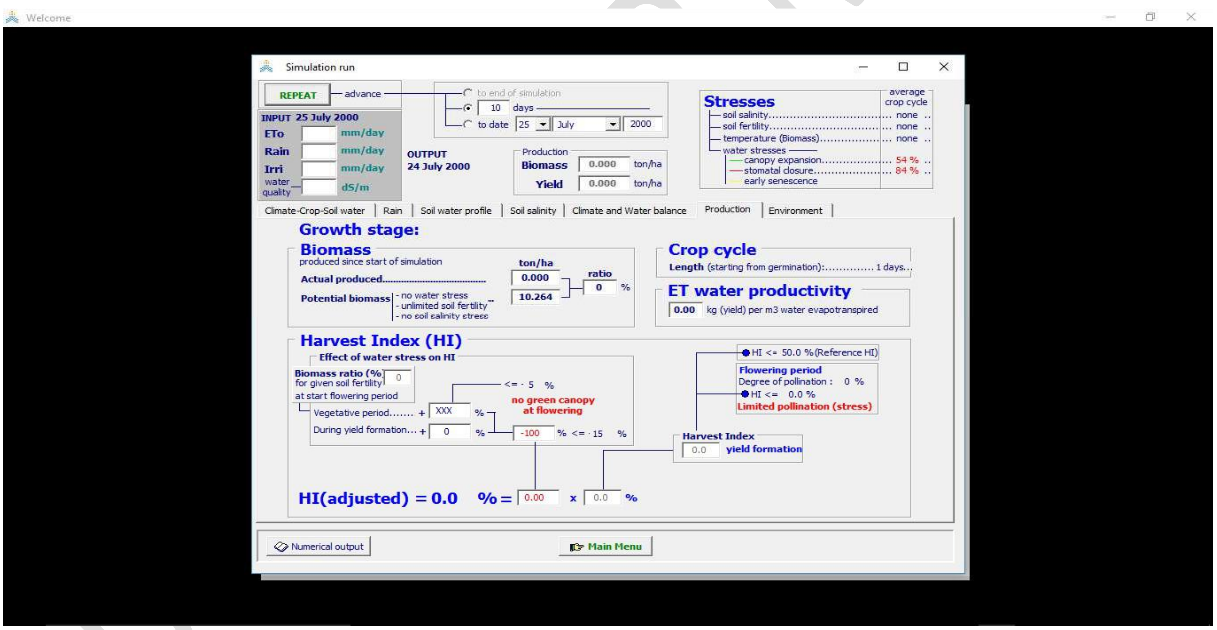


Figure 2: Field Management under Conventional Agriculture = 0.00%

The difference is negligible and hence conservation agriculture should be practiced together with other water efficient practices to maximize yield such as irrigation. Hence conservation agriculture alone under current conditions produce limited results regarding water efficiency. The choice of crops to be grown in these areas should also be revisited. Further detailed studies should be conducted using observation data to further ascertain this aspect of production.

PROXIMITY TO MARKETS

This is a measure of economic viability and farm to market connectedness. Market access is a crucial aspect in market based agricultural systems and market distances, options and linkages are assessed to determine access for Conservation agriculture farms in Eastern Kenya. The proximity of farms to a given market infrastructure was calculated using Zonal statistics in Quantum GIS version 2.12.0:

Observed mean distance: 0.0470879342984 (8km): the actual distance

Expected mean distance: 0.0616079019303 (12 km): distance in the case of a random distribution

Nearest neighbour index: 0.764316472775

Z-Score: -7.42240687564

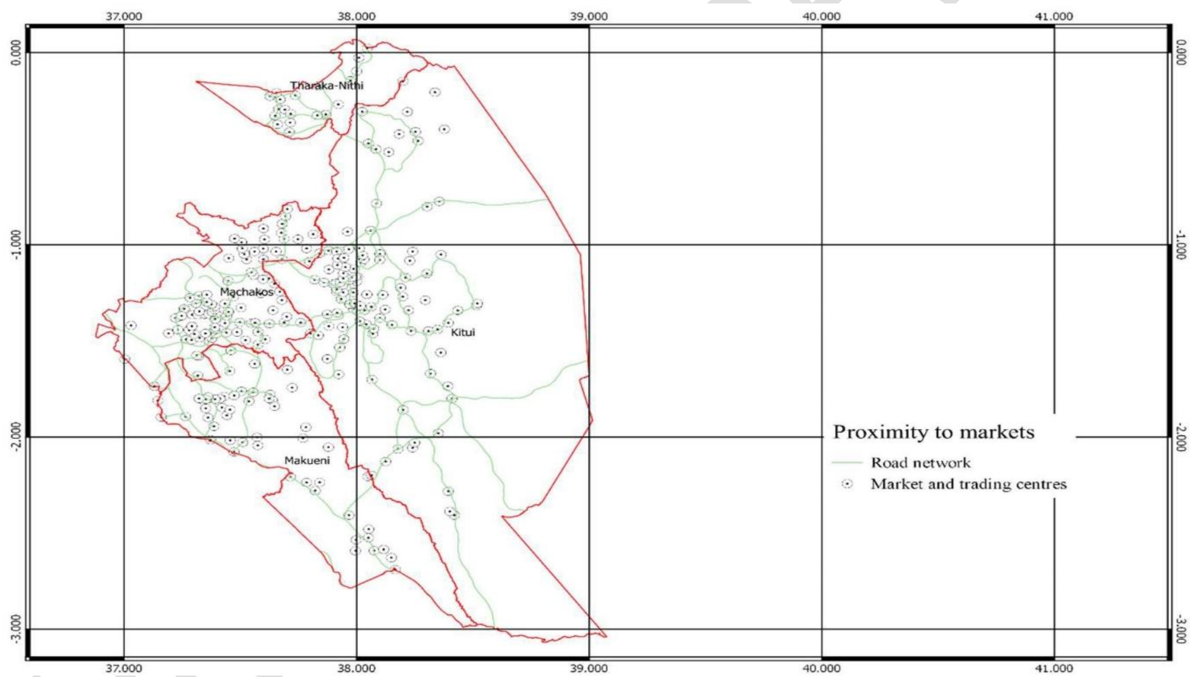


Figure 3: An illustration of markets and road networks in the study area (Source: Author, 2021)

The farming systems are within a maximum of 8-12 km distance to their nearest markets from any point in the study area. The nearest neighbour index describes the distribution of markets (clustered or randomly distributed). A score of 0.76 is described shows that the differences between actual and expected mean distance are less than expected.

A Z-score compares the nearest neighbour index to a theoretical distribution of random patterns, with values between -1 and 1 being within 1 standard deviation of the average random pattern. Positive values above 2 may be said to exhibit a statistically significant degree of dispersal while negative values below -2 exhibit significant clustering. Hence in this case the markets are significantly dispersed throughout the study area. Data obtained from focused group discussions on market options and linkages established was also considered in scoring this particular indicator with an average of 3 market options per farmer and at least 5 linkages created by FAO including an export market for the farmers in collective marketing organizations.

FARMER ORGANIZATION

This is a measure of social sustainability with focus being on farmer to farmer peer groups, collective marketing initiatives, contract farming and Savings societies. This not only shows the farmers ability to exercise their labour rights but also shows their dedication to continuous knowledge, increased savings and a focus on raising their standards of living through continually working towards an increased income, increased savings and a shift in attitude towards commercially oriented farming.

Table:5 **Farmer membership into organizations**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A member in a farmer organization, scheme or SACCO	117	88,0	97,5	97,5
	Not A member in a farmer organization, scheme or SACCO	3	2,3	2,5	100,0
	Total	120	90,2	100,0	
No responses	System	13	9,8		
Total		133	100,0		

FORAGE SUPPLY

This is a measure of the coherence of conservation agriculture in relation to the farming system. Most farming systems are mixed and a balance between biomass allocation to fodder and to mulch has to be struck. With 72 percent of farmers allocating up to 25% of plant biomass to forage the competition for use of plant biomass is inherent. This could undermine conservation agriculture implementation in the long term as soil cover is one of the three main principles of CA. The shift to live cover would reduce the competition for harvested biomass as much as allocating portions of land to grow forage or promoting palatable tree species that thrive in coppicing and pollarding regimes could supplement the requirements for fodder in these small holder systems. The table below shows the percentage of plant biomass for forage

Table:6 Percentage of plant biomass for forage

Portion in percentage		**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	0-25	54	40.7	72	72
	26-50	6	4.6	8	80
	51-75	3	2.3	4	84
	76-100	12	9.1	16	100
	Total	75	56.4	100.0	
Missing	System	58	43.6		
		133	100.0		

VERTICAL INTEGRATION

Mulch supply is a measure of the productive dimension and an expression of on-farm vertical integration. Out of 72 respondents who provided responses, 50% of them allocate up to 50 % of plant biomass to mulch with 33.3% allocating up to 25%. This is attributed to competing requirements between livestock and CA systems in mixed farming systems. The shift towards focusing on live cover i.e. Conservation agriculture with trees will go a long way in increasing the percentage of biomass allocated to mulch. The table shows the allocation of plant biomass to mulch;

Table:7 Allocation of plant biomass to mulch

Portion in percentage		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-25	24	9,0	33.3	33.3
	25-50	36	27.1	50.0	83.3
	50-75	6	4.6	8.3	91.7
	76-100	6	4.6	8.3	100.0
	Total	72	54.1	100.0	
Missing	System	61	45.9		
Total		133	100.0		

FARMER KNOWLEDGE

This is a measure of social sustainability as it measures farmer's positioning to solve problems and implement conservation agriculture on their farms. It also measures the effectiveness of farmer groups based on knowledge sharing and farmer field schools. In the survey, 54% of farmers gauged their knowledge as basic while the other 46% gauged their knowledge as either intermediate or basic. This shows the level of knowledge on CA is moderate and further training to strengthen knowledge levels on CA to ensure sustainability of the practice, as shown in the Table below;

Table:8 Farmer knowledge on CA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Basic	72	54.1	54,5	54,5
	Intermediate	27	20.3	20,5	75,0
	Professional	33	24.8	25,0	100,0
	Total	132	99.2	100,0	
Missing	System	1	0.8		
Total		133	100.0		

GREEN MANURE POTENTIAL

This is a measure of environmental sustainability. The availability of seeds for green manure describes the potential for the use of green manure that are key in integrated nutrient management systems which have the potential to maximize production while enhancing agro-ecosystem stability and resilience. 67.4% of respondents feel that seeds for green manure are very available while 14 % feel the seeds are often available. 16.3% of respondents feel the seeds are rarely available and only 2.3% responded that seeds are not available. Hence from these responses, the green manure potential in the study area is high. The table below shows the green manure potential/availability of seeds for green manure plants. It's worth noting that using a fast-release nutrient type of manure, such as green manure, is highly recommended (Adekiya *et al*., 2020). In addition, Zhou *et al.,* (2020) point out that in southern China, the use of green manure whereby rice straw returns are used , they have been found to boosts agricultural yields as well as soil fertility.

Table:9 Availability of seeds for green manure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not available	3	2,3	2,3	2,3
	Rarely available	21	15,8	16,3	18,6
	Often available	18	13,5	14,0	32,6
	Very available	87	65,4	67,4	100,0
	Total	129	97,0	100,0	
Missing	System	4	3,0		
Total		133	100,0		

Proportion of Farmers Reporting Increased/Reduced Erosion

The role of Conservation agriculture in promoting soil health is tested. 82.3% of respondents credited the reduced erosion on their farms to conservation agriculture. This combined with other benefits of Conservation Agriculture has motivated farmers to integrate conservation agriculture to the management of their farms.

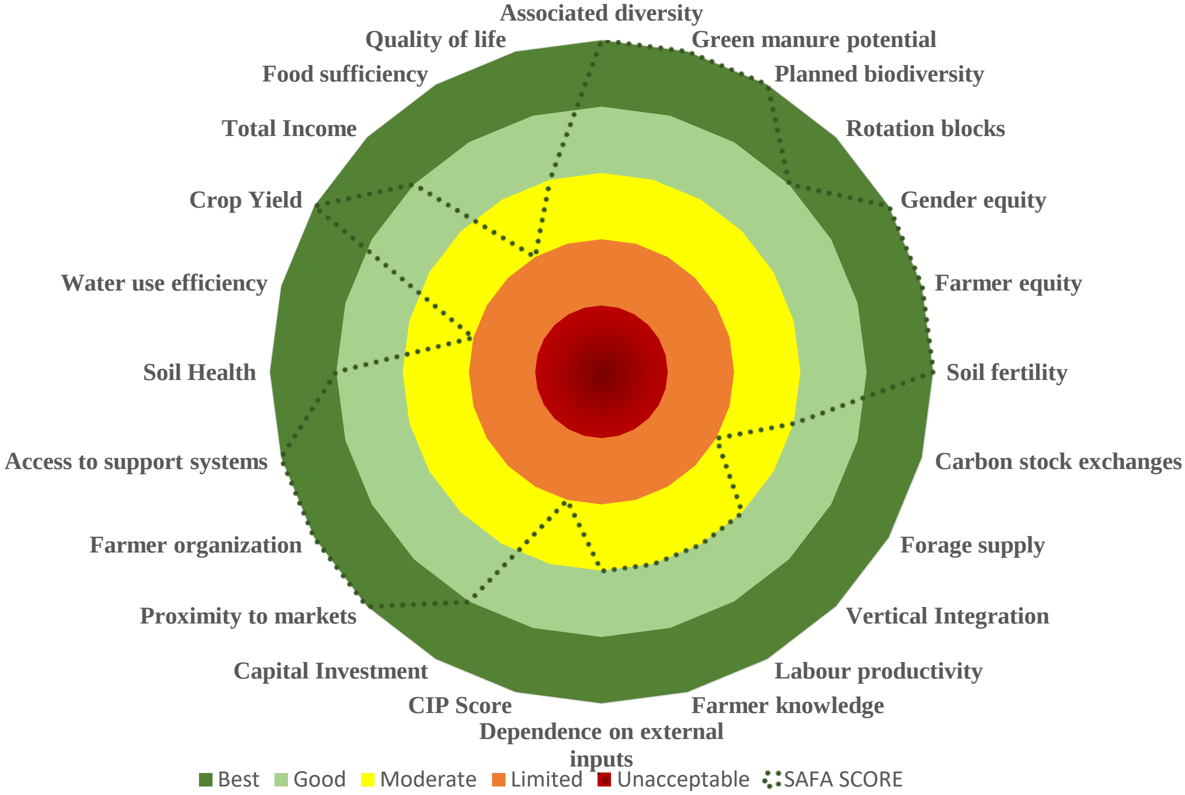
Table:10 Conservation agriculture in promoting soil health

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Reduced erosion: Erosion control	93	69.0	82.3	82.3
	Increased erosion	3	2.3	2.7	85.0
	No difference	17	12.7	15.0	100.0
	Total	113	84.0	100,0	
Missing	System	20	16.0		
Total		133	100,0		

VISUAL AGGREGATION

This study used the SAFA (the Sustainability Assessment of food and agricultural) guideline system to visualize the C.A indicators modelled from the collected and analysed data from the study area. Out of the 24 indicators selected for this study, 10 indicators scored best performances. These are associated diversity, Green manure potential, Planned biodiversity, Gender equity, Farmer equity, Soil fertility, Proximity to markets, Farmer organization, Access to support systems and Crop Yield. Four indicators scored good performance. These include: Rotation blocks, Capital Investment, Soil Health and Total Income. The other 10 indicators scored moderate and limited performances with the following six indicators: Carbon stock exchanges, Vertical Integration, Labour productivity, Farmer knowledge, Dependence on external inputs, Quality of life and the following four indicators scoring limited performance: Forage supply, CIP Score, Water use efficiency, Food sufficiency.

Fig: 4 A visualization of the Sustainability assessment of Food and Agriculture systems scores for selected indicators



The regions in which this study was conducted are classified as Arid and Semi-arid regions according to the agro ecological zoning by (Sombroek, *et al*., 1982). Hence poor scores on water efficiency based on the harvest index modelled using Aqua crop reflects the crop evapotranspiration index in absence of irrigation. In the absence of complementary technologies such as drip irrigation, CA will not be sustainable in the long run, as food poverty would rise. However, Gupta (2019), the strong reliance on groundwater for irrigated agricultural output in South Asia sustains the livelihoods of large numbers of smallholder farmers, yet it is being jeopardized by widespread groundwater overexploitation.

CONCLUSION

A process approach to sustainability adopted in this study gives a preview of the journey of conservation agriculture as applied in Kenya using a case study of four representative farms in four counties. 14 out of 24 indicators show good to best performance while six indicators show moderate performance. Results of four indicators show areas that need urgent attention to improve the sustainability of CA agro-ecosystems. An overall score of 3(indicating moderate performance) was awarded to the agro-ecosystems under CA. The Social dimension and the diversity property of the ecosystem scored the highest performance (4). The least performance was recorded in the Environmental dimension and the functional properties of the agro-ecosystem. In accordance with the Sustainability assessment of food and agriculture systems and as highlighted in the conceptual framework, sustainability is a work in progress and continuous improvement in not just deficient areas but on all system, dimensions directly contribute to the overall sustainability of the agro-ecosystem. As a result, it was suggested recommended that the government, through the ministry of agriculture, invest in improving the adoption of Conservation Agriculture methods, particularly in arid areas like eastern Kenya.

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