Soil carbon enhancing practices: a systematic review of barriers and enablers of adoption

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Abstract

Sustained adoption of soil carbon enhancing practices (SCEPs) at scale remains an aspiration goal to maintain sufficient amount of soil carbon in household farms in order to impact on the sustained farm productivity caused by sustained soil fertility. The objective of this study is to systematically evaluate the current evidence base to identify: (a) which factors enable or constrain adoption of SCEPs and hence maintain soil carbon in Kenya and Ethiopia; (b) to be able to lessons learnt concerning what influences the adoption of the SCEPs for the purpose of maintaining soil fertility among smallholder farms; and (c) how this can be improved going into the future for the purpose of formulating appropriate policies in Kenya and Ethiopia in both the short and long run. A systematic review was conducted using established review methodology and extensive searches of published and unpublished literature sources. Data extraction and quality appraisal of quantitative, qualitative and case studies that met the inclusion criteria were conducted while checking for reliability. A broad range of interrelated enabling and constraining factors was identified for the SCEPs. All the factors matter, and some of most of these factors are important to be considered during planning and implementation of SCEPs aiming at promoting soil carbon sequestration. Despite the limitation in the quantity of evidence, this systematic review provides a useful starting point for the scaling up programmes to ensure more effective adoption of SCEPs. This review also underscores the need for a multidisciplinary approach in understanding what determines the adoption of SCEPs to capture a holistic view.

Keywords Adoption · Determinants · Soil carbon · Review · Influence · Kenya · Ethiopia

1 Introduction

In sites where agriculture production is common, soil erosion and nutrient depletion are typical, and without appropriate measures to maintain soil fertility, the land often becomes unproductive [1]. To counter the negative effect of the soil and nutrient loss, farmers tend to invest in agricultural and sustainable land management (SLM) practices that have the potential of improving land productivity [2]. Among the agricultural and SLM that farmers are investing on, soil carbon enhancing

practices (SCEPs)¹ (such as compost manure, conservation tillage, contour planting, crop residues, crop rotation, drainage ditch, 'fanya juu' terraces, farmyard manure, grass strips etc.) are some of the most common ones [3].

Nearly 80% of the carbon found on the land ecosystem is stored in soils, thus the implementation of SCEPs

¹ Soil carbon enhancing practices as used in this paper mean both agricultural management practices and soil land management practices that enhance carbon sequestration in the soil or that mitigate the loss of soil carbon.

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proficiently helps in the sequestration of atmospheric carbon² in the form of soil organic carbon (SOC). Thus, SCEPs play a significant role in the mitigation of the effects of climate change [4, 5]. Further, SOC is a major element of soil organic matter (SOM) which improves soil structure³ through nutrient release, thereby ensuring the sustainability of soil functions [6]. These, in turn, promote crops growth and quick regeneration of forages and hence livestock production. The adoption of SCEPs, therefore, has the potential of improving farm productivity, farmers' income and food security [7]. However, despite the importance of SCEPs, their adoption in the eastern Africa region is still low [8, 9].

The literature on adoption of agricultural management and SLM practices that enhance sequestration of soil organic carbon or that mitigate the loss of soil carbon—hereafter referred to as SCEPs—is extensive [10, 11] and shows that the decision to adopt these practices is influenced by the socio-economic characteristics of the households, biophysical, plot or farm and institutional characteristics in diverse ways as influenced by the context and the environmental conditions [12–16]. In addition, the adoption of practices that improve soil carbon is also influenced by technological, cultural, production environment and the existing policy in a dissimilar way in different regions of sub-Saharan Africa [17, 18].

The adoption of innovations has been studied extensively in agriculture since the pioneering work on the adoption of hybrid corn in the United States of America (USA) by Griliches [19]. The attention of most studies on adoption was focused on finding answers to questions such as (1) what determines whether a particular farmer adopts or rejects an agricultural innovation, and (2) what exactly determines the diffusion pattern of agricultural innovation in a given population of potential adopters [20–26]. Despite many studies in adoptions, the findings from the majority of the studies often show contradiction as it relates to the importance and effect of any given variable on adoption. The contradiction can be accounted for by the dynamic nature of decisions related to the adoptions by farmers that are also conditioned by their perceptions and information as information continues to become available to them. This study, therefore, conceptualizes the adoption of SCEPs as a multistage decision process

involving the acquisition of information and learning-by-doing from other farmers. This study also takes cognisance of what the theory of adoption refers to as entitlement and command over resources (i.e. natural, physical, human, financial and social capital) that the literature shows to have an effect on the adoption of innovations [27–29]. This is because agricultural innovations are usually introduced in a package to deal with a whole range of agricultural production constraints including low soil fertility and low soil carbon [30].

Despite the enormous literature on adoption of SCEPs, information on the factor that constrains or facilitates the adoption in eastern Africa is limited. The objective of this study is to systematically evaluate the current evidence base to identify: (a) which factors enable or constrain adoption of SCEPs and hence maintain soil carbon in Kenya and Ethiopia; and (b) to be able to lessons learnt concerning what influences the adoption of the SCEPs for the purpose of maintaining soil fertility among small-holder farms and how this can be improved going into the future for the purpose of formulating appropriate policies in both the short and long run. This can help us know whether the effect of specific socio-economic factors can be generalized during the formulation of policies aimed at effectively promoting and facilitating the adoption of SCEPs.

This review is organized as follows: Given the widespread definitions of carbon sequestration, it is vital to specify what this term and others associated with it means in the context of this review. Therefore, in Sect. 2, we provide a definition of the main terms and concepts used throughout this review. Section 3 describes the materials and methods used in this review and introduces the countries of focus. The results of this review are summarized in Sect. 4, while Sect. 5 highlights the conclusion and recommendations based on the findings from the review.

2 Methodology

2.1 Conceptual framework

In this study, we focus on the assessment of the factors that facilitate or constrain the adoption of SCEPs that we conceptually identify as both community (i.e. farmers group) and households level variables (i.e. socio-economic, fixed assets and institutional characteristics). Firstly, household endowment variables have been shown to influence or constrain the adoption or investment on SCEPs (Fig. 1). Abundant adoption literature has identified factors (such as age, education, gender, household size and incomes) that may influence the adoption process. The model developed by Feder et al. [22] presents

² Atmospheric carbon dioxide is the major green house gas that has significantly been linked to global warming, a major effect of climate change in the past decades.

³ Soil constitutes of organic matter, minerals, water, air and soil particles. The organic matter reserves nutrients and packs the air, water and soil particles. This increases infiltration which aid in biological processes, release nutrients, and move them to various parts of the plants.

Fig. 1 A conceptual illustration of the setup for systematic quantitative literature review

one of the initial attempts to deal with interrelations in the adoption of agricultural innovation. The availability of labour for example—represented by the household size—is likely to influence the gross margin of innovation via its effect on yield. Income may influence the initial scale of adopting a given technology by relaxing financial constraints. Farmers' age may influence risk aversion with the view that older farmers are likely to more risk-averse, and therefore likely to have a low adoption rate for new practices. Secondly, the effects of fixed assets such as farm and plot-level variables have also been shown to affect the adoption of SCEPs. The literature, however, underscores that the fixed assets must be borne in advance to allow the adoption of agricultural innovation over a given period. Consequently, inability to access a sizeable farm may interact with the dynamics of adoption (i.e. whether adoption of a given technology will pay-off over a given period) to bring about uncertainty, and this may lead to postponing of adoption. Thirdly, the adoption of SCEPs is also influenced by infrastructure and services variables such as access to credit, information, extension services and market and community group membership. Distance to the market, for example, acts as a proxy for transaction costs associated with the acquisition of inputs and marketing output. Access to the market can, therefore, affect the adoption of SCEPs [31]. In this review, the reader should take into account that none of the reviewed paper shows

the general trends of the SCEPs. To bridge this gap, the present review attempts to provide a general overview of the effect of socio-economic factors on the different SCEPs adopted in Kenya and Ethiopia.

2.2 Search strategy, context and study selection

In order to reduce the scope and challenges associated with the literature review, the literature review contained in this review was limited to only two countries—Kenya and Ethiopia—in eastern Africa. Kenya and Ethiopia have agro-ecological zones ranging from arid, humid and highlands, that experience a large variation in temperature, rainfall and vegetation cover—all of which determine the soil type and farming activities in these areas. Kenya and Ethiopia were chosen as the countries of focus based on the fact that this work is a part of a larger project that aims at scaling up the adoption in the two countries by 2021 [32]. Climate variability has become a threat to agricultural production—which majority (more than 80%) of the population in the both Kenya and Ethiopia depend on for their livelihoods. In addition, the farming systems in the two countries have become vulnerable and have weaker resilience capacity. Therefore, there is a need to invest in SCEPs, particularly those that have the potential (in both the short and long run) to improve crops and livestock yields—both of which are critical for wealth creation, food security and poverty reduction.

To be able to provide an answer to our research objective, we did a systematic analysis of the content of the peer-reviewed and published articles, technical reports and working papers following Pickering and Byrne [33]. The protocol of the 'Preferred Reporting Items for Systematic Recommendations' (PRISMA Statement) from Moher et al. [34] was used (Fig. 2). This approach has been applied widely in published systematic review literature in various subjects such as climate change, energy policy and justice [35], impacts of nature recreation on birds [36], impacts of infrastructure on vegetation and soil [37], failure for environmental sustainability policy implementation [38] and analysis of approaches for ecological restoration [39].

A search for peer-reviewed literature was conducted in English language using the Google Scholar and Scopus online databases and the Boolean search function of "adoption' OR 'Willingness to pay' OR 'willingness to accept' AND 'Sustainable Land Management practices (SLM)' OR 'land management' OR 'agricultural practices', AND 'socio-economic factors' OR 'constraint', OR 'affect' OR 'facilitate' OR 'determine' AND 'investment' OR 'economics of Sustainable Land Management' AND 'Soil carbon'" between August and October 2017 to identify articles. From an initial search of 1020 documentation, 501 documents were excluded because they contained only one

Fig. 2 PRISMA statement describing the steps for systematic quantitative literature review

of the search term without any relation to the adoption of SCEPs, the first 519 documentations were assessed for publication type before dismissing documents that were duplicates, book chapters, reviews or grey literature ($n=218$). The remaining 303 articles were further screened for relevance to the research objective, and 216 more articles were excluded as irrelevant. Additional 43 documents were excluded for quantitative analysis on the basis that they were either not reporting original data, discussed soil carbon but did not contain quantitative data. Consequently, a total of 44 articles were selected for detailed assessment (Fig. 2), and a total of 113 articles are cited in this paper.

The assessment criteria for the articles include the journal and authors; research methods used; subject countries; and the characteristics, influences and reported the outcome of factors constraining or enabling the sequestration of soil carbon (Table 1). We used the assigned field of research categories adapted from the Excellence in Research for Australia (ERA) 2015 submitted journal list

Table 1 Criteria used to review the selected articles on what constrain or enable the adoption of practices that sequester soil carbon

Review categories	
Journal, article and author	The location of the author The journal main discipline The journal research focus The year of publication
Research methods used	The data source(s) The analytical method
Subject country	Countries of interest
Soil carbon enhancing practices	The area where practices are applied Definition of soil carbon enhancing practices The intended purpose of investing in the practice
Factors influencing adoption	Socio-economic factors Farm characteristics Plot characteristics Institutional factors Biophysical factors

[40]. In cases where the journal for the review was missing, the classification was done by the authors based on the publisher's description and the scope of the journal.

The assessment criteria for eligibility were done by reflecting on the mixed methods, after which we determined that qualitative, quantitative and policy/case studies were all eligible, provided that these studies (1) reported experience in one of the SCEPs, (2) included empirically derived information on determinants of uptake of any one of the SCEPs and (3) did not address a switch to other types of soil and land management practices that are not considered as SCEPs. We only considered studies if they had been conducted in Kenya and Ethiopia. We excluded studies undertaken in refugee camps due to the limited generalizability, along with studies that relied solely on the effectiveness of non-governmental organization rather than adoption and use by households.

As for the study selection, we employed a standardized approach in selecting the study with independent verification by at least two authors. The screening of title and abstract was done first followed by an independent random verification for 15% sample of included and excluded abstracts. Finally, the screening of full-text articles. To construct the data tables, the quantitative and qualitative data involving socio-economic factors that determine the adoption of SCEPs available from each of the reviewed study were done using piloted design-specific data extraction forms and summarized these in tables. The verification of extracted data was conducted during the synthesis. The methodological quality of each paper considered was scrutinized. For qualitative studies, Harden et al. [41] criteria cover quality of reporting, reliability of the data, the depth and breadth of analysis, and how well the results reflect the perspective of the studied households was applied. For the quantitative studies, the abridged version of the Liverpool University Quality Assessment Tools (LQAT), developed for prior systematic reviews (e.g. [42]),

was used. These tools comprise several modules: sampling, experience, outcome, analysis, effects, assessment of bias and the overall classification of quality [43]. We organized the finding from this systematic review under four characteristics domains: household endowment, farm-level characteristics, infrastructure and services and biophysical characteristic (Table 2).

3 Data extraction and analysis

Following the conceptual framework (Fig. 1), the data extraction was done in alignment with the four domains, household endowment, farm-level characteristics, infrastructure and services and biophysical characteristic (Table 2). These domains were supported by descriptions and/or definitions from the included studies. The key concepts per domain were then used in the development of data extraction forms, while basic information from the reviewed studies and specific information related to the study objective formed the basis on which the data were extracted as study title, first author name, the year of publication, research design, country of study, study participants and/or stakeholders, interventions (i.e. SCEPs) level of implementation and implementation outcomes (i.e. effects), whether the outcome is positive or negative and the level of significance for each outcome for the quantitative studies and direction of influence for qualitative studies. Finally, the data were extracted for the four domains using a thematic analysis of the models contained in the reviewed papers to identify commonalities and differences. The extracted data were done independently by two reviewers for the selected studies and then jointly agreed upon by all review team. Once all the data were mapped deductively to the four domains, a separate inductive process of domains analysis was used to accommodate the qualitative data. One reviewer would extract the data and perform analysis by the four domains, with

Table 2 The characteristic domains of factors whose influence was reviewed

Domain	Variable in the domains	Acronym
Household endowment	The age of household head	<i>Age_hh</i>
	Gender of the household head	<i>Gend_hh</i>
	Education for the household head	<i>Educ_hh</i>
	Household size	<i>Hh_size</i>
	Off-farm income	<i>Off_inc</i>
	Herd size	<i>Hrd_sze</i>
Institutional characteristics	Land tenure	<i>Lnd_tnr</i>
Farm-level characteristics	Plot slope	<i>Plt_slop</i>
	Farm size	<i>Frm_sze/land</i>
Infrastructure and services	Access to credit	<i>Crdt_acss</i>
	Access to information	<i>Info_acss</i>
	Access to market	<i>Dist_mkt</i>
	Access to extension services	<i>Ext_serv</i>
	Group membership	<i>Grp_memb</i>

Table 3 Variables and how they were measured in the reviewed articles

Acronyms	Variable name (and how they were measured)
<i>Household endowment</i>	
Age_hh	Age of the household head (years)
Educ_hh	Education of the household head (1 if the households head is educated and 0 otherwise)
Gend_hh	Sex of the household head (1 if the households head is male and 0 otherwise)
Hh_size	Household size or family size (the total number of family members in the family (in adult equivalent)
Off_inc	Access to the household to off-farm income, i.e. income from other sources other than crop and livestock (1 if the household head had access and 0 otherwise)
Hrd_size	Herd size represents livestock holding in terms of Tropical Livestock Unit (1 TLU = 250 kg life weight)
<i>Infrastructure and services</i>	
Crdt_acss	Access to credit services (1 if perceived access to credit services and 0 otherwise)
Info_acss	Access to information services (1 if the household head had a radio and 0 otherwise)
Ext_acss	Access to extension services (1 if perceived access and 0 otherwise)
Dist_mkt	Distance to market (distance to the market in walking minutes)
Grp_Memb	Group membership (1 if the household head had access and 0 otherwise)
<i>Farm-level characteristics</i>	
Plt_slop	Plot slope (perceived sloped of the plot: 1 if sloping [slope of any degrees greater than zero] and 0 otherwise).
Frm_siz	Land size (total land size of the household (in hectare [ha] or timad: 1 ha = 4 timad))
<i>Institutional characteristics</i>	
Lnd_tnr	Land tenure (perceived land security of household head: 1 if secured or if the farmer perceive being able to use the plot during his/her lifetime, and 0 otherwise)

a second reviewer validating the results by independently extracting data and performing the analysis for a random sample of the reviewed papers. Finally, the results were then discussed with all members of the review team. Any disagreements were resolved through group discussion and consensus within the review team. This was then followed by the classification of the effect of the different factors in the four domains based on their final impact or effect on the adoption as a positive (+) or a negative (−) according to the reviewed studies. Before summarizing and analysing the explanatory variable affecting the adoption of SCEPs, we first present the description of each explanatory variable (Table 3). A database containing a detailed examination of the effects of the factors that constrain (i.e. negatively affect) or facilitate (i.e. positively affect) the adoption of technologies that increase soil carbon was first compiled in Microsoft Excel and then summarized in Microsoft Word.

4 Results and discussion

4.1 Nature of reviewed literature

About 40%, 24%, 16% and 8% of the quantitative articles had used Probit, Tobit and Logit models, respectively, in identifying socio-economic factors that enable or constrain the adoption of SCEPs among farmers. The remaining 6%, 4%, 2% and 1% of the reviewed literature had used mixed research methods, random effects models,

optimization modelling and endogenous switching model, respectively. In Ethiopia, the average sample size was approximately 350 households with a standard deviation of 500 and more than 60% of the studies had been conducted in the Tigray and Amhara regions in the North and north-western part of Ethiopia, respectively. The remaining 40% were conducted in Oromia, Southern Nation Nationalities (SNNP) and Mixed region. Both Tigray and Amhara regions are situated in a highland and are characterized by a rugged landscape and are therefore prone to land degradation and soil erosion (<http://www.idp-uk.org>).

In Kenya, about 71%, 13%, 6% and 5% of the papers reviewed had used Probit, Probit, OLS and Logit models, respectively, in identifying socio-economic factors influencing the adoption of SCEPs. The rest (i.e. 5%) of the studies had used analysis of variance and partial budget. The average sample size of the households in the reviewed papers was 948 and a standard deviation of 2357.

In Kenya, the review showed that SCEPs are being used in varying intensities on different regions across the country (i.e. Nairobi, Coast, Western/Nyanza, Central, Eastern and Rift valley regions), and this is largely determined by the farming systems. For example, in arid and semi-arid regions (e.g. Eastern, Coast, and lower Central) where rainfall is low and/or unreliable, soils have poor water retention capacity and soil erosion is common leading to low soil organic matter in the soil. In these areas, common practices include soil bunds, fertilizer application, use of cover crops, multi-purpose trees

and grasses [44, 45]. In high potential areas (e.g. Central Highlands, parts of Rift valley and Western) with well-drained fertile soils and reliable rainfall, the population pressure is a challenge. Consequently, intensive agricultural production is very common. In the Central Province, Rift valley and Western regions, soil nutrient replenishment measures such as the application of fertilizer and application of manure are common [46, 47]. This shows widespread use of SCEPs and thus a positive step maintaining soil fertility and therefore land sustainability. It also shows that households are willing to employ various techniques that have the potential of improving the quality of their land.

4.2 A review of determinants of adoption of practices that enhance soil carbon

The results from both Kenya and Ethiopia suggest that different socio-economic factors highlighted (Table 2) had a positive, negative or mixed effect on the adoption of SCEPs (Table 6).

4.2.1 Household endowment

Age of the household head (Age_hh) The age of household head positively influences the adoption of the cut-off drain, cover crops and multiple purpose trees, while it had a mixed effect on the adoption of crop residues, soil/stone bunds in Ethiopia (Tables 4, 6). In Kenya, the age of household head had a positive effect on the adoption of minimum tillage and erosion control (Tables 5, 6). The positive influence of the household age on the adoption of these practices suggests that they require less labour and more experience to install over time. Their maintenance also is less labour demanding. However, the age of the household head constrains the adoption of conservation tillage, drainage ditches, fanya juu terraces, grass strips, gully traps, inorganic fertilizer, intercropping, minimum tillage and soil water conservation in Ethiopia (Table 4), and crop residues, intercropping and inorganic fertilizer in Kenya (Table 5). This could be due to constraints in terms of labour and financial resources and access to information and inputs facing aged household heads [48, 49]. Practices that require large cash outlay (i.e. inorganic fertilizer) are perceived as risky among the aged household heads compared to young household heads [48, 50]. The effect of age of the household on the adoption of SCEPs is therefore not uniform [51].

Gender of the household head (Gend_hh) Male-headed households are more likely to adopt conservation of tillage, crop residues, 'fanya juu' terraces, farmyard manure, cover crops, soil and water conservation and the multi-purpose trees in Ethiopia (Tables 4, 6). In Kenya, male-headed

households are more likely to adopt 'fanya juu' terraces, crop residues, farmyard manure, intercropping and soil/sand bunds in Kenya (Tables 5, 6). This could be because these practices are labour demanding to establish, and male-headed households are less constrained in terms of resources and can, therefore, mobilize extra labour easily compared to their female counterparts [48, 84, 86]. In their study, Ndiritu et al. [82] show that male-headed household easily applies animal manure, as they can employ additional labour compared to female-headed households in Eastern and Western Kenya.

In Ethiopia, male-headed households are less likely to adopt farmyard manure in Ethiopia (Table 4) and minimum tillage in Kenya (Tables 5, 6) suggesting that perception about the usefulness of specific practices in terms of improving soil fertility and enhancing yield among decision-makers could be playing a critical role [51]. This observation is sustained by García de Jalón et al. [91] who observed that male-headed households in Makueni in Kenya have a sceptical response to climate change which acts as a behavioural barrier to adoption. However, the effect of gender on the adoption of minimum tillage and soil/stone bunds was mixed for Ethiopia.

Education of the household head (Educ_hh) Educated household heads were more likely to adopt farmyard manure, 'fanya juu' terraces, grass strips, gully traps, inorganic fertilizers, intercropping, multi-purpose trees, soil/stone bunds and soil water conservation and cover crops in Ethiopia (Tables 4, 6), while they were more likely to adopt soil/stone bunds in Kenya (Tables 5, 6). The positive effect of education on these SCEPs could be due to the enhanced understanding of how to implement them [92] and an understanding of their importance in maintaining soil fertility [83, 85, 86]. In Ethiopia, education has been associated with increased investment in farming [73].

The observed negative influence of education on the adoption of crop residues and minimum tillage in Ethiopia (Tables 4, 6) and farmyard manure, intercropping and multi-purpose trees in Kenya (Tables 5, 6) could be because it helps the households to evaluate practices in terms of their cost and benefits so that practices that are less profitable are also less appealing for adoption. The negative influence of education could also be due to improved access to off-farm income-generating activities [10]. Nevertheless, the education of household head had a mixed effect on the adoption of crop rotation in Ethiopia (Table 6). These findings suggest improving the uptake of SCEPs among farmers need careful consideration of literacy levels among farmers.

Household size (Hh_size) In Ethiopia, household size had a positive influence on the adoption of all SCEPs studied, except the adoption of drainage ditches (Table 4), while in Kenya it had a positive effect on soil and water

Table 4 Influences of different factors on the adoption of soil carbon enhancing practices in Ethiopia

SCEPs practices	Age-hh	Educ-hh	Gend-hh	HH-size	Off-inc	Crdt_acss	Ext_acss	Grp_memb	Source
Compost manure				+++		++			[52]
Compost manure	—***						+++		[50]
Compost manure	—	+	+	—		+	—		[53]
Conservation tillage	—***		+++	+++			+++	+++	[54]
Contour ploughing	+	—	—	+	—	+	+		[53]
Contour ploughing		+			+				[55]
Crop residues	—***	—***	+++	+++					[56]
Crop residues	+++			+++		+++			[52]
Crop rotation	—*				+++				[57]
Crop rotation		+++		++	—**		+++	+++	[58]
Crop rotation				+++					[56]
Crop rotation		—***							[56]
Crop rotation				+++					[52]
Cut-off drain	++			—***					[59]
Drainage ditch	—**								[60]
Fanya juu terraces				++				+++	[60]
Fanya juu terraces					+++				[61]
Fanya juu terraces		+++		+++			+++		[49]
Fanya juu terraces	—**								[62]
Fanya juu terraces				++		++			[63]
Fanya juu terraces		+			+				[55]
Farmyard manure			—**						[57]
Farmyard manure		+++		++	—**		+++	+++	[58]
Farmyard manure				—***					[56]
Grass strips		+++		++	—**		+++	+++	[58]
Grass strips	—**								[62]
Gully traps		+++		+++					[49]
Gully traps	—**								[64]
Inorganic fertilizer	—***	+				+++			[52]
Inorganic fertilizer		++							[57]
Inorganic fertilizer							+++		[54]
Inorganic fertilizer		+							[56]
Intercropping		+++		++	—**		+++	+++	[58]
Intercropping	+	—	+		—	+	+		[53]
Minimum tillage	—***	—***	—***	+++		+	+		[52]
Minimum tillage			+						[57]
Minimum tillage				+++					[56]
Minimum tillage						+	+		[52]
Minimum tillage	+	—	—		—	+			[53]
Multi-purpose trees	+++			+++	+++				[59]
Multi-purpose trees		+++	+++						[65]
Multi-purpose trees		+++		++	—**		+++	+++	[58]
Multi-purpose trees	+++			+++	—***				[66]
Multi-purpose trees	—***		+++	+++				+++	[67]
Multi-purpose trees	—**								[62]
SCEPs practices	Age-hh	Educ-hh	Gend-hh	Hh-size	Off-inc	Crdt_acss	Ext_acss	Grp_memb	Source
Soil water conservation	—**	+	++		—*		++	++	[68]
Soil water conservation		+++	+++		+				[65]
Soil water conservation	—***	+++	++	++					[69]

Table 4 (continued)

SCEPs practices	Age-hh	Educ-hh	Gend-hh	Hh-size	Off-inc	Crdt_acss	Ext_acss	Grp_memb	Source
Soil/stone bunds					+				[70]
Soil/stone bunds							+		[7]
Soil/stone bunds		+					+		[71]
Stone bunds				+					[59]
Stone bunds					-				[61]
Stone bunds				+		+			[63]
Stone terrace	-								[60]
Soil/stone bunds				+				+	[60]
Soil bunds	+		+						[72]
Soil bunds	+	+	-		+		+		[73]
Soil bunds	+			+	+				[66]
Soil bunds	-								[74]
Soil bunds	+	+		+					[49]
Soil bunds	-				-			+	[67]
Soil bunds	+	+		+					[15]
Soil bunds	-								[75]
Soil bunds				+		+			[63]
SCEPs practice	Dist-mkt		Frm-size		Lnd-tnr		Plt-slop	Hrd-size	Source
Compost manure								+	[52]
Compost manure					+	-		+	[54]
Compost manure			-						[53]
Contour ploughing			+			+			[52]
Contour ploughing			+						[53]
Contour ploughing					+				[55]
Crop residues	+							-	[52]
Crop residues			+			-			[56]
Crop rotation					-	+			[58]
Crop rotation	+		+			-		+	[52]
Crop rotation									[57]
Crop rotation			+			+		+	[52]
Cut-off drain			+					+	[59]
Drainage ditches	-		+			+			[60]
Fanya juu terraces			+						[75]
Fanya juu terraces			+					+	[66]
Fanya juu terraces	-					+			[49]
Fanya juu terraces	-		+			+			[60]
Fanya juu terraces			+					+	[63]
Farmyard manure					-	+			[58]
Farmyard manure	+							+	[52]
Farmyard manure						+		+	[57]
Farmyard manure								+	[56]
Grass strips					-	+			[58]
Grass strips	-		+			+			[60]
Grass strips					+				[55]
Gully traps	+		+			+			[49]
Gully traps	-		+			+			[60]
Inorganic fertilizer			+			-		-	[52]
Inorganic fertilizer	-					-		+	[57]
Inorganic fertilizer					+	-		+	[54]

Table 4 (continued)

SCEPs practice	Dist-mkt	Frm-size	Lnd-tnr	Plt-slop	Hrd-size	Source
Inorganic fertilizer		+***		−***	+***	[56]
Intercropping			−*	+***		[58]
Intercropping		−				[53]
Multi-purpose trees						[76]
Multi-purpose trees			−*	+***		[58]
Multi-purpose trees	+**	+***		+***	+***	[59]
Multi-purpose trees		+***			+***	[66]
Multi-purpose trees		+***				[67]
Multi-purpose trees	−***	+**		+***		[60]
Minimum tillage	+**			+***	−***	[52]
Minimum tillage	+*				+***	[57]
Minimum tillage		+		+	+	[53]
SCEPs practice	Dist-mkt	Frm-size	Lnd-tnr	Plt-slop	Hrd-size	Source
Soil water conservation	−**					[68]
Soil water conservation		+***	+*			[54]
Soil water conservation		+***			+***	[77]
Soil/stone bunds		+***				[75]
Soil/stone bunds		+***		+***		[7]
Soil/stone bunds		+*		+*		[71]
Stone bunds					+***	[59]
Stone bunds	+*	+***		+**		[72]
Stone bunds	+**	+**				[61]
Stone bunds	−*	+***	+**			[74]
Stone bunds	−***	+**		+***		[60]
Stone bunds		+***			+***	[63]
Stone bunds		+**	−**	+**	−**	[78]
Soil bunds	−**					[61]
Soil bunds		+**	−**	+**	−**	[78]
Soil bunds		+***			+***	[63]
Soil bunds	−**		+*			[73]
Soil bunds	+***	+**		+**		[49]
Soil bunds		+****				[15]
Soil bunds	−***	+***			+***	[67]
Soil bunds	−***	+**		+***		[60]

NB: −/+ shows the direction of influence for the different factors on soil carbon enhancing practices (SCEPs)

*, **, *** stands for significance at 5, 1 and 0.1% level of significance, respectively

conservation and farmyard manure (Table 5) suggesting that implementing SCEPs could be labour demanding [60, 78, 82, 84, 93, 94]. Labour availability is, therefore, crucial for the adoption of SCEPs [55, 75, 82, 84, 93]. Nevertheless, household size had a mixed effect on the adoption of farmyard manure and inorganic fertilizer in Ethiopia and Kenya, respectively. The reason for this observation could be because the use of farmyard manure is a labour-intensive activity considering collection and application while fertilizer requires resources to acquire. Therefore, both of these practices can introduce as an additional constraint

depending on the size of the households and their needs [83].

Off-farm income (Off_inc) Off-farm income had a positive effect on the adoption of crop residues, grass strips and 'fanya juu' terraces, in Ethiopia (Table 4), and soil and water conservation and crop residues in Kenya (Table 5), suggesting that off-farm income relaxes liquidity constraint thereby facilitating the adoption of practices that require cash outlays (including acquisition of labour and inputs) [95]. In Western Kenya for example, adoption of inorganic fertilizer is common among the

Table 5 Influences of different factors on the adoption of soil carbon enhancing practices in Kenya

SCEPs practice	Age_hh	Educ_hh	Gend_hh	hh_size	Off_inc	Frm_size	Source
Conservation agriculture						+	[79]
Conservation agriculture						-*	[80]
Cover crop	+	+	+				[51]
Crop residue			+				[81]
Crop residue	-*				+	+	[79]
Crop rotation			+		+	-***	[82]
Erosion control					+		[83]
Farmyard manure	+				-**		[84]
Farmyard manure		-**		+			[48]
Farmyard manure		+		+	-**		[85]
Farmyard manure			-***			-*	[82]
Inorganic fertilizer		+		-*			[79]
Inorganic fertilizer		+			-*		[84]
Inorganic fertilizer		-*		+	-***	-***	[48]
Inorganic fertilizer	-***				+	-***	[82]
Inorganic fertilizer	-**					-***	[86]
Inorganic fertilizer					+		[83]
Inorganic fertilizer		+			+	+	[85]
Inorganic fertilizer		+				-*	[87]
Intercropping		-**				-**	[88]
Intercropping	-***	-***				+	[84]
Intercropping		-**	+			-***	[82]
Minimum tillage	+					-***	[84]
Minimum tillage			-***			-***	[82]
Multi-purpose trees		-***					[48]
Multi-purpose trees						+	[89]
Soil bunds						-*	[79]
Soil water conservation				+	+		[84]
Soil water conservation				+			[82]
Stone bunds		+	+			+	[79]
Practice	Hrd-size			Lnd_tnr			Source
Stone bunds				+			[79]
Soil water conservation		-***					[82]
Farmyard manure		-**					[48]
Farmyard manure		+					[82]
Farmyard manure				+			[84]
Inorganic fertilizer				-***			[79]
Inorganic fertilizer		+					[82]
Inorganic fertilizer				+			[83]
Inorganic fertilizer							[87]
Intercropping		+					[82]
Minimum tillage		-**					[84]
Erosion control				-**			[83]
Contour farming				+			[55]
Grass strips				+			[55]
Fanya juu terraces				+			[55]

Table 5 (continued)

Practice	Crdt_acss	Info_acss	Ext_serv	Dist_mkt	Grp_memb	Plt_slop	Source
Conservation agriculture			—*				[79]
Conservation agriculture			+**				[80]
Soil bunds		+***					[79]
Stone bunds					+*	+***	[79]
Soil water conservation			+**			+***	[84]
Soil water conservation	—***			—***		—***	[82]
Farmyard manure			+**	—***		+***	[82]
Intercropping		—**		—***			[88]
Intercropping			+*	+**			[84]
Inorganic fertilizer				+**			[84]
Inorganic fertilizer	+***			—***			[86]
Inorganic fertilizer						+***	[79]
Inorganic fertilizer				—***			[85]
Inorganic fertilizer		+*		—**		—*	[83]
Inorganic fertilizer			+***			—***	[82]
Crop residues			+***			+*	[81]
Crop rotation	—**			+*			[82]
Intercropping			+*	+*	+**		[82]
Minimum tillage	—***		+***		+***		[82]
Multi-purpose trees				—***			[90]

NB: —/+ shows the direction of influence for the different factors on soil carbon enhancing practices (SCEPs)

*, **, *** stands for significance at 5, 1 and 0.1% level of significance, respectively

wealthy farmers as compared to the poor farmers [47, 83, 96]. Off-farm income is therefore important especially in areas with poorly developed credit market [73]. However, off-farm income exerts a negative influence on the adoption of crop rotation, grass strips and intercropping in Ethiopia, crop residues and farmyard manure in Kenya (Tables 4 and 5), suggesting that engagement in other off-farm income-generating activities diverts labour required for implementing SCEPs [67, 85, 97]. Thus, there may be a need for prioritizing farm objectives that can lead to sustainable farm production and livelihood in the long-term.

Livestock holding (Hrd_size) Herd size has a positive effect to the adoption of cut-off drain, multi-purpose trees, compost manure, 'fanya juu' terraces, farmyard manure and soil and water conservation in Ethiopia (Table 4), and intercropping and inorganic fertilizer in Kenya (Table 5) suggesting that livestock could be complementing the implementation of these practices through the income they generate and hence their positive influence [10, 98]. However, the effect of livestock holding on the adoption of crop residues in Ethiopia (Table 4) and soil and water management in Kenya (Table 5) suggesting that livestock could be consuming residues and other available resources that could be used in soil and water management [99].

4.2.2 Farm-level characteristics

Farm size (Frm_size) Farm size had a positive influence on the adoption of all the soil enhancing practices studied in Ethiopia, except conservation agriculture, intercropping and minimum tillage (Table 4). In Kenya, farm size had a positive influence on the adoption of multi-purpose trees (Table 5), suggesting that these practices may not be strictly scale neutral or that the opportunity costs facing households vary by their farm size [86, 100]. The positive effect could also be farm size which has been shown to be correlated with wealth which relaxes financial constraint when used as collateral for the acquisition of credit [95]. Nevertheless, farm size had a mixed effect on the adoption of conservation tillage, crop residues, intercropping, soil/stone bunds and inorganic fertilizer, and a negative effect on minimum tillage in Kenya (Table 5). The negative and the mixed effect of farm size on the adoption of minimum tillage is because the farm size may influence farmers decision differently. For example, a farmer may not worry about soil erosion and degradation, hence reducing their willingness to adopt them [10, 53, 61, 74]. Small farm size may also hinder the adoption of practices that have the potential to sequester carbon [46, 78, 101–103].

Plot slope (Plt_slop) Plot slope had a positive effect on the adoption of all the studied SCEPs except contour

ploughing, crop rotation, minimum tillage and compost manure in Ethiopia (Table 4), and 'fanya juu' terraces, farmyard manure and crop residues in Kenya (Table 5), suggesting that farmers are aware of the negative impact of slopes—such as erosion and loss of soil fertility—on soil carbon. Many soil erosion and fertility loss prevention measures are practised on sloping lands [74, 79, 82].

4.2.3 Infrastructure and services

Access to credit (Crdt_acss) Access to credit has a positive effect on the adoption of compost manure, crop residues, 'fanya juu' terraces, inorganic fertilizer, minimum tillage and soil/stone bunds in Ethiopia (Table 4), and inorganic fertilizer in Kenya (Table 5). Credit relaxes households binding financial constraints to acquire inputs such as fertilizer and probably hire labour. Minimum tillage is not so costly but is an effective measure for ensuring soil fertility [92, 104, 105]. In Kenya, access to credit has a negative effect on crop rotation, minimum tillage, soil and water conservation suggesting that decision relating to the adoption of SCEPs could also be influenced by other hidden issues such as the perception of the decision-makers and the environment among others.

Information access (Info_acss) The access to information has a positive effect on the adoption of inorganic fertilizer, soil and/or stone bunds in Kenya (Table 5), suggesting that information access provides the technical know-how required for the implementation of these practices. Information access can also lead to adoption because of the realization of the benefits associated with the adoption of these practices [86, 87, 89, 103, 106]. Bridging the gap through the provision of benefits associated with the adoption of specific practices increases the adoption or rate of diffusion [81, 82, 107]. Information access, however, tends to constrain the adoption of intercropping (Table 5) suggesting that information access tends to influence the adoption decision for example through comparing the costs and benefits of a practice [108].

Access to the market (Dist_mkt) Distance to the market has a positive effect on the adoption of crop residues, crop rotation, farmyard manure and minimum tillage in Ethiopia (Table 4), and crop rotation and minimum tillage in Kenya (Table 5) suggesting that high transaction may influence the adoption of technologies that rely less on the market to implement and maintain. Distance to the market had a mixed effect on the adoption of the multi-purpose trees, gully traps and soil/stone bunds in Ethiopia (Table 4), and inorganic fertilizer and intercropping in Kenya (Table 5)

suggesting that the adoption of SCEPs depends on other factors beside socio-economic factors. For example, Murage et al. [88] show that improved access to the market is associated with the adoption of inorganic fertilizer, while poor market access tends to constrain it [84]. This finding suggests that the adoption of SCEPs practices could also be due to other factors beside socio-economic factors, and therefore, the scaling up of these practices need not be based on the finding from socio-economic discipline only. There is a need for a multidisciplinary approach to help understand what besides the socio-economic characteristics influences the adoption of SCEPs.

Farmers' organization (Grp_memb) Group memberships have a positive effect on the adoption of conservation tillage, crop rotation, fanya juu terraces, farmyard manure, grass strips, intercropping, multi-purpose trees, soil/stone bunds and soil and water conservation in Ethiopia (Table 4), and 'fanya juu' terraces, minimum tillage, soil/stone bunds and intercropping in Kenya (Table 5). Farmers groups are a source of information exchange, capacity building and a form of social capital [98], suggesting that farmers are able to access information about the benefits of different technologies leading to their adoption [84, 106].

Extension services (Ext_serv) Extension services have a positive effect on the adoption of all the SCEPs studied in Ethiopia, except contour planting, cut-off drains, drainage ditches, grass strips, cover crops and gully traps (Table 4). In Kenya, extension services exert a positive influence on the adoption of soil and water conservation, farmyard manure, minimum tillage, inorganic fertilizer, crop residues and intercropping (Table 5). This suggests that extension services play a crucial role in enhancing learning which leads to the adoption of new technologies [103]. Lack of extension services, therefore, can act as an impediment to the adoption of soil carbon enhancement practices. However, since the extension services do not affect all the practices in a uniform way, policy formulation should take this into account, by not generalizing that it affects the adoption of SCEPs positively.

4.2.4 Institutional characteristics

Land tenure (Lnd_tnr) Land tenure had a positive effect on the adoption of inorganic fertilizer, soil and water conservation, compost manure and soil and water conservation in Ethiopia (Table 4), and farmyard manure and stone and/or soil bunds (Table 5), suggesting that tenure

security provides an impetus to farmers for implementing long-term SCEPs [79, 86]. However, tenure security has a negative effect on the adoption of farmyard manure, grass strips, intercropping, multi-purpose trees in Ethiopia (Table 4), and erosion control and inorganic fertilizer in Kenya (Table 5). Technologies that demand high labour and capital to implement results in spiralling expenditure and given the difficulty in getting sufficient income for employing labourers, they are prohibitive [55]. The mixed effect of land tenure on soil/stone bunds could be due to the differences in the decision-making process as influenced by the type of land ownership (i.e. whether the land is rented or owned) (Ibid). However, farmers who own lands could use their title deeds as collateral to access credit.

4.3 Summary of the review

For ease of identification of the distinct direction of effects of the various SCEPs reviewed, Table 6 provides a general overview of trends showing the influence for the socio-economic factors on SCEPs in Kenya and Ethiopia. This was achieved by qualitatively summarizing the direction of socio-economic, institutional and biophysical influences reported by all reviewed articles on different SCEPs reported in Tables 4 and 5. The factors that constrain the adoption of SCEPs are labelled 'negative' while those that facilitate are labelled 'positive' on columns three and four. Those that have a mixed effect, i.e. the positive and negative effect is labelled 'mixed'. This summary is easier to understand by policymakers, academic and non-academic audience. The results show that although most of the household and farm-level variables have either positive or negative on most of the SCEPs, some inconsistencies were observed suggesting that going forward scientists need to take care when making recommendations based on studies that are not multidisciplinary in nature. This is because, as the review shows, the decision to adopt SCEPs is definitely influenced by socio-economic factors, but the mixed effect by some of the socio-economic factors on some of the SCEPs suggests that there could be other factors such as the environment, history, culture and agro-ecology that could be playing a major role in the adoption of SCEPs, and these need to be considered before policy prescription or recommendation intended for scaling up SCEPs adoption is made.

5 Conclusion and recommendations

This paper provides a review from a large amount of quantitative and qualitative evidence derived from peer-reviewed articles on the socio-economic factors that influence the adoption of various SCEPs. The discussion focused on the influences of household endowment (age, education, gender, household size, livestock holding, farm size and off-farm income), farm-level characteristics (farm size and plot slope) and infrastructure and services (access to credit, access to information, access to extension services, access to the market and membership to farmer's groups) and institutional characteristics (land tenure) on SCEPs. Thus, our review and synthesis underscore the need for taking a multidisciplinary approach in trying to understand why some practices exhibit different patterns of effect from the socio-economic factors.

The review further provides evidence that can help to evolve thinking and policy prescriptions for enhanced adoption of SCEPs. Significant factors that motivate farmers to adopt different SCEPs vary from the household endowment, farm-level characteristics, infrastructure and biophysical factors. The direction of influence by specific factors also tends to vary from positive, negative to mixed effect on various practices in the two countries. This is an indication that policy prescription need not be rushed if sustainability in scaling up the adoption of SCEPs is to be achieved. While most agricultural policies in East Africa delve on infrastructural development for upscaling adoption of SLMPs, this review reveals that policy interventions should target household endowment so as to improve farmers' capacity to adopt SCEPs. For instance, the varied effects of age, education, information access and extension services on the adoption of SCEPs suggest innovative methods in the dissemination of information on these practices. Accommodating both the young and old age groups needs in information delivery, increasing the frequency of training, workshops, seminars and on-farm field demonstrations are feasible in creating awareness for suitable SCEPs in specific geographical spaces. From the review, the impact of off-farm income and access to credit in the adoption of SCEPs are clear-cut, thus approaches such as improving households' access to off-farm income-generating opportunities and encouraging farmers to join

informal rural credit schemes can be used to enhance adoption.

Similarly, our review highlights the effect of gender in the decision to adopt SCEPs. Generally, women compared to their male counterparts lack resources which are required to implement these practices. This is an implication that policy formulation relating to the adoption of SCEPs should be gender-sensitive. Efforts by researchers in coming up with improvised versions of SCEPs that are less labour-intensive and cost-effective are recommended in encouraging women engagement in the adoption of SCEPs. The significance of tenure security in the adoption of SCEPs cannot be overemphasized. This calls for government's involvement in coming up with contracts as a way of formalizing tenure agreements among farmers, a step that would encourage them to make investments on long-term SCEPs such as terracing. Also, farmers could be encouraged to mobilize themselves in groups and acquire land as a mass other than individually investing in small segmented pieces of land that are not economically viable to invest in.

Important to note is that appropriate soil carbon enhancing practice may differ from one location to another depending on the agro-ecological, socio-economic and market conditions. Therefore, rather than searching for a general blueprint, the review also emphasises for looking at factors that tend to constrain or facilitate the adoption of different technologies in a different context, and as such open an avenue for identifying complementarities and trade-offs.

This study further counters the misconception that socio-economic factors affect the adoption of carbon enhancing technologies in either a strictly positive or negative way. This is because the importance of the different factors and the direction of influence vary depending on the nature of the practice in question. This indicates therefore that the adoption of SCEPs practices could be due to other factors beside socio-economic factors, and therefore, the scaling up of these practices needs not be based on the finding from socio-economic discipline only. Taking this into account before scaling up of SCEPs adoption will then allow the interrogation of the likely effect of given socio-economic characteristics on the adoption of specific SCEPs under varying environments, and to ask ourselves what else is missing that can help the adoption patterns and decision. As such, there is a need for further deeper multidisciplinary search of what else accounts for

mixed effects of some of the households' endowment, infrastructure and services, farm-level characteristics and biophysical characteristics on specific SCEPs in a given region and farming systems. Such an approach will provide more robust findings on which targeted recommendations and economic incentives for improved adoption of different soil enhancing practices in different locations can be based. There is a need for a multidisciplinary approach to help understand what besides the socio-economic characteristics influences the adoption of SCEPs. Moreover, such findings may help to design trans-generation policies aimed at increasing the development and uptake of SCEPs in East Africa. Adoption of SCEPs informed by such robust information is likely to be more sustainable in the long-term.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Appendix

See Table 6.

Table 6 A general overview of trends showing the influence for the socio-economic factors on SCEPs in Kenya and Ethiopia

Socio-economic factors	SCEPs practices	Kenya	Ethiopia
Household size, credit access, Land tenure and herd size	Compost manure	Positive	
Plot slope and distance to the market		Negative	
Age of household head	Conservation tillage	Negative	
Gender of the household head, household size and group membership		Positive	
Access to extension services		Positive	Mixed
Farm size			Mixed
Farm size and plot slope	Contour ploughing	Positive	
Age of household head	Crop residues	Mixed	Negative
Education of the household head		Negative	
Gender of the household head		Positive	Positive
Household size, credit access and distance to the market		Positive	
Off-farm income		Positive	Positive
Herd size and plot slope		Negative	
Farm size		Positive	Mixed
Education of the household head and plot slope	Crop rotation	Mixed	
Household size, herd size, farm size, access to extension services and group membership		Positive	
Off-farm income		Negative	
Distance to the market		Positive	Positive
Credit access			Negative
Farm size, herd size and age of household head	Cut-off drain	Positive	
Household size		Negative	
Age of household head and distance to the market	Drainage ditch	Negative	
Farm size and plot slope		Positive	
Age of household head	Fanya juu terraces	Negative	
Education of the household head, household size, off-farm income, access to extension services, group membership, farm size, plot slope, herd size and credit access		Positive	
Distance to the market		Negative	
Education of the household head and herd size	Farmyard manure	Positive	Mixed
Gender of the household head		Negative	Negative
Household size		Mixed	Positive
Off-farm income, distance to the market and plot slope		Positive	Negative
Access to extension services		Positive	Positive
Group membership		Positive	
Land tenure		Negative	Positive
Age of household head, off-farm income, distance to the market and land tenure	Grass strips	Negative	
Access to extension services Education of the household head, household size, group membership, farm size and plot slope		Positive	
Age of household head	Gully traps	Negative	
Education of the household head, household size, farm size and plot slope		Positive	
Distance to the market		Mixed	
Age of household head	Inorganic fertilizer	Negative	Negative
Education of the household head		Positive	Mixed
Access to extension services		Positive	Positive
Credit access		Positive	Positive
Distance to the market		Negative	Mixed
Farm size		Positive	Mixed
Land tenure		Positive	Negative
Plot slope		Negative	Mixed
Herd size		Mixed	Mixed
Household size, off-farm income			Mixed

Table 6 (continued)

Socio-economic factors	SCEPs practices	Kenya	Ethiopia
Access to information	Intercropping		Positive
Age of household head			Negative
Education of the household head		Positive	Negative
Household size and plot slope		Positive	
Gender of the household head			Positive
Off-farm income and land tenure		Negative	
Access to extension services		Positive	Positive
Group membership		Positive	Positive
Farm size and distance to the market			Mixed
Access to information			Negative
Age of household head	Minimum tillage	Negative	Positive
Education of the household head		Negative	
Gender of the household head		Mixed	Negative
Household size		Positive	
Credit access		Positive	Negative
Access to extension services, Distance to the market and plot slope		Positive	Positive
Farm size			Negative
herd size		Mixed	
Group membership			Positive
Age of household head, Gender of the household head, household size, access to extension services, group membership, plot slope, herd size		Multi-purpose trees	Positive
Education of the household head		Positive	Negative
Off-farm income		Mixed	
Distance to the market		Mixed	Negative
Farm size		Positive	Positive
Land tenure		Negative	
Age of household head	Soil/stone bunds	Mixed	
Education of the household head, group membership, Plot slope		Positive	Positive
Gender of the household head		Mixed	Positive
Household size, credit access		Positive	
Off-farm income, distance to the market, herd size		Mixed	
Access to extension services, Farm size		Positive	Mixed
Land tenure		Mixed	Positive
Age of household head	Soil and water conservation	Negative	
Education of the household head, gender of the household head, group membership, farm size, land tenure		Positive	
Household size		Positive	Positive
Off-farm income		Mixed	Positive
Access to extension services		Positive	Positive
Distance to the market		Negative	Negative
herd size		Positive	Negative
Credit access			Negative
Plot slope			Mixed
Age of household head, Gender of the household head, Education of the household head	Cover crops	Positive	
Off-farm income	Erosion control		Positive
Land tenure			Negative

References

- Bewket W, Sterk G (2002) Farmer's participation in soil and water conservation activities in the chemoga watershed, blue Nile basin, Ethiopia. *Land Degrad Dev* 13:189–200
- Giger M, Liniger H, Sauter C, Schwilch G (2018) Economic benefits and costs of sustainable land management technologies: an analysis of WOCAT's global data. *Land Degrad Dev* 29:962–974
- Liniger H, Mekdaschi Studer R, Hauert C, Gurtner M (2011) Sustainable land management in practice: guidelines and best practices for Sub-Saharan Africa. <https://www.wocat.net/en/projects-and-countries/projects/sustainable-land-management-practice-guidelines-and-best-practices-sub-saharan-africa>
- Lal R (2004) Soil carbon sequestration impacts on global climate change and food security. *Science* 304:1623–1627
- Lal R (2008) Carbon sequestration. *Philos Trans R Soc Lond B Biol Sci* 363:815–830
- Powlson DS, Gregory PJ, Whalley WR, Quinton JN, Hopkins DW, Whitmore AP, Hirsch PR, Goulding KWT (2011) Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy* 36:S72–S87
- Bekele W, Drake L (2003) Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde–Lafto area. *Ecol Econ* 46:437–451
- Adimassu Z, Mekonnen K, Yirga C, Kessler A (2014) Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. *Land Degrad Dev* 25:554–564
- Bewket W (2007) Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: acceptance and adoption by farmers. *Land Use Policy* 24:404–416
- Adimassu Z, Langan S, Johnston R (2016) Understanding determinants of farmers' investments in sustainable land management practices in Ethiopia: review and synthesis. *Environ Dev Sustain* 18:1005–1023
- Mutoko M, Shisanya CA, Hein L (2014) Fostering technological transition to sustainable land management through stakeholder collaboration in the western highlands of Kenya. *Land Use Policy* 41:110–120
- Adesina AA, Baidu-Forson J (1995) Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agric Econ* 13:1–9
- Gebremedhin B, Swinton S, Tilahun Y (1999) Effects of stone terraces on crop yields and farm profitability: results of on-farm research in Tigray, northern Ethiopia. *J Soil Water Conserv* 54:568–573
- Requier-Desjardins M, Adhikari B, Sperlich S (2011) Some notes on the economic assessment of land degradation. *Land Degrad Dev* 22:285–298
- Shiferaw B, Holden ST (1998) Resource degradation and adoption of land conservation technologies in the Ethiopian Highlands: a case study in Andit Tid, North Shewa. *Agric Econ* 18:233–247
- Shiferaw B, Holden ST (2001) Farm-level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia. *Environ Dev Econ* 6:335–358
- Obayelu A, Ajayi O, Oluwalana E, Ogunmola O (2017) What does literature say about the determinants of adoption of agricultural technologies by smallholders farmers? *Agric Res Technol Open Access J* 6:555–676
- Wu J, Babcock BA (1998) The choice of tillage, rotation, and soil testing practices: economic and environmental implications. *Am J Agric Econ* 80:494–511
- Griliches Z (1957) Hybrid corn: an exploration in the economics of technological change. *Econometrica* 25:501
- Lindner RK, Pardey PG, Jarrett FG (1982) Distance to information source and the time lag to early adoption of trace element fertilisers. *Aust J Agric Econ* 26:98–113
- Lindner RK (1987) Adoption and diffusion of technology: an overview. In: *Technological change in postharvest handling and transportation of grains in the humid tropics*. ISBN ISBN 0 949511293, pp 143–151
- Feder G, Just R, Silberman D (1981) Adoption of agricultural innovations in developing countries: a survey. *Econ Dev Cult Change* 33:255
- Tsur Y, Sternberg M, Hochman E (1990) Dynamic modelling of innovation process adoption with risk aversion and learning. *Oxf Econ Pap* 42:336–355
- Feder G, Umali DL (1993) The adoption of agricultural innovations, A review. *Technol Forecast Soc Change* 43:215–239
- Leathers HD, Smale M (2006) A Bayesian approach to explaining sequential adoption of components of a technological package. *Am J Agric Econ* 73:734
- Saha A, Love HA, Schwart R (1994) Adoption of emerging technologies under output uncertainty. *Am J Agric Econ* 76:836
- Dulal H, Brodnig G, Onoriose C, Thakur H (2010) Capitalising on assets: vulnerability and adaptation to climate change in Nepal. The World Bank social development papers No 121. The World Bank, Washington
- Eakin H, Bojórquez-Tapia LA (2008) Insights into the composition of household vulnerability from multicriteria decision analysis. *Glob Environ Chang* 18:112–127
- Tompkins EL, Adger WN (2004) Does adaptive management of natural resources enhance resilience to climate change? *Ecol Soc* 9:10
- Feder G, Just RE, Zilberman D (1985) Adoption of agricultural innovation in developing countries: a survey. *Econ Dev Cult Change* 33:255–298
- Kassie M, Shiferaw B, Muricho G (2011) Agricultural technology, crop income, and poverty alleviation in Uganda. *World Dev* 39:1784–1795
- United Nation Environment Programme Promising climate options for Ethiopia, Kenya. <https://www.unenvironment.org/news-and-stories/story/promising-climate-options-ethiopia-kenya>. Accessed on 1 Nov 2019
- Pickering C, Byrne J (2014) The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early-career researchers. *High Educ Res Dev* 33:534–548
- Moher D, Liberati A, Tetzlaff J, Altman DG, Altman D, Antes G, Atkins D, Barbour V, Barrowman N, Berlin JA et al (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement (Chinese edition). *J Chin Integr Med* 7:889–896
- Byrne J, Portanger C (2014) Climate change, energy policy and justice: a systematic review. *Anal Krit* 36:315–344
- Steven R, Pickering C, Guy Castley J (2011) A review of the impacts of nature based recreation on birds. *J Environ Manag* 92:2287–2294
- Ballantyne M, Pickering CM (2015) The impacts of trail infrastructure on vegetation and soils: current literature and future directions. *J Environ Manag* 164:53–64
- Howes M, Wortley L, Potts R, Dedekorkut-Howes A, Serrao-Neumann S, Davidson J, Smith T, Nunn P (2017) Environmental sustainability: a case of policy implementation failure? *Sustainability* 9:165

39. Wortley L, Hero JM, Howes M (2013) Evaluating ecological restoration success: a review of the literature. *Restor Ecol* 21:537–543
40. Australian Research Council (ARC). ERA 2015 submitted journal list. http://www.arc.gov.au/sites/default/files/filedepot/Public/ERA/ERA%202015/ERA2015_Submitted_Journal_ListV2.xlsx. Accessed 11 Feb 2018
41. Harden A, Brunton G, Fletcher A, Oakley A (2009) Teenage pregnancy and social disadvantage: systematic review integrating controlled trials and qualitative studies. *BMJ* 339:1182–1185
42. Pope D, Siddiqui R, Thompson L, Mishra V, Woodruff T, Bruce N (2007) Systematic review and meta-analyses of risk of indoor pollution for low birth weight and stillbirth. *Epidemiology* 18:S113–S114
43. Puzzolo E, Stanistreet D, Pope D, Bruce N, Rehfuess E (2011) What are the enabling or limiting factors influencing the large scale uptake by households of cleaner and more efficient household energy technologies, covering cleaner fuel and improved solid fuel cookstoves? A systematic review. *Protocol*
44. Okeyo AI, Mucheru-Muna M, Mugwe J, Ngetich KF, Mugendi DN, Diels J, Shisanya CA (2014) Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya. *Agric Water Manag* 137:52–58
45. Mganga KZ, Musimba NKR, Nyariki DM (2015) Combining sustainable land management technologies to combat land degradation and improve rural livelihoods in semi-arid lands in Kenya. *Environ Manag* 56:1538–1548
46. Mugwe J, Mucheru-Muna M, Mugendi D, Kung'u J, Bationo A, Mairura F (2009) Adoption potential of selected organic resources for improving soil fertility in the central highlands of Kenya. *Agrofor Syst* 76:467–485
47. Chikowo R, Zingore S, Snapp S, Johnston A (2014) Farm typologies, soil fertility variability and nutrient management in smallholder farming in Sub-Saharan Africa. *Nutr Cycl Agroecosyst* 100:1–18
48. Marennya PP, Barrett CB (2007) Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy* 32:515–536
49. Anley Y, Bogale A, Haile-Gabriel A (2007) Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia. *Land Degrad Dev* 18:289–302
50. Kassie M, Zikhali P, Manjur K, Edwards S (2009) Adoption of organic farming techniques: evidence from a semi-arid region of Ethiopia, Discussion papers dp-09-01-efd, Resources for the future
51. Mwangi HW, Kihurani AW, Wesonga JM, Ariga ES, Kanampiu F (2015) Factors influencing adoption of cover crops for weed management in Machakos and Makueni counties of Kenya. *Eur J Agron* 69:1–9
52. Benin S (2006) Policies and programs affecting land management practices, input use, and productivity in the highlands of Amhara Region, Ethiopia. In: Pender J, Place F, Ehui S (eds) *Strategies for sustainable land management in the East African highlands*. International Food Policy Research Institute, Washington, DC
53. Pender J, Gebremedhin B (2006) Land management, crop production, and household income in the highlands of Tigray, Northern Ethiopia: an econometric analysis. In: Pender J, Place F, Ehui S (eds) *Strategies for sustainable land management in the East African highlands*. International Food Policy Research Institute (IFPRI), Washington, DC. ISBN 0-89629-757-8
54. Kassie M, Zikhali P, Manjur K, Edwards S (2009) Adoption of sustainable agriculture practices: evidence from a semi-arid region of Ethiopia. *Nat Resour Forum* 33:189–198
55. Millington AC, Mutiso SK, Kirby J, O'keefe P (1989) African soil erosion—nature undone and the limitations of technology. *Land Degrad Dev* 1:279–290
56. Benin S, Pender J (2001) Impacts of land redistribution on land management and productivity in the Ethiopian highlands. *Land Degrad Dev* 12:555–568
57. Teklewold H, Kassie M, Shiferaw B (2013) Adoption of multiple sustainable agricultural practices in rural Ethiopia. *J Agric Econ* 64:597–623
58. Wossen T, Berger T, Mequaninte T, Alamirew B (2013) Social network effects on the adoption of sustainable natural resource management practices in Ethiopia. *Int J Sustain Dev World Ecol* 20:477–483
59. Mengstie FA (2009) Assessment of adoption behavior of soil and water conservation practices in the Koga watershed, highlands of Ethiopia, M.Sc. Thesis, Cornell University
60. Schmidt E, Tadesse F (2012) Household and plot level impact of sustainable land and watershed management (SLWM) practices in the Blue Nile. In *Ethiopia Strategy Support Program (ESSP II)*
61. Hagos F, Holden S (2006) Tenure security, resource poverty, public programs, and household plot-level conservation investments in the highlands of northern Ethiopia. *Proc Agric Econ* 34:183–196
62. Motbainor A, Worku A, Kumie A, Seligman H, Laraia B, Kushel M, Willows N, Veuglers P, Raine K, Kuhle S et al (2016) Level and determinants of food insecurity in East and West Gojjam zones of Amhara Region, Ethiopia: a community based comparative cross-sectional study. *BMC Public Health* 16:503
63. Tesfaye A, Negatu W, Brouwer R, van der Zaag P (2014) Understanding soil conservation decision of farmers in the gedeb watershed, Ethiopia. *Land Degrad Dev* 25:71–79
64. Abate GT, Rashid S, Borzaga C, Getnet K (2016) Rural finance and agricultural technology adoption in Ethiopia: does the institutional design of lending organizations matter? *World Dev* 84:235–253
65. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob Environ Chang* 19:248–255
66. Deininger K, Jin S (2006) Tenure security and land-related investment: evidence from Ethiopia. *Eur Econ Rev* 50:1245–1277
67. Gebregziabher G, Rebelo L-M, Notenbaert A, Ergano K (2013) Determinants of adoption of rainwater management technologies among farm households in the Nile River Basin
68. Asfaw D, Neka M (2017) Factors affecting adoption of soil and water conservation practices: the case of Wereillu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. *Int Soil Water Conserv Res* 5:273–279
69. Gebremedhin B, Pender J, Tesfay G (2003) Community natural resource management: the case of woodlots in Northern Ethiopia. *Environ Dev Econ* 8:129–148
70. Mekuria W, Wondie M, Amare T, Wubet A, Feyisa T, Yitaferu B (2018) Restoration of degraded landscapes for ecosystem services in North-Western Ethiopia. *Heliyon* 4:764
71. Asrat P, Belay K, Hamito D (2004) Determinants of farmers' willingness to pay for soil conservation practices in the southeastern highlands of Ethiopia. *Land Degrad Dev* 15:423–438
72. Kassie M, Pender J, Yesuf M, Kohlin G, Bluffstone R, Mulugeta E (2008) Estimating returns to soil conservation adoption in the northern Ethiopian highlands. *Agric Econ* 38:213–232

73. Ketema M, Bauer S (2012) Determinants of adoption and labour intensity of stone-terraces in eastern highlands of Ethiopia. *J Econ Sustain Dev* 3:2222–2855
74. Gebremedhin B, Swinton SM (2003) Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agric Econ* 29:69–84
75. Tadesse M, Belay K (2004) Factors influencing adoption of soil conservation measures in Southern Ethiopia: the case of Gununo area. *J Agric Rural Dev Trop Subtrop* 105:49–62
76. Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environ Sci Policy* 12:413–426
77. Gebremedhin B, Jaleta M (2012) Market orientation and market participation of smallholders in Ethiopia: Implications for commercial transformation. Presented at the 28th triennial conference of the International Association of Agricultural Economists (IAAE), Foz do Iguaçu, Brazil, pp 18–2
78. Teshome A, de Graaff J, Kassie M (2016) Household-level determinants of soil and water conservation adoption phases: evidence from North-Western Ethiopian Highlands. *Environ Manag* 57:620–636
79. Wainaina P, Tongruksawattana S, Qaim M (2016) Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya. *Agric Econ* 47:351–362
80. Aboud A, Sofranko AJ, Ndiaye S (1996) The effect of gender on adoption of conservation practices by heads of farm households in Kenya. *Soc Nat Resour* 9:447–463
81. Jaleta M, Kassie M, Shiferaw B (2013) Tradeoffs in crop residue utilization in mixed crop-livestock systems and implications for conservation agriculture. *Agric Syst* 121:96–105
82. Ndiritu SW, Kassie M, Shiferaw B (2014) Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy* 49:117–127
83. Kamau M, Smale M, Mutua M (2014) Farmer demand for soil fertility management practices in Kenya's grain basket. *Food Secur* 6:793–806
84. Kassie M, Teklewold H, Jaleta M, Marenja P, Erenstein O (2015) Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy* 42:400–411
85. Waithaka MM, Thornton PK, Shepherd KD, Ndiwa NN (2007) Factors affecting the use of fertilizers and manure by smallholders: the case of Vihiga, western Kenya. *Nutr Cycl Agroecosyst* 78:211–224
86. Ogada MJ, Mwabu G, Muchai D (2014) Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agric Food Econ* 2:12
87. Freeman HA, Omiti JM (2003) Fertilizer use in semi-arid areas of Kenya: analysis of smallholder farmers' adoption behavior under liberalized markets. *Nutr Cycl Agroecosyst* 66:23–31
88. Murage AW, Midega CAO, Pittchar JO, Pickett JA, Khan ZR (2015) Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Secur* 7:709–724
89. Nyaga J, Barrios E, Muthuri CW, Öborn I, Matiru V, Sinclair FL (2015) Evaluating factors influencing heterogeneity in agroforestry adoption and practices within smallholder farms in Rift Valley, Kenya. *Agric Ecosyst Environ* 212:106–118
90. Were K, Dick ØB, Singh BR (2014) Exploring the geophysical and socio-economic determinants of land cover changes in Eastern Mau forest reserve and Lake Nakuru drainage basin, Kenya. *GeoJournal* 79:775–790
91. García de Jalón S, Silvestri S, Granados A, Iglesias A (2015) Behavioural barriers in response to climate change in agricultural communities: an example from Kenya. *Reg Environ Chang* 15:851–865
92. Noordn Q, Niang A, Jama B, Nyasimi M (2001) Scaling up adoption and impact of agroforestry technologies: experiences from Western Kenya. *Dev Pract* 11:509–523
93. Simtowe F, Muange E (2013) The diffusion and adoption of green revolution technologies: lessons and policy implications from pigeonpea farmers in Kenya. *Reg Sect Econ Stud* 13:161–178
94. Gebremariam GG, Edriss AK (2010) Valuation of soil conservation practices in Adwa Woreda, Ethiopia: a contingent valuation study. *J Econ Sustain Dev* 3:97–107
95. Ng'ang'a SK, Bulte EH, Giller KE, McIntire JM, Rufino MC (2016) Migration and self-protection against climate change: a case study of Samburu County, Kenya. *World Dev* 84:55–68
96. Mwirigi J, Balana BB, Mugisha J, Walekhwa P, Melamu R, Nakami S, Makenzi P (2014) Socio-economic hurdles to widespread adoption of small-scale biogas digesters in Sub-Saharan Africa: a review. *Biomass Bioenerg* 70:17–25
97. Heyi DD, Mberengwa I (2012) Determinants of farmers' land management practices: the case of Tole district, South West Shewa zone, Oromia National Regional State, Ethiopia. *J Sustain Dev Africa* 14:76–96
98. Ng'ang'a SK, Bulte EH, Giller KE, Ndiwa NN, Kifugo SC, McIntire JM, Herrero M, Rufino MC (2016) Livestock wealth and social capital as insurance against climate risks: a case study of Samburu County in Kenya. *Agric Syst* 146:44–54
99. Wairore JN, Mureithi SM, Wasonga OV, Nyberg G (2016) Benefits derived from rehabilitating a degraded semi-arid rangeland in private enclosures in West Pokot County, Kenya. *Land Degrad Dev* 27:532–541
100. Mugwe J, Mucheru-Muna M, Mugendi DN, Kung'u J, Bationo A, Mairura F (2014) Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya. *Nutr Cycl Agroecosyst* 81:20–29
101. Pisanelli A, Poole J, Franzel S (2008) The adoption of improved tree fallows in western Kenya: farmer practices, knowledge and perception. *For Trees Livelihoods* 18:233–252
102. Kebebe EG, Oosting SJ, Baltenweck I, Duncan AJ (2017) Characterisation of adopters and non-adopters of dairy technologies in Ethiopia and Kenya. *Trop Anim Health Prod* 49:681–690
103. Thuo M, Bell AA, Bravo-Ureta BE, Lachaud MA, Okello DK, Okoko EN, Kidula NL, Deom CM, Puppala N (2014) Effects of social network factors on information acquisition and adoption of improved groundnut varieties: the case of Uganda and Kenya. *Agric Hum Values* 31:339–353
104. Recha CW, Mukopi MN, Otieno JO (2015) Socio-economic determinants of adoption of rainwater harvesting and conservation techniques in semi-arid tharaka sub-county, Kenya. *Land Degrad Dev* 26:765–773
105. Ndiiri JA, Mati BM, Home PG, Odongo B, Uphoff N (2013) Adoption, constraints and economic returns of paddy rice

- under the system of rice intensification in Mwea, Kenya. *Agric Water Manag* 129:44–55
106. Mogaka V, Ehrensperger A, Iiyama M, Birtel M, Heim E, Gmuender S (2014) Understanding the underlying mechanisms of recent *Jatropha curcas* L. adoption by smallholders in Kenya: a rural livelihood assessment in Bondo, Kibwezi, and Kwale districts. *Energy Sustain Dev* 18:9–15
107. Kulecho IK, Weatherhead EK (2006) Adoption and experience of low-cost drip irrigation in Kenya. *Irrig Drain* 55:435–444
108. Ng'ang'a S, Notenbaert A, Mwungu C, Mwongera C, Girvetz E (2017) Cost and benefit analysis for climate-smart soil practices in Western Kenya. Kampala, Uganda

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