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The Contribution of Conservation Agriculture on Environmental Protection in Rwanda

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Abstract

Purpose: The study aimed to assess the contribution of Conservation agriculture on Environmental protection in Rwanda: case of Kayonza District.

Materials and Methods: The study reviewed different studies related to Conservation agriculture and Environmental protection and used qualitative and quantitative approaches. The Data were collected using a questionnaire and face-to-face interview on Sample composed by 404 Respondents from Kayonza district. The data collected and analyzed by using Distributive statistics.

Findings: The study indicated that CA techniques are contributing in environmental protection and there is a relationship between adopting Conservation Agriculture (CA) techniques and environmental protection. The decrease in organic matter content and high soil erosion are affecting soil fertility and health and one of the main causes of global warming is also intensive chemical fertilization of agricultural crops. In contrast, CA techniques combine minimum soil disturbance, mulching, water holding capacity, reduce soil compaction, reduce soil erosion and improve soil fertility and application of organic fertilizers and re use of crop residues, Study have shown that farmers who adopt CA experience the improvement and there improve. The study underscores the importance of adopting CA techniques to reduce the cost and protect environment.

Implications to Theory, Practice and Policy: By adopting CA practices, farmers can contribute to the protection of natural resources, conservation of biodiversity, and mitigation of climate change while maintaining agricultural productivity by promoting sustainable land management practices that conserve soil, water, and biodiversity, mitigate climate change impacts, and reduce environmental degradation associated with conventional agricultural practices. But not all small holder farmers involved in implementing all CA techniques due to different factors, NGOs and Government can collaborate to develop subsidies, grants, and funding programs specifically aimed to promote conservation agriculture. By adopting CA techniques, agriculture in the next decade will have to sustainably produce more food from less land through more efficient use of natural resources and with minimal impact on the environment in order to meet growing population demands.

Keyword: *Conservation Agriculture, Environmental Protection, Soil Erosion, Climate Change*

JEL Codes: *Q18, Q54, Q56*

1.0 INTRODUCTION

In many parts of the world, there is growing concern about the soil productivity and wider environmental impacts of conventional agricultural practices, and particularly tillage (tillage refers to the agricultural treatment of soil by various mechanical mixing methods such as digging, mixing and pouring). by plough, disk or hoe. Governments and farmers are now investigating alternative production methods that maintain soil productivity and structure. The use of cover crops, large crop rotations and straw mulching - a protective layer applied or left on the ground to reduce evaporation, maintain a uniform soil temperature, prevent erosion, control weeds, enrich the soil or preserve fruit - is all clear. and popular alternatives to sustainable farming, whether minimal or no-till. The Food and Agriculture Organization of the United Nations has recently consolidated and marketed these well-known techniques under the name "Conservation Agriculture". (FAO, Food and Agriculture Organization of the United Nations, 2012, 2012), the European Conservation Agriculture Federation (ECAF), and others.

According to its promoters, by focusing on the efficient use of agricultural resources, sustainable agriculture seeks to minimize external inputs through integrated management of soil and water resources (García-Torres, 2013). Its main feature, and indeed its central principle, is the maintenance of a permanent or semi-permanent surface cover, whether living crops or dead mulch, which protects the soil from sun, rain and wind and nourishes soil organisms. This biotic community is important because it provides "biological tillage" to replace traditional tillage operations. (Kassam, 2018). However, especially in the transition phase, the loss of pest and disease control from traditional cultivation requires chemical inputs, ideally used sparingly as part of an integrated pest control system to ensure a healthy biotic community. Thus, while sustainable agriculture consciously uses natural processes like traditional agriculture, it is not synonymous with organic agriculture.

Africa is the lowest emitter of greenhouse gases in the world among the continents, but it is vulnerable to the effects of climate change (Lukas Hermwille, 2017). The IPCC has predicted that temperatures in Africa will rise by 2 to 6 degrees Celsius over the next 100 years (Jagmohan Sharma, 2019) The impact is not limited to rising average temperatures and changing precipitation, but also increasing and increasing droughts, heat stress and floods. These climate risks have a direct negative impact on the natural resources that support agricultural production processes, which negatively affect food security and livelihoods. Africa's agricultural sector has been affected by floods, droughts, soil erosion, land degradation and deforestation, causing migration in and out of Africa (Emilio J. González-Sánchez, 2022).

Africa is still a food scarce region, but it can become the "breadbasket" of the future and sustainable intensification of agricultural production, focusing on soil and water conservation and optimal use of production inputs, with minimal damage to the environment. part of the solution, warns of the impact of projected climate change on food products in Africa, which could decrease significantly: 17.2% for wheat, 14.6% for sorghum and 13.1% for maize (Emilio J. González-Sánchez, 2022). The main areas of focus for agriculture in developing countries are food security, poverty alleviation, economic development, and adaptation to the potential impacts of climate change. Rwanda is a poor country and land is scarce, with only 0.65 hectares of suitable farmland per household. The country suffers from increasing soil fertility and erosion due to steep terrain, continuous cultivationand abundant but poorly distributed rainfall. 0.65 hectares of

arable land can produce enough food for energy and protein, but not cooking oil; animal husbandry to satisfy the need for fat is already at the limit (Venant Rutunga, 2007).

Rwandan agriculture is sustained by poor, less educated smallholder farmers who account for 70% of the export revenues and 90% of the national needs, with less than a half hectare each. As far as employment is concerned, the agricultural sector is regarded as one among the first growth sectors with high job-multiplying effects, as it mainly provides livelihoods and forms the biggest household enterprises. However, attempting to increase agricultural yields and food security is compromised by poor agricultural land management and degradation of land, resulting in a poor soil health. Soil degradation and losses are among the factors compromising productivity; 48.6 t ha^{-1} y^{-1} and 39.2 t ha^{-1} y^{-1} of soil were degraded and lost by water erosion in 2000 and 2015, respectively, leading to a total nationwide loss of approximately 110 and 89 million tons. moreover, as the agriculture in this part of the world depends on rain, climate variability effects will be more pronounced. For instance, in the highly sloped and drought-prone parts of Rwanda, such as the east and part of the north, poor soil management practices, timing of agricultural operations, frequent erosion, delayed rains, leading to droughts, will continue to lead to significant soil degradation and poor yields. From the above, Rwanda looks vulnerable. Based on the need for sustainable land use, the ministry of agriculture considered CA practices as part of the crop intensification program since 2007, in the strategic plan for agriculture transformation 2018–2024 and in the revised Rwanda agriculture policy. (Resources & Livestock, 2018).

Problem Statement

Conservation Agriculture techniques for sustainability of the nutrients in the soil, high productivity and protecting the environment are the techniques adopted by small holder farmer to cope better with the constraints and opportunities of current climate variability. Environmental degradation and climate change have a number of implications for agricultural productivity and reduce the economic contribution of agriculture in a country. Climate change is likely to make matters worse with increases in rainfall variability being predicted (P.J.M. Cooper, 2008).

2.0 LITERATURE REVIEW

Theoretical Review

Protection Motivation Theory (PMT): PMT was first developed by Rogers in 1975, based on the Value Expectation Model originally created to help understand individual human responses to fear appeals. PMT proposes that people protect themselves based on two factors: threat appraisal and coping appraisal. Threat appraisal assesses the severity of the situation and examines how serious the situation is, while coping appraisal is how one responds to the situation (P Norman, 2015). This theory is relevant to conservation agriculture the greater the feeling of fear, the greater the intention of farmers to use conservation agricultural measures. In many cases, farmers do not intend to use conservation agricultural measures because they still do not have a clear idea of the disasters that may occur due to the loss of agricultural resources (Khadijeh Bazrafkan, 2022). PMT has a good ability to predict the intention to use conservation agriculture measures. In other words, this theory can be a reliable theory for creating behavioral changes in agricultural societies.

Conceptual Framework

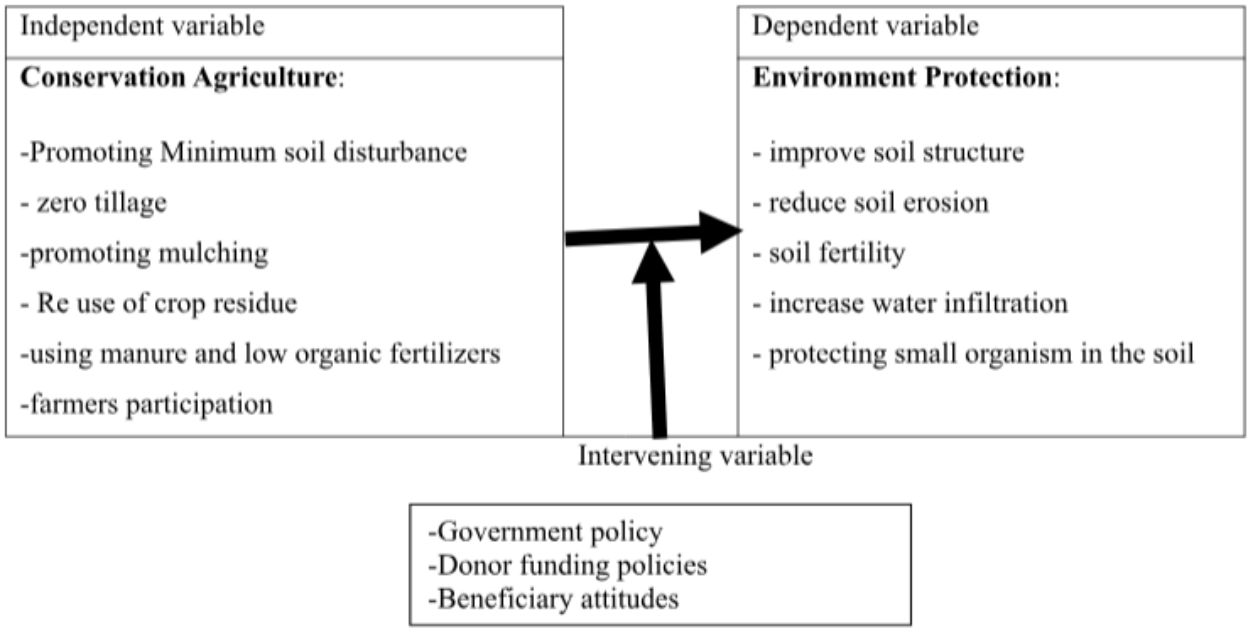

Figure 1: Conceptual Framework

Research Gaps

CA is one of the most important strategies established by Government of Rwanda in environmental protection through agriculture sector and improve the productivity. Therefore, there is no doubt that developing countries cannot get high productivity without CA in order to meet Sustainable Development Goals (SDGs). many CA techniques fail to meet their goals and their objectives due to different reason. For instance, the study done by (Farooq, 2023), (Upreti, 2023) and (Mubonderi, 2023) have methodological gap especially in research design where used descriptive research design which is not possible to show the effect of independent variable on dependent variable. The methodological gap is addressed by adopting descriptive research design and correlation research design to indicate the contribution of CA in environmental protection and economic development in Rwanda by using correlation and regression analysis.

3.0 MATERIALS AND METHODS

Study Location: Kayonza is located in the Eastern Province region among the 7 districts of the province. The distance from Kayonza to the capital of Rwanda (Kigali) is approximately 51km/32mi. The average area of the Kayonza district is 1954 km2. The topography of the Kayonza region consists of many hills and slopes varying in height from 1400 to 1600 meters. The topography is characterized by broad-topped slates and gently sloping hills, except in the east where the slopes are stiff and rocky, with an average annual temperature of 18-26ºC. The annual average rainfall is usually between 1000 and 1200 mm, with more rain in March and April. The population size varies from 346,751 people living in 12 sectors, 50 cells and 421 villages (Mudugudu). With a population change of 65.3, an average growth rate of 5.2% and a population density of 179/km2 (Kayonza, 2018).

Population: The population of interest of this study comprised of farmers who apply CA techniques includes Promoting minimum soil disturbance, Zero tillage, Mulching, re-use of crop residue, using manure and low organic fertilizers in Kayonza District since 2019 (completing 9 agriculture seasons applying CA) from the 5 sectors selected randomly. The total population is 375846 people. Sample and sampling techniques: Slovin's Formula (it's a random sampling technique formula to estimate sampling size) were used to calculate the sample size to reduce sampling error and have high precision

$$n = \frac{N}{1 + N(e)^2}$$

Where n is the sample size, N is the population size=375846 and e is the level of precision (margin error) = 5%. Using the confidence level of 95% and 5% or 0.05 sampling error. The sample size is 404 populations including 400 small holder farmers (by Slovin's formula) and 4 agronomists.

Data Collection: The data that was used includes both primary which collected by using questionnaire and interview for the selected sample and secondary data which extracted from more varied datafiles such as Government publications, websites, books, journal articles and internal records.

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4.0 FINDINGS

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The findings in Table 1 represent the activities that were adopted for conservation in Kayonza which includes Promoting minimum soil disturbance, zero tillage, mulching, Re-use of crop residue, manure and low organic fertilizers. the big number of respondents represented by 82% Indicated that High populations from the sample have adopted techniques of conservation agriculture and the low percentage is 2.2% which indicate the population adopt zero tillage only.

Then the researcher asked the respondents to select among the activities he had been adopt for conservation agriculture and 82% responded that they have adopted all technique among the five techniques, 5% adopt re-use of crop residue only, 4% adopt minimum soil disturbance only, 3.5% they are using mulching only and the lowest is 2.2% of population which adopt zero tillage only.

The findings from the table above shows that not all small holder farmers have the common understanding in all techniques of CA and only 82% are implementing all stated techniques, which means that they are the only one which understand all 3 techniques if CA (Mulching, crop rotation and minimum tillage) but also This percentage indicates a relatively high level of adoption of CA techniques among the surveyed population. It suggests that a significant majority of respondents have implemented the full range of CA practices on their farms or agricultural operations and also This high adoption rate reflect a strong understanding and awareness of CA principles and practices among the respondents. It suggests that they are well-informed about the benefits of CA and have the knowledge and resources to implement the techniques effectively.

e
Microsoft Excel and were presented into Tables. Thereafter, the Pearson correlation of SPSS analyzed how the Conservation agriculture are contributing in environmental protection.

Table 1: CA Activities Adopted in Kayonza

	Frequency	Percent
Promoting minimum soil disturbance	16	4.0
Zero tillage	9	2.2
promote mulching	14	3.5
Re use of crop residue	20	5.0
Manaure and low organic fertilizers	13	3.2
All	328	82.0
Total	**400**	**100.0**

Source: Field Data 2024

Table 2: CA Improve Soil Water-Holding Compacity and Reduce Soil Erosion

	Frequency	Percent
Agree	43	10.8
Strongly disagree	357	89.2
Total	**400**	**100.0**

Source: Field Data 2024

According to the finding from the field highlight that 89.2% of small holder farmers are strongly agree that adopting the techniques of CA have improve the soil water holding capacity and reduce the soil erosion in their farm and there is no disagree in the findings, this indicates that adopting Conservation Agriculture techniques provides smallholder farmers with practical methods to improve soil health, increase water holding capacity, and reduce erosion, thereby promoting sustainable agricultural practices and enhancing resilience to climate.

Table 3: CA Improve the Soil Physical and Chemical Properties in a Farm

	Frequency	Percent
Agree	30	7.5
Strongly agree	370	92.5
Total	**400**	**100.0**

Source: Field Data 2024

Conservation Agriculture (CA) can help improve soil physical and chemical properties on a farm through various practices and principles that promote soil health and fertility (Verma, 2021). By leaving crop residues on the soil surface or incorporating them into the soil through cover cropping, CA practices promote the formation and stability of soil aggregates. This improves soil structure, creating a favorable environment for root growth, water infiltration, and air movement within the soil.

Table 3 present that 92.5 of respondent were strongly agree that CA helped to improve the soil physical(characteristics such as soil structure, texture, porosity, and water-holding capacity) and chemical properties(Soil chemical properties relate to factors such as soil pH, nutrient content, and

the availability of essential elements for plant growth) in a farm which means CA practices promote soil conservation, enhance soil structure, increase organic matter content, improve water retention, and support nutrient cycling. These improvements contribute to sustainable and productive agricultural systems that are resilient to environmental stresses and capable of maintaining long-term productivity.

Table 4: CA Decreases Soil Temperatures and Keeps It Cooler on Hot Days and Warmer on Cold Nights

	Frequency	Percent
Agree	76	19.0
Neutral	6	1.5
Strongly agree	318	79.5
Total	**400**	**100.0**

Source: Field Data 2024

When we say Conservation Agriculture (CA) decreases soil temperatures and keeps it cooler on hot days and warmer on cold nights, it means that CA practices contribute to moderating soil temperature fluctuations, resulting in more stable soil temperatures throughout the day and night.

Table 4 Represent that 79.5% were strongly agree that CA techniques contribute in decreasing soil temperature and keeps it cooler on hot days (shade the soil from direct sunlight) and warmer on cold and nights (insulate the soil and trap heat absorbed during the day) and 1.5% were neutral about CA contribution in decreasing soil temperature and keeps it cooler on hot days and warmer n cold and nights. This means that High number of respondents confirmed that the moderation of soil temperature fluctuations achieved through CA practices contributes to creating a more stable and favorable environment for plant growth and soil microbial activity. By keeping soil temperatures cooler on hot days and warmer on cold nights, CA helps to mitigate the impacts of extreme temperature fluctuations on agricultural productivity and soil health.

Table 5: Mulching Maintaining Soil Moisture

	Frequency	Percent
Agree	44	11.0
Neutral	6	1.5
Strongly agree	350	87.5
Total	**400**	**100.0**

Source: Field Data 2024

Table 5 Present that 87% were strongly agree that Mulching (the one in principles of CA) contribute in maintaining soil moisture, this indicate that mulching contributes to maintaining soil moisture, as indicated by the high percentage of respondents strongly agreeing with this statement, underscores the importance of this practice in environmental protection. Adequate soil moisture is essential for supporting microbial activity, nutrient cycling, and plant growth. By retaining moisture in the soil, mulching contributes to soil health and fertility, promoting the growth of crops

and vegetation. Healthy soils are more resilient to erosion, nutrient loss, and degradation, thus supporting sustainable agriculture and ecosystem function.

Table 6: Is There Any Contribution of CA in Environmental Protection in Kayonza District?

	Frequency	Percent
Yes	381	95.2
No	19	4.8
Total	**400**	**100.0**

Source: Field Data 2024

The table 6 present 95.2% of respondent expressed agreement that CA techniques are contributing in environmental protection in Kayonza district. This level of agreement suggests a strong consensus among respondents regarding the positive impact of CA on environmental sustainability. These contributions may include soil conservation, water management, biodiversity preservation, carbon sequestration, and reduction of chemical inputs.

Other studies (Zhang, 2018) on Conservation Agriculture for Environmental Sustainability confirmed the fact that climate and soil types, have also endorsed the positive roles of soil fertility and moisture (under CA) in elevating the biological functions of microorganisms in balancing the ecosystems, (Haoa, et al., 2016) further indicated that no-tillage, crops rotation, mulching and agroforestry were the sinks of the top three greenhouse gases, i.e., carbon dioxide (CO_2), methane (NH_4) and nitrous oxide (N_2O), and, thus, confer adaptation and mitigation. Hence, CA practices have significant contributions to sustainable environmental conservation focusing on lithosphere, hydrosphere, biosphere and atmosphere. As a result, it is advisable to build the capacity of the smallholder farmers (who build 75% OF Rwandan population) so that they can effectively integrate AC in their farming, it would definitely increase crop yields and environmental services and This would have a long-term positive impact in serving the present needs of the people and environment without compromising the needs of future generations.

5.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources and with minimal impact on the environment. Only by doing this will food production keep pace with demand and the productivity of land be preserved for future generations. The study aims at assessing, the contribution of Conservation Agriculture in Environment protection in Kayonza District. Based on the findings of this study, it was noticed that small holder farmers have the common understanding in all techniques of CA and 82% have them in place, they are strongly agree that adopting the techniques of CA have improve the soil water holding capacity and reduce the soil erosion in their farm and by referring Ahmed 2021, minimum mechanical soil disturbance, crop diversification, and soil mulch cover/crop residue retention, could buffer soil resilience against climate change. CA-practices could increase soil organic carbon and alter pore size distribution; thus, they could improve soil water holding capacity (Ahmed, 2021). 95.2% of respondent expressed agreement that CA techniques are contributing in environmental protection in Kayonza district.

This level of agreement suggests a strong consensus among respondents regarding the positive impact of CA on environmental sustainability. These contributions may include soil conservation, water management, biodiversity preservation, carbon sequestration, and reduction of chemical inputs. The strong consensus among respondents validates the widely recognized environmental benefits associated with CA techniques. This confirmation reinforces the credibility of CA as an effective approach to sustainable agriculture and environmental stewardship and the high percentage of respondents acknowledging the relationship between CA techniques and environmental protection suggests a growing awareness of the environmental impacts of agricultural practices. the study concluded that there is positive effect of CA in environmental protection. by promoting sustainable land management practices that conserve soil, water, and biodiversity, mitigate climate change impacts, and reduce environmental degradation associated with conventional agricultural practices. By adopting CA techniques, farmers can contribute to environmental sustainability and build resilient agricultural systems for future generations as Health, Shelter, Nutrition, employment and savings and others as.

Recommendations

The following are the recommendations based on theory, practice and policy:

Theory

Future researcher should include the challenges faced by small holder farmers in implementation of CA techniques for their development and environmental protection this will contribute to the understanding of how different techniques are adopted and where support is required.

Practice

Based on findings, not all small holder farmers involved in implementing all CA techniques due to different factors including the information on CA techniques. So, government Especially local government authorities should put more effort in emphasizing small holder farmers to adopt CA techniques which is profitable by using available resources and protecting the environment. Develop comprehensive guidelines and training programs for farmers on adopting CA techniques. This includes practical demonstrations, workshops, and knowledge-sharing platforms to promote the adoption of techniques like minimum tillage/zero tillage, mulching/permanent organic soil cover and fertilizer management.

Policy

Collaborate with NGOs and Government to develop subsidies, grants, and funding programs specifically aimed to promote conservation agriculture. setting targets and incentives for farmers who adopt CA techniques and achieve higher productivity for motivations.

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