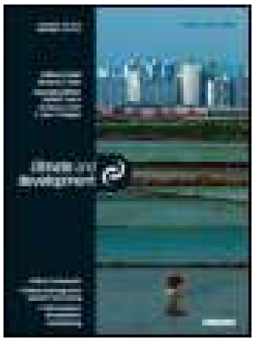

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REVIEW ARTICLE

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Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice

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ABSTRACT
Climate-Smart Agriculture (CSA) presents the opportunity to meet the worldâ€™s increasing food demands in the face of climate variability. It is more responsive to the achievement of Sustainable Development Goals 2 and 13. CSA practices have the potential to alleviate low potato yields among farmers. Investigation of the determinants of practice of CSA would therefore go a long way in informing the efforts to adapt potato production to the effects of climate change. This study explored the determinants of practice of CSA documented by theoretical authorities and empirical studies. The study systematically investigated the need for CSA by reviewing the effect of climate change on potato production. Information from institutional websites and data from FAOSTAT were reviewed. Understanding the financial, natural, physical, and social capital required to execute the CSA technological practices is key to its adoption. Additionally, the mode of communicating the CSA practices determines its adoption, therefore, knowledge of such determinants and that of socioeconomic and institutional factors shapes CSA technological development and diffusion strategies. Understanding of these is essential to tailoring the CSA practices to the farmersâ€™ most pressing needs and to the development of the practices that can easily be accessed and adopted by the farmers.

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Climate change; climate smart agriculture; potato production; socio-economic factors; institutional factors; information dissemination pathways; adoption

1. Introduction

The world's population is expected to increase by one-third by 2050 (Cohen, 2002; Espenshade et al., 2003; Food and Agriculture Organisation [FAO], 2014). With the expected increase in population, agriculture will have to make noticeable adjustments to produce enough food (Serdeczny et al., 2017). However, this production is currently jeopardized by climate change (Aggarwal et al., 2018; FAO, 2014). In case of inappropriate measures, agriculture and food systems will be at higher risk (Lipper et al., 2014; Waaswa & Satognon, 2020). One of the apparent risks and effects is reduced productivity of the major crops (maize, wheat, cassava, potato, rice, beans) as a result of crop failure due to soil degradation coupled with prolonged dry spells (Adhikari et al., 2015; FAO, 2019). This affects the majority of African countries whose economies rely on agriculture (Olorunfemi et al., 2020), leading to 48% of the population in poverty and hunger (Adhikari et al., 2015). Despite the global efforts to reduce hunger, Sub-Saharan Africa (SSA) has a high 2017 Global Hunger Index (GHI) scored at 29.4, that reflects widespread and persistent hunger and malnutrition that possess a massive challenge in the region (Campos & Ortiz, 2020).

It is known that 80% of East Africa's population is below 35 years (Dawit et al., 2018). This young population is expected to contribute to the agricultural production of the region. However, the region is continuously limited by adverse weather conditions (Alliance for a Green Revolution in Africa [AGRA], 2015; Hussein, 2011; Nicholson, 2017; Omambia et al., 2012; Ongoma et al., 2018). These conditions lead to depletion of natural resources like soil, land, water, and ecosystems leading to the region's underperformance (Kanianska, 2016; New Partnership for Africa's Development [NEPAD], 2013; Waaswa & Satognon, 2020; Wynants et al., 2019). East Africa's Climate change forecasts and Kenya, in particular, show an increase in temperatures and regular climate shocks in terms of droughts and floods. This, together with the growing population in Kenya that is expected to increase to 95 million by 2050, creates a risk of famine (Adhikari et al., 2015; Netherlands Development Organisation [SNV], 2019). Over 75% of the population is directly or indirectly employed in the agriculture sector. The sector contributes to about 26% of Kenya's gross domestic product [GDP] (Bolt et al., 2019). Kenya's economy will mostly be affected if appropriate precautions against climate change are not taken. According to Bolt et al. (2019), the productivity of potato, the second most important staple food crop in Kenya, is being lowered by climate change. Nakuru, one of the potato producing counties in Kenya has been exposed to climate variability (Frances, 2015; Mbatiah, 2015; Ministry of Agriculture, Livestock and Fisheries [MoALF], 2016).

Potato is both a food security and an income generating crop to Nakuru farmers (Government of Kenya [GoK], 2014; Taiy et al., 2017). Under favourable conditions in developing countries, potatoes have the potential of yielding an average of 10–15 tons per hectare (NeBambi et al., 2009). This is seldom realized in the Sub Saharan region which attains meager

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yields of 7.8 tons on average per hectare (Taiy et al., 2017). Globally potato yield is seen to decrease up to 32% in case no climate change adaptation measures are taken (Haverkort et al., 2013; Hijmans, 2003). According to FAOSTAT (2020b), Kenya registered a decline in potato yield between 2010 and 2018 from 22.4–8.6 tons per hectare, see Figure 1. This was partly caused by drought, floods, high temperatures and irregular rain patterns coupled with ineffective execution of adaptive strategies (MoALF, 2016; Rateb & Hermas, 2020). The Kenyan counties, besides the low yields per hectare, the yields are anticipated to reduce by 2 and 3 tons during long rainy seasons and optimum conditions respectively (Bolt et al., 2019; Haverkort et al., 2013).

According to Totin et al. (2018), climate-smart agriculture presents the opportunity to meet the world's food demands in the face of climate variability. The triple win effect of CSA, which are (i) increased productivity (ii) mitigation, and (iii) adaptation, are seen as the practical solution to climate change (FAO, 2010). These initiatives are more responsive to the achievement of Sustainable Development Goals (SDGs) 2 and SDG 13 that aim at increasing productivity by adapting to climate change (Rosa, 2017). Several CSA practices have been developed globally and among these include irrigation, deep-ploughing, crop rotation, mixed cropping, terracing, mulching, zero or minimum tillage and cover crops (Cramer et al., 2017; Imran et al., 2018; Lan et al., 2018; Zahra et al., 2019).

Considering its geographical location, Africa has developed and adopted context-specific CSA practices like leaving cleared weeds and biomass to mulch on prepared land, use of hybrid planting materials (Akrofi-Atitianti et al., 2018), crop-livestock diversification, diversification of income-generating activities and other good agronomic practices such as mixed cropping, agroforestry and perennial plantation (Fadina & Barjolle, 2018).

CSA presents a variety of potentials and benefits to the farmers and to the entire food value chain, a good example of the benefits of CSA in East Africa is the planting of mango trees to protect the soil from physical erosion and contribute to families' nutrition (Recha et al., 2016). Additionally, study findings by Akrofi-Atitianti et al. (2018) revealed that CSA practitioners had increased their income by 29% compared to conventional farmers. The difference is attributed to the ability of the CSA technologies to sustain yields under climate variability. According to research conducted in the Teso North Sub-county, Busia County of Kenya, 56.83% of smallholder farmers practice CSA for effective crop and field management, farm risk reduction, and sustainable soil management practices (Wekesa et al., 2018). A study by Mbow et al. (2014) in western Kenya indicated that agroforestry reduced food insecurity during drought and flooding by 25% due to its ability to increase crop yields and income amidst calamity.

Like any other climate change vulnerable country, Kenya has responded to the global call to mitigate and adapt to climate change effects by launching a CSA strategy; which was designed as part of its development programmes that seek to achieve food security and sustainable development at the same time (GoK, 2017). Agroforestry, the use of bunds, water harvesting, composting, improved high yielding varieties, among others, have been developed as CSA technologies (Bernier et al., 2015).

Nakuru County's plan to increase potato yields to 15 tons/ha by 2022 opted for agroforestry, water harvesting, and planting of the short cycle and drought-tolerant potato varieties as significant CSA practices to achieve the desired future (GoK, 2018). Additionally, stakeholders working in the potato sector have come up and recommended several CSA practices with the aim of adapting potato production to the effects of climate change in Nakuru and elsewhere in the World. For example, use of potato apical rooted cuttings, irrigation, use of improved varieties among others (Kibe et al., 2019; Parker et al., 2019). However, studies by Leal Filho et al. (2015) and Nyasimi et al. (2017) give an overview of the bottlenecks that continue to hinder the registration of the expected success. These unveil that a gap still exists between full understanding of the farmers'

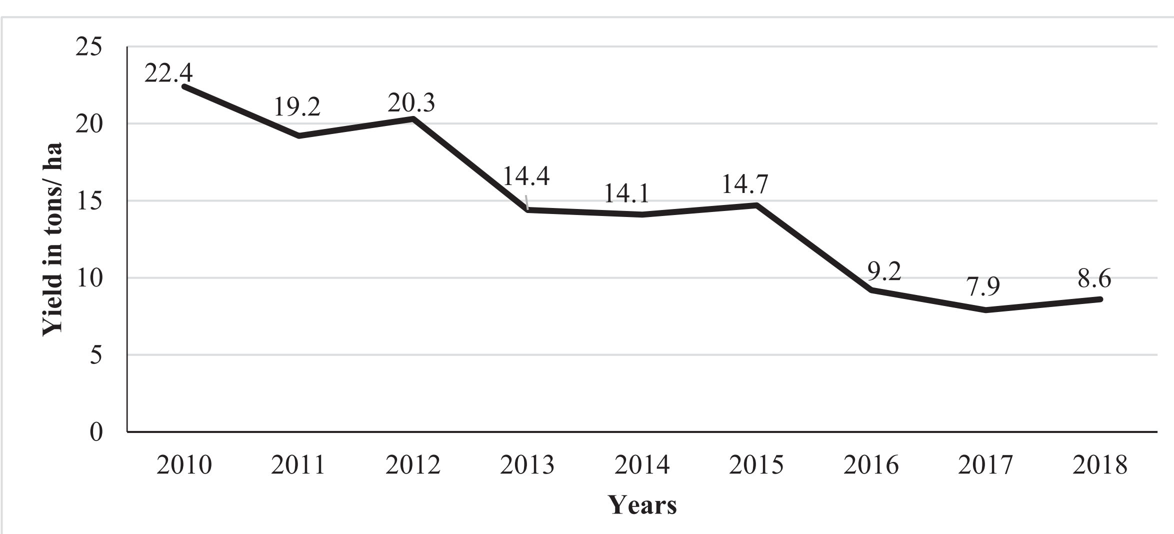

Figure 1. Trends in potato yield per hectare between 2010 and 2018 in Kenya (FAOSTAT, 2020b).

contexts and the CSA practices that are best suited for individual farmers. For effectiveness, proper decisions should be made on which information dissemination channels to be used for scaling out the use of CSA practices (Faling, 2020). The latter adds that if Kenya in particular is to succeed in achieving its objective of incorporating CSA practices in its farming systems as expected by the Kenya Climate Smart Agriculture Project [KCSAP] (GoK, 2018), understanding of the farmer contexts in terms of institutional and socio-economic factors is not only vital but also lays a foundation on which scaling strategies should base. Various institutional and socio-economic factors influence uptake of technologies differently. For example, in some localities, farmer's age may limit uptake of labour-intensive technologies, income may facilitate access to high value technologies and gender may pose barriers for women in some societies in securing recommended technologies. These combined with extension services and training on how technologies are applied, access to credit to fund technology adoption process and Non-government support services may hasten technology adoption process if available and accessible by all (Kane et al., 2018). However, the reverse may hold true if these factors are not available or available but not accessible by everyone. Understanding of how these factors among others affect technology uptake especially CSA is in fact necessary and pivotal in the context of policy, planning, and development. Cautiously derived generalizations about their influence on the use of CSA practices by the smallholder farmers can shed light on appropriate ways for developing future planned CSA practices, policies and other climate change adaptation strategies in a way that accounts for the past failures and successes experienced by local communities and development projects (Faling, 2020). This therefore informs the objective of this study to review the determinants of practice of CSA with a bias on potato production by smallholder farmers in Nakuru, Kenya. The determinants reviewed in this article are categorized into three; the socio-economic factors, the institutional factors and the information dissemination pathways.

2. Materials and methods

The review was carried out to document determinants of practice of CSA by identifying undertakings and studies that tackle the effects of climate variability especially by promoting CSA practices as adaptation strategies among farmers. The study topic provided the key search terms (e.g. effect of climate change on potato production; the CSA in potato production in Kenya; the determinants of CSA adoption/ causal factors (socio-economic factors, the institutional factors, and the information dissemination pathways); and additional search terms like adaptation to climate change, potentials of CSA and potato farming) were consistently applied by quests in Google Scholar, Web of Science, Research4life, and through searches in Google for the Kenyan Government development plans and reports. Searches were also done through Google, in the websites of institutions that promote potato production, sustainable development, CSA, and other climate change adaptation strategies (CCASs) (e.g. World Bank, Consortium of International Agricultural Research Centers (CGIAR)'s research programme on Climate Change, Agriculture and Food Security (CCAFS), FAO, International Potato Centre (CIP), Future Agricultures, African Union Development Agency, The Technical Centre for Agricultural and Rural Cooperation (CTA) and United Nations Development Programme (UNDP)) to warrant a pool of varied literature. Grey literature from institutions was used to address the criticism associated with the use of peer-reviewed literature that may rebate practitioner knowledge in the assessment of climate change adaptation. To avoid the effects caused by the inconsistencies from the grey literature that may weaken the value of the work, it was used together with and or backed up by empirical literature. Also, data were mined from http://www.fao.org/faostat/en/#data for the status of potato production, comparing Africa with other regions and narrowing down to compare Kenya with selected African countries; data showing the importance and various uses potatoes are put to and trends of potato production that were correlated with climate change effects reported in the reviewed manuscripts. The reviewed literature was published between 1994 and 2021. After securing a pool of literature, exclusion criteria were stated and papers, studies, and the data that did not present explicit information necessary to contribute to the body of knowledge on the study topic in regard to the above-specified search terms and the sections entailed in this manuscript were not accepted for this review. Determinants of practice of CSA were selected from the physical, natural, financial, human and social types of capital basing on their context specific ability to influence the practice of CSA. The cited literature in every considered document was identified and scrutinized to find manuscripts relevant to this study that were not identified in the initial steps. Determination of which articles, studies, and data to include in the review was achieved by adhering to the topics to remain within the scope and to be considered for this review, the manuscript at least addressed any of the stated topics. Consideration was based on the relationship between the topic addressed by the manuscripts/ data and its ability to influence the uptake of CSA practices and or explain causes of adoption and dis-adoption. Studies that examined potato production, climate-smart agriculture, and other adaptation strategies to environmental and climate variability but without contributing to the stated topics that this study sought to address were excluded from the review. To guarantee the comprehensiveness of the results, discussions were held after synthesizing the literature with a researcher expert on issues of potato production, sustainable development and food production, working with farmers, climate-smart agriculture technologies, and other CCASs and results reported in the results and discussions section of this manuscript.

Given the criteria followed, this review isn't without flaws: (1) the empirical manuscripts included in this study emanated from extensively discrete communities. This review amalgamates several CSA practices and other CCASs over discrete areas and makes them appear more uniform than reality; (2) the concept of CSA being an emerging area of study, substantial publications might have been made following this review and they have not been studied; (3) despite the review criteria followed, the synthesis based on the topics predetermined by the authors to a certain degree speculates a subjective assessment. Gaps were identified from the reviewed information associated with those topics that may limit the advancement of CSA practices plus other CCASs, and better targeting of the farmers.

3. Results and discussions

3.1. Origin and importance of potato production

The potato originated from the Andean regions of Bolivia and Peru. It was introduced into Spain from South America in the mid-sixteenth century. From Spain, it was introduced to nearby countries and was being cultivated moderately in many European regions. By the seventeenth century, the potato was then distributed beyond Europe into India and China and by the eighteenth century to Japan (Lim, 2016). It became so extensively spread around the globe and essential and was introduced in Africa by Christian missionaries at the end of the seventeenth century through the establishment of small plantations (International Plant Biotechnology Outreach [IPBO], 2019). Its tubers were swiftly adopted in many diets. They became part of the feeding habits of the urban and rural populations. Today, over 158 countries grow potatoes worldwide, and Kenya is among these. Asia and Europe produced more potatoes between 2007 and 2017, with 71% of the world's production total. This is because it is produced as both food and cash crop in these regions (FAOSTAT, 2020a).

Potato production now ranks the third world food crop due to its contribution to the alleviation of food insecurity in the world and gaining more importance in sub-Saharan Africa (IPBO, 2019).

The growing number of potato consumers, interest in potato use as feed for the livestock industry, the need for processed potato products that lead to higher demands of the potato by the food industries, fuel the increasing demand for potato in Africa. Potato exportation potential is another factor that increases potato demand. A typical example in Africa is Egypt (Table 1) that increases its production to satisfy herself, sell to her neighbours, and the European food market (FAO, 2008). African countries have various needs for the potato, for example, utilized as food, seed, and or feed. The potato is a very versatile food crop and can be used in multivariate ways. It is eaten and cooked in different ways, such as boiling, steaming, deep-frying, and roasting (Lim, 2016). It supplied an average of 1.75 million tons of food per year between 2014 and 2017 to the Kenyan population. According to FAOSTAT (2019), Kenya is the highest potato consumer compared to Rwanda, Ethiopia, and Uganda, as seen in Table 1.

Table 1. Annual potato production, food and seed supply per country between 2014 and 2017.

Countries	Parameter	Years			
		2014	2015	2016	2017
Egypt	Food (1000 tons)	3228	3200	3450	3539
	Food supply (kcal/capita/day)	73	71	75	75
	Production (1000 tons)	4611	4955	4113	4325
	Seed (1000 tons)	490	538	298	313
Ethiopia	Food (1000 tons)	617	647	672	706
	Food supply (kcal/capita/day)	11	12	12	12
	Production (1000 tons)	922	1040	921	933
	Seed (1000 tons)	51	53	51	51
Kenya	Food (1000 tons)	1632	1767	1793	1834
	Food supply (kcal/capita/day)	68	72	71	71
	Production (1000 tons)	1626	1963	1336	1520
	Seed (1000 tons)	75	91	65	74
Rwanda	Food (1000 tons)	1079	1069	1095	1118
	Food supply (kcal/capita/day)	191	184	184	183
	Production (1000 tons)	719	743	751	846
	Seed (1000 tons)	42	44	0	50
Uganda	Food (1000 tons)	158	140	169	179
	Food supply (kcal/capita/day)	8	7	8	8
	Production (1000 tons)	181	177	200	250
	Seed (1000 tons)	29	24	27	29

3.2 Effect of climate change on potato production

Climate variability threatens agricultural production systems and food security worldwide. It affects the crops through high temperatures, drought, flooding, and enhanced atmospheric CO_2 caused by changes in climatic factors like wind, relative humidity, rainfall, and solar radiation (Aggarwal et al., 2018). The effects are worse with the potato crop, which is a cool climate crop. It performs well under 20–25°C and below 20 °C for day and night, respectively. Such temperature conditions favour growth and tuberisation. Daily night temperatures of 23 °C and above limit tuber formation. Extreme temperatures lead to heat stress on crops whose warmer temperatures may accelerate the growth of certain crops like melons, grapes, and tomatoes. In the presence of this, other crops such as maize, wheat, and potatoes may experience lower yields (Aggarwal & Singh, 2010). Staple crops like potatoes and other cereal grains may become difficult to grow, thereby rendering them unavailable (Leal Filho, 2020).

Increasing temperature favours pests, diseases, and weed invasions like the soft rot and blackleg, root-knot, nematodes, and *M. persicae*. According to Londhe (2017) and Van der Waals et al. (2013), the development of these pests and diseases will increase with increasing temperature (by about 1.9 °C) over the next 90 years with a significant effect on potato sector. Potato requires 500–750 mm during its growing period of 3–4.5 months, and any deviation from the ideal due to less rainfall during its bulking stage reduces its productivity (Lim, 2016).

Besides this, farmers in highland areas face risks of unpredictable rainfall and rising temperatures due to climate change and variability (Parker et al., 2019). This explains the reduction in yields (46%, from 15 to 7 t/ha) obtained by potato farmers in Kenya between 2016 and 2017. This came following a reduction from 737 mm to 126 mm in seasonal mean rainfall. Nakuru, the largest county under potato cultivation in Kenya, is exposed to drought, heavy rains, floods, and high temperatures with an increase of 1°C since 1981 (MoALF, 2016). This climate variability contributes to the recurring low yields obtained by the farmers.

3.3 The CSA practces in potato production in Kenya

Maintaining agricultural growth and increased food supply while minimizing climate damage is key to building a resilient food production system to meet the developmental goals in affected countries (Aggarwal et al., 2018). Climate-Smart

Agriculture (CSA) seeks to address three challenges that include (i) improving the adaptation capacity of agricultural systems to climate change and its effects, (ii) reducing greenhouse gas emissions from agricultural systems, and (iii) ensuring local and worldwide food security. This is termed as the triple win effect of CSA (Acosta-Alba et al., 2019).

To meet the potato demand, the potato production sector will need to invest in strengthening existing production areas. The access to the new potential potato production areas, new varieties that are well adapted to extremes of heat and drought weather conditions, irrigation equipment that are better adapted to wet soil conditions, and improved irrigation water storage facilities need to be adapted to potato production (Haverkort & Verhagen, 2008).

The study by Parker et al. (2019) showed that climate-smart potato varieties could improve potato productivity in various environments from sea level to high mountain conditions where potato smallholder farmers predominate. In addition to temperature regimes and solar radiation, consideration of several factors that include soil characteristics, nutrient availability, and water use efficiency is vital for the success of this CSA practice. In Kenya, 15 climate-smart potato clones introduced and evaluated between 2013 and 2015 for water-stress tolerance under precipitation averaged 295 mm (range 210–414 mm), yielded significantly higher than the existing varieties (Table 2).

To adapt the potato to overcome the climate change challenges, breeding efforts by CIP have prioritized context-specific heat tolerance, earliness, disease tolerance, and water use efficiency (CIP, 2016). The following; Unica, Lenana, Wanjiku, Chulu, and Nyota varieties have been developed by the breeders and are used by the farmers in Kenya to reduce the risk of yield losses due to stress intolerance and late blight and viral diseases (CIP, 2016). However, for better results, these resistant varieties may be accompanied by the use of phytosanitation and cultural practices, clean fields, biological control, and disease-free tubers (Muthoni et al., 2012). Crop rotation is also one of the CSA approaches that has been adopted by farmers in Kenya. Table 3 shows the different rotation sequences that the farmers have adopted.

The meaning and potential of the CSA technological practices commonly applied/ fostered among a variety of smallholder famers' enterprises including potato production are summarized in Table 4.

3.4 Level and determinants of practice of CSA

Previous studies indicate that CSA practices have been promoted for reasons ranging from conserving soil moisture, reducing erosion, enhancing soil fertility, increasing soil organic matter content, and lowering greenhouse gas emissions (Thierfelder et al., 2017). The latter adds that collective adoption presents imminent and multiple benefits in expressions of stable and enhanced yields, improved livelihoods, and diverse services to the ecosystem. That over 70% of the farmers practice only one to three CSA technologies, betokening that a great potential exists to advance the explicit adoption rates. Other studies also explicate that various CSA technologies are interdependent, others being complimentary, and some are supplanted (Kpadonou et al., 2017), hence practice of a single CSA practice may turn out to be costly and not rewarding. One circumstance that results in low adoption of new practices is that development facilitators lack proof of how the technologies can be realistically included into farming systems. This poses an urge to find out how farmers can realize synergies and reduce trade-offs in executing multiple CSA practices (Steenwerth et al., 2014).

In some parts of the World like Colombia, the major climate hazards comprise reduced precipitation, intensified frost, and heightened daytime temperatures. In the advent of these conditions, CSA presents locally available solutions, however, it is not wide spread in many countries. Several limitations curtail its success and among these include, agriculture being a second option with less priority at the local levels (Aggarwal et al., 2018). Reasons for differences in CSA adoption are unrelated, and heterogeneity in the use of CSA technologies emanates from exposure to climate change risks and information among other factors, for example in Southern Tanzania, farmers who had experienced climatic shocks in the past 5 years were 8.13% more likely to adopt minimum tillage than their counterparts (Mwungu et al., 2018). While in Kirinyaga County, Kenya, 34.7% of respondents used tied ridges and convectional tillage as the broadly used means of water harvesting practices on their farms, and 2.4% of participants did not use any of the mentioned practices (Njeru et al., 2020). This is partly due to the many CSA scaling efforts that do not consider wider socioeconomic factors leading to low adoption, for instance, only 50% of all farmers surveyed by Lopez-Ridaura et al. (2018) in Eastern India benefited from the research station CSA diffused technologies, moreover, these were only relatively wealthier farmers and medium-scale cereal crop farmers. Such groups of farmers are able to search for information and meet the costs it comes with unlike the poor and low resource farmers.

CSA scaling efforts have come to employ a range of means to reach farmers with climatic information for example, in Zambia, the Ministry of Agriculture together with experts at the Zambian Open University and the National

Table 2. Performance of potato clones in water-stressed conditions at average precipitation of 295 mm (range from 210 to 414 mm) across three seasons and three locations between 1300 and 1700 masl in Kenya.

Group by percentage above average of current varieties	Yield (t/ha)	Number of clones
> 40%	22.9	1
> 30%	20.7	5
> 20%	19.4	5
> 10%	18.3	4
Average of current varieties	15.5	

Source: (Parker et al., 2019).

Table 3. Crop rotation sequence practiced by some Kenyan potato farmers.

potato, maize, potato	potato, cabbage, potato
potato, maize + beans, potato	potato, maize/wheat, potato
potato, maize + bean/cabbage,potato	potato, maize + bean/wheat, potato
potato, maize/cabbage,potato	

Source: (Muthoni et al., 2013).

Maize + beans = maize intercropped with beans; maize + beans/cabbage = maize intercropped with beans or cabbage alone; potato, maize, potato = potatoes followed by maize then potatoes in that sequence; maize/cabbage = maize or cabbage (Muthoni et al., 2013).

Table 4. Common CSA practices in Potato Production and their potential.

CSA practice	Meaning	Potential
Drainage management	This encompasses the removal of excess water caused by flooding from the garden through the use of water control structures like channels.	Reduces risks of crop failure due to flooding that may wash away the crops, which may lead to waterlogged conditions which result in rotting of potato tubers.
Agroforestry	Is the intentional planting or guarding against the removal of more than one tree within 12 months on agricultural land or from its borders and on land set aside for purposes of tree planting. It manifests through practices such as planting of fruit trees, windbreaks, live fences, planting on boarders, and execution of strip cropping.	Results into sustainable land use management through soil fertility maintenance, creation of favourable microclimates like shade, and reduces moisture-related stress. It also leads to carbon sequestration, soil erosion prevention, and tree products that offer environmental services.
Synthetic fertilizers	These are substances of manufactured origin that, when applied to the soil, release one or more critical nutrients needed by plants for growth and increased yields.	Compensates for the declining soil fertility and mostly nitrogen deficiency, speeds up crop growth and development to counteract the effects of the short growing seasons. This results in increased productivity and reduced chances of crop failure.
Composting	Refers to the collection and heaping of waste materials of either plant or animal origin such as food remains, crop residues, and or animal manure piled in a pit or any other structure to hasten decomposition and application to cropland soil afterward.	Also compensates for the declining soil fertility, avoids emissions from the use of raw animal manure, improves soil carbon sequestration and increases productivity with low inputs.
Ridge planting	Is the construction of continuous lines of mounded soil on which crops/ potato tubers are planted – ridges constructed along the contours of farmland help to prevent run-off of rainwater, thus controlling soil erosion.	Increases on water retention to compensate for the dry spell and low rainfall, increases nutrient absorption and leads to increased productivity on compacted and sloping marginal areas.
Crop rotation	Is the systematic and planned change of crop plots per season or per year to avoid the depletion of soil nutrients that may occur when the same type of crop is planted in the same area seasonally or yearly. It entails the farmer choosing to alternate crops that can replenish and or help to fix the nutrients used up by the other; this includes scenarios like planting groundnuts after maize.	Compensates for the reduction in soil fertility, increases resistance to pests and diseases, soil structure improvement, contributes to carbon sequestration, prevents erosion and sustains productivity through soil exhaustion avoidance.
Improved crop varieties	Is the use of genetically and phenotypically improved crop planting materials that have been bred for their traits such as increased yield, tolerance to stress (cold and heat), and disease resistance.	Ensures stress (drought, flood, and heat and cold stresses) tolerance and disease resistance; early maturing that avoids crop loss from shorter growing seasons and unreliable rains. It also results in higher productivity and reduces risks of crop failure.
Intercropping	Refers to the planting of two different but complementary crops on the same piece of land at the same time in a mixed pattern, in rows, or done through strip intercropping.	Improves nitrogen fixation and improved soil quality and reduces risks of total crop failure.
Irrigation	Supplying water to crops by making use of labour-saving or increased-efficiency technology, either on a large scale such as a canal/pump system or as a smaller micro-irrigation scheme.	Enables dry season production that compensates for the reduced rainfall. By making offseason production possible, it leads to increased diversification and productivity.
Minimum tillage	Tillage refers to all techniques used to prepare the soil for farming. It entails the loosening by breaking of topsoil using farm implements like hoes. Minimum tillage occurs when land preparation is done by slashing of existing vegetation that allows regrowth of the vegetation followed by the application of herbicides, followed by hand planting using a planting stick. Under minimum tillage practices, residues from vegetation removal are used as mulch to cover the soil surface.	Reduces resource wastage on land preparation, improves water percolation, and amount of organic matter in the soil. This results in improved soil structure and prevents soil erosion. In the long run, it leads to improved productivity through moisture retention and soil compaction and degradation prevention.
Mulching	The covering of the soil surface with a layer of organic residues and allowing for eventual decomposition to smother weed growth and reduce evaporation of soil water.	Reduces soil temperatures compensating for higher air temperatures, compensates for drought and reduced rainfall by improving the moisture retention capacity, reduces emissions from the uncovered soil surface and reduces risks of crop loss.
Rainwater harvesting and storage	The collection and storage of rainwater using a rooftop harvesting into concrete tanks and plastic tanks and use of ponds that collect the runoff.	It avails additional water sources during dry spells. This results in reduced crop/ animal loss when used for irrigation and watering animals leading to increased productivity.
Terracing	Refers to a soil conservation measure put in place to prevent rainfall-runoff mostly on sloping land from building up and causing severe soil erosion. Terraces consist of both ridges and channels constructed in a planned and systematic way across the slope.	Reduces runoff and soil loss that may occur because of water erosion. This results into reduced soil fertility loss and increased water infiltration into the soil.
Apical rooted cuttings	Apical rooted cuttings are produced vegetatively. Instead of letting tissue culture plantlets to mature and yield minitubers in the screen-house, apical rooted cuttings are produced from the plantlets. After rooting, the apical rooted cuttings are grown in the field to yield seed tubers, followed by one to three consecutive generations of field multiplication.	Apical rooted cuttings are more productive and shorten the time required to complete the production cycle by one season. This also avoids crop loss from shorter growing seasons and unreliable rains.
Mini-tubes	Minitubers are progeny tubers of the in vitro derived plantlets. The term is due to their size as they are smaller than normal seed tubers but bigger than in vitro tubers.	Minitubers result into healthier tubers because of the nonexistence of soil-borne diseases. They lead to higher quantity of tuber set per plant and they can be kept until favourable planting conditions, thus escaping harsh weather.

Source: Adapted from Caitlin (2014), Khatri-Chhetri et al. (2017), Mereu et al. (2018) and Parker et al. (2019).
Note: These CSA practices directly or indirectly lead to improved agricultural productivity, reduced GHG emission and results in enhanced resilience

Agricultural Information Services develops the message in a ready-to-use format for the farmers and sent through text messages to the farmers (Odubote & Ajayi, 2020). This is an effective approach, but most farmers being unregistered with text message services keeps many unaware of the CSA practices being promoted and eventually, low adoption rates. Many farmers find challenges in adopting CSA practices, in Kenya, most farmers relied on hand water application with buckets and watering cans to water their vegetables (Chepkoech et al., 2019). This makes it inefficient, backbreaking, ineffective and unaffordable, thereby shunning the weak away from its adoption. In Bungoma County, western Kenya, an average of 53.6% of the farmers who partook in the CSA project, the Kenya Agricultural Carbon Project adopted the practices that were promoted (Cavanagh et al., 2017). However, disaggregation of this into *wealth groups*, the *very poor* and *poor* groups exhibited relatively lower adoption rates of 42 and 49 percent with the *less poor* wealth group showing an adoption rate of 73 percent (Cavanagh et al., 2017). This kind of poorly stratified farmers can best be targeted by disaggregating adaptation and mitigation strategies in order to avoid imposing a burden to the poorest groups of participating farmers in the agrarian communities. Disaggregation can enable developing of economically affordable technologies that suit most farmers' capabilities.

Amadu et al. (2020) add that CSA adoption rates are higher among farmers participating in scaling projects but with higher social capital as measured by group membership and affiliation network, and greater links to formal institutions such as extension visits and access to credit, than non-participants. This affects the aggregate CSA adoption and may undermine the scaling efforts if not taken care of. Related results by Kimathi et al. (2021) in Malawi found out that adoption of CSA practices was greater by 56% amid the participants as opposed to non-project participants. This implies that differences in the socio-economic status greatly impede CSA adoption and the overall realization of the cushioning of farmers against climate change shock. Additionally, partial exposure creates disparities in adoption, for example, an adoption gap of 24.4% was observed by Mujeyi et al. (2020) where the potential adoption rate was 30.7%. This can be attributed to limited access to information, training, group membership, quality seeds, and disparities in agro-ecological zones. On the other hand, the expectation of tangible benefit directs the adoption of CSA, for example where visible benefits are high, men appreciate the role of CSA and thus high rates of adoption. While for women, social processes are key in shaping their decisions on adoption. Based on this, uptake of CSA is most likely to happen when farmers, primarily women, notice that the practices will be free from added drudgery (Khoza et al., 2020). CSA uptake is moderate where farmers have access to information on various CSA practices; have adequate resources to meet the associated costs; have strong social networks and institutions to support the execution of the recommended CSA technologies; where risks are low; CSA can be executed without compromising the continuation of farms; and where CSA cannot impose pressure on natural resources and disputes within resource users. Kaweesa et al. (2020) states that where these conditions were met, over 69 percent of the study participants accepted to adopt the CSA practices. This indicates that low resources endowed farmers who cannot meet these conditions may be reluctant in accepting the CSA practices, thus low adoption rates among such categories. Table 5 maps out some of the CSA technologies/practices and reasons for low adoption.

Given the challenges hampering the adoption of CSA, effective implementation, therefore requires an integrated approach in which science, technology, and decision-making interact with local socioeconomic conditions and cultures (Steenwerth et al., 2014). The low adoption of CSA technologies by agrarian communities increases the chances of yielding to threats posed by climate-related disasters which directly dwarfs livelihoods. The differences in the farmer settings, make adoption patterns not to commensurate with the merits of CSA (García de Jalón et al., 2017). Different investigations have aligned the determinants of adoption into five types of capital which aid in identifying the major reasons for uptake, namely human,[1] financial,[2] physical,[3] social[4] and natural[5] (Below et al., 2012; Gebrehiwot & van der Veen, 2013; Silvestri et al., 2012; Wheeler et al., 2013). Investigations into the determinants can help to draw insights that may guide future efforts working on scaling out various CSA practices (Faling, 2020). This is because for many years, efforts have been directed towards generating and promoting the adoption of food insecurity alleviating technologies, with an assumption that they could be accessed by the farmers and translated into the desired results (Leal Filho et al., 2015; Taylor, 2018). These like most other technologies, end up being diffused to the target farmers without full understanding of their contexts (Zijp, 1994). The selection of the deputies that are extrapolated from the five capital types was based on the relation between the deputies and the uptake of CSA practices. So, the interplays between the information on climate change, institutions, and farmers' socio-economic status could be regarded as social capital indicators.

3.4.1 Socio-economic determinants of practice of CSA by farmers

The socio-economic aspects of agricultural areas determine the adaptation strategies for its dwellers (Dutta & Hazarika, 2020). Some of the socio-economic factors like farm size, education level, age, gender, labour availability, and off-farm income/farmers' income and their influence on practice of CSA have been described below.

3.4.1.1 Farm size. This has a direct effect on the adoption of CSA practices. The study by Waibel et al. (2018) discovered a positive relationship between farm size and CSA practices. They further stated that the early adoption of technologies tends to take place on larger farms. The practice of CSA among smallholder farmers is also curtailed by the fragmented pieces of land, which prevent them from benefiting from the economies of scale (Arslan et al., 2014). According to Etim and Etim (2019), increasing farm size by one-hectare increases the chances of practicing CSA technologies such as conservation agriculture, change in the planting date, and crop diversification. Findings also implied that larger-scale farmers give room for technology testing on part of their extensive lands without fear of jeopardizing the food security of their households. Besides this, the study by Kalungu and Leal Filho (2018) in Kenya found out that the farm size is a crucial factor in technology adoption.

Table 5. Commonly used and promoted CSA TIMPs[a] in Potato Production.

TIMP type	TIMP defined	Barriers to adoption
Soil nutrient management	Customs that preserve soil moisture and enhance soil fertility e.g. covering the soil surface with crop residues, advanced fallow, fertilizer utilization efficiency (Fertilizer management), and composting.	Inadequate crop residues; tradeoffs between applications of crop residues; limitations on the existence of other biomass for fuel and feed; additional manpower demands for manure gathering and spreading; lack of animals to provide manure
Soil and water management	Practices that limit and minimize the volume of soil lost by erosion as well as associated water utilization efficiency by reducing the loss of water through evaporation and water run-off, e.g. rainwater harvesting and storage, irrigation, drainage management, ridge planting, and terraces on-farm slopes.	High labour requirements in preparing and maintaining the desired basins and terraces; perceived inappropriateness for farm-specific scale and context related to labour expenses
Tillage residue management	Opening the soil only when unavoidable; leaving crop remains or weeded grass on the soil surface to lessen soil opening; covering the soil with cereal stalks and legume residues placed along contours instead of burning them.	Multiplication of weeds, pests and diseases, rodents; saturation of soil water; inadequate quantities of the available crop trash.
Agronomic practices	A variety of sustainable agricultural management practices that aim at enhancing soil fertility, increasing crop yields, and contributing to sustainable development, for example, cover crops growing, intercropping, contour farming, crop rotation, improved crop varieties, agroforestry, and use of improved varieties and planting materials (Minitubers and Apical Rooted cuttings for the case of potatoes).	Perceived resource inefficiency e.g space and water by the tree types proposed for agroforestry; insufficient markets for nitrogen-fixing leguminous plants (both input and out-put markets); increased labour requirements; food and nutritional insecurity; trees as hosts for crop pests and diseases; overall increased cost of production.

Sources: TIMPs compiled from Nyongesa et al. (2019). Categorized and defined from Caitlin (2014), Khatri-Chhetri et al. (2017), Mereu et al. (2018) and Parker et al. (2019). Barriers to adoption compiled from Nyongesa et al. (2019), Rusinamhodzi et al. (2011), Giller et al. (2009), Nyberg et al. (2020), Andersson and D'Souza (2014) and Jerneck and Olsson (2013)

Notes: [a]Technologies, Innovations, and Management Practices. *Technology*: This refers to the product of an investigation process that is propitious to the target clients (chiefly farmers), can be profited, and can be registered under intellectual property rights agreements. Examples include genetic materials, breeds, farming and herding practices, etc. *Management practice*: This refers to the direction(s) on the method(s) that is/are deemed essential for technology to realize its maximum output. Examples include various agronomic practices (seeding rates, fertilizer utilization rates, spatial patterns, planting time, land preparing, watering regimes, etc.), protection techniques, for crops; and feed rations for animals, etc. *Innovation*: This refers to a modification of existing technology for completely changed use from the primary designated use. Examples include fireless cooker altered to be a hatchery, etc (Nyongesa et al., 2019).

3.4.1.2 Farmer's education level. Education is one of the critical aspects through which farmers are empowered with the necessary skills and knowledge to execute recommended technologies on their farms. The level of education plays a significant influence on the decision to practice the CSA (Kane et al., 2018). Most educated farmers stand high chances of making better decisions as well as quickly adopting new technologies in farming. The higher level of education increases farming success since it positions farmers to understand and utilize technical information and thereby enabling them to make informed decisions in response to the increasing research findings in agriculture (International Center for Tropical Agriculture (CIAT) & World Bank, 2017). Moreover, farmers' education is correlated with production and marketing as agricultural skills. High literacy levels reduce gender parity in farming activities; thus, all individuals can be able to access and critically assess new technologies, relate with extension and other technology providers, and practice proposed CSA practices (Duffy et al., 2017). Conversely, it was found out that there is a negative correlation between education level and technology adoption in Wote, Kenya (Bernier et al., 2015).

3.4.1.3 Age of the farmer. Age is an indicator of maturity on which inference is made about a person's capability to make sound decisions in farming activities. Young and middle-aged farmers are mostly receptive to adopt new technologies in farming. Age has a direct influence on the household head experience in farming, and according to Kane et al. (2018), young and middle-aged as household heads are most productive and receptive to new technologies. Above 45 years, age is negatively correlated with the adoption of small-scale irrigation farming, and this suggests that adoption is higher among younger farmers (Mango et al., 2018). The study by Khatri-Chhetri et al. (2017) found out that the farmers' age positively influences the choice of different CSA practices like integrated pest management, minimum tillage, site-specific integrated nutrient management, and crop insurance. This contradicts the findings by Amsler et al. (2017) that revealed that Kenyan youths farmers do not know how to adapt to climate change.

3.4.1.4 Gender of the farmer. Gender and climate change are cross-cutting priorities for all development agencies. According to Okello et al. (2018), men and women may have different perceptions of making decisions on climate change adaptation due to differences in access to productive resources, extension services, and employment. This explains the findings by Nyasimi et al. (2017) in Lushoto, Tanzania, that found out about the variance in interests between men and women for CSA. Women have more preference for intercropping crops, whereas men adopt chemical fertilizer, composting, agroforestry system, and cut and carry feeding as CSA practices. The (UNDP, 2010) indicated that women engage more in adaptation activities due to their deep understanding of their immediate environment through their experience in managing natural resources (water, forests, biodiversity, and soil), and their active engagement in climate-sensitive work such as farming activities and fisheries.

However, the study by Duffy et al. (2017) indicates that some CSA practices like conservation tillage can increase the weeding frequency, an activity often performed by women in Africa south of the Sahara. Besides, social norms and structures complicate their ability to adopt some CSA technologies due to differential access to information and other resources like land due to property rights. This creates a barrier that constrains the practice of CSA. In Kenya for example, women unlike their counterpart the men, are curtailed by customs and taboos in accessing agricultural equipment and input stores, public support, finance, markets and transportation (Bernier et al., 2015; Ngigi et al., 2018).

3.4.1.5 Labour availability. Most CSA technologies demand more energy and labour, which is, in most cases, insufficient. For example, conservation agriculture increases the burden of labour on farmers due to an increase in weeding activities (Kakzan et al., 2013). Nevertheless, farmers experience hindrances in the adoption of new productivity-enhancing CSA technologies that lead to increased labour demand. For instance, Murray et al. (2016) pointed out that a critical bottleneck for farmers' tree planting adaptation strategy lies in digging holes, necessary labour needed to dig the larger holes that ensure better tree survival may not be adequate. On the contrary, it was found out in Kenya that labour may not be a limiting factor for large households since they may most likely have enough of it (Ochieng et al., 2017).

3.4.1.6 Off-farm income/ farmers' income. Since most CSA practices are associated with costs, the farmer's on-income and off-farm income are important for its adoption. The willingness of the farmers to pay for CSA technologies is often influenced by the cost of the technologies (Khatri-Chhetri et al., 2017). This means that high farmers' income translates into high access to CSA technologies. Therefore, smallholder farmers with low incomes due to the low yields may not have access to certain CSA technologies (Anuga et al., 2019).

Low budget households may find it challenging to switch from the conventional agricultural practices to the CSA practices like agroforestry since they rely on agricultural production for their continuous income (Arslan et al., 2014). High budget farmers may have more access to information, and this makes them less prone to risks. Besides, when farmers have non-farm options, they can afford to plant trees on the limited available land without compromising household food security, and they can easily meet the agronomic practices' requirements (Deressa et al., 2009). On the other side, high farmers' income may suffer some CSA practices. A study by Ochieng et al. (2017) in rural Kenya found out that high-income farmers tend to specialize in one crop; this decreases the chances of alternating crop varieties and instead results in monoculture as opposed to crop rotation.

3.4.2 Institutional determinants of practice of CSA by farmers

According to Okello et al. (2018), institutional factors influence both the state and local level institutions like the market, land tenure system, Non-governmental organizations (NGOs), credit institutions, and information access, which all have the potential to directly or indirectly influence the adoption and use of CSA practices.

3.4.2.1 Land tenure system. Land tenure gives ownership and access to land. Ownership exerts influence on what kind of activities for which land can be used. Nyanga et al. (2016) argued that farmers with permanent tenure tend to invest in long-term CSA practices. Also, most farmers with secure tenure adopt agroforestry practices with different tree diversity. Conflicts and land disputes pose a significant threat to sustainable agricultural development initiatives like CSA (Anuga et al., 2019). Having no land title constrains most farmers to change the land use from the use of conventional agricultural practices to CSA technologies. Farmers with a short leasehold find little interest in adopting sustainable CSA practices whose benefits can be realized after a long time (Duffy et al., 2017). Bernier et al. (2015) added that in Kenya, land tenure measures are significant in a wide area like forested areas and that they dictate the use to which land can be put, and this may act as a disincentive for the affected farmers to adopt CSA.

3.4.2.2 NGO support. Non-Governmental Organizations (NGOs) are private institutions, either profit or non-profit making bodies. Their presence and support to farming communities influence farmers' decision to adopt CSA technologies (Anuga et al., 2019). These add that NGOs tend to provide farmers with handouts but also with CSA technologies like drought-resistant and high-yielding varieties for compensation against the shock. In the absence of these NGOs, farmers become more vulnerable to the terrifying effects of climate change. However, in Kenya, men are the primary beneficiaries of the NGO CSA projects, and this is attributed to their ability to attend agricultural-based seminars and workshops (Kane et al., 2018).

3.4.2.3 Access to credit. The adoption of CSA comes with a cost in terms of buying technologies like the drought-tolerant varieties and irrigation equipment. Besides, most of the farmers have low incomes; therefore, access to credit may directly and greatly influence the practice of CSA (Lipper, 2017). In turn, access to credit can increase CSA related income-generating investments, influence farmers' role in social networks, builds the ability to deal with shocks of climate events and strengthens farmers' resilience level (Asfaw et al., 2012). The CGIAR's research programme on Climate Change, Agriculture and Food Security (CCAFS) in East Africa affirms access to credit as one of the strong pillars that foster scaling out CSA practices in Kenya (CGIAR, 2015).

3.4.2.4 Access to training on CSA. Farmers' training on CSA topics such as soil-water management, minimum tillage, and crop diversification influences the farmers' adoption of such technologies. Directing CSA pieces of training not only to the farmers but also to extension agents working with farmers to promote CSA breaks the adoption barriers. It creates enabling CSA adoption conditions (Aryal et al., 2018). The effectiveness of the farmers' training on climate risk management depends more on the focus on the training period. Well planned and focused training increase the chances of adoption of climate risk management practices like CSA (Nkonya et al., 2018). Bolt et al. (2019) adds that giving potato farmers in Kenya training on the benefits and costs of crop insurance as a CSA practice provides them with the details of what is required and increases the chances of adoption. Providing smallholder farmers with the knowledge on the use of technologies and why they should be used through training acts as an incentive for their adoption (Kane et al., 2018).

3.4.2.5 Membership in farmer groups. The local institutions play an essential role in the practice of CSA technologies since they constitute of local members who come together and pool resources that may be necessary to access and adopt a given CSA technology. It eases access to the resources that are within and outside the community (Aggarwal & Singh, 2010; Teklewold et al., 2012). Van Rijn et al. (2012) suggest that links of trust and intra-community cooperation can lead to withdrawal behaviour, which makes individuals less likely to adopt and seek new agricultural innovations. For example, actions like planting a drought-resistant crop at the individual level do not require much of institution coordination. However, findings by Okello et al. (2018) present evidence on the importance of collective action in facilitating the adoption of CSA technologies. It facilitates risk pooling and enable people to build assets that help them in withstanding climate change shocks.

3.4.3 Information dissemination pathways as determinants of practice of CSA by farmers

Decisions on which kind of dissemination pathway to use depend on farmers' needs, skills, and use of the information (Nyasimi et al., 2017). Several households rely heavily on friends, relatives, and radio as well as their observations, especially weather information that guides their decisions on CSA strategies (Chengula & Nyambo, 2016; Nyasimi et al., 2017; Van den Broeck & Dercon, 2011). Timely access to information about climate variability helps the farmers to make informed decisions about which CSA technology to adopt. Nyasimi et al. (2017) found out that farmers' access to information can enable them to start planning the CSA practices as the adaptation measures to the changing climate occurring now and that projected in the next 20 years to come. It is unveiled that the desire to improve agricultural productivity motivates over 99% of the farmers in Lushoto to seek for CSA information on new and resistant varieties, irrigation techniques, and sustainable soil fertility improvement measures. In Lushoto, government extension services and farmer's own experience are the primary sources of information. The study by Franzel et al. (2014) in the Nile Basin in Ethiopia showed that limited access to weather information and extension services is a major hindrance to climate change adaptation by changing the planting dates.

3.4.3.1 Schools. These provide a means through which theory is connected with practice; therefore, they are considered to be central to environmental conservation and preservation (Sajal, 2020). For example, in Zambia, the University of Zambia plays the role of transforming communities by scaling up CSA through training, undertaking research, gathering, and documenting CSA evidence. It is also a lead practitioner and agency of the CSA programme (Odubote & Ajayi, 2020).

According to Epstein HaLevi et al. (2020), farmer field schools have objectives of educating farmers to enable rural citizens to access the literature of modern CSA technologies. Besides the agronomic practices, the schools strengthen the resilience capacity of farmers through climate-smart village approaches implemented through field schools (Msaki & Bangali, 2015). A typical example is the Tanzania case, where the adaptive capacity of farmers is built by field schools (Mugabe, 2020). In Kenya, Maseno University together with the University of Reading and the Kenya meteorological services have created a forum that brings together representatives from women groups, development partners, youths groups, the local county government and the private sector to share possible ways of accelerating the diffusion and adoption of CSA (CGIAR, 2015).

3.4.3.2 Radio/ television/ phone. The different ways through which information on CSA is diffused to the farmers affect the farmers' adoption decision. Previous research by Nyasimi et al. (2017) in Lushoto, revealed that the use of video recording during pieces of training on CSA demonstration contributes to the wide distribution of the information by the farmers that attend. By the use of phones, radio, and television, this information reaches more farmers who did not participate in the training; as a result, this increases the adoption rate. Besides, schoolchildren, the potential future farmers prefer the latest information and communication technologies, more so television and mobile phones. The use of television and mobile phones in scaling up CSA practices reaches more farmers and youths as well. The effectiveness of the radio, television, and phone as dissemination pathways depends not only on their successful delivery of the information that influences farmers' decision to adopt but also on the large number of farmers that receive the information (Triomphe et al., 2014).

Kenya is endowed with Information and Communication Technology (ICT); radios, phones, and televisions are trendy among farmers. These enable the farmers to reach the extension agents at any time by phone, listening to radio or television programmes. Listening to radio and television provides a convenience since farmers can do the listening as well as doing other tasks (Manfre & Nordehn, 2013).

3.4.3.3 Neighbours/ friends. Understanding dissemination pathways also involves horizontal information pathways that include peer-to-peer through farmer meetings and face-to-face interactions (Burke, 1999). The majority of the households rely heavily on friends and relatives, as well as their observations mostly from their neighbours for information, particularly weather forecasting information and climate adaptation strategies in the short and long term (Chengula & Nyambo, 2016; Van den Broeck & Dercon, 2011). According to Nyasimi et al. (2017), this approach seems the simplest for CSA practices information diffusion, especially between members of the same family and locality. In their study in Kenya, Bernier et al. (2015) noted that participants (farmers) acknowledged the assistance offered by their neighbours in terms of providing them with agricultural and climate information that informed their adaptation decisions. Franzel et al. (2019)'s research in Malawi, Kenya, and Cameroon found out that mobilizing a few farmers for initial training on CSA practices has a multiplier effect since many organized demonstrations following the training to train fellow farmers. Kalungu and Harris (2013) reported that in Kenya, most farmers adopted

CSA technologies like improved crop varieties by imitating their neighbours.

3.4.3.4 Extension officers. These ought to be the best source of new information on CSA technologies that can increase agricultural productivity and farmer's incomes. For effective extension information delivery, farmers need to be engaged in developing technologies for successful innovation process facilitation and catalyzing the adoption process (Napolitano, 2016). This drives the extension officers to seek new CSA technologies that respond to the changing nature of agriculture and farmers' needs. In the past three decades, extension adapted the model of information dissemination to the farmers' need; and developing closer linkages between agricultural researchers with extension providers and extension providers with farmers to tap into local knowledge, that creates a better understanding of farmers' needs and problems plus obtaining feedback on how technologies are working (Nederlof & Pyburn, 2012).

The Kenyan extension officers work closely with the farmers to initiate the process of technology diffusion and facilitating experience exchange among farmers (Kane et al., 2018). Through joint diffusion and experience sharing, farmers may adopt the technologies that have been implemented by others.

3.5 Knowledge gaps

The literature cites the potentials of CSA, for example, the improved potato varieties being tolerant to pests and diseases and prolonged dry spells. Nonetheless, it does not stipulate the conditions that may limit the realization of such benefits. It also points out the benefits of various CSA practices in addition to the above. However, it does not highlight the biophysical, environmental, and farmer related factors like knowledge about the technology that may jeopardize their potential, other than their practice.

According to the cited literature, several factors (institutional, socio-economic, and informational dissemination pathways) are quoted as being responsible for the practice of CSA. It states that factors like gender limit access to resources necessary for practicing CSA; nevertheless, it does not show the kind of women that are profoundly affected. It leaves unanswered questions on whether the educated and uneducated women are affected the same way. The cited literature also found out that farm size and land tenure systems influence CSA adoption; for example, farmers with large farm size and land titles may adopt some CSA practices like agroforestry without affecting household food security. This finding did not illustrate how this affects intensive farmers operating on small pieces of land. Since these apply recommended fertilizer, which is a CSA technology to maximize yields. They also tend to plant agroforestry tree species as hedge plants. On the other hand, access to credit and NGO support are accredited as significant accelerators of CSA adoption. This is so ambiguous in the sense that it did portray the bottlenecks that constrain farmers from credit access and NGO support. Also, it did not clarify on which kind of credit and which amount that the farmers in question have/ fail to access concerning the CSA technology costs. Additionally, access to training on CSA practices is said to enable farmers to familiarize themselves with CSA practices. That this translates into adoption; however, this is not clear on how long the training should have lasted to enhance farmers' skills on CSA practices. On the other hand, the cited literature backed up access to information as a critical aspect of CSA adoption. Conversely, this is void of facts on which kind of information and from which source that was translated into practice and to which extent.

4. Conclusions and recommendations

CSA presents the potential to alleviate food insecurity in the face of climate variability. Several CSA technological practices have been developed globally, and for Kenya in particular to respond to the decline in the yields of potato and other crops. However, enormous literature points out that development of these technologies is not a panacea to solving the problem. That development of these technologies without full knowledge of the farmers' contexts leads to their underutilization. An in-depth investigation of the subject was conducted by reviewing literature from various databases, institutional websites and data from FAOSTAT. The reviewed literature ranges from 1994 to 2021. The study identified the potentials of CSA and among which include its ability to increase yields during dry season, pests and disease tolerance in crops, water logged conditions tolerant crop varieties, and improvement of soil structure and fertility. However, full knowledge of the farmers for whom these technologies are designed is necessary. Understanding of farmers' contexts, can further enable disaggregation of farmers for better targeting. This eventually increases chances of CSA up take. Farmer's income dictates which CSA technology to adopt and land tenure systems may discourage farmers with short leasehold from practicing agroforestry.

Though the available literature cites the importance and limitations of CSA adoption, other arenas like the role of private agro-companies in the diffusion of CSA practices have been given less attention. An additional gap in the literature is the ambiguity, in regard to the period required to train farmers in order to adopt the CSA, and how size of the land affects practice of CSA among the intensive farmers operating on small pieces of land. The study concludes that there is need to engage the final users of the CSA technologies during their development and that knowledge of the information sharing patterns among farmers is key to successful scaling out of the CSA practices. Understanding these is essential to tailoring the CSA practices to the farmers' most pressing needs and to the development of the practices that farmers are able to access and put into practice.

Notes

1. Human capital refers to fruitful capabilities, conversance, and personal traits and preferences that render an individual extra prolific (García de Jalón et al., 2017; Pindyck & Rubinfeld, 2013). The considered deputies include the level of education, labour availability, and their influence on the practice of CSA.
2. Financial capital is a resource stock that expedites economic production (García de Jalón et al., 2017). The considered deputies

include access to credit, off-farm income/ farmers' income among others.

3. Physical capital refers to specified material assets attained using human prolific pursuits that are utilized to produce a stream of goods or services (García de Jalón et al., 2017). It denotes assets like farm inputs, infrastructure, or technology that augment crop production. The considered deputies include farm size and land ownership.
4. Social capital pictures social networks and comprises of credence, harmony, and interaction among individuals and groups (García de Jalón et al., 2017). The considered deputies include farmer's age, gender, receiving NGO support, access to training on CSA, farmer group's membership, access to CSA information through radio, television or Phone, neighbors/ friends, schools and extension officers.
5. Natural capital refers to a stock that renders ecosystem services of the natural environment that generates an estimable movement of goods and services into the future (García de Jalón et al., 2017). In regards to agriculture, natural capital is represented by climate and soil properties which predestine the appropriateness for agriculture.

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