International Journal of World Policy and Development Studies
ISSN(e): 2415-2331, ISSN(p): 2415-5241
Vol. 6, Issue. 7, pp: 88-96, 2020
URL: https://arpgweb.com/journal/journal/11
DOI: https://doi.org/10.32861/ijwpds.67.88.96

Academic Research Publishing Group

Original Research **Open Access**

Conservation Agriculture: An Agroecological Approach to Adapting and Mitigating Climate Change Impacts on Malawi's Agriculture

Adewale M. Ogunmodede
Department of Agricultural Economics, Faculty of Agriculture, University of Ibadan, Ibadan – Oyo State, Nigeria
Email: adewalemodede@gmail.com

Article History
Received: August 4, 2020
Revised: September 15, 2020
Accepted: September 27, 2020
Published: September 30, 2020

Copyright © 2020 ARPG & Author
This work is licensed under the Creative Commons Attribution International
CC BY: Creative Commons Attribution License 4.0

Abstract

Although Africa's contribution to the world's greenhouse gas emission is the smallest compared to other continents, yet they tend to be affected most by the variability in Climate. Malawi is not an exception to this climate change, as they are not just faced with rising temperatures and variable rainfall patterns, but with reoccurring droughts and severe flooding. Agriculture has been noted to contribute significantly to not only climate change but also has significant impacts on global warming through its greenhouse gas emissions. Nevertheless, not all farming systems impact negatively on climate change. Conservation Agriculture is a farming system that encourages no or minimum soil disturbance, maintenance of a permanent soil cover, and diversification of crop species. These three interlinked principles combined with good agricultural practices promote biodiversity and normal biotic processes, both on and under the ground surface, thereby increasing the productivity and nutrient use efficiency of water, into a more resilient farming system which will help sustain and improve agricultural production. This review looks at Conservation Agriculture practices in the Machinga Agricultural Development Division of Malawi and its role in climate change mitigation and adaptation. This paper shows that Conservation Agriculture has played an active role in the adaptation and mitigation of climate change effect by reducing atmospheric greenhouse gas emissions but suggested there is a need for the government to formulate a CA framework that is founded on the three interlinked principles and not just based on soil and water conservation principles which are currently being advocated and practised.

Keywords: Agroecology; Zero-tillage; Carbon sequestration; Soil organic carbon; Smallholders; Crop residues.

1. Introduction

About 30% of the world's greenhouse gas emissions of CO_2, CH_4, and N_2O triggering changes in climate are known to have been caused by Agriculture (Pachauri *et al.*, 2014). Agriculture is said to have suffered more from the impacts of climate change due to the extremities in weather conditions (hot and cold) which are having negative impacts on its productivity (Kassam *et al.*, 2019). Commercial agriculture is noted for its significant contribution to food production nevertheless, it has also impacted negatively on the soil, water, organisms, and the ecosystem. Commercial agriculture's use of excessive inputs, mechanical tillage, and long-term intensive cultivations has increased soil structure degradation and erosion, causing soil organic matter (SOM) breakdown, reduced carbon sequestration, and poor crop yield (Holland, 2004; Powlson *et al.*, 2014). These environmental problems have necessitated the need for a paradigm shift to an alternative farming system that is economically profitable and environmentally sustainable (Lal and Stewart, 2013; Pachauri *et al.*, 2014). The alternative sustainable production intensification must focus on reducing the impact of climate change on crop production, reducing greenhouse gas (GHG) emission, and mitigating factors causing climate change, leading to increased soil carbon sequestration. The above objectives can be met by an approach that involves a no-till system called Conservation Agriculture (CA). This review will talk more on the role of CA in mitigating and adapting to Climate Change scenarios in Malawi.

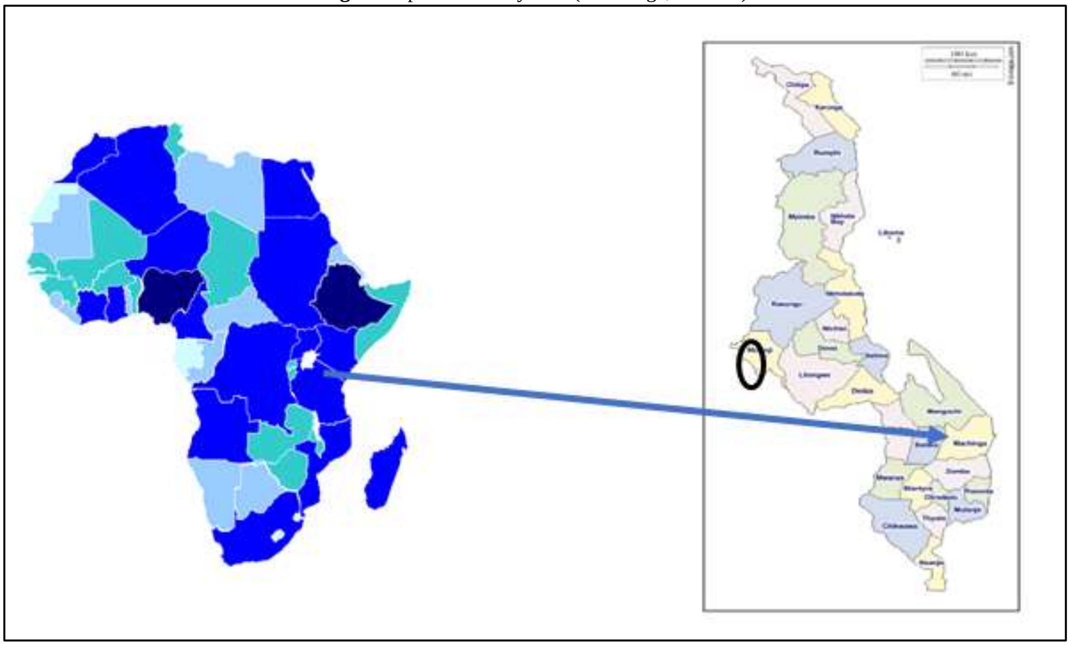
Malawi is a landlocked country located in southeast Africa with over 118,000 km^2 in size. It is one of the most densely populated states in sub-Saharan Africa with a population of 13.08 million according to the 2008 Census having 0.23 ha/person (Government of Malawi, 2009). There is enormous pressure on land resources towards meeting food, income and livelihoods demand of the ever-increasing population leading to a reduction in the potentials of land to yield produce (Mloza-Banda and Anthambwe, 2010). Malawi is divided into four broad demographic units which are the; Highlands, Plateaux, Rift Valley Escarpment, and Rift Valley Plain. The predominant soils are the lithosols, Chromic luvisols, and Haplic lixisols. Its climate is influenced by the differences in topography and closeness to westerly frontal systems impacts from the Indian ocean. With mean annual temperature ranges from 12 ^{o}C to 32^{o}C and rainfall from 500mm in the dry and hot valleys to 3000mm over highlands, its agriculture is majorly made up of small-scale farmers estimated to be 6 million in 2006. They are faced with many problems including dependence on rainfall for production, weak market links, inadequate hybrid seeds, degraded farmland, and limited access to extension services. This has resulted in poor yield and increased food insecurity (Mloza-Banda and Anthambwe, 2010).

2. Material and Method

This review focuses on CA in Malawi's Machinga Agricultural Development Division **(MADD)** and is based on a literature review of relevant peer-reviewed journals on CA and draft reports from the Malawi National Conservation Agriculture Task Force (NCATF).

2.1. Demographic Characteristics of Malawi

Fig-1. Map of the Study area (Machinga, Malawi)



MADD in the Southern Region is one of Malawi's eight Agricultural Development Divisions (**ADDs)** which borders Blantyre **ADD** in the South and Lilongwe **ADD** to the North. It is divided into Zomba, Mangochi, Machinga, and Balaka district offices with the districts subdivided into 34 Extension Planning Areas (EPAs) that are further subdivided into 560 sections. MADD according to the 2012/13 census is made up of 835, 583 farm families (Ministry of Agriculture and Irrigation and Water Development, 2016). Malawi's economy survives on Agriculture which employs about 80% of the workforce, generating 80% foreign earnings and accounting for 39% of the gross domestic product. The smallholders are about 70% of the farmers who are working towards domestic food security and the major crops they cultivate include maize, cassava, sweet potatoes, tobacco, tea, sugar, coffee, and macadamia to meet both domestic and export demands (Government of Malawi, 2007).

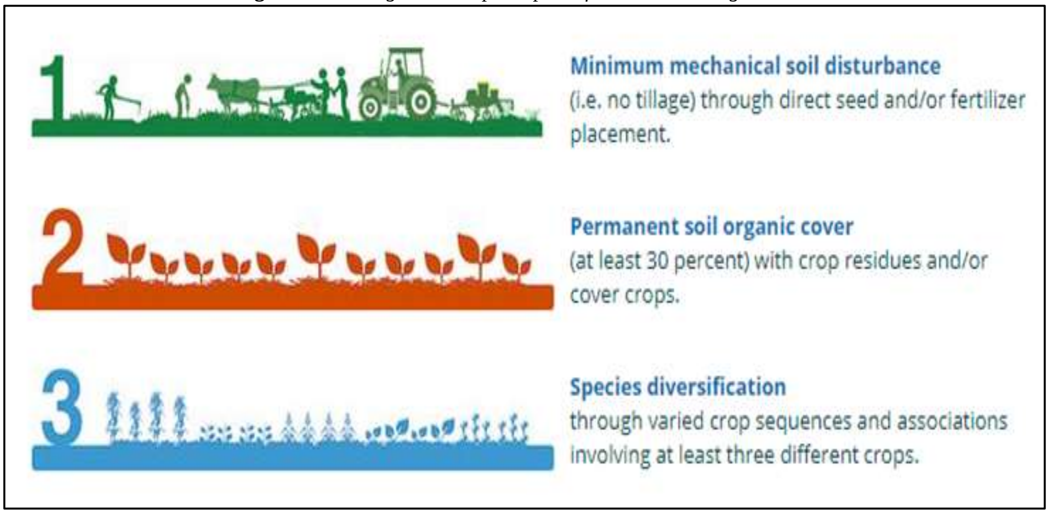
Extremities in weather scenarios like tornadoes, cyclones, floods, and droughts which have negative impacts on agriculture and humans are often a usual occurrence in Malawi. Worthy of mention is the devastating effect of various drought seasons on food security which has hampered the progress of government poverty reduction policies. In the face of this imminent drought, the government had embarked on different soils and water conservation programs with little success. Research has shown that a 1°C increase in temperature under drought condition in Africa can affect a maize farm 100% leading to about 20% yield reduction (Lobell *et al.*, 2011), so there is a need to embrace a farming system that conserves and efficiently utilizes water and soil resource. The paradigm shift to CA has brought a ray of hope of extra drops of water needed by crops especially in drylands of Machinga Malawi through water harvesting (Mloza-Banda and Anthambwe, 2010).

3. Literature Review

3.1. Conservation Agriculture

According to the Food and Agricultural Organization FAO (2018), ''CA is seen as a farming system which encourages permanent soil mulch maintenance, zero/minimum-till, and crop varieties diversification. This system boosts diversity and normal biotic processes on and under the ground surface, leading to an increase in productivity, water, and nutrient use efficiency, making cropping systems to be more resilient, thereby improving and sustaining crop production''. Similarly, Keating *et al.* (2013), opine that CA is a well-implemented soil management procedures with the potential to increase yields and income through its increased SOM. Deliberate plans which focus on mitigating GHG emissions through agricultural practices have been implemented by two-thirds of developing countries. To achieve CA's goal, three principles are applied together alongside good agricultural practices. The principles are the use of minimum/zero tillage practice, permanent soil mulch, and diversified cropping. The figure below gives a detailed account of the CA principle.

Figure-2. *Showing the three principles of Conservation Agriculture*

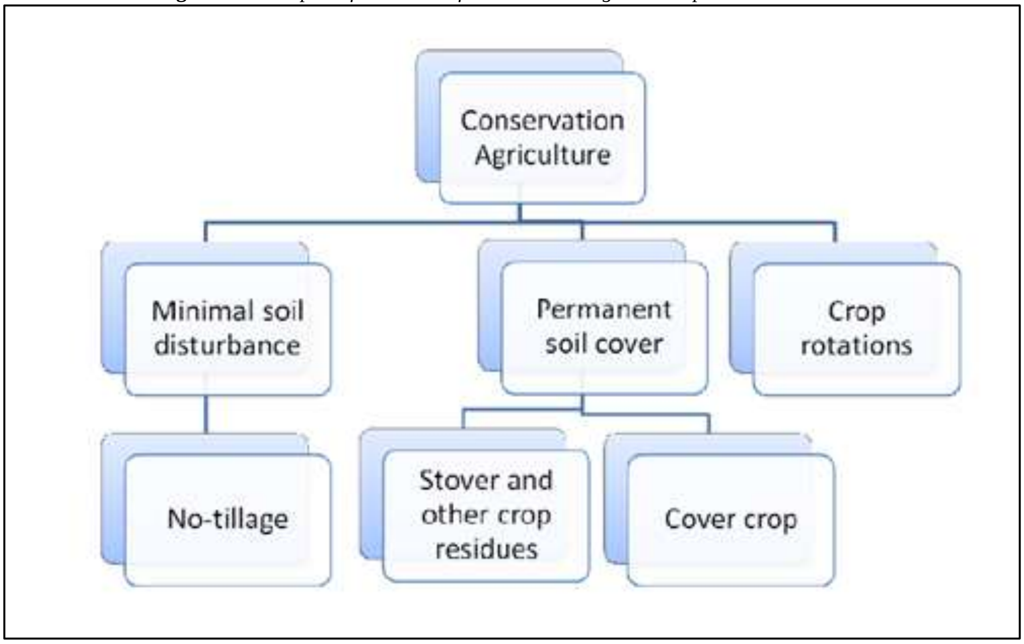


Source: *Food and Agricultural Organization FAO (2018).*

3.2. Conservation Agriculture in Malawi

Pressures and over-exploitative farming practices such as ploughing, continuous cropping, and bush burning have led to severe degradation of farmlands, SOM, and soil structure in Malawi (Mussa, 2007). Research by Smalling (1998), shows that increased pressures on Malawi's soils made it lose on average N, P, K of 40, 7, and 32kg/ha/year while soil loss due to erosion is about 50 tonnes/ha/year. It has been realised that to fight against food insecurity and poverty in Malawi, there is a need to embrace a farming system that focuses on good soil and water management, and this is what CA entails. Locally, CA is known as ''ulimi wa mlera nthaka" in Chichewa, which means "farming that focuses on nursing the land." In 2002, a national workshop at Bunda College of Agriculture helped revive the focus on CA. The workshop led to the establishment of National Taskforce on CA whose work is to coordinate CA activities in Malawi (Kumwenda *et al.*, 2002). CA, therefore, represents the paradigm shift needed by Malawi's agriculture to ensure increased productivity in the face of degraded soils, climate change, and unpredictable weather. CA is mostly practised by Maize farmers in Malawi's MADD.

Figure-3. *Conceptual framework of Conservation Agriculture practised in Malawi*



Source: *Mloza-Banda and Anthambwe (2010).*

Malawi's Ministry of Agriculture and Food Security (MoAFS) has been at the forefront of promoting and coordinating of CA activities in Malawi. In conjunction with MoAFS, other organisations are playing an active role in the crusade of CA practices. Although some of these organisations focus on using CA to promote their projects, others use it as a fulcrum for increased food production. Due to various actors having different promotional goals, it is very hard to define what CA principle entails in Malawi. The National Conservation Agriculture Taskforce (NCATF) set its definition of what CA entails but at different agricultural districts level, there is a wide range of CA principles been practised. These disparities are fuelled by inadequate skills, little collaborations between the many implementers, and experience of the actors themselves. Generally, research has shown that an average Malawian farmer sees CA as a system based on soil and water conservation principles only (Mloza-Banda *et al.*, 2012). The table below shows the various actors promoting CA in Malawi.

Table-1. *Organisations promoting Conservation agriculture in Machinga*

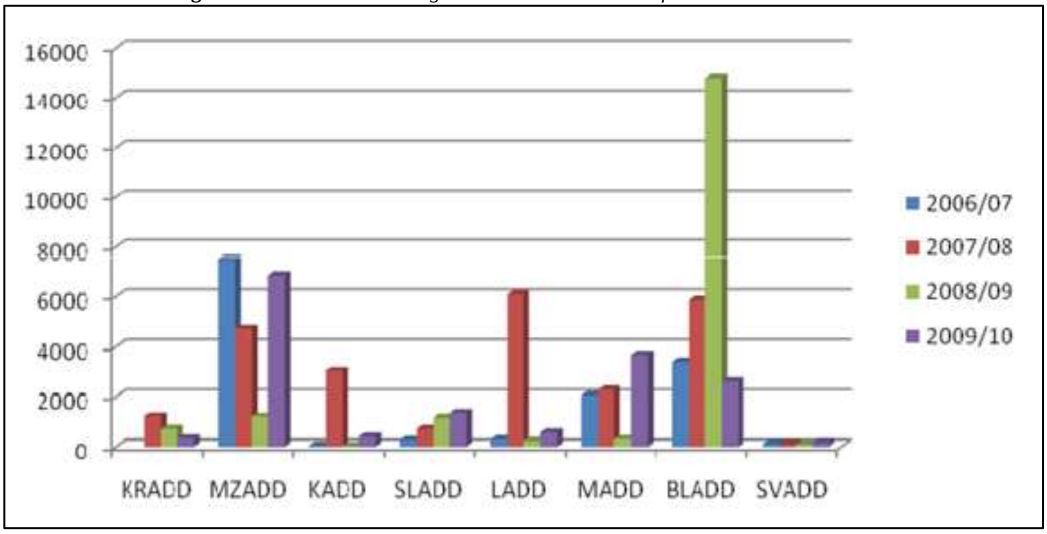
Organization	District
FIDP + MoAIWD	Balaka
Concern Universal*	Balaka
FAO + MoAIWD	Balaka
ASWAp (MoAIWD)	Balaka, Machinga, Mangochi, Zomba
Sub-Saharan Challenge Project- ICRAF	Balaka, Machinga, Zomba
Total Land Care	Machinga, Zomba
DAPP	Zomba
FAO + MoAIWD (Enhancing Food Security and Rural Livelihoods Programme)*	Balaka, Machinga
Lake Chilwa Basin Climate Change Adaptation	Machinga, Zomba
Emmanuel International	Zomba
NASFAM	Zomba
*phased out; GoM-	

Source: (Mloza-Banda *et al.*, 2012)

Figure-4. *A maize and groundnut farm based on Conservation Agriculture in Machinga, Malawi*

Source: (Demeter, 2019).

Figure-5. *Cumulative hectarages under CA in the ADDs from 2006/07 to 2009/10*



Legend:
Agricultural Development Divions (ADDs), KRADD: Karonga ADD, MZADD: Mzuzu ADD, KADD: Kasungu ADD' SLADD: Salima ADDD, Lilongwe ADD, MADD: Machinga ADD, BLADD: Blantyre ADD, SVADD: Shire Valley ADD
Source: Mloza-Banda and Anthambwe (2010).

4. Analysis of Conservation Agriculture Contributions to Greenhouse gas Emissions and Climate Change

According to Intergovernmental Panel on Climate Change IPCC (2007), human activities are one of the major contributors to GHG emissions into the atmosphere resulting in about 0.74°C increase in global mean temperature for ten years now. Agriculture is known to contribute significantly to greenhouse gas emission through plants and animals by releasing a large quantity of carbon-dioxide, nitrous-oxide, and methane into the atmosphere. Decaying of plants and animals produce through the activities of micro-organisms or burning of agricultural waste results in a significant release of carbon dioxide into the atmosphere. It is worthy to note that the causative natural and primary anthropogenic factors contributing to the much talked about variable climate are carbon-dioxide ($C0_2$), nitrous oxide (N_2O), and methane (CH_4). Agricultural activities contribute to these greenhouse gas emissions which are an important factor in Climate Change. About 6% of total GHG emissions of 427.5Tg CO_2 counterparts in the United States were contributed by Agriculture. Delgado *et al*. (2011), posited that Nitrous-oxide emissions are from farmland soil activities (215.5 Tg CO_2 counterparts) whereas methane is from the fermentation of agricultural wastes (140.8 Tg CO_2 equivalents), both gotten during microbial action on animal manure. Burning fossil fuel during agricultural activities releases CO_2 into the atmosphere. It was also observed that from 1990 – 2008, the emissions of Methane through agricultural activities increased by 14.4% and that of Nitrous-oxide increased by more than 7%. The table below shows the contributions of agriculture to GHGs in the USA.

Table-2. Agricultural contributions to GHG emissions in the United States (Tg CO2 equivalent)

Gas/Source	1990	1995	2000	2005	2006	2007	2008
CH_4	**169.6**	**185.9**	**183.7**	**186.7**	**188.1**	**194.2**	**194.0**
Enteric fermentation	132.4	143.7	136.8	136.7	139.0	141.2	140.8
Manure management	29.3	33.9	38.6	42.2	42.3	45.9	45.0
Rice cultivation	7.1	7.6	7.5	6.8	5.9	6.2	7.2
Field burning of agricultural residues	0.8	0.7	0.9	0.9	0.9	1.0	1.0
N_2O	**218.3**	**221.8**	**227.2**	**233.0**	**229.1**	**228.8**	**233.5**
Agricultural soil management	203.5	205.9	210.1	215.8	211.2	211.0	215.9
Manure management	14.4	15.5	16.7	16.6	17.3	17.3	17.1
Field burning of agricultutal residues	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Total	**387.8**	**407.7**	**410.9**	**419.7**	**417.2**	**423.0**	**427.5**

Note: Totals may not sum due to independent rounding

Source: Delgado *et al*. (2011)

Table-3. *Conservation Agriculture's Carbon sequestration rates for each climatic zone in Africa*

	Carbon sequestration rate for CA in annual crops (Mg ha^{-1} yr^{-1})	Carbon sequestration rate for CA in woody crops (Mg ha^{-1} yr^{-1})
Mediterranean	0.44	1.29
Sahel	0.50	0.12
Tropical	1.02	0.79
Equatorial	1.56	0.26

Source: Gonzalez-Sanchez *et al*. (2019).

One of the known sources of Nitrous-oxide emissions in Conservation Agriculture is through its use of Nitrogen fertilizer. Nitrous oxide is emitted as a result of various stages of the Nitrogen cycle in the soil such as denitrification and nitrification. The anaerobic activities going on in the rumen of ruminant animals and other fermentation processes are also responsible for GHG emissions. Also, animal manure causes the release of methane through its favourable environment that supports the anaerobic condition of these microorganisms that breaks it down. In the same vein, Nitrogen is lost through runoff and leaching of the soils as it passes through groundwater, estuaries, and streams.

Several studies have also shown that replacing gasoline with biofuel help reduce GHG emissions as the biofuel aids carbon sequestration by its feedstock continual growth (Smith and Olesen, 2010). CA requires less fossil fuel energy-use because of its principle of minimum soil disturbance leading to lower carbon emission. The use of crop residues as mulch also helps conserve and maintain soil and plants organic carbon as most crops dry matter weight contains between 40% - 50% of Carbon. These increases in soil carbon are called soil Carbon sink. The contributions of CA to GHGs emissions qualify it to be Climate-Smart Agriculture (CSA), as it helps to improve food security through intensive sustainable production thereby providing solutions to problems of adaption and mitigation to Climate change Food and Agricultural Organization FAO (2010). Since there is little or no bush burning, minimum tillage, and less fuel energy use; greenhouse gas emissions are reduced with CA as there is a need for only little field operations for planting and crop management. The use of the no-till principle reduces the losses of CO_2 to micro-organism respiration and SOM oxidation. Therefore, CA activities perform a vital part in the world's carbon cycle as it's three interlinked principles results in soil carbon sink increases (González-Sánchez *et al.*, 2012). To ensure a favourable impact on food security and global climate change, there is a need to move away from tillage Agriculture to Conservation Agriculture as CA is more appropriate to smallholders' farmers especially in Malawi and Africa in general because it requires lower capital investment and inputs.

Table-4. *Comparative analysis of current soil organic carbon fixed annually by CA and tillage agriculture in Africa*

Country	No-tillage adoption* (ha)	Carbon sequestration rate in no-tillage (Mg ha^{-1} yr^{-1})	Current annual carbon sequestration (Mg yr^{-1})	Climatic zone
Algeria	5,600	0.44	2,464	Mediterranean
Ghana	30,000	1.56	46,800	Equatorial
Kenya	33,100	1.02	33,762	Tropical
Lesotho	2,000	1.02	2,040	Tropical
Madagascar	9,000	1.56	14,040	Equatorial
Malawi	211,000	1.02	215,220	Tropical
Morocco	10,500	0.44	4,620	Mediterranean
Mozambique	289,000	1.02	294,780	Tropical
Namibia	340	0.50	170	Sahel
South Africa	439,000	1.02	447,780	Tropical
Sudan	10,000	0.50	5,000	Sahel
Swaziland	1,300	1.02	1,326	Tropical
Tanzania	32,600	1.02	33,252	Tropical
Tunisia	12,000	0.44	5,280	Mediterranean
Uganda	7,800	1.56	12,168	Equatorial
Zambia	316,000	1.02	322,320	Tropical
Zimbabwe	100,000	1.02	102,000	Tropical
TOTAL	1,509,240		1,543,022	

Source: (Kassam *et al.*, 2019)

5. Adapting and Mitigating Climate Change

Climate change (CC) poses a great global food security challenges with the yearly increase in the world's population. Agriculture is currently faced with two-fold problems posed by climate change, which is to adapt and mitigate this variability in the climate. Both scenarios aimed at reducing emissions from agricultural activities. The problem now at hand is how to feed the additional projected 2.4 billion people by 2050. Climate Change is said to impact negatively on Agriculture with increases in erosion, temperature, food prices, inputs, desertification, and reduction in water resources (Delgado *et al.*, 2011). To ensure food security and sustainability, the best approach is to promote a farming system that maximizes soil and water conservation which helps in ameliorating the impact of Climate Change on agriculture. CA practices is an effective way of dealing with a changing climate before us.

An effective way CA is contributing to variability in climate adaptation is by reducing crop vulnerability. With little fertilizer application, CA practices have produced more yield compared to Conventional agriculture with its efficient utilization of nutrient inputs and reduction in emission from burning plant residues (Dumanski *et al.*, 2006). Whereas, the major focus of climate change mitigation is to reduce emissions of the greenhouse gases and increase the soil carbon sink. Therefore, all the mitigation and adaptation strategies highlighted below affects the soil characteristics and nutrient cycling, and the carbon and nitrogen cycle of the ecosystem. These practices conserve soil systems, water quality, and economic returns for farmers. From my in-depth review of scientific journals such as; Berry *et al.* (2003), Delgado *et al.* (2011), Eagle *et al.* (2010), Kassam *et al.* (2019), Kinyumu (2012), Lal (2009), Mutuo *et al.* (2005), Smith and Olesen (2010), the following strategies for adapting and mitigating climate change has been identified below.

5.1. Strategies Aimed at Adapting to Climate Change Scenarios

- **Minimum energy-use**: CA saves fuel costs as it utilises minimum tillage. It also saves energy by using wind and solar to power the farm.
- **Fertilizer efficiency**: increasing the efficiency of nutrient uptake for optimal yield.
- **Permanent Soil cover**: Soil cover helps to reduce erosion, protect the soil nutrients, conserve moisture, and protects soil organisms.
- **Crop-rotation:** erosion and water requirements reduction. Aids the quality of soil and water, nitrogen loss reduction.

- **Crop diversity**: planting various types of crops is key to adapting to the variable climate, pest, and disease pressures.
- **Zero tillage:** encourages minimal soil disturbance reduces erosion and maintains soil structure.
- **Water efficiency**: CA efficiently utilizes water especially in dry areas or during drought

as a reduction in water usage is pertinent in years to come to deal with changes in climate, particularly in drier regions. It also encourages water harvesting in semi-arid areas.

- **Hybrid varieties**: research leading to the development of new crop varieties that are resistant to drought, variable temperature pests, and diseases will go a long way in climate change adaptability.
- **Irrigation**: helps in water loss reduction. It contributes to the conservation of water quality through its irrigation practices and efficiencies.
- **Agroforestry:** Windbreaks for crops, minimize impacts of extreme windstorms. Many researchers have argued that promoting agroforestry helps to solve the problems of mitigation, adaptation, and increasing resilience of our food systems to climate change needed to ensure food security. Agroforestry with CA helps in greater sequestering of carbon than one without agroforestry and this has helped smallholders in Malawi to mitigate and adapt to climate change scenarios.
- **Cover-cropping:** This, coupled with little irrigation helps to increase latter crop yields, reduces erosion and loss of Nitrogen in the soil. Also encourages water and Nitrogen to use efficiency in the soil.
- Placing value on agricultural products that have good water-footprint and environmental traits.
- Synchronizing planting and harvesting operations in line with varying seasons
- Encouraging activities that Increase carbon sequestration to improve soil functions.
- Use of precision farming in increasing CA effectiveness in adapting to climate change in both spatial and temporal variability.
- Adopting practices that prevent erosion and protects from weather extremities.

While we realized that CA is indeed beneficial to the environment, we cannot but highlight some problems encountered with CA in Machinga, Malawi. The use of permanent soil cover makes it harder for farmers to weed their farms manually, as most Malawi's farmers are smallholders and CA encourages only minimum tillage. The use of chemicals for weeding increases the cost of productions of these farmers and some researches have also shown the infestation of CA farms in Malawi by Termites because of the use of crop residues as mulch, which makes weeding tedious and they destroy their crops too. The farmers also noticed reduced yield in tuber crops CA farms due to little or no-tillage. Despite the problems noted above, the benefits of engaging in CA is far more beneficial than not engaging in it Mloza-Banda *et al.* (2012).

5.2. Strategies Aimed at Mitigating Climate Change

- **Gas Losses minimization**: application of CA Principles on farms can help decrease methane and other GHG emissions.
- **Soil Function:** Increases in soil carbon aids carbon sequestration which is beneficial to the environment and soil functions. Soil carbon sequestration is the removal of CO_2 from the atmosphere and stored in the soil. This is activities are carried out by the plants through the photosynthetic process in which carbon is stored as soil organic carbon.
- **Agroforestry:** Planting trees contributes to landscape diversity by benefiting the environment such as alley cropping and silvopasture which can serve as windbreakers and can also be used to sequester significant Carbon from the atmosphere.
- **Crop diversity:** Diverse cropping is a key to mitigation to a variable climate.
- **Efficient water use**: Use of more efficient irrigation systems such as drip system helps reduce soils and nutrients leaching. It also increases efficiencies in water usage needed for climate change adaptations.
- **Crop rotation:** erosion and water requirements reduction. Aids quality of soil and water, nitrogen loss reduction.
- **Cover crops**: This coupled with little irrigation helps to increase latter crop yields, reduces erosion and loss of Nitrogen in the soil. Also encourages water and Nitrogen to use efficiency in the soil**.**
- **Perennial Crops**: Planting of perennial crops like switchgrass functions as a carbon sequester which improves soil functions and protects the ecosystem than grains in supply energy.
- **Precision farming:** Use of precision farming in increasing CA effectiveness in adapting to climate change in both spatial and temporal variability.
- Working on appropriate ruminants feeding management, edible oils use, and proper vaccinations will help reduce Methane emissions.
- Use of slow-release Nitrogen-fertilizers at appropriate rates, placement, and timing will help reduce N_2O emissions and increase Nitrogen-use efficiencies of crops.
- Trapping energy and nutrients from animal waste and crop residue
- **Promoting energy-use efficiency:** of fuel and other products using renewable energy**.**
- Releasing of oxygen into the atmosphere through plants fixing atmospheric carbon by photosynthetic activities.
- **CA practices** can help contribute to atmospheric Carbon sequestration in agricultural soils, reduction in GHG, and consumption of fossil fuel.

- Improving grazing management.

Although some farming systems may be more sustainable than others in some aspects, assessing them singly will make them fall short of sustainability principles (Ogunmodede, 2018). Excerpts from various literature cited above have shown the unique contributions of CA to adaptation and mitigation to climate change. While no one farming system can wholly solve this climate change and global warming problems, there is a necessity for more research on an integrated farming system that will focus on aggregating all the sustainable and good agricultural practices that are already embedded in the various agricultural systems already available now.

6. Conclusion

This review has shown clearly that Conservation Agriculture is a promising sustainable farming system that can efficiently contribute to adaptation and mitigation of climate change in Malawi. It can help increase soil carbon sequestration thereby reducing CO_2 and other greenhouse gas emissions in the atmosphere. CA has shown that it is a farming system that countries in African should embrace to fulfill the Paris agreement and the Kyoto protocol which focuses on mitigation and adaptation to climate change. Coupled with the rapid growth in world population and food demand, intensive agricultural production will continue to contribute significantly to increasing greenhouse gas emissions, unless more sustainable and climate-friendly systems are adopted. So, the challenge of agriculture now is both to reduce GHG emissions and adapt to the variable climate we are experiencing now, and this is what CA hopes to achieve. This study realised that CA principles have not been adopted fully across the farming community in Machinga, Malawi. It is proposed that the National Conservation Agricultural Strategy of Malawi should formulate a CA framework that is founded on the three interlinked principles and not just based on soil and water conservation principles which are currently being advocated and practised. Also, there is a need for MoAFS to expose farmers to different CA practices especially through participatory activity and on-farm demonstrations to show the benefits and practicality of the CA farming system.

References

Berry, J. K., Detgado, J. A., Khosla, R. and Pierce, F. J. (2003). Precision conservation for environmental sustainability. *Journal of Soil and Water Conservation*, 58(6): 332-39. Available: http://www.jswconline.org/content/58/6/332.short

Delgado, J. A., Groffman, P. M., Nearing, M. A., Goddard, T., Reicosky, D., Lal, R. and Salon, P. (2011). Conservation practices to mitigate and adapt to climate change. *Journal of Soil and Water Conservation*, 66(4): 118A-29A. Available: https://doi.org/10.2489/jswc.66.4.118a

Demeter, S. M. (2019). Agronomy. Available: https://demeterseed.mw/service/agronomy/

Dumanski, J., Peiretti, R., Benites, J. R., McGarry, D., Pieri, C. and Benetis, J., 2006. "The paradigm of conservation agriculture." In *Proc. World Association of Soil and Water Conservation.*

Eagle, A., Henry, L., Olander, L., Haugen-Kozyra, K., Millar, N. and Robertson, G. P. (2010). Greenhouse gas mitigation potential of agricultural land management in the United States. A synthesis of the literature. Technical working group on agricultural greenhouse gases. (t-agg) report. Available: http://lter.kbs.msu.edu/docs/robertson/eagle+et+al.+2011+nicholas+inst.pdf

Food and Agricultural Organization FAO (2010). *Climate Smart Agriculture" Policies, practices and financing for food security adaptation and mitigation.* Food and Agricultural Organization of the United Nations: Rome. http://www.fao.org/ag/ca/

Food and Agricultural Organization FAO (2018). Conservation Agriculture. Available: http://www.fao.org/conservation-agriculture/en/

Gonzalez-Sanchez, E. J., Veroz-Gonzalez, O., Conway, G., Moreno-Garcia, M., Kassam, A., Mkomwa, S. and Carbonell-Bojollo, R. (2019). Meta-analysis on carbon sequestration through Conservation Agriculture in Africa. *Soil and Tillage Research,* 190: 22–30. Available: https://doi.org/10.1016/j.still.2019.02.020

González-Sánchez, E. J., Ordóñez-Fernández, R., Carbonell-Bojollo, R., Veroz-González, O. and Gil-Ribes, J. A. (2012). Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. *Soil and Tillage Research*: Available: https://doi.org/10.1016/j.still.2012.03.001

Government of Malawi (2007). *Poverty and vulnerability assessment – investing in our future.* GOM/World Bank: Lilongwe, Malawi.

Government of Malawi (2009). *Malawi poverty reduction strategy paper.* World Bank. http://poverty.worldbank.org/files/Malawi_PRSP.pdf

Holland, J. (2004). The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems and Environment*, 103(1): 1-25.

Intergovernmental Panel on Climate Change IPCC (2007). *Summary for policymakers. In climate change 2007: The physical science basis. Contribution of working group i to the fourth assessment report of the intergovernmental panel on climate change, eds. S. Solomon, d. Qin, m. Manning, z. Chen, m. Marquis, k.B.* Cambridge University Press. https://www.ipcc-wg1.unibe.ch/publications/wg1-ar4/ar4-wg1-spm.pdf

Kassam, A., Friedrich, T. and Derpsch, R. (2019). Global spread of conservation agriculture. *International Journal of Environmental Studies*, 76(1): 29-51. Available: https://doi.org/10.1080/00207233.2018.1494927

Keating, B., Carberry, P. and Dixon, J. (2013). Agricultural intensification and the food security challenge in sub-Saharan Africa. In Agro-Ecological Intensification of Agricultural Systems in the African Highlands.

Routledge 40-55. Available: https://www.taylorfrancis.com/books/e/9781136292279/chapters/10.4324/9780203114742-9

Kinyumu, D. M. (2012). Is conservation agriculture a solution to dry land rain-fed farming? Experiences and perceptions of smallholder farmers in Laikipia District, Kenya. *Journal of Developments in Sustainable Agriculture*, 7: 134-47. Available: https://www.jstage.jst.go.jp/article/jdsa/7/2/7_134/_pdf

Kumwenda, W., Mloza-Banda, H. R., Manda, M. and Bwalya, M., 2002. "National workshop conservation farming for sustainable agriculture." In *Lilongwe, Malawi.*

Lal, R. (2009). Carbon sequestration. *Philos. Trans. Biol. Sci.*, 363(1492): 815-30. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2610111/

Lal, R. and Stewart, B. (2013). *Principles of sustainable soil management in agroecosystems.* CRC Press. https://www.taylorfrancis.com/books/9781466513471

Lobell, D. B., Bänziger, M., Magorokosho, C. and Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. *Nature Climate Change*, 1(1): 42-45. Available: https://doi.org/10.1038/nclimate1043

Ministry of Agriculture and Irrigation and Water Development, M. (2016). Agriculture development divisions. Available: http://www.agriculture.gov.mw/index.php/2016-03-17-20-24-29/agriculture-development-divisions

Mloza-Banda and Anthambwe, S. J. (2010). *Conservation agriculture programmes and projects in.* Impacts and lessons: Malawi.

Mloza-Banda, Kambewa, D., Sikwese, M. M. G., Kamoto, J. and Mloza-Banda, H. R. (2012). An assessment of the processes and pathways to achieve innovation in Conservation Agriculture in Malawi: A case of Machinga Agricultural Development. *Third RUFORUM Biennial Meeting*: Available: http://repository.ruforum.org/sites/default/files/Mloza-Banda,C.etal..pdf

Mussa, J., 2007. "Status of conservation agriculture in Malawi." In *Presented at the launching ceremony of the malawi national conservation agriculture task force, Lilongwe, Malawi.*

Mutuo, P., Cadisch, G., Albrecht, A., Palm, C. A. and Verchot, L. (2005). Potential of agroforestry for carbon sequestration and mitigation of greenhouse gas emissions from soils in the tropics. *Nutrient Cycling in Agroecosystems*, 71(1): 43-54. Available: https://doi.org/10.1007/s10705-004-5285-6

Ogunmodede, A. M. (2018). *Environmental analysis of sustainable use and management of soil and water in agriculture: A review of organic agriculture in Australia, Unpublished Masters review.* Royal Agricultural University: Cirencester. 17.

Pachauri, R., Allen, M., Barros, V., Broome, J., Cramer, W., Christ, R. and Dubash, N. K., 2014. "Climate change 2014: Synthesis report." In *Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. IPCC.*

Powlson, D., Stirling, C., Jat, M., Gerard, B., Palm, C. A., Sanchez, P. A. and Cassman, K. G. (2014). Limited potential of no-till agriculture for climate change mitigation. *Nature Climate Change*, 4(8): 678. Available: https://www.nature.com/articles/nclimate2292

Smalling, E. M. A. (1998). Nutrient flows and balances as indicators of productivity and sustainability in Sub-Saharan Africa agro-ecosystems. *Agriculture, Ecosystems and Environment*, (71): 13-46.

Smith, P. and Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *Journal of Agricultural Science*, 148(5): 543-52. Available: https://doi.org/10.1017/S0021859610000341