“Conservation Agriculture,” Possible Climate Change Adaptation Option in Taita Hills, Kenya

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Abstract

The vicious cycle of food insecurity in Kenya and Africa at large is partly attributed to the high reliance on rainfed agriculture, which makes production systems vulnerable to the adverse impacts of climate change and variability. Conservation agriculture (CA) has been disseminated as a climate-smart practice that operates on three main principles to realize the multiple benefits of making

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crop production systems more resilient to climate change impacts, enhancing food security, and providing environmental services, such as carbon sequestration. As a major source of livelihood in the Taita Hills, agriculture is constrained by climate change owing to its rainfed nature. The yield and environmental and economic benefits of CA make it a suitable alternative approach to sustainable agricultural intensification, which is fundamentally different from conventional approaches based on intensive tillage and often disrupts ecosystem functions. This chapter provides the rationale for enhancing the adoption of CA in the Taita Hills by evaluating the current challenges affecting crop production, the role of CA in addressing the challenges and its potential benefits, and the barriers that must be overcome in order to promote its wide-scale adoption. A number of constraints appear to hinder the wide-scale adoption of CA in the Taita Hills, including lack of awareness, tenure-related issues, and weak policy and institutional support. Addressing these constraints will help catalyze investments for upscaling CA in the Taita Hills, with potential for replication in other parts of the country.

Keywords

Food insecurity · climate change and variability · vulnerability · tillage · conservation agriculture

Introduction

Despite being the backbone of many sub-Saharan Africa (SSA) economies, agriculture remains predominantly (95%) rainfed and therefore vulnerable to the impacts of climate change and variability (Adhikari et al. 2015). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) presented strong evidence that surface temperatures across Africa have increased by 0.5–2 °C over the past 100 years. The report further indicates that from 1950 onward, climate change has altered the magnitude and frequency of extreme weather events. The frequency of cold days, cold nights, and frost has decreased, whereas the frequency of hot days, hot nights, and heat waves has increased (IPCC 2014). In addition, the recently released IPCC Special Report on global warming of 1.5 °C emphasizes that there are significant negative impacts at 1.5 °C temperature increase above pre-industrial levels and highlights that the observed warming in 2017 already reached 1 °C above pre-industrial levels (IPCC 2018). Since global warming of 1.5 °C is associated with extreme weather events, it poses a high risk to unique and vulnerable systems in Africa, especially agriculture, which is highly sensitive to weather and climate variables, including temperature, precipitation, and extreme weather events, such as droughts, floods, and severe storms.

The high spatial and temporal variability of rainfall, high temperatures, extreme weather events such as droughts and floods, and degradation of the sector's natural resource base (land, water, etc.) affect the agricultural production and thus food security. Even during seasons with favorable weather conditions, poor agronomic practices have been indicated to limit crop production. According to the Montpellier Report (2015), projections show an approximately 20% increase in hunger and malnutrition levels in SSA due to climate change-related impacts. Therefore, the biggest challenge for SSA remains, i.e., meeting the required food needs through sustainable intensification practices, considering the continued reliance on rainfed agriculture.

In Kenya, the key staple crops include maize, beans, and cruciferous vegetables. As an example, maize is consumed by over 90% of the total population as a staple crop (Ochieng' et al. 2017). However, crop production is primarily done by smallholder farmers who have limited resources for investing in sustainable production practices. Kiboi et al. (2019) noted that the maize productivity in Kenya is currently very low (1.0 ton ha^{-1}) relative to the attainable potential of 6–8 ton ha^{-1}. The huge gap in maize yield is primarily attributed to low soil fertility across the country's cropland resulting from poor management and nutrient mining without proper replenishment. Erratic patterns of rainfall and high frequency of droughts interacting with lack of investment in practices that conserve soil and water also contribute to low crop yields (Ochieng' et al. 2017). As the population continues to grow and climate change impacts aggravate, the situation in Kenya is likely to worsen over the coming years. The scaling up and out of practices that can support crop production even in periods of sporadic rainfall through soil water retention and increased organic matter can help break the vicious cycle.

Conservation agriculture (CA) has been disseminated as a climate-smart practice for intensifying crop production and increasing farmers' resilience to climate change (Sommer et al. 2018). The Special Report on Climate Change by the IPCC (2019) indicates that conservation agricultural practices have the potential to restore degraded land and enhance food security. However, the statistics provided by the Food and Agriculture Organization (FAO) show that the uptake of conservation agriculture in Kenya is still very low and far from the recommended 10% adoption rate, which is considered as the threshold level that can spur widespread adoption of the climate-smart agricultural technique in the country. Statistics further show that of the 5.8 million ha of arable land in Kenya, only 40,000 ha is under CA, 70% of which is by large-scale farmers (Mutuku et al. 2020).

The agriculture in Kenya is a major driver of the economy and the entire food systems. It is a major source of livelihood for the majority of Kenyan people in terms of food security, economic growth, employment creation, and foreign exchange earnings. As a major source of livelihood and well-being in the Taita Hills, agriculture remains highly sensitive and exposed to the impacts of climate change. This emphasizes the need to create an enabling environment to increase investments in sustainable agricultural practices that enhance farmers' buffer capacity while increasing productivity in the long term. The CA practice in particular has the potential to offset these impacts and make agricultural systems more resilient to a changing climate.

This chapter therefore provides the rationale for enhancing the adoption of CA in the Taita Hills by evaluating the current challenges affecting crop production, the role of CA, and its potential benefits as well as the challenges and barriers that must be overcome in order to promote its wide-scale adoption The findings of this chapter will enable policy makers to prioritize investments for scaling up the adoption of CA practice in the Taita Hills, with potential for replication in other parts of the country.

Status of Sustainable Agriculture in Kenya

A number of practices have been promoted as sustainable practices to enhance the resilience of farming systems in Kenya. These include agroforestry, soil and water conservation techniques such as terracing and irrigation, integrated soil fertility management, crop diversification, and conservation agriculture, inter alia (Kurgat et al. 2018). Despite the potential that these farming practices present for smallholder farming households and the environment, their adoption remains generally low in Kenya. The low adoption of sustainable agricultural practices is mainly attributed to barriers, such as low awareness, inadequate technical know-how, limited access to extension services, small farm sizes, and lack of capital.

Considering the smallholder nature of farming systems in Kenya, high population growth, and fragmented land holdings, the adoption of sustainable intensification farming practices is the most viable option to increase agricultural productivity (i.e., crop yield per unit area) to meet the constantly increasing food needs (FAO 2011a). It is also important to make production systems more resilient to biotic and abiotic stresses, especially those triggered by climate change, by maintaining soils in a carbon-rich state. In addition, avoiding further degradation of agricultural land and ecosystem services and rehabilitating the already-degraded agricultural land are urgent.

To achieve this, a shift is required from the current conventional tillage (CT)-based production systems of agricultural intensification as they have negative impacts on crucial natural resources, such as soil and water (Dumansky et al. 2014). The degradation of land resources is often accompanied by a decline in crop yields, hence the need for an alternative approach to agricultural production that is both ecologically sustainable and profitable (Jat et al. 2014). Another challenge for agriculture today lies in its environmental footprint and contribution to climate change. According to the IPCC (2014), agriculture contributes approximately 30% of the total greenhouse gas (GHGs) emissions comprising CO_2, N_2O, and CH_4 and is also affected by the impacts of climate change.

The sustainable intensification of the agricultural production paradigm proposed by the FAO (2011a) emphasizes the need for agricultural practices that are productive and remunerative, which enhance both the resilience of the natural resource base and environment and provide environmental services, such as carbon sequestration. This implies that the sustainable intensification of crop production should not only reduce climate change impacts on crop production but also address the causes of climate change through GHG emission reduction. Moreover, sustainable intensification practices should enhance above- and belowground biodiversity within the crop production systems to achieve better productivity. According to Jat et al.

(2014), CA delivers on all of the aforementioned goals. The CA practice promotes the soil’s biological activity, thus stabilizing the yields in the long term and increasing the soil’s sequestration capacity.

The Concept of CA

Conservation agriculture is described as an approach to managing agro-ecosystems for improved and sustained productivity, increased profits, and food security while preserving and enhancing the natural resource base and the environment (FAO 2014a). CA is founded on three main principles, namely:

- Minimum or no tillage: This entails the minimum soil disturbance during planting, weeding, or harvesting. In special cases, seeding may be done in strips or bands, taking care to disturb less than 25% of the soil surface (FAO 2014b).
- Maintaining permanent organic mulch on the soil comprising of crop residues or cover crops.
- Diversifying the species of crops grown through sequences, rotations, or where perennial crops are involved using a balanced mix of leguminous and non-leguminous crops.

Through the three overarching principles, CA aims to conserve, improve, and make more efficient use of natural resources through integrated management of available soil, water, and biological resources (Vanlauwe et al. 2014a). This enhances environmental conservation and sustained agricultural production. CA has also been shown to reduce crop vulnerability to extreme weather events. For instance, in drought conditions, it reduces crop water requirements by up to 30%, makes better use of soil water, and facilitates deeper rooting of crops. In extremely wet conditions, CA facilitates rainwater infiltration, reducing the risk of soil erosion and downstream flooding.

The minimum soil disturbance principle of CA emphasizes the need for direct seeding, and once the soil condition has been well developed, tillage should be eliminated altogether. Soil disturbance from cultural practices such as weeding should be as minimal as possible, and a permanent or semi-permanent organic soil cover should be maintained all year round. This can be in the form of intercrops, cover crops, or mulch acquired from the residues of the previous crop. In addition, the diversification of crop rotations, association, and sequences adapted to the local environmental conditions should be practiced regularly (Njeru 2016). These help in maintaining above- and belowground biodiversity, fixing nutrients such as nitrogen into the soil, building soil organic matter, and suppressing the buildup of pests. The crop rotation principle also enhances soil fertility when legumes are included. The sequencing of crops according to seasons in the crop rotation cycle further minimizes the buildup of insect pests and diseases while optimizing nutrient use between the different types of crops.

The Benefits of CA

Impacts on Soil Quality

Soil is considered to be of good quality when it can sustain biological productivity, maintain environmental quality, and promote plant and animal health. The positive impact of CA with respect to soil quality improvement is often exhibited by an increase in soil organic carbon, good infiltration rates, high water-holding capacity, and good soil structure (Naab et al. 2017; Bamutaze et al. 2019; Mgolozeli et al. 2020). For instance, in their study, Mgolozeli et al. (2020) demonstrated the effect of CA in improving soil organic carbon particularly in the top 10-cm soil depth, promoting higher soil aggregate stability and improving the overall condition of the soil. Comparative studies of the infiltration capacity of soils under no-tillage (NT) and CT systems showed that soils in the NT system had higher total infiltration, and in the final steady state, the NT plots had an infiltration rate that was four times that of the CT plots (Fig. 1).

A conversion to conservation tillage from the conventional practices, in line with the CA principles, therefore helps improve soil structure and soil organic carbon, reduce the soil erosion risk, conserve soil moisture, reduce soil temperature fluctuations, improve soil quality, and the regulatory role it plays in the environment (Dube et al. 2012; Kakaire et al. 2015).

Impacts on Soil Carbon

Conventional tillage practices, such as the disk and chisel plough, are often associated with the significant loss of soil carbon (Fig. 2). The intensive cultivation of agricultural land has been shown to result in low amounts of soil carbon, limiting not

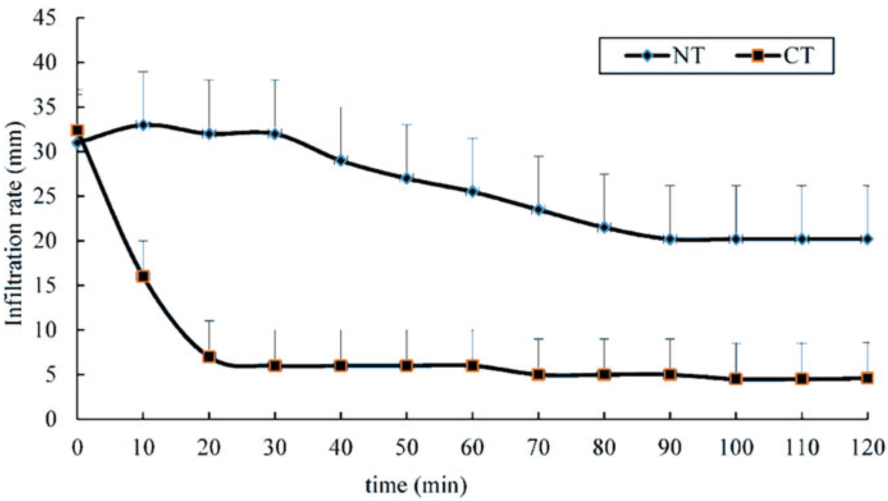

Fig. 1 Changes in the soil infiltration rate within 120 min under no-tillage (NT) and conventional tillage (CT) treatments. (Source: Mgolozeli et al. 2020)

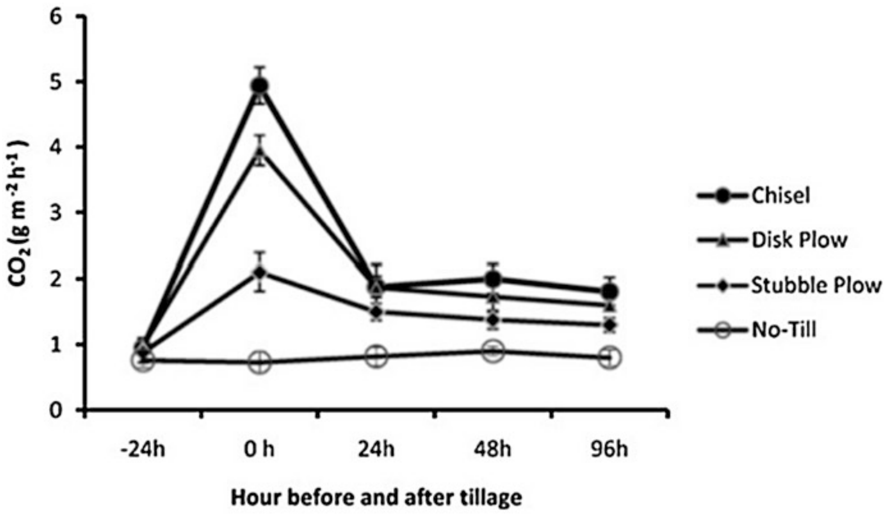

Fig. 2 CO_2 fluxes from soils associated with full tillage and NT systems. (Source: Mgolozeli et al. 2020)

just the soils’ carbon sequestration capacity but also productive capacity (Dube et al. 2012). Under a changing climate, organic mulch has the potential to enhance soil productivity through the moderation of soil temperatures. For instance, combining mulching and NT can help combat climate change by enhancing carbon sequestration processes while minimizing CO_2 emissions into the atmosphere (Haddaway et al. 2016). Thus, aside from the increased productivity and soil and land restoration, CA realizes additional benefits of environmental sustainability.

Economic Benefits

In addition to the potential of CA in sustaining crop production, the practice has also been established to realize economic benefits for farmers. The findings from a study by Micheni et al. (2015) showed that although the initial costs for CA establishments, especially with weeding, were high in the first two seasons, the net income from NT systems was significantly higher compared with that of CT practices in the long term. For instance, in the fourth season, the CA costs significantly decreased to USD 24/ha compared with the constant costs of conventional systems of USD 88/ha. High cost saving was realized from the elimination of land preparation and weeding, which are common agronomic practices in CT systems. These findings are comparable with those of Guto et al. (2012) and Naab et al. (2017) who indicated that the net income from CA was higher than that of conventional systems. The low labor requirements in the CA system imply that there will be more time available to engage in off-farm income-generating activities. Additional studies from Morocco show that for many smallholder farmers, the economic gain attained from a practice supersedes the gains made in soil conservation when it comes to the adoption of labor-saving technologies (Mrabet et al. 2012). The benefits accruing from NT practices are therefore not just ecological/environmental but also reduced production costs and higher incomes to improve the well-being of farm families.

Overview of Climate Change Risks and Vulnerability in the Taita Hills

The Taita Hills are located in the Taita–Taveta County within the coastal region that lies in South Eastern Kenya. The hills form the northernmost part of the 850-km^2 stretch of the Eastern Arc Mountains in Kenya and lie within the Tsavo ecosystem which is mainly semiarid. The hills extend through different altitudinal zones depicting different agro-ecological zones within the area (Fig. 3).

Climatic and non-climatic factors interact to make the Taita Hills vulnerable to the impacts of climate change. According to Waithaka et al. (2013), some of the visible changes associated with climate change and variability in the area include the degradation of soils from moisture stress and high temperatures, limited rainfall as observed in the reduction of the volume of water in rivers, and increased frequency of extreme weather events such as floods and droughts, among others. According to the GoK (2017), the Taita Hills experience two major rainfall seasons: the long-rains season experienced between March and May (MAM) and the short-rains season experienced between October and December (OND), which in turn give rise to two planting seasons. Farmers rely on both seasons for the cultivation of their staple crops. However, the short-rains season has been noted to be more reliable than the long-rains season (GoK 2017). This is because the long-rains season is characterized

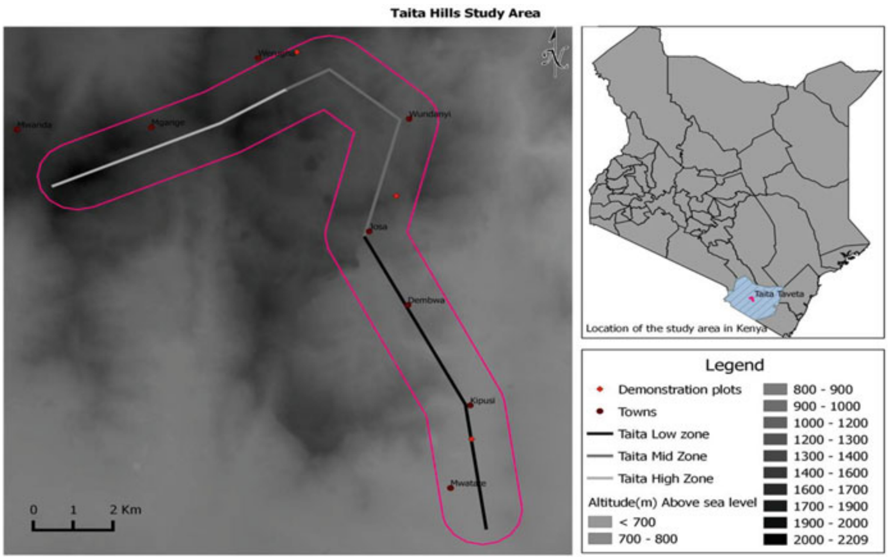

Fig. 3 Geographical location of the study area (Source: Motaroki 2016)

by, among other factors, unreliable rainfall patterns, whereby the onset of rain is delayed and cessation occurs very early in the season.

Non-climatic factors, such as high population growth, high poverty levels, poor farming methods, deforestation, and low use of technology, also have negative impacts on the status of agricultural resources, such as land and water. Due to the high rates of population growth, the area is currently characterized by small fragmented land holdings that are cultivated frequently with minimal conservation efforts, thus resulting in highly degraded soils with low fertility (Maeda 2012). A study by Muya et al. (2019) in the Taita Hills showed that in the maize-based and horticultural systems that are intensely cultivated, the amount of soil C was very low (1.6%) compared with soils under forests where the amount of C was about 7.6%. The land use intensity (LUI) in horticulture and maize-based systems was found to be over 30% compared with the LUI in forest systems (less than 2%). A similar trend was observed in the productivity index (PI), with the highest (40–50%) being recorded in natural forest and grassland and the lowest (15–20%) in horticultural and maize-based systems. The study concluded that the low soil quality and low productivity in horticulture and maize-based systems were associated with the intensification of land use as a result of inadequate knowledge on the appropriate management practices to apply. High poverty levels and lack of information cause people to engage in unsustainable practices, such as deforestation and poor farming methods, which result in land degradation. In the areas that have undergone deforestation, soil erosion has been indicated to be a major problem, with most of the terrain characterized by deep gullies.

Climatic Variability in the Taita Hills

Analysis of rainfall data for the County showed an overall declining trend in the amount of rainfall received in the various agro-ecological zones since the 1960s. The time series plot for Wundanyi (mid-altitude agro-ecological zone) showed a decline in the amount of rainfall received, the average for the years between 1993 and 2006 being less than 600 mm. This is an area that initially received between 900 and 1200 mm of rainfall per season, thus indicating a large deficit in the mentioned years (Fig. 4).

The time series analysis of Maktau in the lower zone shows the highest amount of rainfall recorded to be 626.4 mm in 1967; otherwise, there is a general declining trend in the years following 1967, with most of them receiving less than 350 mm of rainfall. This is below the average precipitation range for the lowlands which lies between 350 and 400 mm. Furthermore, the optimum rainfall condition for productive agriculture in the lowland areas is 450 mm, considering the maize variety grown. However, the time series shows the amount of rainfall received to be less than 450 mm for the period when rainfall was recorded in the weather station at Maktau (Fig. 5).

The time series analysis for the short rainy season (OND) also shows a general declining trend of observed rainfall in all the three agro-ecological zones. In the high-altitude zone, the average annual rainfall received is below 700 mm for an area that received more than 1000 mm in the past years. Similar trends are observed in the

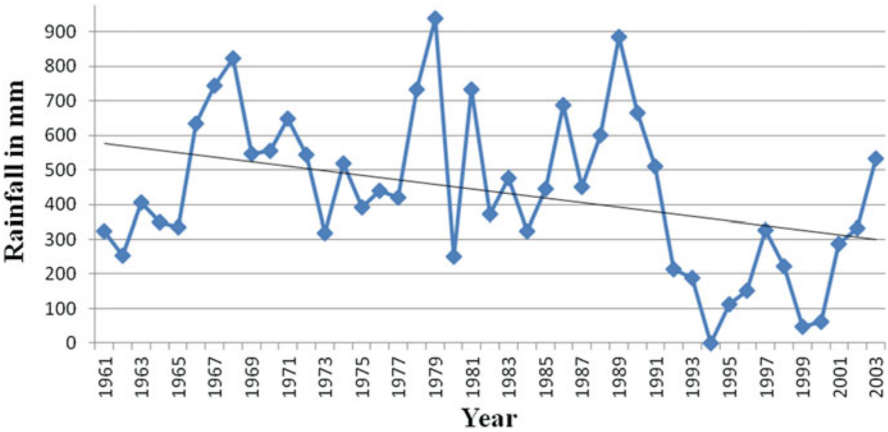

Fig. 4 Time series plot of MAM rainfall season for Wundanyi–1480 m.a.s.l (Source: Motaroki 2016)

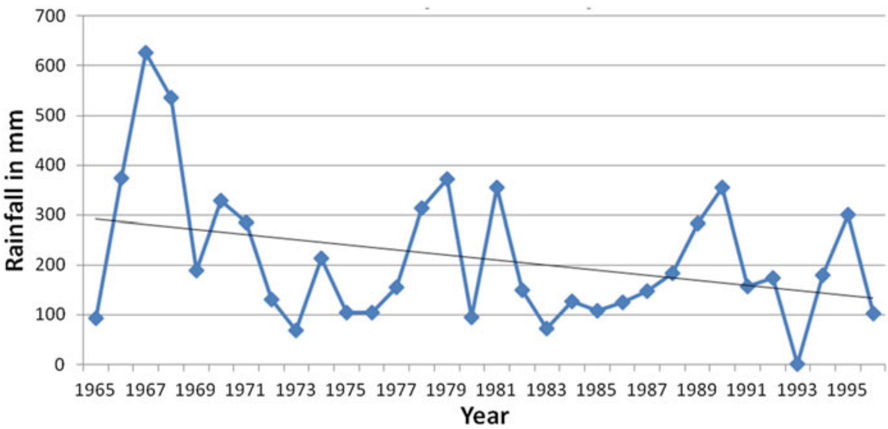

Fig. 5 Time series plot of MAM rainfall season for Maktau–700 m.a.s.l (Source: Motaroki 2016).

mid- and low-altitude agro-ecological zones where the average annual rainfall remains below 600 mm and 400 mm, respectively.

This is in agreement with the farmers' perception of variations in rainfall. The respondents from the focus group discussions (FGDs) conducted in each of the three agro-ecological zones noted that they were aware of the changes in rainfall that had taken place in the Taita Hills area over the past 20 years. The most obvious changes in rainfall reported by the respondents included drought and erratic rainfall patterns characterized by late onset and early cessation of seasonal rainfall. More specifically, drought was reported to be the most serious event, as it usually results in the loss of the entire crop, whereas erratic rainfall patterns resulted in a decline in crop yield and food shortages. Similarly, studies on the Taita Hills by Mwalusepo et al. (2015) established that the farmers were aware of the climate variability and change within their localities and the perceived changes in rainfall regimes and temperatures as well as the implications on their livelihoods.

Drought has already been indicated as a threat to food security in Kenya and is reported by the GoK (2012) as an important cause of crop losses in the Taita Hills. Observations from the IPCC (2014) show that rainfall in East Africa is likely to increase in the twenty-first century, which will be indicated by an increase in the number of extreme wet days to roughly 20%. However, even if the amount of rainfall recorded in the preceding years increased, it may not translate to improved agricultural production because the projected increases in temperature will lead to high evapotranspiration rates, thus causing water scarcity. Farmers also noted significant temperature variation with the cycles for crops like maize getting shorter and bean farming particularly in the high altitude areas that were initially very cold becoming more favorable. The high temperatures have also been accompanied by an increase in the incidence of pests and diseases that causes the decline in productivity in both crops and livestock. According to the Food and Agriculture Organization, FAO (2016), the production techniques that are part of conservation agriculture, for example, crop rotations and maintenance of a permanent soil cover, enhance soil and water conservation, thus enabling crops to withstand periods associated with rainfall variability and drought.

Crop Production Trends

The data from Osano *et al*. (2018) show that 80% of the total households in the Taita–Taveta County engage in maize production, 46% in bean crop production, and 31% in cowpea production. However, while the acreage under crop production has continuously increased, yields have continuously declined over the years due to climate change and other factors (Table 1). The overall productivity of major staple crops is very low, hence the need for better farming technologies and improved varieties. The maize crop in particular is highly sensitive to fluctuations in climate, with moisture and heat stress identified as the primary hazards for the crop.

Table 1 Short-rains crop production in the Taita–Taveta County in 2017

Crop	Acreage (ha) planted in the short-rains season	Long term average (LTA) acreage planted in the short-rains season	Actual production (90 kg bags) in the short-rains seasons	LTA production (90 kg bags) in the short-rains season
Maize	9172	9600	7849	60965
Cowpeas	805	810	4035	6830
Green grams	1079	1289	5186	5930

Source: Osano *et al*. (2018)

Table 2 Long-rains crop production in 2017

Crops	Acreage (ha) planted during the long-rains season	LTA (ha) (5 years) planted during the long-rains season	Actual long-rains production (90 kg bags)	Long-rains seasons LTA production (90 kg bags)
Maize	3681	7380	5522	22140
Beans	1069	1735	3207	10410
Green grams	1123	1566	4492	8613

Source: GoK (2017)

The land area under maize and cowpea cultivation during the 2017 short-rains season was near the long-term average (LTA), excluding the land area under green gram cultivation, which was 16% below the LTA (Osano et al. 2018). Despite the slight reduction in acreage under cultivation, the actual production of green grams was better than that of maize and beans. The 2017 short-rains seasons was also characterized by an 87% decline for maize production, 40% for bean production, and 13% for green gram production compared with the LTA (Table 1). The decline in maize production was attributed to late onset of the short rains, poor rainfall distribution both in time and in space, early cessation of rains, and crop damage caused by wildlife. Cowpea was affected by increased plucking of leaves by farmers for vegetable consumption, which negatively affected the yields and the crop's growth, hence reducing the production.

The County is mainly dependent on short rains for crop production, whereas the long rains that have increasingly become unreliable contribute 20% of the food requirements in the County. Table 2 shows the production of maize, beans, and green grams, which are the major crops grown during the long rains. The area under maize, bean, and green gram production declined by 50%, 38.4%, and 28.3%, respectively, due to prior weather forecasts, indicating the possibility of reduced rainfall during the long rains. Poor performance of the preceding short-rains seasons also contributed to the farmers' reluctance in cultivating large areas during the long-rains season (Muraguri and Nyamai 2017).

There was a significant decline in the production of all the three major crops: 75% for maize, 69.2% for beans, and 47.8% for green grams. Such a decline is mainly attributed to poor rainfall distribution in time and space as well as late onset and early cessation of rainfall. This is in agreement with the findings from a household survey targeting 600 households in the area where respondents noted that food shortages are currently on the rise, and farmers do not obtain enough yields as they did in the past. The main reasons reported for this were climatic events, including erratic rainfall patterns, above- and below-average rainfall, strong winds, floods, and frost. Other factors mentioned were high occurrence of pests, such as bean aphids, bean weevils, and cutworms, soil factors especially poor soil fertility, poor agronomic practices, and lack of inputs. The decline in crop production is a clear indication that farmers need to adopt CA which has shown potential to increase production through the integrated management of available soil, water, and biological resources (FAO

2018). This reduces the vulnerability of crops to extreme weather events, such as droughts and floods, thus sustaining crop production.

Soil-Related Constraints

Soils are the foundation for agricultural production, hence the need for their sustainable use and management. The fertility status of soil determines the level of crop yields achieved. According to the GoK (2014), soil degradation is a major challenge to agricultural production in the Taita Hills, which leads to a decline in soil fertility. Based on the results from the household survey (Table 3), 63.3% of the respondents considered their soils to be moderately fertile, 15% noted that it was poor, 18.7% reported their soils to be very fertile, whereas 3% did not know the fertility status of their soils. When asked whether there had been a change in the fertility of their soils considering the quantity of yields obtained over the last 10 years, 55.9% indicated that it had declined, 25.2% reported it remained the same, whereas 15.2% reported that it had improved. The key factors responsible for the decline in soil fertility include continuous ploughing reported by 22.9% of the respondents, drought reported by 13.5%, use of inputs mentioned by 13.7%, floods reported by 9%, and lack of inputs reported by 2.2%. Those whose soil fertility had improved attributed such an improvement to enhanced land use practices. However, a larger percentage (29.7%) did not know the reason for the decline in the fertility of their soils.

Although the use of farm inputs, such as improved seeds, fertilizers, pesticides, and herbicides, is essential to achieve optimum crop production, assessments at the county level show that such use is generally low in the County. The low rates of input

Table 3 Soil fertility status in the Taita Hills

Soil Factors	High Zone	Mid Zone	Low Zone	Total
Soil Fertility N = 401				
Very Fertile	32	15	28	75
Moderate	89	76	89	254
Poor	20	24	16	60
Do not know	1	1	10	12
Change in Soil Fertility N = 401				
Improved	17	27	17	61
Same	37	19	45	101
Declined	86	69	69	224
No response	2	1	12	15
Reasons for the Decline in Soil Fertility				
Continuous tillage	38	28	26	92
Droughts	30	10	14	54
Use of inputs	12	40	5	57
Floods	5	11	22	38
Lack of inputs	5	3	1	9
Improved land use practices	13	7	12	32
Do not know	31	40	48	119

use is attributed to a number of reasons, including high input prices, limited access due to the distance to markets, and failure to access inputs at the right time (GoK 2014). From the survey, the various inputs used in producing maize (staple crop) include commercial fertilizer reported by 24.2% of the respondents, improved seed variety reported by 35.9%, manure reported by 30.7%, and pesticides reported by 4.5%. However, the inputs used in common bean production were minimal, including commercial fertilizer reported by only 2% of the respondents, improved seed reported by 6.2%, manure reported by 4.7%, and pesticides reported by 0.2% of the respondents. Farmers attribute their constant low yields to the use of poor-quality seed, lack of fertilizer, and manure amendments during planting.

Coping and Adaptation Strategies Currently Employed by Farmers

Just like most households in SSA, households in the Taita Hills rely on a combination of informal risk-sharing arrangements to cope with the impacts of climate change and variability. These include, for example, taking cash loans from neighbors and relatives to buy food, relying on remittances, and sending children to live with relatives (Shuaibu et al. 2014). These coping mechanisms are not sufficient or sustainable to address the challenges, and they are even more limited for the poor, landless and unemployed individuals, women, children, and large-sized households who are more vulnerable (Shuaibu et al. 2014). The respondents reported various ways in which they are coping up with the climatic events impacting their households. In coping with drought events, most of the respondents (70.9%) reported that they bought food, 6.6% sought off-farm employment, 2.8% ate different types of food, 4.7% borrowed from friends and relatives, 2.8% relied on food aid from the government, and only 2.3% changed their farming practices. However, while coping strategies such as buying food may help them in the short term, it is important to find long-term sustainable solutions, such as a shift into sustainable farming practices or livelihood diversification to off-farm activities that generate income to buffer against climate shocks (Table 4).

Table 4 Actions taken to cope with drought

Action (N=213)	High Zone	Mid Zone	Low Zone	Total
Did nothing	4	1	8	**13**
Assistance from friends/relatives	3	3	4	**10**
Relied on savings	5	2	1	**8**
Government food aid	2	3	1	**6**
Changed farming practice	0	2	3	**5**
Bought food	48	35	68	**151**
Sought off-farm employment	5	5	4	**14**
Ate different types of food	2	1	3	**6**

(Source: Motaroki 2016)

According to the MoALF (2016), the government of the Taita–Taveta County has supported and promoted adaptation strategies, such as drought-tolerant varieties of crops, rainwater-harvesting techniques, growing of trees, terracing, and other climate-smart agricultural practices. However, despite the critical role that CA plays in restoring degraded soils, stabilizing yields in the long term, and enhancing food security, few studies have attempted to assess its role in making smallholder farming systems more resilient to the impacts of climate change.

Conservation Agriculture to Enhance Adaptation in the Taita Hills

Projections show that in the period 2021–2065, the temperature in the Taita–Taveta County will increase by 0.4 °C, with greater changes expected in the long-rains season (MAM) (MoALF 2016). During the same period, projections show a 0.8% increase in precipitation in the long-rains season and a 6% increase in the short-rains season (OND). However, high evapotranspiration rates resulting from high temperatures will lead to prolonged moisture stress. The number of consecutive days experiencing moisture stress is expected to increase from 70 to around 85–90 in the long-rains season but is projected to decrease from 80 consecutive days to approximately 30 in the short-rains season.

Conservation agriculture in the Taita Hills has the potential to restore soil fertility and sustain agricultural production by stabilizing yields even during periods of sporadic rainfall and increased moisture stress, which are expected to increase in the future, while achieving other co-benefits, such as soil erosion control and reduced labor demands. However, making substantial gains from CA requires understanding when and where the practice is most effective. According to Mutuku et al. (2020), smallholder farming systems have large variations in terms of soil properties and rainfall conditions, which in turn affect the impact of CA-based practices on crop yields. There are also differences in the physical, biological, and chemical conditions of soils at the field scale as well as variations in weather patterns over time and scale.

Case Study of CA in the Taita Hills

Although few studies have tried to assess the potential of CA in the Taita Hills, the experimental assessments of CA in comparison with conventional farming practices undertaken by Motaroki (2016) established that the practice can help in increasing crop production, particularly in the semiarid lowlands.

Case Study 1

A participatory learning and action approach was used to set up demonstration plots in each of the three agro-ecological zones to compare yields from conventional tillage practices and CA for two consecutive seasons. There

(continued)

was no visible difference in the key yield indicators for the two seasons examined in both the high and mid-altitude agro-ecological zones. This could be explained by the fact that farmers in the high and mid-zones do not experience extreme conditions of drought as the lower zones. However, for the two seasons studied, there was a large visible difference in all the yield indicators for the CA treatment compared with the conventional tillage practices in the low-altitude agro-ecological zone. The zone lies in an arid and semiarid land area characterized by low rains for most parts of the year and poor soils. The effect of mulch in conserving soil moisture as well as the combined effect of organic and inorganic fertilizers could explain the immediate change in the observed yield for the area. As a matter of fact, in the second season, only the CA plot sustained crop growth, whereas the entire crop died when the conventional practices were used due to low and erratic rainfall.

Case study 1 emphasizes the importance of soil protection using mulch and the role that good agronomic practices play in minimizing the growth of weeds, promoting the growth of healthy plants, and consequently improving crop yields, especially in the drier lower zone. The conventionally grown farmers' practice plots are characterized by poor crop growth and exposure to surface runoff. Furthermore, the fact that only the CA treatment yielded results during the JJAS season further reinforces the importance of CA in arid and semiarid zones as well as the need to invest in drought-tolerant varieties of crops. Similarly, on-farm experimentation of CA by Micheni et al. (2015) showed that in drier environments, crop yield response to CA was immediate, whereas in the wetter (highland) zones, significant advantages in yield were observed from the third season onwards.

Barriers to Effective Uptake of CA

According to Njeru (2016), the issue of land tenure is a major factor influencing the adoption of CA in Kenya and many countries in Africa. There is a very low possibility of farmers investing in land with unsecured access in the long term. Particularly, considering the small sizes of land holdings in the Taita Hills, farmers have a tendency to rent in more land for their crop production. Farmers have reservations about adopting soil conservation practices such as CA because chances are high that the owners will claim their land back as soon as the fertility increases and they notice increased yields. Moreover, when farmers rent in land, they are more interested in maximizing profits from their tenancy; hence, investments in conservation practices such as CA that realizes benefits in the long term are not their priority.

Table 5 Barriers to CA Uptake

Barrier s (N= 105)	High Zone	Mid Zone	Low Zone	Total
Small farm size	5	2	2	**9**
Expensive	1	3	4	**8**
Not profitable	29	5	10	**44**
Risk-prone	1	7	8	**16**
No specific reason	10	4	13	**27**

In the initial years, CA increases weeds on the farm and requires additional inputs, without necessarily increasing yields. It may take up to 4 years before farmers can notice any differences in yields after adopting CA since the restoration of soil fertility takes time. In the field assessment of CA, Motaroki (2016) established that in the two seasons examined, minimal changes in yield were observed between the CA and CT plots, especially in the high and mid-altitude agro-ecological zones. As such, farmers renting a plot for less than 5 years are less likely to adopt CA as their primary concern is to increase production and profits in the short term rather than increase the quality of soils they will only use temporarily. This implies that in order to scale up and enhance widespread adoption of CA in the Taita Hills, assuring farmers of tenure security is critical.

Further, a transition from tillage-based systems to CA incurs significant costs, and for the resource-poor farmers in the Taita Hills, this may be a hindrance to their adoption of the practice. It is therefore important to provide financial support and enable the initial stages of CA adoption by giving farmers the necessary incentives in the form of subsidies. In their analysis, Kassam et al. (2014) noted that there have been cases in SSA where farmers reverted to their conventional farming practices once support for CA adoption was stopped. The above observations are in line with the results from the household surveys which showed that with regard to farmers’ knowledge of the CA practice, 39.7% of the survey respondents stated that they were aware about the practice, having been introduced to it through seminar and by neighbors, agricultural extension officers, and the radio. However, only 3.7% of those who were aware about CA practiced it on their farms, stating several barriers, such as high risk and lack of economic returns (Table 5).

Cultural barriers have also been identified as one of the greatest challenges to CA adoption that has been reported in Kenya (Njeru 2016). For as long as they have been farmers, Kenyans and Africans at large have always tilled their lands such that the introduction of zero or minimum tillage faces resistance and skepticism. Another important challenge arises from the slash-and-burn system that is common in many parts of the country and Africa at large, which diminishes the availability of crop residues for mulching and incorporation into the soil (Kassam et al. 2014). Furthermore, studies show that many farmers are reluctant to use herbicides in their farms, making weed management a challenge and a hindrance to optimum crop production. Giving these farmers support in understanding new concepts and principles will create the desired change in the mindset and promote commitment to a long-term process of changing their production systems and testing and adapting new practices and technologies.

Studies by Pretty et al. (2011) have shown social capital to be an important prerequisite for a wide-scale adoption of sustainable practices. Farmers often have a tendency to trust their peers more than their formal advisors when evaluating potential innovations for their farms. This in effect emphasizes the importance and role of farmer organizations in embracing CA and drawing in more members within the locality to adopt the practice. Furthermore, scaling up CA to achieve impact at the local, sub-national, and national level will require a strong enabling policy and institutional environment characterized by training and enhanced access to knowledge, research, and the required inputs. If properly organized, the farmer groups or organizations can use their bargaining power to pressure local governments and institutions to create the required reforms to upscale CA (Kassam et al. 2014).

Lessons Learned, Limitations, and Recommendations for Future Research

Conservation agriculture has been shown to stabilize yields in the long term and increase the soil's ability to sequester carbon, thereby delivering on both adaptation and mitigation goals. However, a number of barriers still hinder its effective upscaling to promote widespread adoption in the Taita Hills. Overcoming these barriers will require implementing a number of measures, including incentivizing resource-poor farmers in terms of tenure security and subsidies, enhancing farmers' understanding on the benefits of CA activities such as minimum tillage, creating an enabling environment through institutional and policy support, and leveraging on social capital in target localities to promote the adoption of CA, inter alia. The case study that informed this chapter was only conducted for two seasons, which hindered the evaluation of the significant differences between the treatments used. As such, future research will need to explore the possibility of conducting field assessments over several seasons and where possible replicate the treatments in order to assess whether significant differences in the actual yield exist between CA and conventional farming methods.

Conclusion

Studies conducted in the Taita Hills have established that climate change and variability are occurring in the area as characterized by erratic rainfall patterns, high temperatures, and increased frequency of extreme weather events, such as droughts and floods. This poses a major threat to farming, which is the major source of livelihood in the area, considering that it is mostly rainfed and thus under the direct impacts of climate variability and change. Although CA has been established to maintain the soil in a carbon-rich condition and sustain production under a changing climate, its adoption remains slow due to existing barriers. To overcome these barriers and catalyze investments for upscaling and bringing about the desired reforms to advance the CA cause, strategies (policy, technological, and institutional) must be put in place for an effective adoption. These include assuring farmers of tenure security, providing financial and technical support through appropriate subsidies, capacity development, and gender-responsive policies, inter alia.

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