Conservation Agriculture as a Strategy to Cope with Climate Change in Sub-Saharan Africa: The Case of Nampula, Mozambique

Name: Carlton Pomeroy
Affiliation: CAS (Culturally Appropriate Solutions)

Name: Antonio Aljofre
Affiliation: CNFA Mozambique

Keywords:

Abstract

This study reviews evidence on the practice, outcomes, and future potential of Conservation Agriculture (CA) in farming systems in sub-Saharan Africa as an approach to increasing food security, alleviating poverty, conserving biodiversity and ecosystem services, and supporting climate change adaptation and mitigation. Agriculture is the major economic activity in Northern Mozambique conducted by smallholder subsistence farmers depending on manual agriculture with few or no external inputs used. One of the big problems is low soil productivity due to soil degradation mainly derived from land clearance (deforestation) and agricultural depletion of soil nutrients (from poor farming practice), local farmers usually shift from one area to another, looking for fertile soils and by doing so, they effectively spread the problems of inappropriate soil management practice which causes decreasing adaptability of the farming systems to climatic changes. AENA (National Association of Rural Extension) implemented a CA project using a farming systems approach that fosters natural ecological processes to increase agricultural yields and sustainability by minimizing soil disturbance, maintaining permanent soil cover, and diversifying crop rotations. In this study we conducted a formative evaluation including interviews with 20 male and 60 female farmers within the districts of Moma, Angoche, and Meconta. Some 95% of those interviewed saw positive ecological benefits (based on soil indicators from the Natural Resources Conservation Service, 1995), 93% for economic benefits (based on FAO, 2011), as well as an 89% reporting the climatic adaptation of the system. The continent currently faces multiple severe challenges associated with land degradation, rapid population growth, and climate change. In this context, Conservation Agriculture offers the promise of locally adapted, low-external-input agricultural systems that can be adopted by the poorest and most vulnerable farming communities.

1. Introduction

The paper examines the ecological and economic costs and benefits, as well as the climatic adaptation of a Conservation Agriculture system. Smallholders represent public sector extension's priority target. The region of Nampula, Mozambique has unpredictable climatic conditions (including intense droughts, unpredictable rains, floods and uncontrolled fires) and where many people's lives depend on the productivity of their crops. AENA (National Association of Rural Extension) and the local partner implemented a Conservation Agriculture (CA) project using a farming systems approach which includes simple techniques that protect and improve the quality of the soil without costing the farmers additional resources, such as using inter-row mulching and planting nitrogen-fixing legumes during the dry season to rehabilitate the land. It also involves teaching farmers of the damage that is done to the soil through the use of certain conventional techniques such as slash and burn, examines the ecological and economic costs and benefits, as well as the climatic adaptation of the system. All of these techniques increase the resilience of cropping and livelihood systems to climate change.

2. Research Site and Farming Systems

Farming systems in Nampula are cassava-based systems; in general, there is a mix of crops each year, either through sole cropping or intercropping. However, the production by the same farm of a variety of crops maturing at different time produces a spread-out food calendar. Intercropping associations include: cassava (Manihot esculenta), pigeon pea (Cajanus cajan), groundnut (Arachis hypogoea); velvet bean (Mucuna pruriens), maize (Zea mays), and/or cowpea (Vigna unguiculata). Legumes are grown year-round as almost every farmer grows groundnuts, cowpea, pigeon pea, velvet bean, roundnut (Vigna subterra), and green gram (Vigna radiata). Some of these legumes are short-cycled and can be harvested between March and May (groundnut, cowpea, roundnut, green gram) whilst some are long cycled and are harvested in the dry season (pigeon pea, velvet bean). These legumes play a fundamental role in cultivated ecosystems fixing atmospheric nitrogen.

Farmers neither use synthetic fertilizers nor organic sources such as manure. The only return to the system is represented by crop residues, though most of these are often burnt. The difference between nutrient inputs and nutrient outputs are very negative. The decline of fertility is very fast in sandy soils and slower in more clayey soils.

Farmers practice "slashes and burn", meaning crops use almost exclusively nutrient stocks from the natural vegetation and from the soil. The fire quickly releases nutrients, particularly phosphorus, potassium, calcium, and magnesium, contained in the branches and the litter. Most nitrogen however is lost through gaseous forms. These nutrients would otherwise be released slowly through decomposition, over several years. Proposing an alternative to this slash and burn system would imply the provision of nutrients from another source, organic or inorganic.

3. Farming Systems and Feasibility of Conservation Agriculture (CA)

Conservation Agriculture can increase the ability of smallholder farmers to adapt to climate change by reducing vulnerability to drought and enriching the local natural resource base on which farm productivity depends. Conservation Agriculture aims at increasing the annual input of fresh organic matter, controlling soil organic material losses through soil erosion, and reducing the rate of soil organic material mineralization.

Replacing the "slash and burn" system with a "slash and Conservation Agriculture (CA) system" would allow farmers not only to use soil nutrients more efficiently, but also to make more use of nutrients contained in the natural vegetation. This would mean that fields can be cultivated for a longer period of time, and with a higher productivity, thus potentially reducing the need for land conversion (FAO, 2011).

Conservation Agriculture is a powerful mechanism to adapt to climate change by increasing resilience to drought and increasing water-use efficiency. Climate change is believed to have a great impact on soils. Increasing temperature would increase oxidation of the organic carbon in soil. Its levels will go down further. Incidence of runoff /wind erosion may increase due to increase in extreme events. These changes may reflect themselves in poorer soil fertility, loss of soil biota, water stress and ground water depletion (FAO, 2011). In this study the ecological benefits from CA are operationally defined as "increase in soil fertility", "retention of soil moisture", "long-term yield increase", "decreasing yield variations", "greater food security", "increased growing time of an area", and "production per Ha." (Natural Resources Conservation Service, 1995; p. 5).

In this project Conservation Agriculture demanded a commitment of learning by the farmers which include the formation of cooperatives or other agricultural associations. In this manner the farmers learned together and are able to implement marketing strategies Potential economic benefits of CA are operationally defined as "savings in time", "savings in labour", and "better price because they sell as a group". The costs are "farmers need new management skills", "formation and operation of farmers' groups", and "development of appropriate technical packages and training programmes" (ECAF, 2001; p.2; Natural Resources Conservation Service, 1995; FAO, 2011; and FAO, 2001).

For the most vulnerable people as well as adaptation is the major concern for climate change. According to Smit et al. (1999; 2000) and the IPCC (2001), adaptation refers to the "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts" (p. 12). More specifically, it refers to "processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate" (IPCC, 2001). Climate change adaptation in the Conservation Agriculture techniques are defined in this study as "mulch farming", "conservation tillage", "cover cropping", and "recycling of bio-solids" (FAO, 2008; p. 7).

Small-scale farmers are among the first to feel the impacts of climate change because of their greater dependence on the natural environment. Often these producers are subsistence producers or have very limited resources even if they do sell produce their ability is limited and any disturbance in production, including climate change, can have result in starvation or poverty. Extreme climate variability (drought, floods and frost) can destroy the economies and welfare of poor rural families because they lack technologies, social protection mechanisms (such as benefits, insurance and savings) and adequate protection for their crops and animals. In this study the indicators of climate change and the adaptability of CA are measured by looking at "insect pests being more frequent", "impoverishment of the crops in warmer regions due to heat stress", "soil erosion", "inability to cultivate the land due to waterlogging", "lower yields", "crop damage and even crop failure", and "increased risk of uncontrolled wildfires" (Adapted from IPCC WG II, 2007; p. 16).

4. Goals and Methods

Methodologically, the guide for interview was based on Bernard's ideas for semi-structured interviews (Bernard, 1995) and Kvale's writings on dynamic, positive interaction (Kvale, 2004). Semi structured interviews are based on tight-rope walking between on one hand openness to the informant's associations from the questions – the informant can, through his answers; influence the directions of the interview.

Semi-structured interviews allow for the interviewer to follow the general research questions without losing valuable information that may give important additional information. As compared to a structured questionnaire in which there is a list of questions to ask, a semi-structured interview allows the researcher to ask follow up questions and receive feedback from the interviewees. This information, furthermore, may be quantified more easily than just ethnographic methods. The method provides a timely research method with the flexibility for additional information.

Interviews with 20 male and 60 female farmers were conducted within the districts of Moma, Angoche, and Meconta. The interviews examined the ecological and economic costs and benefits, as well as the climatic adaptation of the system. We also interviewed 18 representatives from government extension and NGO's on the impact of current extension activities.

A number of researchers have tried to develop systematic methods for analysing written narratives generated through open-ended surveys or other qualitative data collection techniques (e.g., Bernard, 1994; Carey, 1994a, 1994b; Gorden, 1992; Miles and Huberman, 1994; Patton, 1990). The interviewers recorded notes and then used the notes to write expanded English summaries of each respondent's answers to the questions. The coding of qualitative data entails assigning unique labels to text passages that contain references to specific categories of information (Bernard, 1994; Gorden, 1992; Miles and Huberman, 1994).

To ensure reliability of the coding scheme, another person assisted in reviewing the transcript and used the coding scheme to code the data. Results were then shared and any discrepancies were discussed and resolved. Changes in the coding scheme included additions, deletions, and clarifications. Once the data was coded the data was then divided into themes. The data was then reviewed within the themes or categories, and an understanding of each theme was reached.

Healy and Perry (2000) explicate on the judging validity and reliability within the realism paradigm which relies on multiple perceptions about a single reality. They argue the involvement of triangulation of several data sources and their interpretations with those multiple perceptions in the realism paradigm. The information from the interviews was triangulated with literature provided by ECAF (2001), Natural Resources Conservation Service (1995), FAO, (2001), FAO (2011), and IPCC WG II (2007). Furthermore the data from the farmers was compared to the data from the 18 key informants from extension and government agencies.

These categories (benefits including: savings in time, savings in labour, better price because they sell as a group, Increase in soil fertility, retention of soil moisture, long-term yield increase, decreasing yield variations, greater food security, increase in growing time of an area, and increased production per Ha. As well as costs including: farmer needs new management skills, requiring farmer's time commitment to learning and experimentation formation and operation of farmers' groups, and high perceived risk to farmers because of technological uncertainty) were then used to create indices for economic benefits and costs for conservation agriculture as well as ecological benefits. The interviews were each coded as "0" for "no" and "1" for "yes". Factor analysis was used to examine the standards content validity, predictive validity, concurrent validity, and construct validity (American Psychological Association, 1954). The index for economic benefits included "savings in time", "savings in labour", and "better price because they sell as a group and costs for conservation agriculture" had a score of .74. The index for economic costs was composed of "farmer needs new management skills – requiring farmer's time commitment to learning and experimentation", "formation and operation of farmers' groups – high perceived risk to farmers because of technological uncertainty", and development of appropriate technical packages and training programmes and received a score of .79 (ECAF, 2001; p.2; Natural Resources Conservation Service, 1995; FAO, 2011; and FAO, 2001).

Categories for practices that allow for climate change adaptation in the agriculture sector were composed of "mulch farming", "conservation tillage", "cover cropping", and "recycling of Bio-solids" (FAO, 2008; p. 7). The interviews were each coded as "0" for "no" and "1" for "yes" for each of the practices being utilized. "Increase in soil fertility", "retention of soil moisture", " long-term yield increase, "decreasing yield variations", "greater food security", "increase in growing time of an area", and "increased production per Ha." composed the categories for ecological benefits as each response was coded as "0" for "no" and "1" for "yes". Together these comprised the ecological index and received a factor score of .82 (Natural Resources Conservation Service, 1995; p. 5).

The impacts of climate change in the agriculture sector have categories and then indicators: 1) more frequent heat waves and warm periods with indicators of "insect pests more frequent" and "impoverishment of the crops in warmer regions due to heat stress", 2) more frequent intense precipitation events in most regions with indicators of "soil erosion", "inability to cultivate the land due to waterlogging", 3) increase in areas affected by drought with indicators of "lower yields", "crop damage and even crop failure", and "increased risk of uncontrolled wildfires" (IPCC WG II, 2007; p. 16). These categories were used to compare the old "slash and burn system" to the "Slash and Conservation Agriculture" system. Each of these categories were each coded as "0" for "no" and "1" for "yes" and evaluated as a percentage using SPSS.

4. Results

"Conservation Agriculture" includes a minimum till system, integrated pest management, green manures, management of fertilization, multiplication of disease resistant cassava stock, and the introduction of alternative high value crops. The results showed that 93.75% of the respondents felt that there was a savings in time and labour in the conservation agriculture (see Table 1). Some 93.75% felt that they could get a better price because they could sell the produce as a group (see Table 1).

All of the respondents felt these benefits came at a cost as they had needed new management skills, had to form and operate farmers' groups, and develop appropriate technical packages and training programmes (see Table 1). This information was also shared with extension agents that explained the great amount of labour and time that went into training the groups in techniques of conservation agriculture, organizational and accounting skills.

Many of the farmers used to burn the land but are now using conservation agriculture. They first learned how to do this in a demonstration plot and then started practicing the activity; all those interviewed said they are using the techniques (see Table 2). The vast majority (95%) feel there are both ecological benefits including an increase in soil fertility, retention of soil moisture, long-term yield increase, decreasing yield variations, greater food security, increase in growing time of an area, and increased production per Ha. (See Table 3).

Table 1. Potential economic benefits and costs associated with conservation agriculture.

Benefit	Male		Female		
	Yes	**No**	**Yes**	**No**	Total Percentage
Savings in time	18	2	58	2	93.75%
Savings in labour	18	2	58	2	93.75%
Better price because they sell as a group	17	3	58	2	93.75%
Cost	**Male**		**Female**		
	Yes	**No**	**Yes**	**No**	Total Percentage
Farmer needs new management skills – requiring farmer's time commitment to learning and experimentation	20	0	60	0	100.00%
Formation and operation of farmers' groups – High perceived risk to farmers because of technological uncertainty	20	0	60	0	100.00%
Development of appropriate technical packages and training programmes	20	0	60	0	100.00%

(ECAF, 2001; Natural Resources Conservation Service, 1995; FAO, 2011; and FAO, 2001; N=80, 20 Male and 60 female)

Table 2 Categories for practices that allow for climate change adaptation in the agriculture sector.

	Male		Female		
	Yes	**No**	**Yes**	**No**	**Total Percentage**
Mulch farming	20	0	60	0	100.00%
Conservation Tillage	20	0	60	0	100.00%
Cover cropping	20	0	60	0	100.00%
Recycling of Bio-solids	20	0	60	0	100.00%

(FAO, 2008).

Table 3. Potential ecological benefits from conservation agriculture.

Benefit	Male		Female		
	Yes	**No**	**Yes**	**No**	Total Percentage
Increase in soil fertility	18	2	58	2	95.00%
Retention of soil moisture	18	2	58	2	95.00%
Long-term yield increase	18	2	58	2	95.00%
Decreasing yield variations	18	2	58	2	95.00%
Greater food security	18	2	58	2	95.00%
Increase in growing time of an area	18	2	58	2	95.00%
Increased production per Ha.	18	2	58	2	95.00%

(Natural Resources Conservation Service, 1995; N=80, 20 Male and 60 female)

All those interviewed indicated that there have been more erratic weather patterns with random rainfall and extended dry periods. Many of those interviewed indicated that there were indicators of climate change including impoverishment of the crops due to heat stress (83.75%), soil erosion (95%), inability to cultivate the land due to waterlogging (95%), lower yields (93.75%), crop damage and even crop failure (93.75%), and increased risk of uncontrolled wildfires (95%; see Table 4).

Table 4. Crop indicators of climate change.

	Male		Female		
	Yes	**No**	**Yes**	**No**	**Total Percentage**
Insect pests more frequent	17	3	50	10	83.75%
Impoverishment of the crops due to heat stress	17	3	50	10	83.75%
Soil erosion	18	2	58	2	95.00%
Inability to cultivate the land due to water-logging	18	2	58	2	95.00%
Lower yields	17	3	58	2	93.75%
Crop damage and even crop failure	17	3	58	2	93.75%
Increased risk of uncontrolled wildfires	18	2	58	2	95.00%

(IPCC WG II, 2007)

Overall the respondents were positive of the ability of Conservation Agriculture to adapt to climate change. The majority (88.75%) felt that the CA system adapted to insect pests (see Table 5.) Some 96.25% reported the ability to adapt to impoverishment of the crops due to heat stress especially because of intercropping and use of cover crops and mulch. A vast majority felt that the CA had the ability to adapt to improve lower yields (88.75%), adapt to crop damage, and avoid crop failure (88.75%). Others felt conservation helped deal with extreme weather with 88.75% reporting its ability to prevent soil erosion and being able to cultivate the land due to waterlogging (62.25%). Only 50% felt that it could adapt to uncontrolled wildfires as many people who still burn lose control of their burns.

Table 5. Ability of Conservation Agriculture to adapt to climate change.

Insect pests more frequent	Male		Female		
	Yes	**No**	**Yes**	**No**	**Total Percentage**
Ability to adapt to insect pests	18	2	53	7	88.75%
Ability to adapt to impoverishment of the crops due to heat stress	18	2	53	7	88.75%
Ability to prevent soil erosion	18	2	53	7	88.75%
Ability to adapt to the inability to cultivate the land due to waterlogging	12	8	42	18	66.25%
Ability to improve lower yields	17	3	54	6	88.75%
Ability to adapt to crop damage and avoid crop failure	17	3	54	6	88.75%
Ability to adapt to increased risk of un-controlled wildfires	10	10	30	30	50.00%

5. Discussion

Because of the limited resources they have at their disposal, and because of the formidable barriers they face to effective action, Mozambicans are amongst the most vulnerable people to climate change in the world. This is particularly true of people living in drought and flood prone areas. Smallholders, composed of family farms, represent almost 85% of the rural population, and they cultivate 95% of the area. Thus, this sector is central to concerns about alleviation, production increase, food security, all which are dramatically impacted by climate change in Mozambique. As noted by Pertev and King (2000), small scale agricultural development is central to the elimination of poverty and hunger in developing countries.

The growing importance of natural resource management in agriculture requires a reversal of current resource degradation in key areas. Climate change is raising temperatures, changing weather patterns in ways that accentuate extremes like flooding and drought. Water resources for irrigated agriculture are becoming scarce. In a positive vein, research increasingly points up the potential for significant productivity gains through improved practices for farming systems.

AENA (National Association of Rural Extension) is working to improve the quality and quantity of food crops produced by the population while maintaining or improving ecosystem productivity. AENA is having a significant impact. This project is well designed both in terms of technology, community needs, motivation, and staff. This combination has allowed the project to have a very strong impact. There is still a need to improve both the capacities of the extension agents and the communities.

Those interviewed have seen economic benefit from the conservation agriculture. They learned not to burn and to plant in lines increasing the number of plants per Ha. At the same time in the old system they can only plant for one year, however, they can now expand this time from three to five years. Respondents have seen an economic impact apart from the increased production from conservation agriculture. They sell their products together and a receive a better price.

For small- and medium-scale farmers, this fosters the more efficient and sustainable use of water and other inputs, lower production costs, better management of biotic stresses, and enhanced system diversity and production. The massive adoption of conservation agriculture is a truly revolutionary challenge, which is highly positive for the environment and the economy. This change is not easy for farmers as it signifies a new training in important techniques/ operations for the crop management. Namely, an updating of knowledge and of new techniques, such as direct sowing and the handling of plant covers and the control of new weed species, as well as a certain amount of investment.

The conservation agriculture project is more than just a short term project. It is actually trying to make a cultural change from a slash and burn system. The farmers as well as AENA extension agents have been able to successfully implement substantial change.

5. References

American Psychological Association. (1954). Technical recommendations for psychological tests and diagnostic techniques. Psychological Bulletin, 51 (2).

Bernard, H. R. (1994). Research methods in anthropology: Qualitative and quantitative approaches. 2d edition. Thousand Oaks, CA: Sage Publications

Carey, J. W. (1994a). Methods for analyzing responses to open-ended survey questions.. Atlanta: Centers for Disease Control and Prevention, Division of Tuberculosis Elimination.

Carey, J. W. (1994b). Improving international HIV program planning: Systematic interview methods in the context of programmatic needs assessment. Masters thesis in Public Health, Emory University, Atlanta.

ECAF, (2001). *Conservation agriculture in Europe.* (www.ecaf.org/English/First.htm)

FAO. (2001). The economics of soil productivity in Africa. Soils Bulletin. Rome.

FAO, (2008). What is conservation agriculture. in: Conservation Agriculture website of FAO, www.fao.org/ag/ca/1a.html.

FAO. (2011). The State of food and agriculture. Women in agriculture. Closing the gender gap for development. Rome: Food and Agriculture Organisation of the United Nations.2

Gorden, R. (1992). Basic interviewing skills. Itasca, IL: F. E. Peacock;

Healy, M., & Perry, C. (2000). Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm. Qualitative Market Research – An International Journal, 3(3), 118-126.

IPCC TAR WG1 (2001), Houghton, J.T.; Ding, Y.; Griggs, D.J.; Noguer, M.; van der Linden, P.J.; Dai, X.; Maskell, K.; and Johnson, C.A., ed., Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

IPCC, (2007). Climate Change 2007: Impacts, adaptation and vulnerability. Contribution of working group ii to the fourth assessment report of the intergovernmental panel on climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

Kvale, S. (2004) Inter Views: An introduction to qualitative research interviewing. Sage Publications, London.

Miles, M. B. & Huberman A. M. (1994). Qualitative Data Analysis. 2d edition. Thousand Oaks, CA: Sage Publications.

Natural Resources Conservation Service (USDA, NRCS), 1995. Soil quality. NRCS:RCA Issue Brief 5. US Department of Agriculture, Washington Patton, M. Q. 1990. Qualitative Evaluation and Research Methods. Newbury Park, CA: Sage Publications.

Pertev, R. & King, D. 2000. The essential role of farmers' organizations in developing countries. Agriculture and Rural Development, 7(1): 28–30,

Smit, B., Burton, I., Klein, R.J.T., Street, R., (1999). The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change 4, 199–213.

Smit, B., Burton, I., Klein, R., Wandel, J.,(2000). An anatomy of adaptation to climate change and variability. Climatic Change 45, 223–251.