

Synergies and trade-offs of selected climate smart agriculture practices in Irish potato farming, Kenya

Robert John O Ogola & Kevin Okoth Ouko |

To cite this article: Robert John O Ogola & Kevin Okoth Ouko | (2021) Synergies and trade-offs of selected climate smart agriculture practices in Irish potato farming, Kenya, Cogent Food & Agriculture, 7:1, 1948257, DOI: [10.1080/23311932.2021.1948257](https://doi.org/10.1080/23311932.2021.1948257)

To link to this article: <https://doi.org/10.1080/23311932.2021.1948257>



© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.



Published online: 06 Jul 2021.



Submit your article to this journal [↗](#)



Article views: 136



View related articles [↗](#)



View Crossmark data [↗](#)



Received: 9 February 2021
Accepted: 23 June 2021

*Corresponding author Robert John O Ogola, Water Systems and Global Change Group, Department of Environmental Sciences, Wageningen University & Research, P.O. Box 47, 6700 AA, Wageningen, The Netherlands
E-mail: robertjohn57@gmail.com

Reviewing editor:
Manuel Tejada Moral, University of Seville, Seville SPAIN

Additional information is available at the end of the article

SOIL & CROP SCIENCES | RESEARCH ARTICLE

Synergies and trade-offs of selected climate smart agriculture practices in Irish potato farming, Kenya

Robert John O Ogola^{1*} and Kevin Okoth Ouko²

Abstract: Research on and disseminating Climate Smart Agricultural (CSA) practices has led to increased awareness and farmers' capacity to develop resilient agricultural production systems for sustainable livelihoods and food security while addressing climate change adaptation and mitigation. Thus, there is a potential in gaining valuable insight into how Irish potato smallholder farmers should respond to current and future climate risks. However, studies exploring and linking expert opinion on synergies and trade-offs in adapting the CSA practices are limited. This study integrated qualitative and quantitative data from 22 expert surveys and semi-structured questionnaires to answer the following objectives: 1) Which top five CSA practices are currently used by Irish potato farmers and which ones are preferred by experts in response to climate change adaptation in Kenya? 2) How do the selected CSA practices perform in Irish potato farming in Kenya? 3) Which synergies and trade-offs occur upon implementation of these CSA practices? The study found that CSA practices most preferred by both experts and farmers are improved crop varieties, efficient use of agrochemicals, early land preparation, diversified crop production, efficient use of inorganic fertilizer, irrigation and changing planting dates. These selected CSA practices indicated the productivity pillar to be the best performing CSA pillar synergistically while trade-offs to occur across CSA pillars. These findings can inform different potato value chain stakeholders on the synergies and trade-off dynamics associated with adopting CSA practices for climate

ABOUT THE AUTHOR



Robert John O Ogola

The first author is a graduate of Master of Science in Climate Studies (Ecological and Agro-Ecological Systems) at Wageningen University & Research, the Netherlands. He is an Orange Knowledge Programme (OKP) scholar. He is also an Agribusiness Officer at the County Government of Kisumu, Kenya. The second author, Kevin Okoth Ouko is a Doctoral Fellow in Food Security and Sustainable Agriculture at Jaramogi Oginga Odinga University of Science and Technology, Kenya. He is also an African Economic Research Consortium (AERC) graduate under a Collaborative Master of Science in Agricultural and Applied Economics (CMAAE) programme and a Part-Time Lecturer of Agricultural Economics and Agribusiness Management at Rongo University, Kenya.

PUBLIC INTEREST STATEMENT

In recent years, climate change has adversely impacted Kenya's agriculture and thus affected the livelihood of people depending on agriculture. Unpredicted rainfall patterns, rising temperatures, floods, droughts and water scarcity have impacted food production systems. Climate Smart Agriculture (CSA) has emerged as one of the solutions to the changing climate. Productivity, adaptation and mitigation are important CSA pillars necessary to adjust to the changing scenario. Synergies and trade-offs from CSA pillars have been studied before but not specifically related to growing Irish potatoes. This study contributes to the literature by considering Irish potato as it contributes to food security, income generation and its promotion in sub-Saharan Africa (SSA) countries.

change adaptation. In conclusion, while CSA practices are perceived as essential, most preferred CSA practices are focused on increased production and adaptation, while mitigation goals receive less attention. The findings of this study provide an important basis for recommendation to farmers and policymakers. This study calls for sustainable and innovative ways that help to upscale the selected CSA practices in Irish potato farming in Kenya and beyond.

Subjects: Agriculture & Environmental Sciences; Botany; Plant & Animal Ecology; Soil Sciences; Environmental Issues; Environment & Society; Biodiversity & Conservation; Environmental Policy; Environmental Law - Environmental Studies; Environmental Change & Pollution

Keywords: synergies; trade-offs; climate change; climate smart agriculture; Irish potato; Kenya

1. Introduction

Agriculture is recognized globally as a highly vulnerable sector to climate change and the risks from climatic variations pose an imminent danger to the food security and sustainability of livelihoods (Singh et al., 2021). Globally, Irish potato ranks as the world's fourth most produced food crop after wheat, rice and maize (Chapman, 2012; Okello et al., 2016) and its production is prone to climatic variations. The world's top potato producing regions are China leading with an average annual production of 99.1 million tons followed by the European Union producing 56.2 million tons. In the third position, India produces 48.6 million tons. Africa has an area estimate of 1.9 million hectares (ha) under Irish potato which yields 26 million tons (FAOSTAT, 2018). In sub-Saharan Africa (SSA), Egypt is the leading potato-producing country with 4.9 million tons, followed by Algeria, 4.65 million tons. In the third position is South Africa producing a capacity of 2.47 million tons. In comparison, Kenya is ranked in the fifth position, with an estimated 1.87 million tons harvested annually in 217,315 ha (FAOSTAT (2018). Production of Irish potato as one of the main crop of the group of root and tuber crops has been expanding in Kenya due to its economic benefits and promotion of the value chain by the Kenyan government (Kangogo et al., 2020). Irish potato contributes to poverty alleviation through income generation to an estimated 800,000 farmers directly involved in its production in Kenya (Muthoni et al., 2017). Irish potato value chain employs over 2.5 million Kenyans as market agents, transporters, vendors, processors, vendors and retailers (Okello et al., 2016).

Nevertheless, the net effects of climate change on Irish potatoes will either have positive or negative effects depending on the specific production regions and the ability of farmers to adapt production practices to changing conditions (Ndegwa et al., 2020). Several approaches for adapting and mitigating climate change effects on agricultural production have been developed and recommended. One such approach is Climate-Smart Agriculture (CSA), which has gained traction in most African countries (Lipper et al., 2014). CSA is based on three interim goals: increasing agricultural productivity and incomes sustainably and equitably, creating healthy food systems and farming livelihoods to become more resilient and minimizing agricultural greenhouse emissions (Gurung et al., 2016). CSA promotes the efficient use of land, water and other environmental resources to attain higher yields, put more carbon in the soil, greater adaptation to prolonged dry spells and unpredictable rainfall seasons. CSA has shown to be highly promising, combining the advantage of sustainable increases in agricultural production, transformation and growth of robust agricultural and food security systems. Thus, whether technology is CSA, is based on its impact on these outcomes and agricultural interventions that meet these goals are considered "climate-smart" (FAO, 2013). Additionally, CSA approach leads to reduced agricultural emissions of greenhouse gases (GHGs), leading to achieving Sustainable Development Goal (SDG) 13 of addressing climate action (Abegunde et al., 2020; Ahmad et al., 2020).

Improving uptake and intensification of farm-level utilization of climate-smart agriculture (CSA) strategies among farmers is essential to develop resilient production systems for sustainable livelihoods and food security while addressing climate change adaptation and mitigation. Synergies and tradeoffs are characteristics of climate-smart agricultural interventions. Many farm-based management practices and technologies deliver two or three of the three climate-smart benefits (Kurgat et al., 2020). According to Mainali et al. (2018), synergy is an interaction among two or more actions, which will lead to an impact greater or less than the sum of individual effects. Therefore, synergies are positive outcomes, while trade-offs are negative outcomes. CSA practices are not supposed to be alternative targets but parallel outputs of CSA to Irish potato farmers in Kenya. Although trade-offs in the three pillars of CSA (productivity, adaptation and mitigation) are inevitable, achieving adaptation and mitigation in Irish potato production without compromising its production and availability potential is still a huge challenge to policymakers and researchers.

A holistic approach is critical to achieve the maximum potential benefits of the CSA practices and reduce the trade-offs from the CSA practice. The trade-off in implementing the CSA practices varies and may affect both the farmers' output and the environment. Irish potato farmers strive to get as much production from their harvest as possible, which may be affected by the type of practices or input they use in their farms. Combining different technologies can increase the farm's productivity, hence increasing the farm income (Mwongera et al., 2017). However, the adoption of some technologies can increase labour use, emissions and pollution, leading to trade-offs (Klapwijk et al., 2014). Thus, CSA requires planning to address trade-offs and synergies between productivity, adaptation and mitigation.

In search of locally appropriate options to increase farming system's resilience and livelihoods to climate variability, trade-off analysis has emerged as a key process to assess agricultural innovations' suitability (Shikuku et al., 2015). In Irish potato production, there are several possible adaptation options for managing moderate to extreme climate risks. Changes in crop management practices, general field management, farm risk reduction, soil conservation and information access practices are essential in improving agricultural adaptability to climate change (Muthoni et al., 2017). These options also increase crop yield, boost production efficiencies and net farm incomes and where possible, minimize greenhouse gas emissions. Many of them have successfully increased production, revenue and established the resilience of agricultural communities in many ways (Gurung et al., 2016).

Although CSA strives to simultaneously improve the three pillars of production, adaptation and climate change mitigation, it acknowledges that not every recommended practice applied in every place can achieve such a triple win. In Kenya, there are knowledge gaps on how Irish potato farmers can achieve synergies and minimize trade-offs in implementing various CSA interventions. There is thus a need for multi-stakeholder analysis of possible strategies to upscale CSA technologies. Therefore, this study sought to address this knowledge gap by undertaking synergies and trade-off analysis in adapting CSA technologies in the context of smallholder Irish potato farmers in Kenya from the experts' perspective. The study will contribute to the scanty literature on expert's opinion analysis in climate change, adaptation and mitigation in Irish potato production in Kenya.

2. Methodology

2.1. Identifying CSA practices

First, in identifying the relevant CSA practices among Irish potato farmers, a desktop search involving searching for information online was done. This was based on secondary data collected from online databases including Science Direct, Scopus, RefSeek and CAB abstracts. Additionally, we scoped for information using an iterative process in published literature from selected international institutions involved directly and indirectly in climate-smart agriculture. These included Climate Change, Agriculture and Food Security (CCAFS) programme under the Consortium of

International Agricultural Research Centers (CGIAR) and the International Center for Tropical Agriculture (CIAT).

In the preliminary search, 258 articles were selected from the search engines and databases output, 78 articles identified through other sources such as reports were also selected. The study also reviewed dissertations approved between the years 2009 and 2020. After limiting to articles with full text, the total number reduced to 75 which were then reviewed; however, non-research articles and dissertations which were not available were omitted. Finally, the 45 articles that were found eligible and relevant for the review were selected for the study. Their contents were thoroughly reviewed to determine the CSA practices being used for climate adaptation in Irish potato farming.

The list of CSA practices retrieved from the literature review was sent to different Climate Change and Value Chain Experts. The list was assessed, and 19 suitable CSA practices were identified for the three CSA pillars based on five CSA strategies namely Crop management practices, General field management practices, Farm risk reduction practices, Soil conservation practices and Information access practices as in [Table 1](#).

Table 1. CSA strategies and practices identified through literature review

CSA strategy	CSA practice identified through literature
(1) Crop management practices	• Use of improved crop varieties
	• Use of legumes in crop rotation
	• Use of cover crops
	• Changing planting dates
	• Efficient use of inorganic fertilizers,
	• Early land preparations
	• Efficient use of agrochemicals (pesticides and herbicides)
(1) General field management practices	• Agroforestry such as use of live barriers, planting trees on cropland
(1) Farm risk reduction practices	• Diversified crop production
	• Irrigation
	• Crop insurance
(1) Soil & water conservation practices	• Use of organic fertilizers
	• Mulching
	• Minimum tillage
	• Ridges, farm terracing, hedges, stone lines, water harvesting structures
(1) Information access practices	• Farmer-to-farmer knowledge sharing
	• Membership to farmer associations
	• Received education/training on how to access weather information by an organization
	• Get access to information of market prices of produce & inputs

2.2. Expert's selection

Purposive sampling method was used to select 28 experts for this study as there was no consensus required on the number of participants required since this was a Delphi study (Roy et al., 2014). The following inclusion criteria were used to select the experts involved in this study:

- (i) Individuals who have been directly involved in Irish potato research, expansion, management and marketing for at least 5 years
- (ii) Individuals who have been engaged or consulted for a minimum of 10 cumulative years in agricultural policymaking in the potato value chain within the government or private sector.
- (iii) Individuals from academic, non-governmental organizations (NGO) and government involved in Climate Smart Agriculture potato value chain.

Out of the 28 CSA experts selected, 22 responded to the invitation to join the study and completed the questionnaire and the interviews. Six of the selected CSA experts declined, citing time constraints, resulting in a response rate of 78.6%. Table 2 shows the distribution of experts from various institutions engaged in the study.

2.3. Evaluating expert's opinions

Expert elicitation was done through semi-structured questionnaires and interviews. This was to assess the subjective judgments of experts working in Kenya, who were familiar with the subject on technical topics at a given point in time (Hagerman et al., 2010). The data collection process took place between September and October 2020 via email, google forms, zoom and telephone calls. The Delphi online survey was implemented to enhance questionnaire performance by facilitating the process and saving expert's time. The combination of the web-based survey platform and the questionnaire simplified statistical analysis and avoided the requirements of paper-based surveys, restricted data input and computational errors often recorded in Delphi studies (Cam et al., 2002)

Questionnaires were prepared in English using Google forms and consisted of the following structure:

- (a) Personal details (with an emphasis on the professional activity and organization of the participants).
- (b) Contribution of selected CSA practices to CSA pillars.
- (c) The extent of implementation of the CSA adaptation practices.

When returned, the questionnaires that included missing values, experts were contacted to provide the values at fault. In case experts did not reply to this request, incomplete values were imputed using the following rule: the most common answer from the experts was used. If an expert did not respond to any question for a given CSA practice, no values were imputed. Incomplete entries were only imputed when the expert responded to the questions for a given CSA practice, but certain values were missing.

Expert opinion is an established method for gathering knowledge in the absence of data (Kuster et al., 2015). However, the methodology of this study was subject to some limitations; the study was based on expert opinions on selected CSA practices as it was impossible to work with farmers due to COVID-19 pandemic outbreak. Since the study was based on semi-structured questionnaires and interviews with the experts, the results were limited to expert knowledge and opinions; a greater number of experts would have increased the study power; however, this was difficult to achieve because of the limited number of experts in the field who were contacted and responded to the survey. Further, this study looked at the short-term synergies and trade-offs at the farm level rather than the long term based on the data generated from the experts.

Table 2. Distribution of experts from various institutions engaged in the study

Name of institution	Number of experts interviewed	Percentage (%)
Consultative Group for International Agricultural Research (CGIAR)	4	18.18
Agrico East Africa Ltd	1	4.55
International potato Center (CIP)	1	4.55
Netherlands Development Organization (SNV World)	4	18.18
Ministry of Agriculture (MoA)	4	18.18
National Potato Council of Kenya (NPCK)	4	18.18
Kenya Plant Health Inspectorate Services (KEPHIS)	1	4.55
Kenya Agricultural and Livestock Research Organization (KALRO)	1	4.55
Jomo Kenyatta University of Agriculture Technology (JKUAT)	2	9.08
Total	22	100

3. Data analysis

3.1. Ranking of CSA practices

All the 19 listed CSA practices were put forward for scoring exercise to get the top 5 practices both currently used by the farmers and those preferred by the experts. The study compared each CSA practice's overall performance based on each practice's totals garnered from the scoring process. The ranking was based on the average points of the total score per practice per rank divided by the number of experts. The practice with the highest points was ranked number 1, and the one with the least points was ranked last. Experts were asked to select the top 5 CSA practices out of the 19 listed CSA practices based on their perceptions and priorities in terms of the 3 CSA pillars. The scoring was also based on the changes experts have observed on various CSA practices and their knowledge due to farmers' adopting the CSA practices over the past 10 years. In each top 5 rankings, 5 points were used to rate each practice. Any time a practice was selected in rank 1, it got 5 points and for rank 5 it got 1 point, sequentially. Each practice's total points were then calculated by multiplying the number of responses in selection by points per rank. The result was then averaged by dividing the results by the total number of participating experts. The practices were then ranked with number one getting the highest average point and the last one garnering the least points (Appendix 1 and 2).

4. Synergies and trade-offs analysis

Experts were asked to score the CSA practices they selected within the three CSA pillars to assess how each practice performs in Irish potato value chain. The data collection entailed scoring the top 5 practices expert preferred using a 3-point Likert scale for the performance level: high = 3, medium = 2 and low = 1. Each practice's total points were calculated by multiplying the number of responses in selection by points per performance. The result was then averaged by dividing by the number of participating experts. The average scores were then normalized into values ranging between 0 and 1 where, with the value 0 meaning low contribution to the pillar and 1 high contribution to the pillar (Appendix 3). The normalized averages were then rated weight range of low (0–0.33), medium (0.34–0.66) and high (0.67–1.00) pillar performances, respectively. The result was then plotted in a spider graph to visualize and analyze how each practice selected was building the synergies and trade-offs to the CSA pillars

The data management and preparation for analysis were using SPSS Version 26.0 statistical software.

5. Results and discussion

5.1. Expert preference versus farmer current top 5 CSA practices

Figure 1 presents the top 5 CSA practices most preferred by experts. These practices included improved crop varieties (rank 1), efficient use of inorganic fertilizers (rank 2), efficient use of agrochemicals (rank 3), early land preparation (rank 4) and diversified crop production (rank 5). On the other hand, the top 5 farmer ranked CSA practices included improved crop varieties (rank 1), irrigation (rank 2), efficient use of inorganic fertilizer (rank 3), early land preparation (rank 4) and changing planting dates (rank 5) in Figure 2. It was noted that the experts preferred the 5 top practices because of availability of information; simplicity in their implementation; their ability to better address the factors limiting production; capability of helping farmers get high returns on their investments; and their resilience to climate change effects. The top five CSA

Figure 1. Response (%) on expert CSA practices preference.

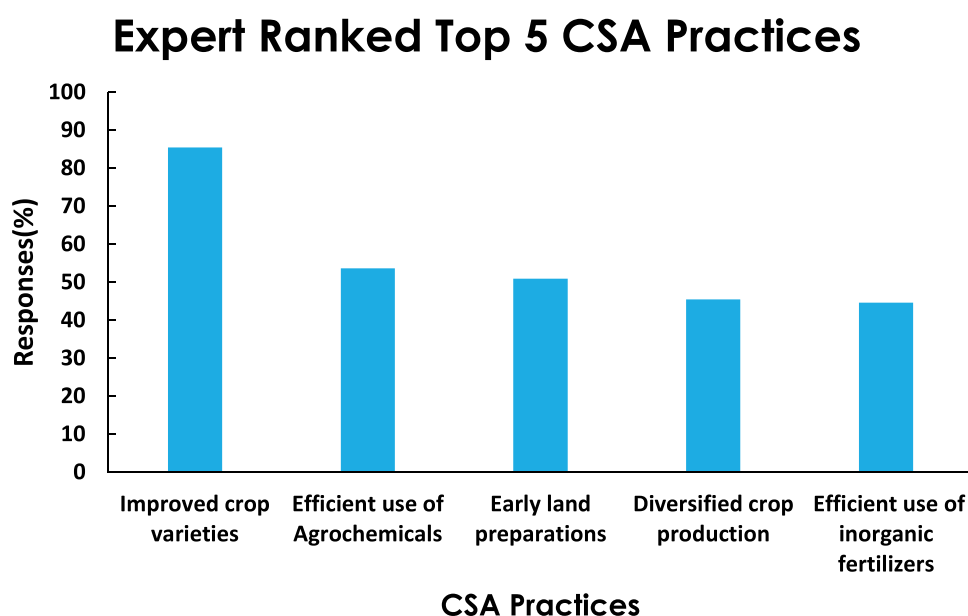
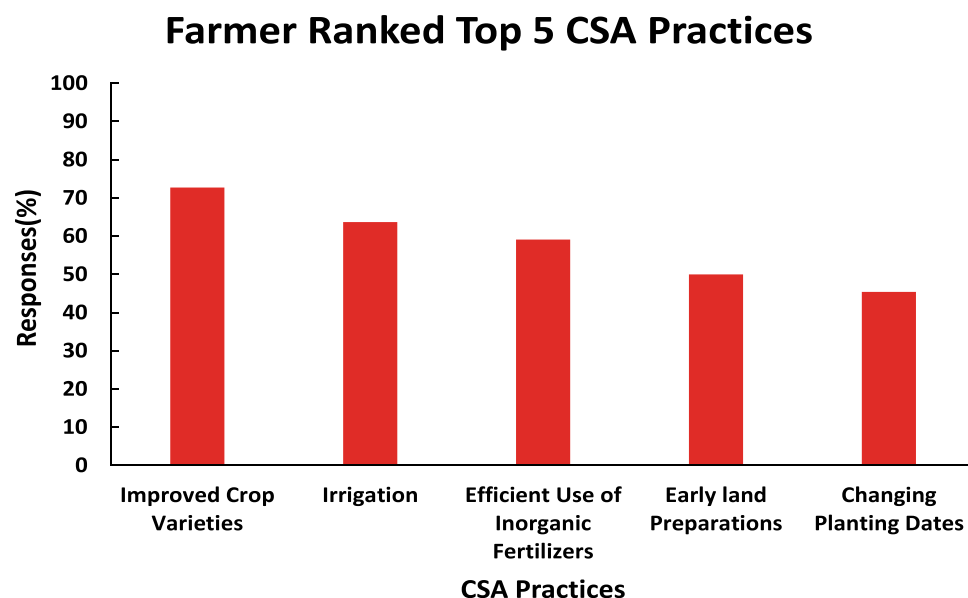


Figure 2. Expert response (%) on farmer CSA practices currently being implemented.



practices selected are among the priority practices being scaled in the west and east sub-Saharan countries such as Ethiopia and Nigeria (Juana et al., 2013; Onoja et al., 2019).

6. CSA pillar(s) performance for expert preference and current farmer top 5 CSA practices

The study assessed the overall pillar performance for each CSA practice based on the average points per pillar.

7. Productivity pillar

The use of improved crop varieties, efficient use of inorganic fertilizers, early land preparations, diversified crop production and efficient use of agrochemicals (pesticides, fungicides and herbicides) were assessed highly for productivity pillar, making them high contributors to agricultural production. In contrast, changing planting date and irrigation had medium weights (Figure 3).

8. Adaptation pillar

Diversified crop production, early land preparations, efficient use of inorganic fertilizers, improved crop varieties and changing planting dates were evaluated high for adaptation pillar, hence highly efficient to cushion Irish potato against effects of climate change. In contrast, efficient use of agrochemicals and irrigation had a medium weight making them efficient for adaptation (Figure 4).

Figure 3. Productivity pillar performance.

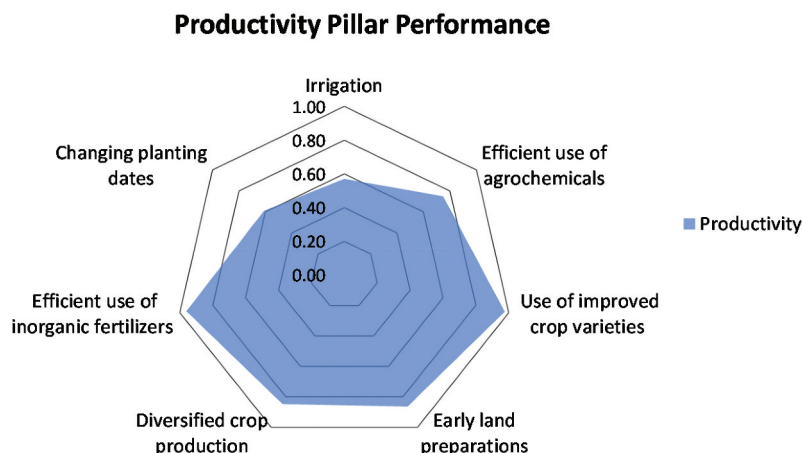
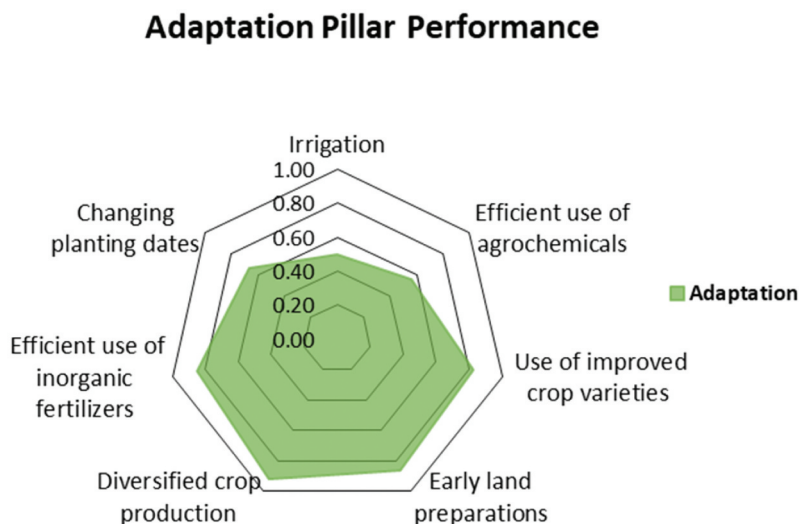


Figure 4. Adaptation pillar performance.



9. Mitigation pillar

The results further indicated improved crop varieties, diversified crop production, irrigation, changing planting dates practices to offer high mitigation for climate change effects to Irish potato production. Simultaneously, the efficient use of agrochemicals and efficient use of inorganic fertilizers showed medium mitigation to CC effects (Figure 5). However, early land preparation showed a lower weight of 0.18. Similarly, Hengsdijk and Verhagen (2013) confirmed that mitigation could be achieved through efficient use of fertilizer, irrigation, rotation of potato with crops that have high residual carbon biomass and efficient use of pesticides.

10. Synergies and trade-offs analysis among selected CSA practices

In this study, low weights, i.e., ≤ 0.33 in pillar performances, were considered to cause trade-offs, while medium-high weights ≥ 0.34 showed synergies. However, the practices that had weights ≥ 0.67 were deemed to provide high synergies. Overall, all the practices were considered to create synergies among the three pillars of productivity, adaptation and mitigation except early land preparation which created a trade-off in the mitigation pillar (Table 3). The result showed that the productivity pillar performed best with the implementation of the selected CSA practices. The productivity pillar was highly synergetic, followed by the adaptation and mitigation pillar (Table 3).

Figure 5. Mitigation pillar performance.

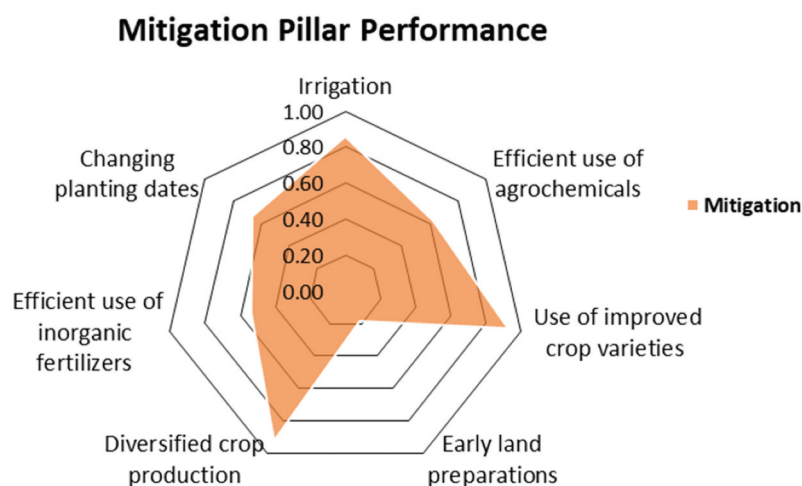


Table 3. CSA synergies and trade-offs

CSA practice	Production	Adaptation	Mitigation
Use of improved crop varieties	++	++	++
Efficient use of agrochemicals (e.g., pesticides & herbicides)	++	+	+
Early land preparation	++	++	-
Diversified Crop production	++	++	++
Efficient use of inorganic fertilizer	++	++	+
Irrigation	+	+	++
Changing planting dates	++	++	++

Trade-off(-) synergies medium (+) synergies high (++)

The study showed that improved crop varieties resulted in high synergies across all the CSA pillars. This could be attributed to the fact that farmers are assured that improved crop varieties produce the highest yields, are adapted to the harsh environmental conditions and reduce the amount of agrochemicals such as pesticides and fungicide significantly as most of the improved seeds are pests and disease resistant as compared to local seeds. The findings were consistent with previous studies (Nigussie et al., 2016; Solomon et al., 2019), who found that improved seeds performed better and were more adaptable compared to local potato seeds. Similarly, Schulte-Geldermann (2013) and Aheisibwe et al. (2016) found that low potato productivity in SSA resulted from low-quality seeds that farmers use thereby reducing the potential yield that can be realized. Devaux et al. (2014) noted that promotion and adoption of improved seeds are a potential approach towards solving the loss and improving yields for African farmers hence reducing food insecurity. On the contrary, studies by Ajayi et al. (2007), Okello et al. (2016) and Wainaina et al. (2014) argued that improved crop varieties increase agrochemicals use such as pesticides, herbicides and inorganic fertilizers if not complemented with natural resources management technologies that boost soil fertility, reduce pest and weed prevalence causing trade-offs rather than a synergy in mitigation pillar. This indicates that a trade-off exists between crop productivity and pollution mitigation through agrochemical use emissions. Wainaina et al. (2014) further suggest improving soil fertility using organic fertilizer for better and sustainable production from improved crop variety use.

Most African agricultural soils (65%) are characterized by poor soil quality due to soil erosions and acidification (Obalum et al., 2012; Shamie et al., 2015; Tully et al., 2015). This has led to the continuous use of inorganic fertilizers to provide immediate soil fertility to crops. Continuous excess use of agrochemicals such as inorganic fertilizers has been found to cause soil toxicity, deficiencies in some major and minor nutrients causing deterioration of soil quality and emissions to the environment (Abera et al., 2018; NING et al., 2017; Schulte-Geldermann, 2013). Furthermore, the use of fertilizers alone has been found not adequate to boost crop yield; however, it should always be combined with organic fertilizer for sustainable production and reverse soil degradation (Abera et al., 2018; Agegnehu et al., 2014; Shamie et al., 2015). Several empirical studies also show that farmers do not adhere to agrochemicals prescriptions because of high pests and disease infestation (Muthoni et al., 2017; Singbo, 2012; Verhagen et al., 2014). In the current study, efficient use of agrochemicals was found to be a major challenge among farmers in Kenya. The experts explained that farmers always do not follow the recommended application criteria of agrochemicals use. They elaborated that most farmers believe that a more concentrated solution in their spray quickly kills and eradicates pests and diseases than the prescribed dosage. The increased use of agrochemicals translates to increased emissions in the manufacture and transport of agrochemicals resulting in trade-offs.

Efficient use of inorganic fertilizers indicated high synergies for the productivity and adaptation pillar. However, the degree of synergy for mitigation was relatively lower than other pillars. This finding is consistent with that of Verhagen et al. (2014) who found that efficient use of inorganic fertilizers had a drawback associated with highly degraded soils. The study further notes that increased productivity of Irish potato in the Rift valley region requires more energy-demanding inputs such as nitrogen fertilizer and energy, which increases the GHG emission per unit land area required and thereby affecting the mitigation pillar.

In the case of early land preparation, the experts revealed that CSA practices benefit farmers in various ways. They noted that the practice leads to exposure of pests that burrow themselves into the soil because of the hot sun to reduce the menace, reduced effects of weed re-growth quickly after ploughing (reducing herbicide use), better land preparation as compared to when it is raining. Furthermore, farmers are likely to plant on time to maximize on rainfall for better production. This helps farmers to adapt well to climate change and variability in the potato growing areas. However, early land preparation resulted in a trade-off in the mitigation pillar. Experts stated that since land preparation involves tillage of the land, this causes carbon stored in the soil as

organic matter to respire, causing carbon dioxide emissions and thus affecting the amount of soil carbon storage. The trade-off result is well documented in previous studies such as that of Mwangera et al. (2017), who found that it is impossible to cultivate potato without tilling the land, which in turn influences soil carbon stock. Potato cultivation requires fine tilth and continuous earthing up for high-quality and bigger potatoes.

Diversified crop production as a CSA practice provided high synergies across all the three CSA pillars. The experts highlighted some of the benefits of diversified crop production such as increasing biodiversity, reducing vulnerability to various weather effects, reducing total crop failure to farmers and enhancing food sufficiency among potato growing households. Moreover, crop diversity also reduces soil erosion, reduces pest and disease problems and crop failure due to wilting due to hot temperatures. These results were in line with previous studies (Lin, 2011; Truscott et al., 2009) which found that crop diversity has proved to increase resilience and biodiversity on farms, improve soil fertility and control pests and diseases. Other similar studies in Tanzania and Zimbabwe revealed that crop diversity results in significant improvement in crop productivity, income from crops and food security indicators, as measured by food consumption scores and household dietary diversity scores (Kimaro et al., 2019; Kurgat et al., 2020; Makate et al., 2016). However, a major challenge exists among smallholder farmers in Kenya with respect to crop diversification attributed to the land size under farm production. Majority of farmers possess small parcels of land, while on the other hand, they wish to get more yields and returns on investments. In the case of potato production, most farmers find it hard to apportion part of their parcel of land for other crops in fear of reducing the acreage under potato production. This makes crop diversification a challenge among farmers. Similarly, previous studies (Deininger et al., 2009; Kassie et al., 2010; Wekesa et al., 2018) also reported that the land size determines the number and type of CSA practices being implemented.

The study also found that irrigation was an important CSA practice for crop production under current climate change. Irrigation provided medium synergies on productivity and adaptation pillar with high synergy on mitigation pillar. For productivity, the experts recommended irrigation as a CSA practice to increase sustained production than rainfed agriculture. Nuutinen et al. (2017), notes that 40% of the world's agricultural production is under irrigation. In this study, irrigation was found to help farmers stabilize potato production by supplementing rainfall and keeping the soil moist for the crop during the dry periods. Moreover, farmers would produce off-seasons making them fetch good prices in the markets and during dry season's farmers have little problems with pests and diseases. Verhagen et al. (2014) assert that irrigation as a response to drought creates synergies for potato production by increasing potato yield due to few cases of pest infestations as opposed to the wet season. However, contrary to the mitigation pillar result, experts argued that though irrigation can be useful for the productivity pillar, it also comes with some trade-offs. The trade-off is as a result of increased use of scarce water and energy (fuel consumption) needed for irrigation during the dry season, which affects the mitigation pillar. Nuutinen et al. (2017) suggests that policymakers should encourage farmers to invest in appropriate and sustainable approaches such as the use of solar-driven and drip irrigation systems to increase water productivity, save water and energy should be of high priority. Long-term soil and water conservation structures such as water pans to store water for use in future during droughts for irrigation would also help reduce pressure on scarce water and thus contribute to solving the trade-offs.

Finally, the study revealed that 45% of the experts' responses indicated that farmers currently use changing planting dates as an adaptation strategy. The use of changing the planting date showed high synergies across the three CSA pillars. Kenyan agricultural sector and SSA in general largely depend on rainfed agriculture. Rainfall is an important factor considered by smallholder farmers in Kenya for crop production. Due to the changing climate and variability, the average months for planting have shifted due to rainfall onset variations. The experts revealed that resource-poor farmers now adjust to the changes and wait until the rains start to fall. The shifts

in planting dates attributed to the fact that the country's potato farming majorly depends on rainfed agriculture. The change in the rain calendar has forced majority of Irish potato farmers who cannot afford irrigation as an alternative source of water to adjust their planting dates. This has caused farmers to incur production losses due to poor predictability of rainfall patterns to start sowing. Previously, smallholder farmers in Kenya started planting with the onset of long rains in March and June and the short rains from September to November (Muthoni et al., 2017). However, due to climate change impact, the new calendar for regular planting dates now depends on reliable weather forecast following the rainfall pattern shifts. It can be noted that most sub-Saharan Africa farmers cannot meet the level of investment required on adaptation infrastructure such as irrigation for continued production; hence, they resort to changing planting dates as the easiest option on CCV (Kinuthia et al., 2018; Komba & Muchapondwa, 2012). However, changing planting dates affect the farmer's production cycle and income as delays in rainfall result in a delay in planting time for the season.

11. Conclusion and recommendations

This study assessed the top 5 CSA practices preferred by experts versus currently used in Irish potato farming. It also evaluated the synergies and trade-offs upon CSA practices implementation by farmers in Kenya. First, the use of improved crop varieties, efficient use of agrochemicals (e.g., pesticides, fungicides & herbicides), early land preparation, diversified crop production and efficient use of inorganic fertilizers were the top 5 most preferred practices by experts. Simultaneously, irrigation and changing planting dates from the farmer replaced the efficient use of agrochemicals and diversified crop production on the experts' list. However, the result showed that among the top 5 CSA practices in both cases, farmers were using changing of planting dates and irrigation instead of efficient use of agrochemicals and diversified crop production preferred by experts. Secondly, the top 5 selected CSA practices showed synergies across CSA pillars except for early land preparation which revealed a trade-off on the mitigation pillar. Selected CSA practices prioritized productivity over adaptation or mitigation pillars. CSA practices have the opportunity to improve farm productivity, adaptation and mitigation to climate change. Further, this study looked at synergies and trade-offs on CSA pillar's performance of each CSA practice. Synergies and trade-offs are key to realizing productivity, mitigation and adaptation in Irish potato production in Kenya and worldwide. The study found that implementing some CSA practices could cause synergies on one pillar and trade-offs on other pillars by affecting other practices and resources. Therefore, a clear and consistent policy framework is necessary for the successful adoption and up-scaling of CSA. The framework should include clear guidelines, extension services, incentives and technical infrastructure and policy harmonization to avoid trade-offs between CSA pillars.

Based on the findings of this study, the following recommendations can be made:

- (1) Further research on the development and availability of better seed varieties resistant to emerging diseases and pests, e.g., potato cyst nematode, bacterial and viral diseases to increase the supply at affordable prices to smallholder farmers is necessary. More importantly, the attributes of the certified seeds need to be communicated well to the farmers. To enhance adoption, extensive promotion of the improved varieties through on-farm demonstrations for wider reach is recommended, especially targeting specific locations with a low probability of adoption.
- (2) Policy interventions that encourage the combination of inorganic and organic fertilizers should be established to improve soil quality and sustainable Irish potato farming.
- (3) National and regional policies on small-scale irrigation farming that will ensure that farmers do not suffer a total loss of their agricultural produce due to climate variability and change should be formulated. Solution for farmers to invest in appropriate and sustainable approaches such as solar-driven and drip irrigation systems are essential. Additionally, long-term soil and water conservation structures such as terraces to reduce the loss of fertile soils and water pans

to store water to be used during droughts for irrigation would help solve the trade-offs among CSA practices

- (4) To reduce the vulnerability of farmers to climate-related risks, the government needs to improve farmers' access to climate information through innovative dissemination pathways. This will help reduce uncertainties among Irish potato farmers on the uptake of CSA practices and enable farmers to accurately plan their farming activities.

In addition, we recommend that future studies similar to this should include all the Irish potato stakeholders including farmers to validate the findings of this study.

Funding

The authors received no direct funding for this research.

Author details

Robert John O Ogola¹

E-mail: robertjohn57@gmail.com

ORCID ID: <http://orcid.org/0000-0003-4962-5178>

Kevin Okoth Ouko²

ORCID ID: <http://orcid.org/0000-0001-9894-5042>

¹ Water Systems and Global Change Group, Department of Environmental Sciences, Wageningen University & Research, Wageningen, The Netherlands.

² Department of Agricultural Economics and Agribusiness Management, School of Agricultural and Food Sciences, Jaramogi Oginga Odinga University of Science and Technology, Bondo, Kenya.

Disclosure Statement

The authors declare no competing interests

Conflict of interest

The authors declare no conflict of interest.

Citation information

Cite this article as: Synergies and trade-offs of selected climate smart agriculture practices in Irish potato farming, Kenya, Robert John O Ogola & Kevin Okoth Ouko, *Cogent Food & Agriculture* (2021), 7: 1948257.

References

- Abegunde, V. O., Sibanda, M., & Obi, A. (2020). Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. *Sustainability*, 12(1), 195. <https://doi.org/10.3390/SU12010195>
- Abera, T., Tufa, T., Midega, T., Kumbi, H., & Tola, B. (2018). Effect of integrated inorganic and organic fertilizers on yield and yield components of barley in Liben Jawi District. *International Journal of Agronomy*, 2018(1), 1–7. <https://doi.org/10.1155/2018/2973286>
- Agegnehu, G., Lakew, B., & Nelson, P. N. (2014). Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian highlands. *Archives of Agronomy and Soil Science*, 60(9), 1261–1275. <https://doi.org/10.1080/03650340.2014.881474>
- Aheisibwe, A. R., Barekye, A., Namugga, P., & Byarugaba, A. A. (2016). Challenges and opportunities for quality seed potato availability and production in Uganda. *Uganda Journal of Agricultural Sciences*, 16(2), 149. <https://doi.org/10.4314/ujas.v16i2.1>
- Ahmad, F., Talukdar, N. R., Uddin, M., & Goparaju, L. (2020). Climate smart agriculture, need for 21st century to achieve socioeconomic and climate resilience agriculture in India: A geospatial perspective. *Ecological Questions*, 31(1), 1–21. <https://doi.org/10.12775/EQ.2020.008>
- Ajayi, O. C., Akinnifesi, F. K., Sileshi, G., & Chakeredza, S. (2007). Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. *Natural Resources Forum*, 31(4), 306–317. <https://doi.org/10.1111/j.1477-8947.2007.00163.x>
- Cam, K. M., Mcknight, P. E., & Doctor, J. N. (2002). *The Delphi method online : Medical expert consensus via the Internet* (pp. 58888).
- Chapman, R. I. (2012). Population genetics of the Potato Psyllid, *Bactericera cockerelli*. Biology Theses. Paper 6. The University of Texas at Tyler. <http://hdl.handle.net/10950/89>
- Deininger, K., Ali, D., & Alemu, T. (2009). Impacts of land certification on tenure security, investment, and land markets: Evidence from Ethiopia. *Discussion Papers* October.
- Devaux, A., Kromann, P., & Ortiz, O. (2014). Potatoes for sustainable global food security. *Potato Research*, 57(3–4), 185–199. <https://doi.org/10.1007/s11540-014-9265-1>
- FAO. (2013). *Statistical yearbook: World food and agriculture*.
- FAOSTAT. (2018). Irish potato production trends in Kenya between. (2008–2018). Retrived from. <http://www.fao.org/faostat/en/#compare>
- Gurung, A., Basnet, B. B., Paudel, B., Chaudhary, P., & Bhatta, K. (2016). Scaling up Pathways for Climate-Smart Agriculture Technologies and Practices in Nepal. Local Initiatives for Biodiversity, Research and Development (LI-BIRD), and CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS). <https://cdkn.org/wp-content/uploads/2017/07/CSA-Scaling-Up-Pathways.pdf>
- Hagerman, S., Dowlatabadi, H., Satterfield, T., & McDaniels, T. (2010). Expert views on biodiversity conservation in an era of climate change. *Global Environmental Change*, 20(1), 192–207. <https://doi.org/10.1016/j.gloenvcha.2009.10.005>
- Hengsdijk, H., & Verhagen, A. (2013). Linking climate smart agriculture and good agriculture practices: case studies on consumption potatoes in South Africa, the Netherlands and Ethiopia (No. 508). Plant Research International Wageningen UR. http://www.researchgate.net/profile/H_Hengsdijk/publication/264346884_Linking_Climate_Smart_Agriculture_and_Good_Agricultural_Practices_Case_studies_on_consumption_potatoes_in_South_Africa_the_Netherlands_and_Ethiopia/links/53d93e7f0cf2631430c3b920.pdf
- J. Kinuthia, K., Inoti, S. K., & Nakhone, L. (2018). Factors Influencing Farmer's Choice of Crop Production Response Strategies to Climate Change and

- Variability in Narok East Sub-county, Kenya. *JNIRD - Journal of Natural Resources and Development*, 8, 69–77. <https://doi.org/10.5027/jnrd.v8i0.07>
- Juana, J. S., Kahaka, Z., & Okurut, F. N. (2013). Farmers' perceptions and adaptations to climate change in sub-Saharan Africa: A synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science*, 5(4), 121
- Kangogo, D., Dentoni, D., & Bijman, J. (2020). Determinants of farm resilience to climate change: The role of farmer entrepreneurship and value chain collaborations. *Sustainability*, 12(3), 868
- Kassie, M., Zikhali, P., Pender, J., & Köhlin, G. (2010). The economics of sustainable land management practices in the Ethiopian highlands. *Journal of Agricultural Economics*, 61(3), 605–627. <https://doi.org/10.1111/j.1477-9552.2010.00263.x>
- Kimaro, A. A., Sererya, O. G., Matata, P., Uckert, G., Hafner, J., Graef, F., ... & Rosenstock, T. S. (2019). Understanding the multidimensionality of climate-smartness: Examples from agroforestry in Tanzania. In *The climate-smart agriculture papers* (pp. 153–162). Springer, Cham
- Klapwijk, C. J., van Wijk, M. T., Rosenstock, T. S., van Asten, P. J. A., Thornton, P. K., & Giller, K. E. (2014). Analysis of trade-offs in agricultural systems: Current status and way forward. *Current Opinion in Environmental Sustainability*, 6(1), 110–115. Issue. <https://doi.org/10.1016/j.cosust.2013.11.012>
- Komba, C., & Muchapondwa, E. (2012). Adaptation to climate change by smallholder farmers in Tanzania. Economic research Southern Africa (ERSA) working paper, 299(5), 67–91. http://www.econrsa.org/system/files/publications/working_papers/wp299.pdf
- Kurgat, B.K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L. and Rosenstock, T.S., 2020. Adoption of climate-smart agriculture technologies in Tanzania. *Frontiers in Sustainable Food Systems*, 4, p.55. <https://doi.org/10.3389/fsufs.2020.00055>
- Kuster, K., Cousin, M. E., Jemmi, T., Schüpbach-Regula, G., & Magouras, I. (2015). Expert opinion on the perceived effectiveness and importance of on-farm bio-security measures for cattle and swine farms in Switzerland. *PLoS One*, 10(12), e0144533. <https://doi.org/10.1371/journal.pone.0144533>
- Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. *BioScience*, 61(3), 183–193. <https://doi.org/10.1525/bio.2011.61.3.4>
- Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimah, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sessa, R., Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, 4(12), 1068–1072. <https://doi.org/10.1038/nclimate2437>
- Mainali, B., Luukkanen, J., Silveira, S., & Kaivo-Oja, J. (2018). Evaluating synergies and trade-offs among Sustainable Development Goals (SDGs): Explorative analyses of development paths in South Asia and Sub-Saharan Africa. *Sustainability*, 10(3), 815. <https://doi.org/10.3390/su10030815>
- Makate, C., Wang, R., Makate, M., & Mango, N. (2016). Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. *SpringerPlus*, 5(1), 1. <https://doi.org/10.1186/s40064-016-2802-4>
- Muthoni, J., Mbiyu, M., Muthoni, J., Muraya, A., & Aronsson, A.-C. (2017). Climatic Change, Its Likely Impact on Potato (*Solanum tuberosum* L.) Production in Kenya and Plausible Coping Measures Climatic Change, Its Likely Impact on Potato (*Solanum tuberosum* L.) Production in Kenya. *International Journal of Horticulture*, 7(14): 115–123. <https://doi.org/10.5376/ijh.2017.07.0014>
- Muthoni, J., Shimelis, H., & Melis, R. (2013). Potato production in Kenya: Farming systems and production constraints. *Journal of Agricultural Science*, 51, 182–197. <https://doi.org/10.5539/jas.v5n5p182>
- Mwongera, C., Läderach, P., Acosta, M., Ampaire, E., Eitzinger, A., Lamanna, C., Mwungu, C., Shikuku, K., Twyman, J., Winowiecki, L. (2017). Assess whole-farm trade-offs and synergies for climate-smart agriculture. *International Center for Tropical Agriculture (CIAT)*. Cali. CO. 8p. https://cgspace.cgiar.org/bitstream/handle/10568/89095/http://Lesson_3_13dec.pdf
- Ndegwa, B. W., Okaka, F., & Omondi, P. (2020). Impacts of climate change and variability on Irish potato production. *International Journal of Research and Innovation in Social Science (IJRISS)*, Volume IV, Issue II, February 2020 2454–6186
- Nigussie, Z., Alemayehu, G., Adgo, E., Tewodros, Y., & Freyer, B. (2016). Reasons for acceptance of improved potato varieties by smallholder producers. *International Journal of Vegetable Science*, 22(4), 346–352. <https://doi.org/10.1080/19315260.2015.1048402>
- NING, C. C., Gao, P. D., Wang, B. Q., Lin, W. P., JIANG, N. H., & Cai, K. Z. (2017). Impacts of chemical fertilizer reduction and organic amendments supplementation on soil nutrient, enzyme activity and heavy metal content. *Journal of Integrative Agriculture*, 16 (8), 1819–1831. [https://doi.org/10.1016/S2095-3119\(16\)61476-4](https://doi.org/10.1016/S2095-3119(16)61476-4)
- Nuutinen, M., Schneidman, J. M., & Schnetzer, J. (2017). Summary report : Online learning event on “irrigation in climate-smart agriculture – challenges and responses”. FAO. http://www.fao.org/fileadmin/user_upload/faowater/docs/bari2017/BARI_CN_FINAL.pdf
- Obalum, S. E., Buri, M. M., Nwite, J. C., Hermansah, Watanabe, H., Watanabe, Y., Igwe, C. A., & Wakatsuki, T. (2012). Soil degradation-induced decline in productivity of Sub-Saharan African soils: The prospects of looking downwards the lowlands with the sawah ecotechnology. *Applied and Environmental Soil Science*, vol. 2012, Article ID 673926, 1–10. <https://doi.org/10.1155/2012/673926>
- Okello, J. J., Zhou, Y., Kwikiriza, N., Ogutu, S., Barker, I., Schulte-Geldermann, E., ... & Atieno, E. (2016). Welfare-environmental quality tradeoffs of promoting use of certified seed potato in tropical highlands of Africa: Evidence from central highlands of Kenya. *Agricultural and Applied Economics Association (AAEA)*, (No. 333-2016-14490), pp. 1–18. doi:10.22004/ag.econ.236242
- Onoja, A. O., Abrahma, A. Z., Girma, A., & Achike, A. I. (2019). Climate-smart agricultural practices (CSA) adoption by crop farmers in semi-arid regions of west and east Africa: evidence from Nigeria and Ethiopia. In *Climate Change-Resilient Agriculture and Agroforestry* (pp. 89–113). Springer, Cham. https://doi.org/10.1007/978-3-319-75004-0_6
- Roy, R., Chan, N. W., & Ahmed, Q. N. (2014). A Delphi study to determine sustainability factors: The case of rice farming in Bangladesh. *Journal of Sustainability Science and Management*, 9(1), 56–68. <https://rmc.umt.edu.my/wp-content/uploads/sites/51/2015/02/5w.pdf>
- Schulte-Geldermann, E. (2013). Tackling low potato yields in Eastern Africa: an overview of constraints and potential strategies.- In: Woldegiorgis, G.; Schulz, S.; Berihun, B. (eds.). *Seed potato tuber production and*

- dissemination, experiences, challenges and prospects: Proceedings. National Workshop on Seed Potato Tuber Production and Dissemination. Bahir Dar (Ethiopia). 12–14 Mar 2012. (Ethiopia). Ethiopian Institute of Agricultural Research (EIAR); Amhara Regional Agricultural Research Institute (ARARI); International Potato Center ISBN 978-99944-53-87-x. pp. 72–80. <https://hdl.handle.net/10568/57049>
- Shamie, Z., Mutegi, J., Agesa, B., Tamene, L., & Kihara, J. (2015). Soil degradation in sub-Saharan Africa and crop production options for soil rehabilitation. *Better Crops*, 99(1), 24–26. [http://www.ipni.net/publication/bettercrops.nsf/0/71F86528D5A072AF85257E14005D9047/\\$FILE/BC%202015-1%20p24.pdf](http://www.ipni.net/publication/bettercrops.nsf/0/71F86528D5A072AF85257E14005D9047/$FILE/BC%202015-1%20p24.pdf)
- Shikuku, K. M., Mwongera, C., Winowiecki, L. A., Twyman, J., Atibo, C., & Läderach, P. (2015). *Understanding farmers' indicators in climate-smart agriculture prioritization in Nwoya District, Northern Uganda*. Publication CIAT.
- Singbo, A. (2012). Analyzing efficiency of vegetable production in Benin. Wageningen UR. <https://cdkn.org/wp-content/uploads/2017/07/CSA-Scaling-Up-Pathways.pdf><https://library.wur.nl/WebQuery/wurpubs/fulltext/212094>
- Singh, N. P., Anand, B., Singh, S., Srivastava, S. K., Rao, C. S., Rao, K. V., & Bal, S. K. (2021). Synergies and trade-offs for climate-resilient agriculture in India: An agro-climatic zone assessment. *Climatic Change*, 164(1–2), 1–2. <https://doi.org/10.1007/s10584-021-02969-6>
- Solomon, F., Asrat, A., Daniel, T., Zenebe, G., & Eshetu, A. (2019). Evaluation of potato (*Solanum tuberosum* L.) varieties for yield and yield components. *Journal of Horticulture and Forestry*, 11(3), 48–53. <https://doi.org/10.5897/JHF2016.0475>
- Truscott, L., Aranda, D., Nagarajan, P., Travaglini, A. L., & Tovignan, S. (2009). A snapshot of crop diversification in organic cotton farming. https://textileexchange.org/wp-content/uploads/2017/08/TextileExchange-A_Snapshot_of_Crop_Diversification-2010.pdf
- Tully, K., Sullivan, C., Weil, R., & Sanchez, P. (2015). The state of soil degradation in sub-Saharan Africa: Baselines, trajectories, and solutions. *Sustainability (Switzerland)*, 7(6), 6523–6552. <https://doi.org/10.3390/su7066523>
- Verhagen, A., Schaap, B.F., Pulleman, M.M., Hengsdijk, H. and Achterbosch, T.J., 2014. Climate-smart agriculture as a guiding principle for agricultural transformation. In *The food puzzle: pathways to securing food for all* (pp. 55–57). Wageningen UR
- Wainaina, P. W., Tongruksawattana, S., & Qaim, M. (2014). Improved seeds, fertilizer or natural resource management? Evidence from Kenya's smallholder maize farmers. *European Association of Agricultural Economists (EAAE)*, (No. 727-2016-50460), (pp. 1–14). doi:10.22004/ag.econ.182644
- Wekesa, Bright Masakha, Oscar Ingasia Ayuya, and Job Kibiwot Lagat (2018). "Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya." *Agriculture & Food Security* 7 (1); PP 1–14. <https://doi.org/10.1186/s40066-018-0230-0>

Appendix 1. Expert ranked CSA practices

CSA Practices	Average	Rank
Use of improved crop varieties	4.3	1
Efficient use of chemicals (pesticides and herbicides)	2.7	2
Early land preparations	2.5	3
Diversified crop production	2.3	4
Efficient use of inorganic fertilizers	2.2	5
Use of legumes in crop rotation	2.2	6
Changing planting dates	2.2	6
Use of organic fertilizers	2.0	8
Irrigation	1.9	9
Received education/training on how to access weather information by an organization	1.7	10
Crop insurance	1.6	11
Get access to information of market prices of produce & inputs	1.5	12
Establishment of Ridges, farm terracing, hedges, stone lines	1.5	13
Belong to farmer associations	1.5	13
Minimum tillage	1.3	15
Agroforestry	1.3	16
Mulching	1.1	17
Share one-on-one information with colleagues (Farmer-to- farmer knowledge sharing)	1.1	18
Use of cover crops	0.9	19

Appendix 2. Farmer current CSA practices

CSA Practices	Respondents	Rank Percentage	Rank
Use of improved crop varieties	16	73%	1
Irrigation	14	64%	2
Efficient use of inorganic fertilizers	13	59%	3
Early land preparations	11	50%	4
Changing planting dates	10	45%	5
Belong to farmer associations	7	32%	6
Mulching	7	32%	6
Efficient use of agrochemicals	6	27%	8
Use of legumes in crop rotation	4	18%	9
Establishment of Farm water conservation structures	4	18%	10
Use of organic fertilizers	3	14%	11
Farmer-to- farmer knowledge sharing	3	14%	12
Access weather information & trainings	2	9%	13
Crop insurance	2	9%	13
Agroforestry	2	9%	15
Diversified crop production	1	5%	16
Access market information	1	5%	17

Appendix 3. CSA Synergies and Trade-offs (normalized data)

CSA Practices	Productivity	Adaptation	Mitigation
Use of improved crop varieties	0.98	0.83	0.93
Efficient use of chemicals (pesticides and herbicides)	0.75	0.56	0.63
Early land preparations	0.86	0.86	0.18
Diversified crop production	0.85	0.92	0.92
Efficient use of inorganic fertilizers	0.96	0.85	0.54
Use of legumes in crop rotation	0.61	0.67	0.67
Changing planting dates	0.58	0.63	0.71
Use of organic fertilizers	0.57	0.50	0.86
Irrigation	0.89	0.61	0.93
Received education/training on how to access weather information by an organization	0.86	0.86	0.59
Crop insurance	0.64	0.79	1.00
Get access to information of market prices of produce & inputs	0.83	0.89	0.78
Establishment of Ridges, farm terracing, hedges, stone lines	1.00	0.57	0.86
Belong to farmer associations	0.56	0.75	0.44
Minimum tillage	0.31	0.44	1.00
Planting trees on crop land	0.40	0.45	0.80
Mulching	0.92	0.50	0.50
Share one-on-one information with colleagues (Farmer-to-farmer knowledge sharing)	0.71	0.86	0.86
Use of cover crops	0.36	0.86	1.00



© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format.

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

***Cogent Food & Agriculture* (ISSN: 2331-1932) is published by Cogent OA, part of Taylor & Francis Group.**

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com

