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Review A meta-analysis of adoption studies of climate-smart agriculture practices (CSAPs) in Ethiopia

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Corresponding Author:	Assefa Abegaz, PhD Addis Ababa University Addis Ababa, Addis Ababa ETHIOPIA
First Author:	Assefa Abegaz, PhD
Order of Authors:	Assefa Abegaz, PhD
	Wuletawu Abera, PhD
	Stephanie Jaquet, PhD
	Lulseged Tamene, PhD
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Suggested Reviewers:	Musa H. AHMED, PhD Professor, Haramaya University musahasen@gmail.com Has an extensive experience in studies of adoption of multiple agricultural practices/technologies in the Ethiopian Agricultural practices.
	Aslihan Arslan, PhD International Fund for Agricultural Development a.arslan@ifad.org Has great experience in adoption studies of agricultural technology, in particular, and recently has published A meta-analysis of the adoption of agricultural technology in Sub-Saharan Africa.
	Paul M. Barasa, PhD University of KwaZulu-Natal - Pietermaritzburg Campus Joel.Botai@weathersa.co.za Has an extensive research practices in adoption of Climate-Smart Agriculture practices in Africa.

	Christine Lamanna, PhD Center for International Forestry Research (CIFOR-ICRAF) c.lamanna@cgiar.org She is a climate-change ecologist and decision analyst with ICRAF's Climate Change Unit, working on targeting climate-smart agricultural interventions throughout Africa to inform national policies.
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Journal of Climate Risk Management

Dear respected Journal Editorial Manager,

I am very much happy to submit the review manuscript “A meta-analysis of adoption studies of climate-smart agriculture practices (CSAPs) in Ethiopia” to your high impact Journal (Climate Risk Management). We believe, our manuscript is within the scope of the journal. Therefore, on behalf of myself and co-authors, I submit the manuscript for your consideration for publication.

Sincerely,

Authors: Assefa Abegaz, Wuletawu Abera, Stephanie Jaquet, Lulseged Tamene

Review

A meta-analysis of adoption studies of climate-smart agriculture practices (CSAPs) in Ethiopia

Assefa Abegaz*[a], Wuletawu Abera[b], Stephanie Jaquet[c], Lulseged Tamene[b]

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Abstract

The objectives of this review were to synthesize adoption studies of climate-smart agricultural practices (CSAPs); examine their adoption status, including gender considerations, socioeconomic benefits, and constraints to CSAP adoption; identify gaps in the current CSAP adoption literature, and highlight future CSAP research and policy directions. Following a systematic literature review procedure, a total of 100 articles published between 2001 and 2021 in Ethiopia were reviewed. Although all the publications were about the highlands of Ethiopia, over 80% came from the regions of Oromiya, Amhara, and South Nations and Nationalities. The most adopted practice was soil and water conservation (SWC), with a mean adoption rate of 61.5%, followed by integrated soil fertility management, and agroforestry with mean adoption rates of 56.5% and 48.8%, respectively. Gender analysis was considered in the studies of: all improved livestock management; a little higher than a half of the SWC; and over 75% of the remaining five practices. Quantified socioeconomic benefits were reported in only 46 papers. Greater farm income; increased land productivity; higher yields; increased food availability; and reduced household poverty were among the reported benefits of adopters compared to their counterparts. Among the aggregated constraints, socioeconomic factors and knowledge/awareness were ranked the two highest, followed by labor shortage and limited market access. The study highlighted research gaps: a lack of national-scale studies and studies focusing on drought prone regions; and 37% and 46% of the studies, respectively, didn't consider gender, and analysis of socioeconomic benefits of adoption of CSAPs. It also highlighted future policy directions.

Keywords: Adoption constraint; Adoption status; Climate-smart agriculture; Gender analysis; Policy support; Socioeconomic benefits

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[a]Department of Geography and Environmental Studies, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia.
[b]International Center for Tropical Agriculture (CIAT), P.O. Box 5689, Addis Ababa, Ethiopia.
[c]International Center for Tropical Agriculture (CIAT), Nairobi, Kenya
* Corresponding Author: assefa.abegaz@gmail.con, assefa.abegaz@aau.edu.et

1. Introduction

Agriculture underpins Ethiopia's economic sector. It employs over 85% of the working population (Ministry of Agriculture [MOA], 2017), supports the livelihoods of millions of people (Njeru et al., 2016), and contributes 43% of the national GDP (Ethiopian Panel on Climate Change [EPCC], 2015). However, land degradation poses a serious challenge in cultivated lands of Ethiopia. Since the sector is profoundly dependent on rainfed production systems, the problem has been exacerbated by climate change. Climate-smart agricultural practices (CSAPs) have been proposed for adapting to and mitigating the negative effects of climate change, and to help ensure the sustainability of agricultural production and food security (FAO, 2016). More recently, a wide range of CSAPs have been promoted in Africa. These include: soil and water conservation (SWC); integrated soil fertility management (ISFM); agroforestry (AF); water harvesting and small-scale irrigation (WHSSI); conservation agriculture (CA); adoption of improved crop varieties (ICV); improved livestock management (ILM), and other practices (e.g. biogas development; energy-saving cooking stoves, and weather index-based agricultural insurance) (World Bank, 2018).

Empirical evidence is available on the impacts of proven agricultural practices in reversing agricultural land degradation trends, enhancing smallholder farmers' capacities to mitigate climate-change impacts, and improving agricultural systems' resilience, and thereby increasing agricultural productivity (Abera et al., 2020; Adimassu et al., 2018; Chen et al., 2020; Hishe et al., 2017; Lal, 2011, 2014; World Bank, 2012; Xiao, 2015). While the evidence of the benefits of CSAPs on agricultural biophysical conditions are strong, smallholder farmers' CSAP adoption is minimal in sub-Saharan Africa in general (African Climate Smart Agriculture Summit [ACSAS], 2014; Arslan et al., 2022). CSAP adoption refers to the use of one, or a combination of two or more of such practices by smallholder farmers (FAO, 2016). It is considered as a fundamental route to sustainably increasing productivity, supporting farmers' adaptation capacity to mitigate the impact of climate change, and reducing greenhouse gas (GHG) emissions (FAO, 2010).

CSA adoption has received increasing attention from academics, researchers, development agents, and policymakers worldwide (World Bank, 2018). Nevertheless, generally in Africa, and particularly in Ethiopia, empirical studies are still limited and fragmented. More so, review studies of CSAPs are scarce and limited in scope (such studies include, Asrat & Anteneh, 2019; Barasa et al., 2021; Haile & Kasa, 2015; Iticha, 2019; Tadesse & Baihilu, 2017; Mulualem & Yebo, 2015; Zerssa et al., 2021). None of these review studies have: i) dealt with a systematic mapping of the research areas of studied practices; ii) synthesized progression of adoption publication, or iii) made comparative analyses on the adoption status of practices, socioeconomic welfare of adopted practices to rural households, and constraints to scaling-up the practices. In Ethiopia, there is a dearth of comparative-systematic literature reviews with a broader scope on the adoption of CSAPs that have been identified as a best-bet practices elsewhere in the world.

The objective of this study was, therefore, to review scientific literature on CSAPs' adoption in Ethiopia and the specific objectives were to: 1) synthesize studies (what practices, sites, timeseries, and methods) of CSAPs adoption were conducted so far; 2) examine the status/rates of adoption of these practices by rural householders, and considering gender, and socioeconomic benefits; and 3) identify gaps in the current adoption literature and possible future research directions.

2. Materials and methods

2.1. The study area

Ethiopia is situated in the Horn of Africa approximately between 3.4°N and 14.9°N, and 33.0°E and 48.0°E with an area of 1,104,300 km^2. With a dividing elevation of 1,500 m above sea level, the land masses below and above are broadly defined as lowlands and highlands of Ethiopia, respectively (International Food Policy Research Institute and Central Statistical Agency [IFPRI & CSA], 2006). The mean annual rainfall pattern is characterized by a large variation in spatial and temporal distributions. It varies between 2,700 mm in the southwestern highlands and less than 200 mm in some parts of the northeastern and southeastern lowlands of Ethiopia (Dinku et al., 2018). The annual mean temperature ranges from 6.0^{0}C in the highlands to less than 30^{0}C in the lowlands (Dinku et al., 2018). On the basis of the highest political administration unit, Ethiopia has nine regional states and two city governances.

2.2. Methods

This study adopted a systematic literature review (SLR) method, which has been used and acknowledged as valuable method by many researchers (Danese et al., 2018; Mihalache & Mihalache, 2016; Xia et al., 2018). This method helps to reduce bias and errors, and improves the rigorous review process, and also helps to organize the literature in specific contents/themes (Mihalache & Mihalache, 2016; Tranfeld et al., 2003). As recommended by many researchers, the systematic literature review was performed in three steps (Xia et al., 2018). Step 1: Data sourcing and developing meta-database (planning, document search, and documentation); step 2: Filtering retrieved publication using inclusion and/or exclusion criteria; and step 3: Content analysis (literature meta-analysis).

2.2.1 Data sourcing and developing meta-database

First, an excel template was developed and relevant data/information of each article were captured. During this step, comprehensive search topics were considered to retrieve scientific publications that dealt with adoption of CSAPs of Ethiopia. The search keywords/themes were defined to cover the scope and research topics within the subject matter of adoption of: “sustainable land management”; “climate-smart agriculture”, or “precision agriculture”, or “precision farming”, or “smart farming”– each with technologies/practices of “integrated nutrient management”, or “integrated soil fertility management”, or “conservation agriculture”, or “soil and water conservation”, or “agroforestry”, or “crop residue management”, or “crop rotation”, or “water harvesting and small scale irrigation”, or “improved crop varieties”, or “improved livestock management”, or “biogas development and use”, or “energy-saving cooking stoves”, or “weather forecasting”. The study area of the retrieved documents was restricted to Ethiopia, while the search was open-ended regarding the study period.

The retrieved scientific publications (peer-reviewed articles and book chapters) related to adoption of practices (as defined in the search keywords/themes above) of Ethiopia, and published in English language were obtained by searching in scientific databases of CAB, Google Scholar, and Scopus. These databases are widely used in most review studies, because they make available a wide range of peer-reviewed research documents in almost all disciplines.

From the retrieved documents, we captured title of the publication, journal in which the paper is published, year of publication, absolute location (when possible, latitude, longitude), and relative locations (districts and/or regional state) of the study area, sample size used in the study (number of adopters and non-adopters), studied practices, inclusion/exclusion of gender analysis in the study, methods of studies, constraints to the adoption of the practice(s), and socioeconomic benefits of smallholder farmers from the adopted practices (if reported). In step 1, after removing duplicated papers, a total of over 220 publications were retained for further analysis.

2.2.2. Refining publications based on exclusion criteria

In the next step, irrelevant documents in relation to this study were removed using exclusion criteria, i.e., excluding publication of studies that didn't dealt with adoption of any practice of CSA; laboratory and/or research center's experimental studies; literature review; and editorial and commentaries. Through this process, 140 articles/papers were retained. The validity of each of these articles was verified by referring the journal's site score and its continuity from the "List of Scopus Indexed Journals" database (LSIJ, 2022: https://www.ardaconference.com/blog/list-of-scopus-indexed-journals/ (consulted on February 2022), and we verified that only 100 papers were drawn from reputable journals that have a "Scopus site score". From each of 73 journals, one published adoption paper was drawn. While from each of eight journals, two publications; from one journal, three publications; and from each of two journals four publications were drawn. The Journal of International Soil and Water Conservation, and the Journal of Sustainability had the most publications (each with four publications), while the Journal of Environmental System Research was in the 2nd position with three publications. With this scenario, we built confidence that these papers are dependable and we used them for content analysis (Appendix A: Lists of publications used for content analysis).

2.2.3 Content analysis (literature meta-analysis)

The third step involved content analysis, comprising thematic classification of studied practices, and descriptive and quantitative analysis (Xia et al., 2018). For the thematic analysis, components of studied practices were grouped into seven thematical areas (Table 1).

Table 1. Climate-smart agriculture thematic areas and components of studied practices

Thematic areas	Components of studied practices
1. Soil and water conservation (SWC)	bench and hillside terraces, level and graded soil bunds, level and graded fanya juu, check dams, cut-off drain, area closure, gulley rehabilitation, grass strip, soil bunds, stone bunds, soil-stone bunds, water ways and contour farming.
2. Integrated soil fertility management (ISFM)	a combined use of inorganic and organic fertilizers or integrated use of organic, inorganic fertilizers, and measures to control soil erosion, and to correct soil acidity (Hörner & Wollni, 2021; Vanlauwe et al., 2010).
3. Agroforestry (AF)	home gardens/homestead tree planting; scattered trees in croplands (parklands); trees on grazing lands; the *Enset*-Coffee gardens; coffee shade based scattered trees; woodlots; and farm boundary tree practices.
4. Water harvesting and small-scale irrigation (WHSSI)	capturing runoff from rooftops; local catchments; seasonal floodwaters from local streams; and on-farm water conservation practices (tie-ridging, hand-dug wells and ponds) (MOA, 2011).
5. Improved crop variety (ICV)	Studies on drought resistant, early maturing, and high yielding crop varieties.
6. Conservation agriculture (CA)	one, or a combination of two or more of reduced/minimum tillage; soil cover/mulching of organic materials (straw and/or other crop residues including cover crops); and crop rotation with nitrogen-fixing legumes (FAO, 2010).
7. Improved livestock management (ILM)	grazing management, feed improvement, breed improvement (Branca et al., 2013; FAO, 2016; Saguye, 2017).

For the descriptive analysis, content categories of article's journal title; year of publication; study/research location where the publication data were drawn; studied practice; inclusion/exclusion of gender in the study; research methods and data collection tools used; and reported constraints to the adoption of the studied practice were considered.

Research methods used were packed into five groups (cross sectional; mathematical; on-farm experiment with-and-without; longitudinal; and remote sensing). Data collection tools/methods were grouped into five categories (household survey questionnaire; field data collection; in-depth interview; focus group discussion; and secondary data collection tools).

Reported constraints to the adoption of the studied practice were grouped into 12 categories: i) *Knowledge/awareness* (includes farmers' education, extension service, training, weak technical support from the extension agent, lack of awareness on the impact of climate change and the benefit/profitability of practices, and weak monitoring and evaluation of practices); ii) *Socioeconomic factors* (includes small plot size/land shortage, age of the household head, size of household, off-farm activity, duration of the practice to provide returns); iii) *Shortage of labor* (includes labor unavailability, labor intensiveness of the practice); iv) *limited access to market*; v) *limited access to credit*; vi) limited capital/finance; vii) *limited access to farmers' social organization/institutions* (includes access to local institutional services, membership in local organizations); viii) *land tenure system*; vix) *limited access to irrigation*; x) *insufficient local organic material*; xi) *limited access to seedling*; and xii) *weather/climate*.

For quantitative analysis, data were extracted and documented including: study sample size (number of adopters and non-adopters, and adoption rate (if it is reported)); annual number of adoption publications; socioeconomic benefits of adopters (in monetary form in Eth. Birr or USD); and increases in household income and food security, yield and land productivity.

To examine annual progression and total number of CSAPs adoption publications, absolute numbers were considered. But in the case of several studied practices, frequency is used, because in one publication, the results of one or more practices were reported, therefore, the total frequency of studied practices is greater than the absolute number of publications. The same approach was used in the cases of examining research methods and data collection tools used, and reported constraints to the adoption of practices.

In order to mathematically estimate the change/increase in the number of publications over time, the number of annual publications was plotted on the Y-axis, and the corresponding year on the X-axis; and Quadratic Non-linear Regression Model was fitted.

Mapping of the spatial distribution of the research areas was done using the ArcGIS tool. Absolute locations of studies were mapped using median values of the reported ranges of latitude and longitude of the study area, while the study areas with no latitudes and longitudes, but with mentioning of district's name, the relative location is mapped approximately at the center of the district. National and sub-national studies were excluded from mapping; however, their data were used at the national level analysis.

The adoption rate of each practice was computed as the percentage ratio between number of adopters and total studied sample size. Then after, Kifle et al. (2020) adoption status classes of very high, high, medium, low and very low, respectively, with greater than 70, 60-70, 50-59, 40-49, and below 40% of adopters was adopted. One-way ANOVA test was used to investigate whether the adoption rate difference between practices is statistically significant or not, at the 0.05 level.

3. Results and discussion

3.1 Studied adopted practices overtime spatial distribution

3.1.1. Categories of adopted CSAPs

Fig. 1 shows frequencies of publications that dealt with adoption of CSAPs in Ethiopia from 2001 to 2021 by individual practices, and a total of seven categories of adopted practices were studied. Soil and water conservation was the most studied adoption practice, with 53 papers followed by adoption of ISFM and AF, as they were studied by 25 and 24 research teams, respectively. The fourth most studied adoption practice was WHSSI with 20 publications. Studies of ICV and CA adoption ranked fifth and sixth with 17 and 16 publications, respectively. Adoption on improved livestock management with only seven articles was the least studied practice.

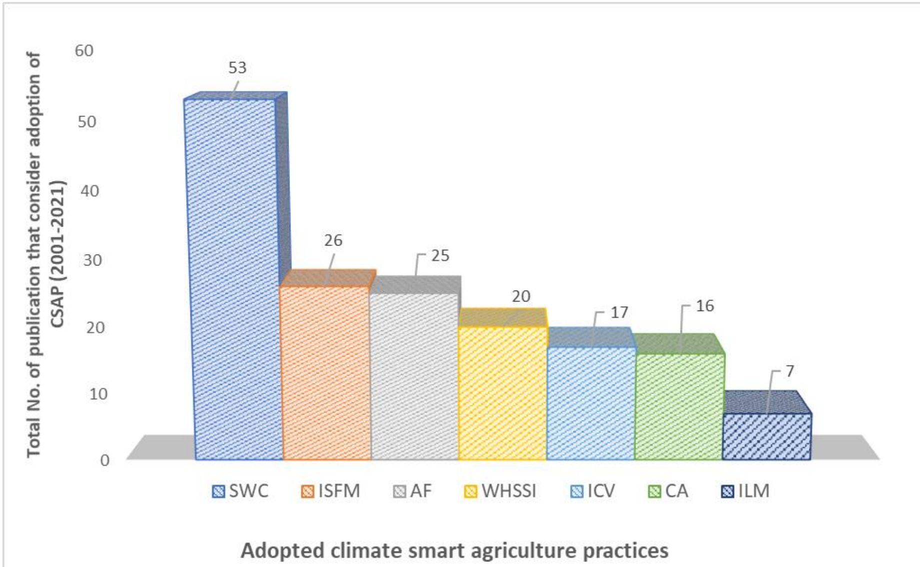

Figure 1. Frequencies of studied practices from 2001 to 2021 by adopted practice categories. Note that in one publication, one, or more practices were studied, therefore, the total frequency of studied practices is 164, which is greater than the absolute number of publications, i.e., 100. SWC= soil and water conservation; ISFM = integrated soil fertility management; AF = agroforestry; WHSSI= water harvesting and small-scale irrigation; ICV = improved crop variety; CA = conservation agriculture; ILM = improved livestock management.

3.1.2. Climate-smart agriculture practice adoption studies overtime

The first published research paper on the adoption of CSAPs appeared for Ethiopia in 2001, with only one article by Enki et al. (2001). Likewise, in each of 2004, and 2010, there was only one publication, and in 2007 there were three publications, while in between these years (i.e., in 2002, 2003, 2005, 2006, 2008 and 2009) there were no publications (Fig. 2A). Accordingly, in the first decade (2001-2011) the total publications were only seven. In the second decade (2012-2021), annual publication notably increased from two in 2012, to 14 articles in 2021, with an annual growth rate of about 1.2 articles. In general, from 2001 to 2021, there was a total of 100 publications, with an average of five publications per year. In terms of temporal pattern, the number of publications over the last two decades can be best estimated using a Quadratic Non-linear Regression Model (R^2 = 0.86), which showed a slower gradient at the early period (until 2009) and steeper gradient at the later period which indicates that future publication progression will continue with increasing gradient (Fig. 2A)

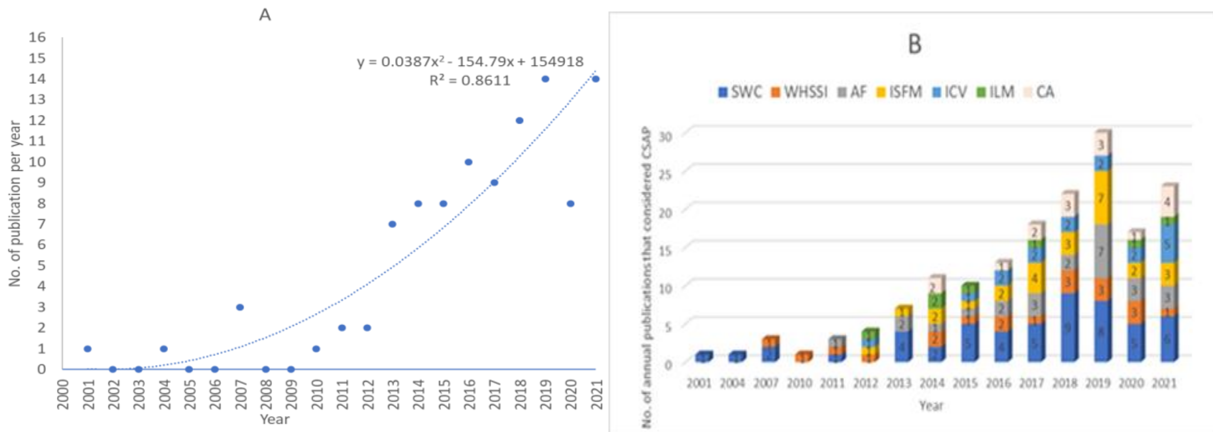

Figure 2. Scatter plots and Quadratic Non-linear Regression Model of the changes in number of CSAPs adoption publications (A), annual stacked frequencies of progression of practices (B) of Ethiopia, 2001 to 2021

This momentous growth suggests a growing interest of researchers in adoption studies, and also the research topic is increasing. This also indicates that over the last 20 years, research of adoption of CSAPs was progressively considered to be an important means of building scientific knowledge in order to design appropriate agricultural practices, so as to curb the impacts of climate change (World Bank, 2018).

Fig. 2B presents stacked annual publications by practices and their corresponding number. In each of 2001 and 2004, there was only one publication, and both of these publications considered only adoption of SWC practice.

Publications of adoption of SWC as a theme of CSAP started in 2001 (Enki et al., 2021), and gradually grew until 2018, with nine publications and then declined to six in 2021 (Fig. 2B). During the study period, 53% of the total 100 reviewed papers, dealt with adoption of SWC practice. In 2007, there were three publications, two on SWC (Amsalu & de Graaff, 2007; Bewket, 2007) and one on WHSSI (Ayalneh et al., 2007). In 2010, there was only one publication (Teshome et al., 2010) on adoption of WHSSI. In 2011, there were two more publications of which, the study by Mekonen and Tesfahunegn (2011) considered both SWC and AF, while the study by Bacha et al. (2011) considered only WHSSI. In

2012, adoption of four practices were published in two articles, i.e., three practices (ISFM, WHSSI and ILM) in Legesse et al. (2013); and the other one (ICV) in Goshu et al. (2012)

From 2014-2016, the number of studied practices increased to six, with a total annual practices' frequency between 11 and 13. In 2017, 2020 and 2021, there were publications on all the seven adopted practices, with a total annual practices' frequency of 18, 17, and 23, respectively (Fig. 2B). Publication of WHSSI started in 2007 (Ayalneh et al., 2007) and continued until 2021, except in 2013. Except in 2012, AF practice was published from 2011 until 2021. Publication on ISFM started in 2012 and continued with no interruption until 2021.

Despite research on adoption of CSAPs increasing in Ethiopia, emphasis has been only on a few practices. Out of the studied practices, one-third was on SWC, and nearly one-fifth each was on ISFM and AF, suggesting research gaps in adoption studies in ICV and ILM.

3.1.3. Spatial distributions of CSAPs adoption studies

Out of the total 100 reviewed articles, the research data of the seven articles were from semi-national scale studies, i.e., three articles were from the studies that considered five regional states ("subnational scale"), and the other four articles were "regional scale" that considered two regional states (Fig. 3B). The research data of the other 93 publications were either from district, or watershed ("local scale") studies, associated with specific regional states, therefore, the spatial distribution of these research areas is mapped on Fig. 3A. In this mapping, research areas of seven papers were excluded, because they were not associated with any specific regional state of Ethiopia.

Out of the total review papers, the highest number (37 papers) focused on the Oromiya region, followed by Amhara, and SNNP regions, with 27 and 17 papers, respectively, while there were no publications relating to Somalia, Gambella and Harari regions (Figs. 3A&B).

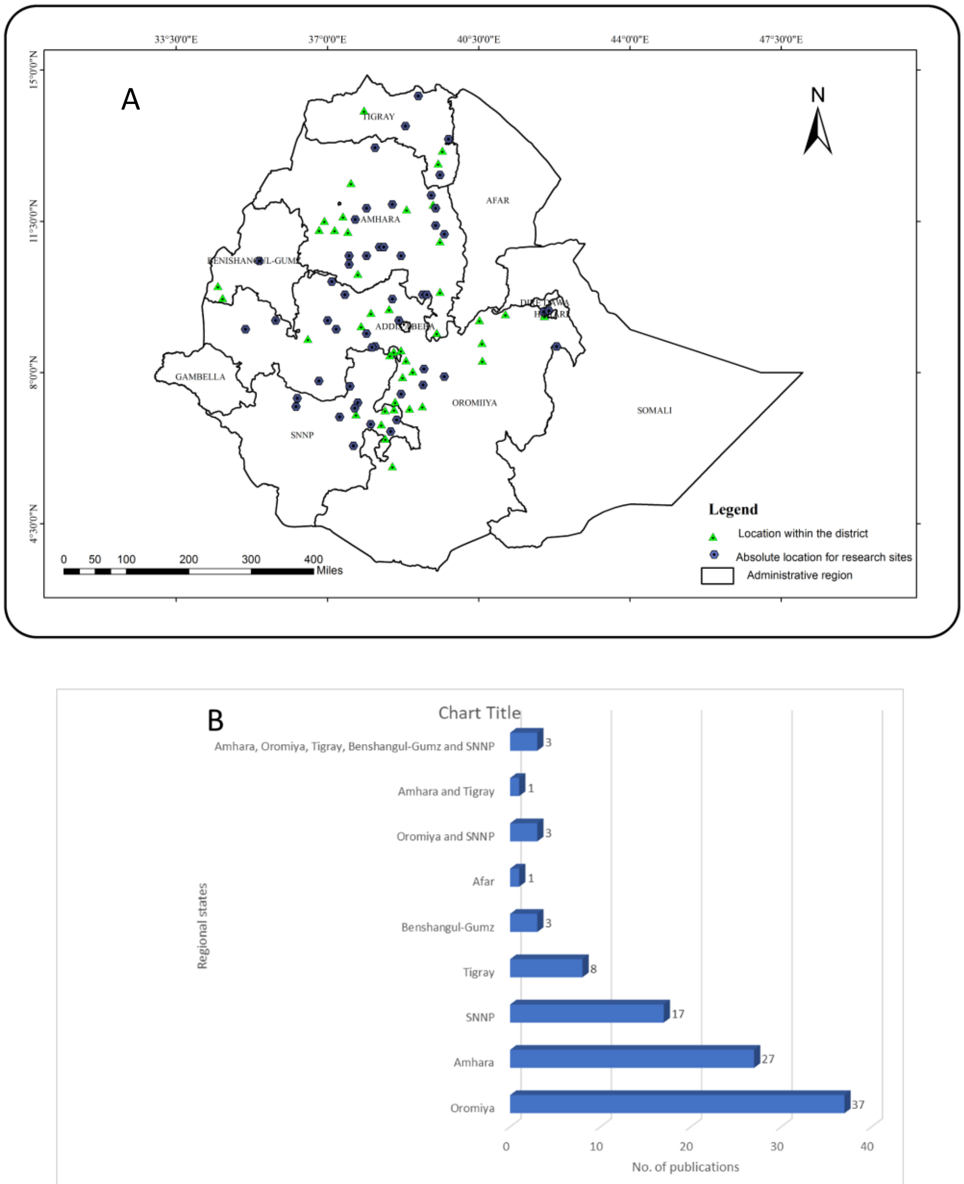

Figure 3. Spatial distribution of research sites of adoption of CSAP (A), and number of published articles by regional states of Ethiopia (B), 2001-2021.

With regard to the publication of SWC, over 80% was from research linked to three regions (SNNP, Oromiya and Amhara). The regional relative percentage distribution of research areas of other practices is very similar to that of SWC. In general, out of the total 164 publication frequencies of adopted practices, 130 (79.3%) was from the Oromiya, Amhara and SNNP regions (Table 2).

The highest publication frequencies of ISFM (38.5%) were from Amhara region, followed by Oromiya, SNNP, and Benshangul-Gumz, with 26.9, 19.2, and 7.7% of total publication frequencies for ISFM practices, respectively (Table 2). For the remaining two publications, the research data was from the semi-national source, which involved Amhara, Oromiya, Tigray, Benshangul-Gumz, and SNNP regions.

This study revealed that no CSA adoption research was conducted in the three regional states of Gambella, Harari and Somala, and only one in Afar region. These regions are situated at lowlands and periphery of Ethiopia with either relatively lower land degradation rates, or most probably researchers and projects didn't go there to do research due to its periphery and remoteness. However, the regions are drought prone and highly vulnerable to climate-change impacts. On the other hand, although almost all previous adoption publications data were collected from the highlands of Ethiopia; Oromiya, Amhara, and SNNP are the most predominant regions with over 80% of the total publications over the last 20 years (Fig. 3B). These results confirm that most CSAPs studies are region specific, and highlights the need to support and enhance adoption studies in the remaining regions.

Table 2. Frequencies and percentage of studied practices by regional states of Ethiopia, 2001-2021.

Regional state	Adopted practices & their frequencies and percentages							
	ISFM	CA	SWC	WHSSI	ICV	AF	ILM	Total
Oromiya	7 (26.9)	5 (31.3)	14 (26.4)	5 (25.0)	5 (29.4)	6 (24.0)	4 (57.1)	46
Amhara	10 (38.5)	3 (18.8)	14 (26.4)	6 (30.0)	6 (35.3)	7 (28.0)	2 (28.6)	48
SNNP	5 (19.2)	4 (25.0)	15 (28.3)	2 (10.0)	2 (11.8)	7 (28.0)	1 (14.3)	36
Tigray	0	1 (6.3)	5 (9.4)	2 (10.0)	1 (5.9)	3 (12.0)	0	12
Benshangul-Gumz	2 (7.7)	0	2 (3.8)	1 (5.0)	1 (5.9)	1 (4)	0	7
Afara	0	0	1 (1.9)	0	0	0	0	1
Oromiya & SNNP	0	2 (12.5)	0	3 (15.0)	0	0	0	5
Amhar & Tigray	0	0	1 (1.9)	0	0	0	0	1
Amhara, Oromiya, Tigray, Benshangul-Gumz & SNNP	2 (7.7)	1 (6.3)	1 (1.9)	1 (5.0)	2 (11.8)	1 (4.0)	0	8
Total	26	16	53	20	17	25	7	164

Note: Figures in parenthesis are percentages of total frequencies of practices within adopted practice.

3.2 Research m*ethods and data collection tools of CSAPs adoption studies*

3.2.1 Research Methods

Table 3 presents research methods that have been used by previous CSAP adoption studies. Each study has applied either only one, a combination of two, or integration of three or more methods, depending on the objectives of the research. Accordingly, the summation of the five methods used by all studies of the seven practices was 185 (Table 3). The most applied method was cross sectional and descriptive (which involves survey and observational study), with a total frequency of 158 (85.4%), with ≥ 80% of the time within each of the practices. ILM studies adopted a sole cross-sectional method, while, a tenth of the studies of ISFM applied cross-sectional methods. The least-used method was remote sensing, which was applied only in four studies (2.2% of the total frequencies of methods used), particularly for SWC followed by CA and AF practices. All the five methods were used in the studies of three practices: CA, SWC, and AF, while four methods (cross-sectional, mathematical, on-farm experiment with-and-without the practices, and longitudinal) were used in the studies of WHSSI. Three methods (cross-sectional, mathematical and longitudinal) were used in studies of ISFM and ICV.

Table 3. Frequency of research methods used by previous studies of adoption of CSAP in Ethiopia, 2001-2021.

	Research methods used					
Studied adopted practices	Cross sectional	Mathematical /modeling	On-farm experimental with-and-without	Longitudinal	Remote sensing	Total
Integrated soil fertility management	25 (89.3)	1 (3.6)	0 (0)	2 (7.1)	0 (0)	28
Conservation agriculture	16 (80.0)	1 (5.0)	1 (5.0)	1 (5.0)	1 (5.0)	20
Soil and water conservation practices	51 (85.0)	3 (5.0)	3 (5.0)	1 (1.7)	2 (3.3)	60
Water harvesting and small-scale irrigation	18 (81.8)	1 (4.5)	2 (9.1)	1 (4.5)	0 (0)	22
Improved crop variety	16 (88.9)	1 (5.6)	0 (0)	1 (5.6)	0 (0)	18
Agroforestry	25 (83.3)	2 (6.7)	1 (3.3)	1 (3.3)	1 (3.3)	30
Improved livestock	7 (100)	0 (0)	0 (0)	0 (0)	0 (0)	7
Total	158 (85.4)	9 (4.9)	7 (3.8)	7 (3.8)	4 (2.2)	185

Figures in parentheses are percentages of total number of methods used by previous studies within adopted practices

Reviewed articles which used the cross-sectional method involved quantitative measurements of two or more variables. They provided an in-depth and valuable descriptive, and correlational discussion on topical issues at a set point in time. However, since the generated results are at a set point in time (snapshots or statics), they could not be used for future prediction, and also, they didn't determine cause-and-effect relationships. Mathematical/modeling methods involved the use of econometrics and statistics to represent the socioeconomic benefits from adopted practices, however, only for a particular time. The on-farm experiment with-and-without method involved measuring data from those who are using the practice and comparing it with their counterparts on their farm fields.

3.2.2 Data collection tools/methods used by previous studies

Table 4 presents research data collection tool/methods that have been used by previous CSAP adoption studies. In general, in this review, we have summarized the data collection tool/methods in five categories: household survey questionnaire and field survey and data collection, in-depth interview, focus group discussion, and secondary data collection. Each of the studies has applied either only one, a combination of two, or integration of three or more tools/methods (Table 4). Accordingly, the frequency summation of the five tools/methods used by all studies of the seven practices was 369, of which the highest frequency (119; 32.2%) was in studies of SWC (Table 4).

Table 4. Frequency of research data collection tools/methods used by previous CSAP adoption studies in Ethiopia, 2001-2021.

	Data collection tool/methods used					
Studied adopted practices	Household survey questionnaire	Field data collection	In-depth interview	Focus group discussion	Secondary data collection tool	Total
Soil and water conservation practices	51 (42.9)	4 (3.4)	32 (26.9)	28 (23.5)	4 (3.4)	119
Integrated soil fertility management	26 (45.6)	1 (1.8)	14 (24.6)	15 (26.3)	1 (1.8)	57
Agroforestry	24 (38.7)	4 (6.5)	16 (25.8)	16 (25.8)	2 (3.2)	62
Water harvesting and small-scale irrigation	18 (36.0)	4 (8.0)	13 (26.0)	14 (28.0)	1 (2.0)	50
Improved crop variety	17 (50.0)	0 (0)	9 (26.5)	8 (23.5)	0 (0)	34
Conservation agriculture	16 (48.5)	2 (6.1)	7 (21.2)	7 (21.2)	1 (3.0)	33
Improved livestock	7 (50)	0 (0)	3 (21.4)	4 (28.6)	0 (0)	14
Total	159 (43.1)	15 (4.1)	94 (25.5)	92 (24.9)	9 (2.4)	369

Figures in parentheses are percentages of total number of methods used by previous studies with in adopted practices

In the studies of all practices, the most applied tool was the household survey questionnaire, with a total frequency of 159 (43.1%), with ≥ 36% of the time within each of the practices, followed by in-depth interview and focus group discussion, each with a quarter of the total frequency, while the least used tool was secondary data collection, with a 2.9% of the total frequency of tool used. The secondary data collection tool was used only once in each of ISFM, CA, and WHSSI; twice in AF; and four times in SWC studies. Excepting field data collection and secondary data collection tools, the remaining three tools were used in the studies of all practices, albeit at varying intensities. Both field data collection and secondary data collection tools were not used in any studies of ICV and LIM practices (Table 4).

3.3. Adoption status of CSA practices

3.3.1 Adoption status of CSA practices by category

Soil and water conservation (SWC) is predominately used in the central and northern highland regions of Ethiopia, where soil erosion is one of the major limiting factors for agricultural production (Alemu & Melesse, 2020; Alemu et al., 2019; Amsalu & De Graaff, 2007; Gadisa & Hailu, 2020). In recognition of its importance for reducing soil erosion and land degradation, and boosting land productivity, Ethiopia started SWC many years ago, and a large scale SWC practice has been underway since the 1980s (Engdawork & Bork, 2014; Kosmowski, 2018). Since then, the government has focused on this program, and various donors and development partners have been engaged in providing technical and financial support towards its widespread implementation in different parts of the country (Kosmowski, 2018). Accordingly, until 2015, under the integrated watershed management program, over 1.7 million ha of land were treated under area closure, and on over 2 million ha of land, physical and biological soil conservation measures were applied in different parts of Ethiopia (FAO, 2016).

This review confirms that SWC is the most adopted practice, with a 61.5% mean adoption rate, which can be rated as high based on Kifle et al. (2020). This adoption rate is significantly higher by 26.8, 22.9, 20.5, 15.2, and 12.7% than the adoption rates of ILM, WHSSI, ICV, CA and AF, respectively (Table 5, P<0.05). Although, the adoption rate of SWC is higher by 4.9% than ISFM, the difference is not statistically significant. The highest adoption rate of SWC could be because, it is one of the oldest approaches that has been supported by the government campaign.

Table 5. Mean adoption status of individual CSAPs, and one-way ANOVA test and post hoc analysis.

(I) Adopted practices[1]	(J) adopted practices	Mean Difference (I-J)	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Integrated soil fertility management (56.54)	Conservation agriculture	10.23	6.902	-3.41	23.86
	Soil and water conservation	-4.93	5.201	-15.21	5.34
	Water harvesting and small-scale irrigation	17.99**	6.460	5.23	30.75
	Improved crop variety	15.54*	6.775	2.16	28.92
	Agroforestry	7.74	6.084	-4.28	19.76
	Improved livestock	21.82*	9.249	3.56	40.09
Conservation agriculture (46.31)	Soil and water conservation	-15.16*	6.196	-27.40	-2.92
	Water harvesting and small-scale irrigation	7.76	7.285	-6.63	22.15
	Improved crop variety	5.31	7.566	-9.63	20.26
	Agroforestry	-2.49	6.954	-16.22	11.25
	Improved livestock	11.60	9.843	-7.84	31.04
Soil and water conservation (61.47)	Water harvesting and small-scale irrigation	22.92***	5.700	11.66	34.18
	Improved crop variety	20.47***	6.054	8.51	32.43
	Agroforestry	12.67*	5.270	2.26	23.08
	Improved livestock	26.76**	8.735	9.50	44.01
Water harvesting and small-scale irrigation (38.55)	Improved crop variety	-2.45	7.165	-16.60	11.70
	Agroforestry	-10.25	6.516	-23.12	2.62
	Improved livestock	3.84	9.539	-15.01	22.68
Improved crop variety (41.00)	Agroforestry	-7.80	6.828	-21.29	5.69
Agroforestry (48.80)	Improved livestock	14.07	9.288	-4.26	32.43
Improved livestock management (34.71)	Improved crop variety	-6.29	9.755	-12.98	25.55

*, **, ***. The mean difference is significant at the 0.05, 0.001 and 0.001 level, respectively.
[1]Figures in parentheses are mean adoption rates

Although the adoption status of this practice is rated as high, many studies claimed that SWC did not adequately address the decline of soil fertility and agricultural productivity (Fikirie et al., 2018; Mulualem & Yebo, 2015) and the achievements were far below expectation, because many of the SWC components have not been well integrated with other soil fertility management practices (Lemma et al., 2015).

ISFM is the second most adopted practice with a mean adoption rate of 56.5%. This adoption status could be attributed to the prevailing conditions of population growth, over cultivation, and small plot size which forced farmers to use one or a combination of two or more inputs of this practice. The practice is also being supported by a good extension campaign.

The adoption rate of this practice (56.5%) is significantly higher by 21.8, 18.0, and 15.5% than that of ILM, WHSSI, and ICV, respectively (Table 5, $P<0.05$). Although, the adoption rate of ISFM is higher by 10.2, and 7.7% than that of CA and AF, respectively, the differences are not statistically significant at $p<0.05$. According to Kifle et al. (2020) the adoption status of ISFM is rated as medium.

The development of ISFM is a result of a series of transitions in soil fertility management paradigms from 1960s to 1990s (Guteta & Abegaz, 2016a,b). This practice has been introduced in different parts of the country to boost soil health, increase crop productivity, and mitigate the impacts of climate change (Abeje et al., 2019; Marie et al., 2020). Along these lines, many studies recommended it as the best-bet and most feasible option which could provide a more holistic, lower cost, and sustainable solution considering the complex socioeconomic and biophysical characteristics of the country (Agegnehu & Tilahun, 2017; Guteta & Abegaz, 2016a,b; Mulualem & Yebo, 2015; Vanlauwe et al., 2010). However, many studies have claimed that adoption of this practice in various parts of Ethiopia was limited because of lack of proper implementation and wider dissemination (Hörner & Wollni, 2021).

Agroforestry is the third most adopted practice with a mean adoption rate of 48.8%. This adoption rate is significantly lower by 12.7% than that of SWC (Table 5, $P<0.05$). Although, the adoption rate of AF is higher by 14.1, 10.3, and 7.8% than that of ILM, WHSSI, and ICV, respectively, and lower by 7.7% than that of ISFM, the differences are not statistically significant at $p<0.05$. According to Kifle et al. (2020) the adoption status of AF is rated as low. However, many studies have reported that it is a best-bet practice, for the reason that it provides additional food, fuel woods, and various ecosystem services in an integrated manner (Amare et al., 2019; Gebru et al., 2019; Kassie, 2018).

Farmers' adoption rate of CA is at the fourth position after SWC, ISFM, and AF, with a mean adoption percentage of 46.3. With this rate, the adoption status of CA is rated as low (Kifle et al., 2020). The adoption rate of CA is significantly lower by 15.2% than that of SWC (Table 4, P<0.05). On the other hand, although, the adoption rate of CA is higher by 11.6, 7.8, and 5.3% than that of ILM, WHSSI, and ICV, respectively, and lower by 2.3% than that of AF, the differences are not statistically significant at p<0.05. The promotion of CA began in 1998, and in 2010, it was implemented on smallholder farms in 12 districts of the Amhara, Oromia and Tigray regions (FAO, 2016), and subsequently, its implementation continued in different parts of the country.

The adoption rate of ICV ranked fifth after SWC, ISFM, AF, and CA, with a 41.0% mean adoption rate. With this rate, the adoption status of IVC is rated as low (Kifle et al., 2020). The adoption rate of ICV is significantly lower than that of SWC and ISFM by 20.5, and 15.54% respectively (Table 5, P<0.05). On the other hand, although, the adoption rate of ICV is higher by 2.5% than that of WHSSI, and lower by 7.8, 6.3, and 5.3% than that of AF, ILV, and CA, the differences are not statistically significant at p<0.05.

Water harvesting and small-scale irrigation adoption ranks sixth, with a 38.6% mean adoption rate, and its adoption status is rated as very low (Kifle et al., 2020). The adoption rate of WHSSI is significantly lower than that of SWC, and ISFM by 22.9, and 18.0% respectively (Table 5, P<0.01). On the other hand, although, the adoption rate of WHSSI is higher by 3.8% than that of ILM, and lower by 10.3, 7.8, and 2.5% than that of AF, CA, and ICV, the differences are not statistically significant at p<0.05.

Traditional and small-scale irrigation use in Ethiopia dates back several decades, and continues to be an integral part of Ethiopian agriculture (Awulachew & Merrey, 2007; Bacha et al., 2011; Hagos et al., 2009; Makombe et al., 2007; Mengistie & Kidane, 2016), while modern irrigation was started in the early 1950s when the Dutch company introduced the technologies and practices in the Upper Awash Valley in sugar-cane plantations (Bekele et al., 2012; Mengistie & Kidane, 2016; MoA, 2011).

According to the findings of this review, WHSSI is an important practice for reducing risks associated with rainfall variability, increasing cropping diversification and intensity, increasing employment opportunities, improving household consumption, increasing income of rural households, and reducing poverty at household level (Yihdego et al., 2015). Most recently, WHSSI has become one of the policy priorities of the Ethiopian Government for poverty reduction, resilience against climate change and economic growth. However, development of WHSSI in Ethiopia is limited, while the country is endowed with an estimated 122 billion cubic meters of surface water and 3.7 million ha of potential irrigable land (MOA, 2011). The same reference reported that only 10- 12% of the total potential irrigable land is used under traditional and modern irrigation schemes. Subsequently, the role of irrigation to the development of the national economy is limited when considering its potential (MOA, 2011).

In terms of animal headcounts, the livestock sector of Ethiopia is the largest in Africa. It contributes 20% to the national GDP (MacDonald & Simon, 2011). However, the impact of climate change on Ethiopian livestock production potential is huge (EPCC, 2015; Gashaw et al., 2014). In order to curb such negative impacts, adopting farm animal genetic resources, improving feed and feeding systems, herd diversification and production system adjustment or intensification have been recommended (Climate Resilience Green Economy [CRGE], 2011). Accordingly, the Ethiopian Drought Resilient and Sustainable Livelihoods Program (DRSLP) was launched in 2013, aiming at adoption of water resource development and rangelands management, along with various capacity building activities of livestock production (FAO, 2016).

However, this review revealed that ILM is the least-adopted practice, with a 34.7% mean adoption rate, and so is rated as very low. It is also the least-studied practice, with a 4.8% of the total frequency of the studied practices. The adoption rate of ILM is significantly lower than that of SWC, and ISFM by 26.8, and 21.8%, respectively (Table 5, $P<0.05$). Although, the adoption rate of ILM is lower than that of CA, AF, WHSSI, and ICV, the differences are not statistically significant at $p<0.05$.

3.3.2. Status of adoption of CSAPs by regional states

The mean adoption rate by regional states ranges from 48.3% in Oromiya region to 56.0% in SNNP region (Table 6), however, this variation was not statistically significant at p=0.05 (adoption rate of Afar region (81.0%) is excluded from the ANOVA analysis, since the rate is generated from only one study). The SNNP, the Amhara, and the Tigray regions' farmers' adoption status, are rated as medium, with the mean adoption rates between 53 and 57%. The Benshangul_Gumz and the Oromiay regions' farmers' adoption status are rated as low, with the mean adoption rates between 48 and 49%.

In Oromiya region, the most adopted practice is CA (59.4%), which could be attributed to the availability of a relative excess of local organic material for mulching, and a relatively good biophysical environment for crop rotation. The least-adopted practice is ILM (30.8%). However, the variation in adoption rates between practices is not statistically significant at $p<0.05$. With regard to the adoption status of each practice, SWC, CA and AF are at medium status; ISFM and ICV are at low status, and WHSSI and ILM are ranked as very low status.

In Amhara region, the most adopted practice is SWC (66.6%), which could be because of higher land degradation problem. WHSSI (30.3%) is the least adopted practice. In this region, the adoption rate of SWC is significantly higher by 36.3, 35.9 and 21.8% than the adoption rates of WHSSI, CA and ICV, respectively ($P<0.05$). The second most adopted practice is ISFM (60.2%). This rate is also significantly higher by 29.8, and 29.5% than the adoption rates of WHSSI, and CA, respectively ($P<0.05$). With regard to the adoption status of each practice, SWC and ISFM are at high status; ILM is at medium status; AF, and ICV are at low status; while WHSSI and CA are at very low status.

In SNNP region, the most adopted practice is ISFM (68.4%), followed by SWC and CA, with adoption rate of 62.0 and 60.5%, respectively. These adoption rates are significantly higher than the adoption rates of WHSSI, IVC and AF ($P<0.05$). The least adopted practice is ILM. The adoption status of ISFM, SWC, and AF is high. The adoption status of AF is low, while for the rest of practices it is very low.

Table 6. Mean adoption rate of individual CSAPs by regional states of Ethiopia

Regional states	Adopted practices and rates of adoption															
	ISFM		CA		SWC		WHSSI		ICV		AF		ILM		Total	
	No.	Mean %	No.	Mean %	No.	Mean %	No.	Mean %	No.	Mean %	No.	Mean %	No.	Mean %	No	Mean %
Oromiya	7	44.6	5	59.4	15	54.5	4	39.3	5	42.6	6	50.3	4	30.8	46	48.3
Amhara	10	60.2	3	30.7	14	66.6	6	30.3	6	44.8	7	45.6	2	50.0	48	53.1
SNNP	5	68.4	4	60.5	15	62.0	2	38.0	2	39.0	7	46.7	1	20.0	36	56.0
Tigray	0		1	45.0	5	66.8	2	48.5	1	15.0	3	56.7	0		12	55.1
Benshangul-Gumz	2	58.5	0		2	41.0	1	55.0	1	51.0	1	36.0	0		7	48.7
Afar	0		0		1	81.0	0		0		0		0		1	81.0
Total	24	57.2	13	52.0	52	61.1	15	37.8	15	41.7	24	48.1	7	34.7	150	52.4

For Tigray region, the retrieved published papers dealt about only five practices (Table 6). The most adopted practice is SWC (66.8%), with its adoption status of high, which could be because of higher land degradation problem. The adoption rate of AF (56.7%) is at the second position, with adoption status of medium, while the adoption rate of WHSSI (48.5%) and CA (45.0%) are at the third and the fourth positions, respectively, and the adoption status of both practices is low.

Also, for Benshangul-Gumz region, the retrieved published papers reported only five practices (Table 6). The most adopted practice is ISFM (58.5%), and followed by WHSSI (55.0%), and ICV (51.0%); where the adoption status of the three practices is medium.

3.4. Gender-sensitive and gender-blind adoption studies

Gender was considered in over two-third of the total studied practices (Fig. 4A). In terms of specific practices, all studies of ILM considered gender. In a more than half of the studies of SWC practice, and in over three fourth of the studies of the remaining five practices, gender was considered.

In terms of specific region, a half of the studies of Tigray region, and over 53% of the studies of other regions considered gender, while a study of the Afar region, and all sub-national studies considered gender (Fig. 4B).

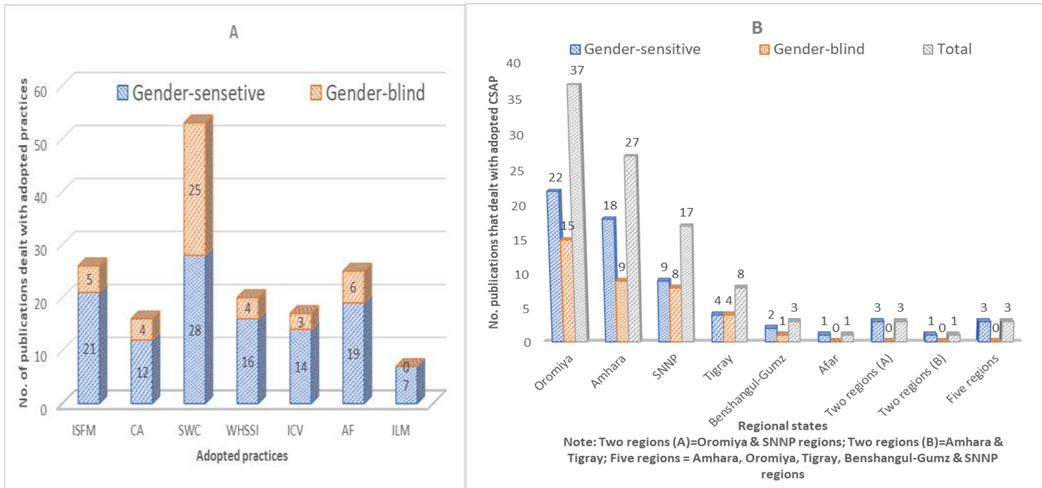

Figure 4. Gender-sensitive and gender-blind adoption studies of CSAPs by adopted practices (A), and by regional states of Ethiopia (B).

3.5. Some socioeconomic benefits of adopters of CSAPs

In only 46 of the 100 reviewed papers, the mean value of reported socioeconomic benefits of adopters of CSAPs was reported (Table 7). Reported benefits were higher yields, greater farm income, increased food security/availability, increased land productivity, and reduced household poverty.

Reported benefits of adoption of SWC practice include: i) increased grain yield between 20 and 198% per household per year (Challa, 2021; Kosmowski, 2018; Mekonen & Tesfahunegn, 2011; Tesfaye et al., 2018; Yaebiyo et al., 2015); ii) increased grain yield between 25 and 46% (Challa, 2021; Dufera et al., 2020; Sileshi et al., 2019;Yaebiyo et al., 2015); iii) increased monetary income between 6,359 and 6,376 Eth. Birr per ha per year (Addisu et al., 2015; Sileshi et al., 2019); iv) increased grain yield between 5.5 and 7.2 tons per ha per year (Adgo et al., 2013; Challa, 2021); and v) 61% increase in land productivity (Enki et al., 2001).

Reported benefits of adoption of WHSSI include: i) increased household income between 5181 and 151,419 Eth. Birr (Adela et al., 2019; Adugna et al., 2014; Ayalneh et al., 2007; Beyan et al., 2014; Mengistie & Kidane, 2016; Temesgen et al., 2018; Yihdego et al., 2015); between 2,003 and 5,500 USD per household per year (Adela et al., 2019; Teshome et al., 2010); and increased monetary income between 29 and 193% per household per year (Adela et al., 2019; Adugna et al., 2014; Ayalneh et al., 2007; Beyan et al., 2014; Temesgen et al., 2018). Also 32% increased grain yield per household per year (Mengistie & Kidane, 2016) and 28% increased land productivity (Adela et al., 2019) were reported.

In a study of CA by Tadesse et al. (2021), a 38% grain yield increase per household per year was reported, while in a study of ISFM by Teklewold et al. (2019), a 5% higher food security of adopters than non-adopters per household was reported.

Table 7. Some socioeconomic benefits of adopted CSAP to the smallholder farmers as reported by previous studies

Adopted practices*		Increased income in Eth Birr per year per household	Increase in income in USD/year/household	Increased monetary income in % per year/household	Increased grain yield (kg/ha/year)	Increased grain yield in % per household/year	Land productivity increased in %	Reduced poverty in % per household	Increased food security in % per household
SWC	N	3		4	2	5	1		
	Mean	6,370		32	6,341	65	61		
ISFM	N								1
	Mean								5
CA	N					1			
	Mean					38			
WHSSI	N	7	2	5		1		1	
	Mean	28,458	3,751	69		32		28	
ICV	N			1	1	2			1
	Mean			42	1,000	84			2
AF	N	2		3			1		
	Mean	10,262		75			84		
ILM	N					2			
	Mean					65			
Total	N	12	2	13	3	11	2	1	2
	Mean	19,903	3,752	57	4,561	63	73	28	4

* SWC=Soil and water conservation; ISFM = Integrated soil fertility management; CA =Conservation agriculture; WHSSI=Water harvesting and small-scale irrigation; ICV=Improved crop variety; AF=Agroforestry; ILM=Improved livestock management

3.6. Constraints for adoption of CSAPs

This section presents the meta-analysis of constraints to scaling CSAPs among the rural households of Ethiopia, on the assumption that generated evidence could be used by policymakers, development partners, and extension workers to address the constraints. Constraints of adoption of CSAPs were grouped in 12 categories and presented in Fig.5.

They are presented in aggregated form for all (the seven) practices (Fig. 5A), and in disaggregated form for individual practices (Figs. 5B-5G).

For all aggregated practices, knowledge/awareness and socioeconomic factors were the highest-ranked constraints, each reported in 112 studied practices (i.e., 68.3%) (Fig 5A). In comparison to other constraints such as shortage of labor, limited access to market, and limited access to credit with frequencies of 51, 40, and 36, respectively.

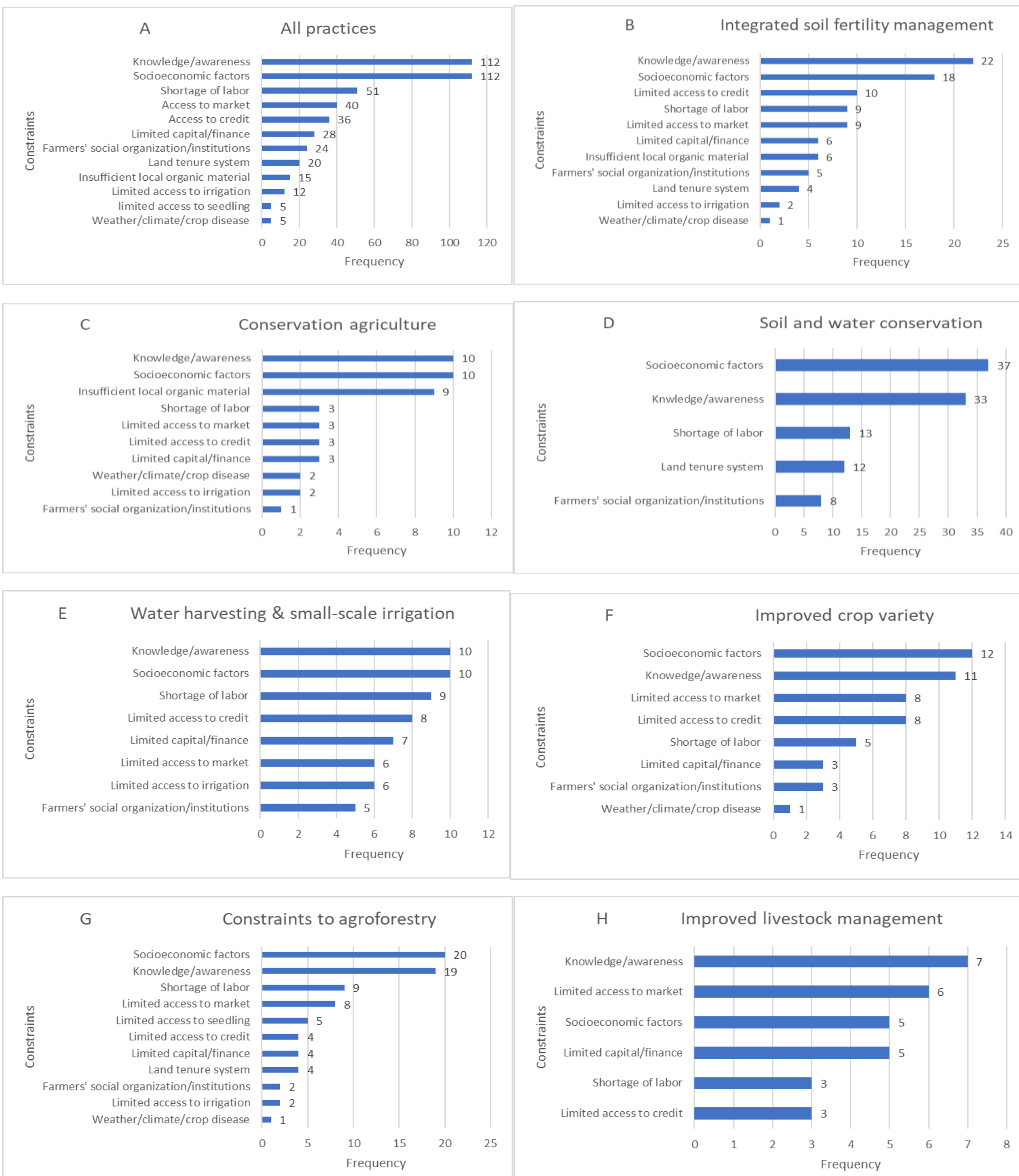

Figure 5. Frequencies of reported constraints to scaling-up of adoption in aggregated for all practices (A); and disaggregated by particular CSAPs: Integrated soil fertility management (B); conservation agriculture (C); soil and water conservation (D); water harvesting and small-scale irrigation (E); improved crop variety (F); Agroforestry (G); and improved livestock management (H).

Knowledge/awareness and socioeconomic factors are considered to be much higher constraints to CSAP adoption. In terms of knowledge/awareness, many studies have reported that farmers with a better educational level, access to agricultural extension services and technical support, and monitoring practices positively affected adoption practices (Kifle et al., 2020). In terms of socioeconomic factors, farmers with relatively higher plot sizes, higher household sizes, and greater off-farm activities were reported as factors positively affecting adoption (Kifle et al., 2020). This in turn, highlighted that the two constraints are prominent and need urgent actions in order to scale up CSAPs in Ethiopian agricultural systems. Similarly, factors such as better access to market, credit, and financial capital were reported as factors positively and significantly enhancing farmers adoption of CSAP (Kifle et al., 2020). On the other hand, categories of weather/climate and crops' disease; and limited access to seedlings were in the two last positions each with frequencies of five (Fig. 5A).

In terms of individual practices, the number of reported constraints ranged from five in SWC (Fig. 5D) to 11 in AF (Fig. 5G), with varied frequencies among categories, ranging from one (weather/climate/crop disease; Figs. 5B, F, G) to 37 (socioeconomic factors; Fig. 5D). Some constraints are common to all practices, while some are specific to some others. For example, limited knowledge/awareness appears in all practices either in the first, or the second position, while the land tenure system is reported in three practices (ISFM, SWC, and AF), insufficient local organic material in two practices (ISFM and CA), and limited access to seedling in only one practice (AF).

Constraints by regional states are presented in Fig. 6. The number of reported constraints ranged from four in Benshangul-Gumz to 12 in Oromiya; with varied frequencies among categories, ranging from one to 39. For Amhara and Tigray regions the categories of socioeconomic factors; and knowledge/awareness appear in the first and the second positions, respectively, while for Oromiya and Benshangul-Gumz regions, they appear in the reverse positions. In SNNP region, the two constraints appear in the two first positions with frequencies of 25.

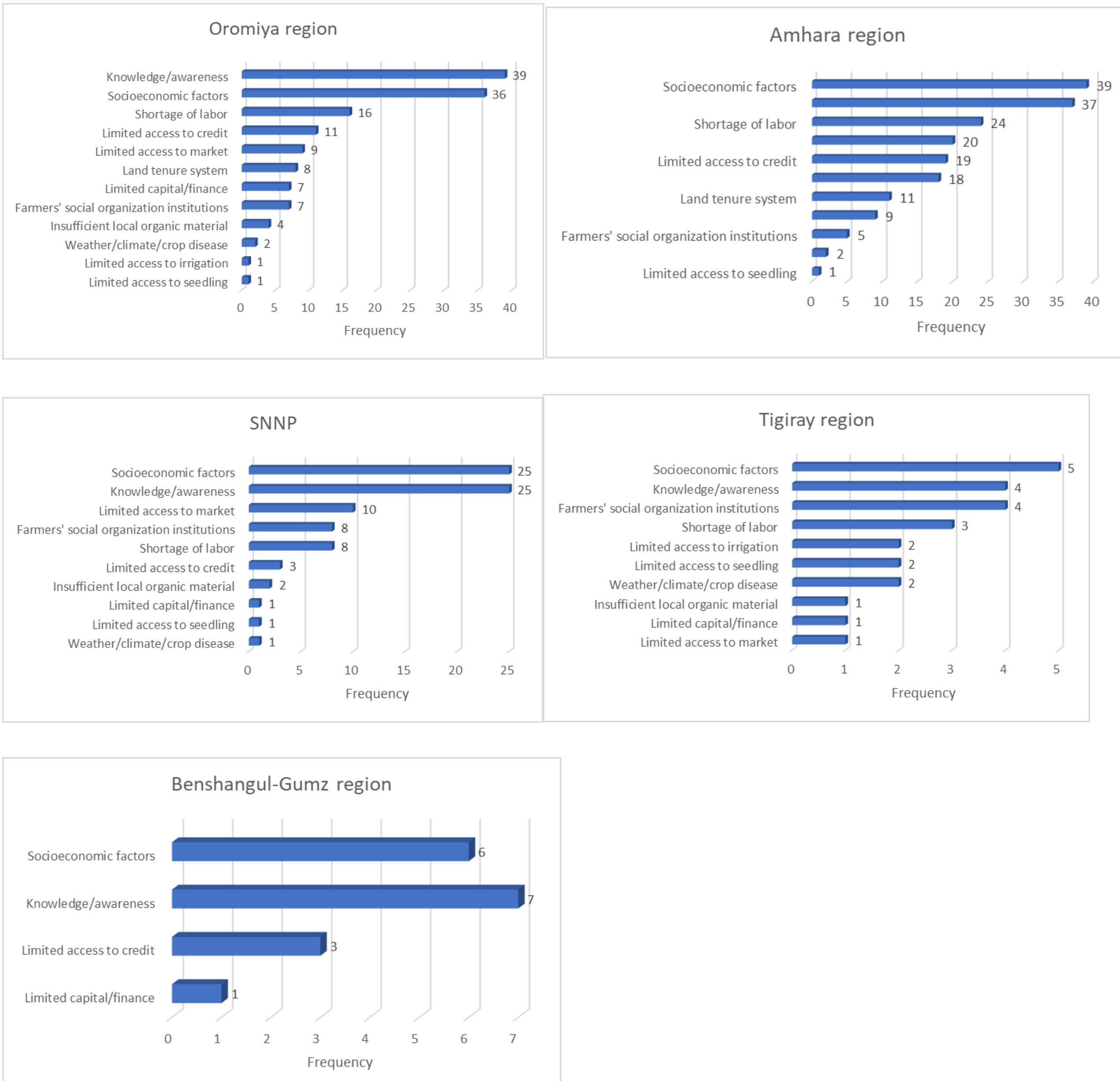

Figure 6. Frequencies of reported constraints to CSAP adoption by regional states. In a study of Afar region only two constraints (land tenure system, and land resource and socioeconomic factors) were reported, therefore, figure for this region is not produced.

4. Concluding remarks

With continued population growth, human demands will increase exponentially in the coming decades, including in Ethiopia. This increasing demand is expected to be supplied through (i) sustainably increasing land productivity, and/or (ii) increasing the area of cultivated land (MOA, 2011). In the recent sustainable development domain, the former is more attractive and viable than the latter or than a combination of the two. However, sustainably increasing land productivity depends on adoption of locally-appropriate practices, and biophysical environments including climate. Nowadays, climate change is becoming a serious threat to agricultural systems in developing countries including in Ethiopia (Agbenyo et al., 2022; Rohil et al., 2018). Accordingly, different CSAPs have been initiated and implemented, and also different studies have been conducted at regional, subnational, and local scales to examine adoption of the practices and agricultural biophysical benefits of implemented CSAPs. Therefore, this review has synthesized CSAP studies conducted between 2001 and 2021, in Ethiopia. Based on the review results the following concluding remarks are presented below.

Since 2001, research on CSAPs adoption has been increasing in Ethiopia, but with greater emphasis on SWC, ISFM and AF, and less emphasis on ILM, ICV, and WHSSI. Studies on other important practices such as biogas development and use, energy-saving cooking stoves, and weather forecasting information were missing. Therefore, future adoption research on CSAPs should consider these lesser studied practices, and other practices not considered by previous studies.

This review reveals the research gap at national scale, and also the need for more studies on subnational/regional scale. Evaluating CSAPs adoption statuses and their associated benefits and constraints at multiple scales helps to “zoom in” and “zoom out” the issues so as to understand how they manifest at local scale and then how the local issues are related to regional and national issues, and vice versa.

The review clearly highlighted the research gap particularly in the drought prone regions of Harari, Somalia and Afar regions. Considering these regions in the future research will help scaling-up CSAPs adoption, realizing their outcomes in the regions, and then enhancing the national plan of agricultural transformation.

In terms of methods of study, none of the reviewed articles have used dynamic simulation models, which could have been used to describe spatial and temporal changes in CSAPs adoption in response to farmers' socioeconomic factors, policy requirements and/or environmental drivers such as weather and climate change (Jones et al., 2017; Thornton et al., 2018).

The adoption rate of individual CSAPs varies widely among smallholder farmers ranging from 9% in both CA and WHSSI to 100% in SWC, while the adoption status of practices is rated as i) very low for WHSSI and ILM, ii) low for AF, CA, and ICV, iii) medium for ISFM, and iv) high for SWC. This indicates that adoption statuses of WHSSI, ILM, AF, CA, and ICV are in their infancy in Ethiopia. It implies that these practices are not contributing their share to the growth of agriculture sector of Ethiopia, therefore, the federal, regional governments, development agents, and agricultural extension agents should proactively work to help farmers to adopt these practices.

Only 63 of the 100 reviewed papers considered gender. This attests that future agricultural adoption studies should be gender sensitive, because it is critical to realize long lasting, sustainable, and equitable adoption outcomes for both men and women.

One of the potential impacts of CSAPs is their additional socioeconomic benefits to that already obtained from the farm, which is also considered as a stepping stone to scaling-up of adoption. However, this review indicates that 54% of the previous adoption studies didn't consider analysis of any of the anticipated socioeconomic benefits of adoption of CSAPs. This research gap noted that future adoption studies should consider at least one socioeconomic benefit of adopted practices.

Among the twelve categories of constraints of adoption of CSAPs in Ethiopia, the top five were knowledge/awareness, socioeconomic factors, shortage of labor, limited access to market, and limited access to credit. Since adoption is a continuous process, overcoming these and other constraints might guarantee adoption action. Therefore, in order to overcome the identified adoption constraints, the following policy-related actions (but not exhaustive) could be undertaken. These actions are consistent with that of the Ethiopian Green Economy Strategy actions set out for its first pillar, i.e., "improving crop and livestock production practices for higher food security and farmer income while reducing emissions" (CRGE, 2011).

Limited knowledge/awareness. In this regard, the primary action of regional government could be enhancing extension services and farmers trainings. Farmers' trainings and iterative contacts between farmers and agricultural extension service agents might help to disseminate information among users in order to promote locally-relevant and practicable CSAPs adoption.

Socioeconomic factors. Interventions like income supplements (safety net), income diversification, and social protection for high priority groups (for example, for those with shortage of land, older age groups, or small families) could help to boost CSAP adoption.

Shortage of labor. Introduce less labor-intensive farm management practices and technologies.

Limited access to market. Federal and regional governments should build roads so that farmers could increase access to urban markets through better transport, and earn greater income from their produce, which in turn would increase the potential of farmers to adopt CSAPs.

Limited access to credit and limited capital/finance. Limited access to credit and finance is a major constraint for adopting some of practices, such as WHSSI and ILM, because these practices require relatively high upfront costs. Therefore, federal and regional governments should create a system for farmers access to credit and microfinance.

Limited access to farmers' social organization/institutions. Regional governments should identify required institutions which could help farmers to adopt CSAPs, and then establish these where they were not available; or if they are already in place, strengthen them to help adoption of locally-relevant practices.

Land tenure system. This constraint is reported in ISFM, SWC and AF, because these practices are with long-term returns, while farmers are more interested to adopt practices which offer short-term returns, particularly when they feel that their land use is not secure. Therefore, land certification could help to guarantee farmers to adopt these practices.

Limited access to irrigation. Create access to rural households to locally relevant irrigation techniques accompanied by farmers' capacity building and training, so that they can more easily adopt and more effectively apply the CSAPs.

Limitation of the review

Like most literature studies, this review may have the following limitations. Firstly, although we believed that a comprehensive collection of papers on Ethiopian CSAP adoption has been reviewed, the papers used in this sample is unlikely to be exhaustive. Secondly, since the review was based on online searches, studies that are not available online would have been missed. Regardless of these limitations, we believe that the review covers scientific papers of the adoption of CSAPs in Ethiopia.

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Declarations

Conflict of interest. The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

References

Abebe, T. (2013). Determinants of crop diversity and composition in Enset-coffee agroforestry homegardens of Southern Ethiopia.

Abeje, T., M., Tsunekawa, A., Adgo, E., Haregeweyn, N., Nigussie, Z., Ayalew, Z., ... & Berihun, D. (2019). Exploring drivers of livelihood diversification and its effect on adoption of sustainable land management practices in the Upper Blue Nile Basin, Ethiopia. Sustainability, 11(10), 2991.

Abera, W., Tamene, L., Tibebe, D., Adimassu, Z., Kassa, H., Hailu, H., et al. (2020). Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia. Land Degradation and Development, 31(1), 37–52.

Abiy, G., Getahun, Y., & Genene, M. (2015). Assessment of farmers' perception and adaptation mechanism to soil erosion problem in Shomba Kichib, Gimbo District, Kaffa Zone, South West Ethiopia. African Journal of Agricultural Research, 10(27), 2608-2616.

ACSAS (African Climate Smart Agriculture Summit) (2014). Twenty-third ordinary session. Equatorial Guinea, Malabo. 26–27 June 2014. http://africacsa.org/introducing-the-africa-csa-alliance-ascaa/.

Addisu, D. A., Husen, M. A., & Demeku, M. A. (2015). Determinants of adopting techniques of soil and water conservation in Goromti Watershed, Western Ethiopia. Journal of Soil Science and Environmental Management, 6(6), 168-177.

Adela, F. A., Aurbacher, J., & Abebe, G. K. (2019). Small-scale irrigation scheme governance-poverty nexus: evidence from Ethiopia. Food Security, 11(4), 897-913.

Adgo, E., Teshome, A., & Mati, B. (2013). Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia. Agricultural Water Management, 117, 55-61.

Adimassu, Z., Langan, S., Barron, J. (2018). Highlights of Soil and Water Conservation Investments in Four Regions of Ethiopia, vol. 182. International Water Management Institute (IWMI). http://www.iwmi. cgiar.org/Publications/Working_Papers/working/wor182.pdf.

Adugna, E., Ermias, A., Mekonnen, A., & Mihret, D. (2014). The role of small scale irrigation in poverty reduction. Journal of Development and Agricultural economics, 6(1), 12-21.

Agbenyo, W., Yuansheng Jiang, Xinxin Jia, Jingyi Wang, Gideon Ntim-Amo, Rahman Dunya, Anthony Siaw, Isaac Asare and Martinson Ankrah Twumasi (2022). Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. Int. J. Environ. Res. Public Health 19, 3804.

Agegnehu, G.; Tilahun Amede, T. 2017. Integrated Soil Fertility and Plant Nutrient Management in Tropical Agro-Ecosystems: A Review. Pedosphere, 27, 662–680.

Agidew, A. M. A., & Singh, K. N. (2019). Factors affecting the adoption of sustainable land management practices at farm level in the North Eastern Highlands of Ethiopia: The Teleyayen sub-watershed case study. J Environ Pollut Manage, 2, 103.

Ahmed, M. H. (2014). Farmer's Decision To Practice Crop Rotation in Arsi Negelle, Ethiopia: What are the Determinants?. International Journal of Sustainable Agricultural Research, 1(1), 19-27.

Ahmed, M. H. (2015). Adoption of multiple agricultural technologies in maize production of the Central Rift Valley of Ethiopia. Studies in Agricultural Economics, 117(1316-2016-102848), 162-168.

Ahmed, M. H., Geleta, K. M., Tazeze, A., Mesfin, H. M., & Tilahun, E. A. (2017). Cropping systems diversification, improved seed, manure and inorganic fertilizer adoption by maize producers of eastern Ethiopia. Journal of Economic Structures, 6(1), 1-16.

Alemu, M. D., Kebede, A., & Moges, A. (2019). Farmers' perception of soil erosion and adoption of soil conservation technologies at Geshy sub-catchment, Gojeb River catchment, Ethiopia. Agricultural Sciences, 10(01), 46.

Alemu, W. G., & Melesse, A. M. (2020). Impacts of longterm conservation measures on ecosystem services in Northwest Ethiopia. International Soil and Water Conservation Research, 8(1), 47-55.
Amare, D., Wondie, M., Mekuria, W., & Darr, D. (2019). Agroforestry of smallholder farmers in Ethiopia: practices and benefits. Small-scale Forestry, 18(1), 39-56.
Amsalu, A., & de Graaff, J. (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecological economics, 61(2-3), 294-302.
Arage, A. (2021). Assessment of Farmer's Perception and Adoption of Agroforestry Practices: The Case of Assosa District, Western Ethiopia. American Journal of Applied Scientific Research, 7(2), 15-21.
Arslan, A., Floress, K., Lamanna, C., Lipper, L., & Rosenstock, T. S. (2022). A meta-analysis of the adoption of agricultural technology in Sub-Saharan Africa. PLOS Sustainability and Transformation, 1(7), e0000018.
Ashuro, B., & Takele, S. (2019). Assessment of Farmers' Perception towards the Adoption of Soil and Water Conservation Practices and Soil Quality in Kechabira Woreda; Southern Ethiopia. Assessment, 6(11).
Asnake, B., & Elias, E. (2017). Challenges and extents of Soil and Water Conservation measures in Guba-Lafto Woreda of North Wollo, Ethiopia. Journal of Agricultural Research and Development, 7(2), 103-110.
Asrat and Anteneh, 2019. The determinants of irrigation participation and its impact on the pastoralist and agropastoralists income in Ethiopia: A review study. Cogent Food & Agriculture 5 (1679700).
Asrat, M., & Babiso, B. (2020). Smallholder Farmers Adaptation to Climate Change and Determinants of their Adaptation Choices in Hobicha, Southern Ethiopia. Agricultural Research & Technology: Open Access Journal, 25(1), 28-36.
Asrat, P., & Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. Ecological processes, 7(1), 1-13.
Aweke, C. S., Hassen, J. Y., Wordofa, M. G., Moges, D. K., Endris, G. S., & Rorisa, D. T. (2021). Impact assessment of agricultural technologies on household food consumption and dietary diversity in eastern Ethiopia. Journal of Agriculture and Food Research, 4, 100141.
Awulachew, S. B., & Merrey, D. J. (2007). Assessment of small scale irrigation and water harvesting in Ethiopian agricultural development. International Water Management Institute (IWMI).
Ayalneh, W., Woldu, Z., Gebremedhin, B., Tadesse, G., & Peden, D. (2007). The benefits and environmental effect of community based small scale irrigation development in the Awash river basin, Ethiopia: a case study of four community based irrigation schemes. SINET: Ethiopian Journal of Science, 30(2), 135-142.
Ayichew, L. (2019). Determinants of apple based agroforestry technology adoption in Lay Gayint district northwestern Ethiopia. International journal of research in agriculture and forestry, 6(1), 38-48.
Bacha, D., Namara, R., Bogale, A., & Tesfaye, A. (2011). Impact of small-scale irrigation on household poverty: empirical evidence from the Ambo district in Ethiopia. Irrigation and Drainage, 60(1), 1-10.
Barasa, P. M., Botai, C. M., Botai, J. O., & Mabhaudhi, T. (2021). A review of climate-smart agriculture research and applications in Africa. Agronomy, 11(6), 1255.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., & Van Damme, P. (2019). Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. NJAS-Wageningen Journal of Life Sciences, 88, 96-104.

Bekele, Y., Tadesse, N., & Konka, B. (2012). Preliminary study on the impact of water quality and irrigation practices on soil salinity and crop production, Gergera Watershed, Atsbi-Wonberta, Tigray, Northern Ethiopia. Momona Ethiopian Journal of Science, 4(1), 29-46.

Belay, M., & Bewket, W. (2013). Farmers' livelihood assets and adoption of sustainable land management practices in north-western highlands of Ethiopia. International journal of environmental studies, 70(2), 284-301.

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(2), 404-416.

Beyan, A., Jema, H., & Adem, K. (2014). Effect of small-scale irrigation on the farm households' income of rural farmers: The case of Girawa district, east Hararghe, Oromia, Ethiopia. Asian Journal of Agriculture and Rural Development, 4(393-2016-23780), 257-266.

Biratu, A. A., & Asmamaw, D. K. (2016). Farmers' perception of soil erosion and participation in soil and water conservation activities in the Gusha Temela watershed, Arsi, Ethiopia. International Journal of River Basin Management, 14(3), 329-336.

Birhanu, A., & Meseret, D. (2013). Structural soil and water conservation practices in Farta District, North Western Ethiopia: an investigation on factors influencing continued Use. Science, Technology and Arts Research Journal, 2(4), 114-121.

Branca G, McCarthy N, Lipper L, Jolejole MC (2013) Food security, climate change and sustainable land management: a review. Agronomy for Sustainable Development 33(4): pp. 635-650. FAO of the United Nations.

Cafer, A. M., & Rikoon, J. S. (2018). Adoption of new technologies by smallholder farmers: the contributions of extension, research institutes, cooperatives, and access to cash for improving tef production in Ethiopia. Agriculture and human values, 35(3), 685-699.

Challa, T.G., (2021). Adoption and impacts of natural resource conservation in Arsi zone, Ethiopia. International Journal of Research - GRANTHAALAYAH, 9(9), 234-270. doi: 10.29121/granthaalayah.v9.i7.2021.4060.

Chen, D., Wei, W., Daryanto, S., & Tarolli, P. (2020). Does terracing enhance soil organic carbon sequestration? A nationalscale data analysis in China. Science of the Total Environment, 721, 137751.

CRGE (Ethiopia's Climate Resilience Green Economy) 2011. Green Economy Strategy, Federal Republic of Ethiopia

Danese, P., Manfe, V., & Romano, P. (2018). A systematic literature review on recent lean research: Stateof-the-art and future directions. International Journal of Management Reviews, 20(2), 579–605.

Debie, E. (2021). Smallholder farmers' decisions to the combined use of soil conservation practices in Tiwa watershed, Northwest highlands of Ethiopia. Heliyon, 7(1), e05958.

Dessie, Z., Nigatu, L. and Woldeamanue, T. (2020). The contribution of agroforestry practices in reducing deforestation and improving livelihoods of households in Kombolcha district, east Hararghe Zone, Ethiopia. Journal of Forestry and Environment 2(2): 06-24, 2020. DOI: 10.5829/idosi.jfe.2020.06.24

Dilebo, T. T. (2017). Determinants of adoption of soil and water conservation practices at household level in Aletawendo District, Sidama Zone, SNNPR, Ethiopia. World Journal of Innovative Research, 3(4), 262510.

Dinku, T., Thomson, M. C., Cousin, R., del Corral, J., Ceccato, P., Hansen, J., & Connor, S. J. (2018). Enhancing national climate services (ENACTS) for development in Africa. Climate and Development, 10(7), 664–672

Dufera, B., Dube, D. K., & Aschalew, A. (2020). Socio-Economic Impacts, and Factors Affecting Adoption of Watershed Management Practices Between the Treated and Untreated Micro-Watersheds in the Chirachasub-Watershed of Ethiopia. PalArch's Journal of Archaeology of Egypt/Egyptology, 17(9), 4528-4548.

Duguma, L. A. (2013). Financial analysis of agroforestry land uses and its implications for smallholder farmers livelihood improvement in Ethiopia. Agroforestry systems, 87(1), 217-231.

Engdawork, A., & Bork, H. R. (2014). Long-term indigenous soil conservation technology in the Chencha Area, Southern Ethiopia: origin, characteristics, and sustainability. Ambio, 43(7), 932-942.

Enki, M., Belay, K., & Dadi, L. (2001). Determinants of adoption of physical soil conservation measures in central highlands of Ethiopia the case of three districts of North Shewa. Agrekon, 40(3), 293-315.

EPCC (Ethiopian Panel on Climate Change), (2015). First Assessment Report, Working Group II Agriculture and Food Security, Published by the Ethiopian Academy of Sciences.

FAO, 2010. “Climate-Smart” Agriculture Policies, Practices and Financing for Food Security, Adaptation and Mitigation

FAO, 2016. Ethiopia Climate-Smart Agriculture Scoping Study. by Jirata, M., Grey, S. and Kilawe, E., Addis Ababa, Ethiopia

Fikirie, K. (2021). Determinants of Adoption of Soil and Water Conservation Technologies in Coffee-Growing Areas of Ethiopia. Int. J. Sci. Food Agric, 5, 189-198.

Gadisa, S., & Hailu, L. (2020). Effect of level soil bund and fayna juu on soil physico-chemical properties, and farmers adoption towards the practice at Dale Wabera District, Western Ethiopia. American Journal of Environmental Protection, 9(5), 107-20.

Gashaw, T., Asresie, A., and Haylom, M. (2014). Climate change and livestock production in Ethiopia. Advances in Life Science and Technology, 22, 39-42.

Gebeyanesh, W. Z., Bahilu, B., & Birhanu, D. (2017). Assessment of farmers’ perception towards soil and water conservation in Obi Koji Peasant Association, Woliso District, South West Shewa Ethiopia. Journal of Ecology and the Natural Environment, 9(3), 45-52.

Gebremeskel, G., Gebremicael, T. G., Hagos, H., Gebremedhin, T., & Kifle, M. (2018). Farmers’ perception towards the challenges and determinant factors in the adoption of drip irrigation in the semi-arid areas of Tigray, Ethiopia. Sustainable Water Resources Management, 4(3), 527-537.

Gebru, B. M., Wang, S. W., Kim, S. J., & Lee, W. K. (2019). Socio-ecological niche and factors affecting agroforestry practice adoption in different agroecologies of southern Tigray, Ethiopia. Sustainability, 11(13), 3729.

Gebru, M., Holden, S. T., & Alfnes, F. (2021). Adoption analysis of agricultural technologies in the semiarid northern Ethiopia: a panel data analysis. Agricultural and Food Economics, 9(1), 1-16.

Gedefaw, M., Denghua, Y., Hao, W., Alemu, B., Chanie, M., & Agitew, G. (2018). Evaluation of adoption behavior of soil and water conservation practices in the Simein Mountain National Park, Highlands of Ethiopia. Cogent food & agriculture, 4(1), 1513782.

Goshu, D., Kassa, B., & Ketema, M. (2012). Does crop diversification enhance household food security? Evidence from rural Ethiopia.

Goshu, D., Kassa, B., Ketema, M. (2012). Does crop diversification enhance household food security? evidence from rural ethiopia. Adv. Agric, 2, 13.
Guteta, D., & Abegaz, A. (2016a). Determinants of Integrated Soil Fertility Management adoption under annual cropping system in Arsamma watershed, southwestern Ethiopian Highlands. African Geographical Review, 35(2), 95-116.
Guteta, D., & Abegaz, A. (2016b). Factors influencing scaling up of agroforestry-based spatial land-use integration for soil fertility management in Arsamma Watershed, Southwestern Ethiopian Highlands. Journal of Environmental Planning and Management, 59(10), 1795-1812.
Hagos, F., Makombe, G., Namara, R. E., & Awulachew, S. B. (2009). Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation (Vol. 128). IWMI.
Haile, G. G., & Kasa, A. K. (2015). Irrigation in Ethiopia: A review. Academia journal of agricultural research, 3(10), 264-269.
Hishe, S., Lyimo, J., & Bewket, W. (2017). Soil and water conservation effects on soil properties in the Middle Silluh Valley, northern Ethiopia. International Soil and Water Conservation Research, 5(3), 231–240.
Horamo, Y., Chitakira, M., Yessoufou, K., & Woldemichael, G. (2020). Adoption of Introduced Homestead Agro-Forestry Technologies in Lemo Woreda, Hadiya Zone, Southern Ethiopia.
Hörner, D., & Wollni, M. (2021). Integrated soil fertility management and household welfare in Ethiopia. Food Policy, 100, 102022.
IFPRI and CSA (International Food Policy Research Institute and Central Statistical Agency). (2006). National Atlas of Ethiopia. Addis Ababa: CSA.
Iticha, M. D. (2019). Review on the Impact of Small Scale Irrigation Scheme on Household Income and Poverty Reduction in Ethiopia. Journal of Economics and Sustainable Development, 10, 5 (54-61).
Jaleta, M., Kassie, M., Marenya, P., Yirga, C., & Erenstein, O. (2018). Impact of improved maize adoption on household food security of maize producing smallholder farmers in Ethiopia. Food Security, 10(1), 81-93.
Jones, J. W., Antle, J. M., Basso, B., Boote, K. J., Conant, R. T., Foster, I., ... & Wheeler, T. R. (2017). Brief history of agricultural systems modeling. Agricultural systems, 155, 240-254.
Kassa, G. (2021). Determinants of Farmer's Participation in Soil and Water Conservation Practices in North-Central Highlands of Ethiopia. Fields of Interests, 1.
Kassa, Y., Giziew, A., & Ayalew, D. (2021). Determinants of adoption and intensity of improved faba bean cultivars in the central highlands of Ethiopia: a double-hurdle approach. CABI Agriculture and Bioscience, 2(1), 1-12.
Kassie, G. W. (2016). Agroforestry and land productivity: Evidence from rural Ethiopia. Cogent Food & Agriculture, 2(1), 1259140.
Kassie, G. W. (2018). Agroforestry and farm income diversification: synergy or trade-off? The case of Ethiopia. Environmental Systems Research, 6(1), 1-14.
Keno, M. T., Wamatu, J., Alkhtib, A., Tolemariam, T., Demeke, S., & Janssens, G. P. J. (2021). Barley Straw Use for Animal Feed and Soil Mulch in Ethiopian Highlands Mixed Crop-Livestock Systems. Sustainability, 13(11), 5879.
Kifle, T., Yayeh, D., & Mulugeta, M. (2020). Determinants of the Adoption of Climate-Smart Agricultural Practices in Siyadebrina Wayu District, North Shewa, Ethiopia.
Kosmowski, F. (2018). Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia. Agricultural water management, 204, 11-16.

Lal, R. (2011). Soil carbon sequestration. FAO, SOLAW background thematic report-TR04B.

Lal, R. (2014). Soil conservation and ecosystem services. International Soil and Water Conservation Research, 2(3), 36–47.

Lanckriet, S., Araya, T., Derudder, B., Cornelis, W., Bauer, H., Govaerts, B., ... & Nyssen, J. (2014). Toward practical implementation of conservation agriculture: a case study in the May Zeg-Zeg Catchment (Ethiopia). Agroecology and Sustainable Food Systems, 38(8), 913-935.

Legesse, B., Ayele, Y., & Bewket, W. (2013). Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, West Hararghe, Ethiopia. Asian Journal of Empirical Research, 3(3), 251-265.

Lemma, T., Menfes, T., & Fantaw, Y. (2015). Effects of integrating different soil and water conservation measures into hillside area closure on selected soil properties in Hawassa Zuria District, Ethiopia. Journal of Soil Science and Environmental Management, 6(10), 268-274.

LSIJ (List of Scopus Indexed Journals) (2022). List of Scopus Indexed Journals. https://www.ardaconference.com/blog/list-of-scopus-indexed-journals/ (consulted on February 2022).

MacDonald, M., & Simon, J. (2011). Climate, food security and growth. Ethiopia's complex relationship with livestock. Policy Brief, 3, 123-124.

Makombe, G., Kelemework, D., & Aredo, D. (2007). A comparative analysis of rainfed and irrigated agricultural production in Ethiopia. Irrigation and Drainage Systems, 21(1), 35-44.

Marie, M., Yirga, F., Haile, M., & Tquabo, F. (2020). Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. Heliyon, 6(4), e03867.

Mekonen, K., & Tesfahunegn, G. B. (2011). Impact assessment of soil and water conservation measures at Medego watershed in Tigray, northern Ethiopia. Maejo International Journal of Science and Technology, 5(3), 312.

Mekuriaw, A., Heinimann, A., Zeleke, G., & Hurni, H. (2018). Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. International soil and water conservation research, 6(1), 23-30.

Melesse, K., & Jemal, J. (2013). Dairy Technology Impacts on Livelihoods Of Dairy Producers In Central Ethiopia. International Journal of Food and Agricultural Economics (IJFAEC), 1(1128-2016-91998), 109-118.

Mena, M. M., Madalcho, A. B., Gulfo, E., & Gismu, G. (2018). Community Adoption of Watershed Management Practices at Kindo Didaye District, Southern Ethiopia. Int. J. Environ. Sci. Nat. Resour, 14, 32-39.

Mengistie, D., & Kidane, D. (2016). Assessment of the impact of small-scale irrigation on household livelihood improvement at Gubalafto District, North Wollo, Ethiopia. Agriculture, 6(3), 27.

Mengistu, F., & Assefa, E. (2019). Farmers' decision to adopt watershed management practices in Gibe basin, southwest Ethiopia. International soil and water conservation research, 7(4), 376-387.

Mihalache, M., & Mihalache, O. R. (2016). A decisional framework of offshoring: Integrating insights from 25 years of research to provide direction for future. Decision Sciences, 47(6), 1103–1149.

Miheretu, B. A. (2014). Farmers' perception and adoption of soil and water conservation measures: the case of Gidan Wereda, North Wello, Ethiopia. Journal of Economics and Sustainable Development, 5(24), 1-10.

Miheretu, B. A., & Yimer, A. A. (2017). Determinants of farmers' adoption of land management practices in Gelana sub-watershed of Northern highlands of Ethiopia. Ecological processes, 6(1), 1-11.
MOA (Ministry of Agriculture) (2011). Small-scale irrigation capacity building strategy for Ethiopia. Natural Resource Management Directorate, Addis Ababa, Ethiopia.
MOA (2017). Agricultural transformation agency (ATA), Ethiopia's Agricultural Extension Strategy: Vision, Systemic Bottlenecks and Priority Interventions, Addis Ababa, Ethiopia, 2017.
Mohammed, M. A., & Takel, A. (2018). Agro-pastorals' adoption of soil and water conservation (SWC) technologies: The case of Aba'ala district in Afar Region, Ethiopia. International Journal of Biodiversity and Conservation, 10(7), 303-318.
Mulualem, T., & Yebo, B. (2015). Review on integrated soil fertility management for better crop production in Ethiopia. Sky Journal of Agricultural Research, 4(1), 021-032.
Mulu, A., Adgo, E., & Nigussie, Z. (2016). Assessment of Farmers Participation and Their Knowledge on Sustainability of Improved Soil and Water Conservation Activities in Enebsie Sarmidir District: A Case Study of Guansa and Shola Watersheds. African Journal of Basic & Applied Sciences, 8(2), 73-79.
Njeru, E., Grey, S., & Kilawe, E. (2016). Eastern Africa climate-smart agriculture scoping study: Ethiopia, Kenya and Uganda. FAO, Addis Ababa, Ethiopia.
Nurie, D. F., Fufa, B., & Bekele, W. (2013). Determinants of the use of soil conservation technologies by smallholder farmers: The case of Hulet Eju Enesie District, East Gojjam Zone, Ethiopia. Asian Journal of Agriculture and Food Sciences, 1(4).
Rohila, A. K., Shehrawat, P. S., Malik, J. S. (2018). Awareness, constraints and prospects of climate smart agricultural practices (CSAP). Journal of Agrometeorology, 20: 167-171
Saguye, T. S. (2017). Assessment of Farmers' Perception of Climate Change and Variability and It's Implication for Implementation of Climate-Smart Agricultural Practices: The Case of Geze Gofa District, Southern Ethiopia. Assessment, 30, 1-15.
Sani, S., Haji, J., & Goshu, D. (2016). Climate change adaptation strategies of smallholder farmers: The case of Assosa District, Western Ethiopia. Journal of Environment and Earth Science, 6(7), 9-15.
Shako, M., Dinku, A., & Mosisa, W. (2021). Constraints of Adoption of Agricultural Extension Package Technologies on Sorghum Crop Production at Smallholder Farm Household Level: Evidence from West Hararghe Zone, Oromia, Ethiopia. Advances in Agriculture, 2021.
Sileshi, M., Kadigi, R., Mutabazi, K., & Sieber, S. (2019). Determinants for adoption of physical soil and water conservation measures by smallholder farmers in Ethiopia. International soil and water conservation research, 7(4), 354-361.
Tadesse, M., & Baihilu, B. (2017). Review on participatory small-scale irrigation schemes and small-scale rainwater harvesting technology development and its contribution to household food security in Ethiopia. International Journal of Water Resources and Environmental Engineering, 9(3), 54-63.
Tadesse, M., & Belay, K. (2004). Factors influencing adoption of soil conservation measures in southern Ethiopia: the case of Gununo area. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 105(1), 49-62.
Tadesse, M., Simane, B., Abera, W., Tamene, L., Ambaw, G., Recha, J. W., ... & Solomon, D. (2021). The effect of climate-smart agriculture on soil fertility, crop yield, and soil carbon in southern ethiopia. Sustainability, 13(8), 4515.

Teferi Alemaw, A., Mezgebo Hailu, A., & Kahsay, S. T. (2021). Adoption of maize varieties on smallholder farmers' market participation in Oromia Regional State, Ethiopia. African Journal of Science, Technology, Innovation and Development, 13(2), 185-192.

Tekeste, K. (2021). Climate-Smart Agricultural (CSA) practices and its implications to food security in Siyadebrina Wayu District, Ethiopia. African Journal of Agricultural Research, 17(1), 92-103.

Teklewold, H., Gebrehiwot, T., & Bezabih, M. (2019). Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia. World Development, 122, 38-53.

Teklewold, H., Mekonnen, A., & Kohlin, G. (2019). Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia. Climate and Development, 11(2), 180-192.

Temesgen, H., Mengistu, K., & Fekadu, B. (2018). Evaluating the impact of small-scale irrigation practice on household income in Abay Chomen District of Oromia National Regional State, Ethiopia. Journal of Development and Agricultural Economics, 10(12), 384-393.

Tesfaye, G., Debebe, Y., & Yakob, T. (2018). Impact of participatory integrated watershed management on hydrological, environment of watershed and socio-economic, case study at Somodo Watershed, South Western Ethiopia. The International Journal of Earth & Environmental Sciences, 3(1), 1-7.

Tesfaye, S., Bedada, B., & Mesay, Y. (2016). Impact of improved wheat technology adoption on productivity and income in Ethiopia. African Crop Science Journal, 24(s1), 127-135.

Teshome, A., Adgo, E., & Mati, B. (2010). Impact of water harvesting ponds on household incomes and rural livelihoods in Minjar Shenkora district of Ethiopia. Ecohydrology & Hydrobiology, 10(2-4), 315-322.

Teshome, A., De Graaff, J., & Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: Evidence from North-Western Ethiopian highlands. Environmental management, 57(3), 620-636.

Tessema, Y. M., Asafu-Adjaye, J., Kassie, M., & Mallawaarachchi, T. (2016). Do neighbours matter in technology adoption? The case of conservation tillage in northwest Ethiopia. African Journal of Agricultural and Resource Economics, 11(311-2016-5659), 211-225.

Thornton, P. K., Whitbread, A., Baedeker, T., Cairns, J., Claessens, L., Baethgen, W., ... & Keating, B. (2018). A framework for priority-setting in climate smart agriculture research. Agricultural Systems, 167, 161-175.

Tranfeld, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), 207–222.

Tsadik, E. T., Tamir, B., & Sahile, Z. (2015). The impact of village poultry technology adoption on the livelihood of smallholder farmers in Central Oromia Region, Ethiopia. Journal of Biology, Agriculture and Healthcare, 5(17), 59-69.

Tsegaye, W., LaRovere, R., Mwabu, G., & Kassie, G. T. (2017). Adoption and farm-level impact of conservation agriculture in Central Ethiopia. Environment, Development and Sustainability, 19(6), 2517-2533.

Tsige, M. (2019). Who benefits from production outcomes? Gendered production relations among climate-smart agriculture technology users in rural Ethiopia. Rural Sociology, 84(4), 799-825.

Tsige, M., Synnevåg, G., & Aune, J. B. (2020). Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers. Scientific African, 7, e00250.

Urgessa Waktola, T., & Fekadu, K. (2021). Adoption of coffee shade agroforestry technology and shade tree management in gobu seyo district, east wollega, oromia. Advances in Agriculture, 2021.

Urgessa, T., & Amsalu, B. (2014). Farmers' perceptions and adaptations to climate change through conservation agriculture: the case of guto gida and sasiga districts, western Ethiopia. Academia Journal of Agricultural Research, 2(10), 207-224.

Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., ... & Sanginga, N. (2010). Integrated soil fertility management: operational definition and consequences for implementation and dissemination. Outlook on agriculture, 39(1), 17-24.

Wale, E., & Chianu, J. N. (2015). Farmers' Demand for Extra Yield from Improved Tef [(Eragrostis tef (Zucc.) Trotter] Varieties in Ethiopia: Implications for Crop Improvement and Agricultural Extension. Journal of Agricultural Science and Technology, 17(6), 1449-1462.

Wolancho, K. W. (2015). Evaluating watershed management activities of campaign work in Southern nations, nationalities and peoples' regional state of Ethiopia. Environmental Systems Research, 4(1), 1-13.

Wolka, K., Moges, A., & Yimer, F. (2013). Farmers' perception of the effects of soil and water conservation structures on crop production: The case of Bokole watershed, Southern Ethiopia. African journal of environmental science and technology, 7(11), 990-1000.

Wordofa, M. G., Okoyo, E. N., & Erkalo, E. (2020). Factors influencing adoption of improved structural soil and water conservation measures in Eastern Ethiopia. Environmental Systems Research, 9(1), 1-11.

World Bank (2018). Scaling up climate-smart agriculture through the Africa climate business plan. World Bank, Washington, DC.

World Bank, (2012). Carbon sequestration in agricultural soils. Reprt No. 6 7 3 9 5 - G L B, The World Bank.

Xia, N., Zou, P. X. W. W., Grifn, M. A., Wang, X., & Zhong, R. (2018). Towards integrating construction risk management and stakeholder management: A systematic literature review and future research agendas. International Journal of Project Management, 36(5), 701–715.

Xiao, C. (2015). Soil Organic Carbon Storage (Sequestration) Principles and management: Potential Role for Recycled Organic Materials in Agricultural Soils of Washington State. https://fortress.wa.gov/ecy/ publications/SummaryPages/1507005.html.

Yaebiyo, G. M., Tesfay, Y., & Assefa, D. (2015). Socio-economic impact assessment of integrated watershed management in Sheka watershed, Ethiopia. Journal of Economics and Sustainable Development, 6(9), 202-212.

Yihdego, A. G., Gebru, A. A., & Gelaye, M. T. (2015). The impact of small-scale irrigation on income of rural farm households: Evidence from Ahferom Woreda in Tigray, Ethiopia. International Journal of Business and Economics Research, 4(4), 217-228.

Zerssa et al., 2021. Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture. Agriculture, 11 (192).

Appendix A

List of papers used for content analysis by their author(s). Full information of the papers is given in the reference section.

SN	Paper by author(s)	SN	Paper by author(s)	SN	Paper by author(s)	SN	Paper by author(s)
1	Abebe, 2013	26	Belay and Bewket, 2013	51	Jaleta et al., 2018	76	Sileshi et al.., 2019

2	Abeje et al., 2019	27	Bewket, 2007	52	Kassa, 2021	77	Tadesse & Belay, 2004
3	Abiy et al., 2015	28	Beyan et al., 2014	53	Kassa et al., 2021	78	Tadesse et al., 2021
4	Addisu et al., 2015	29	Biratu & Asmamaw, 2016	54	Kassie, 2016	79	Teferi Alemaw et al., 2021
5	Adela et al., 2019	30	Birhanu & Meseret, 2013	55	Kassie, 2018	80	Tekeste, 2021
6	Adgo et al., 2013	31	Cafer & Rikoon, 2018	56	Keno et al., 2021	81	Teklewold et al., 2019
7	Adugna et al., 2014	32	Challa, 2021	57	Kifle et al., 2020	82	Teklewold et al., 2019
8	Agidew & Singh, 2019	33	Debie, 2021	58	Kosmowski, 2018	83	Temesgen et al., 2018
9	Ahmed, 2014	34	Dessie et al., 2020	59	Lanckriet et al., 2024	84	Tesfaye et al., 2016
10	Ahmed, 2015	35	Dilebo, 2017	60	Legesse et al., 2012	85	Tesfaye et al., 2018
11	Ahmed et al., 2017	36	Dufera et al., 2020	61	Marie et al., 2020	86	Teshome et al., 2010
12	Alemu & Melesse, 2020	37	Duguma, 2013	62	Mekonen & Tesfahunegn, 2011	87	Teshome et al., 2016
13	Alemu et al., 2019	38	Engdawork & Bork, 2014	63	Mekuriaw et al., 2018	88	Tessema et al., 2016
14	Amare et al., 2019	39	Fikirie, 2021	64	Melesse & Jemal, 2013	89	Tsadik et al., 2015
15	Amsalua & de Graaff, 2007	40	Enki et al., 2001	65	Mena et al., 2018	90	Tsegaye et al., 2017
16	Arage, 2021	41	Gadisa and Hailu, 2020	66	Mengistie & Kidane, 2016	91	Tsige, 2019
17	Ashuro & Takele, 2019	42	Gebeyanesh et al., 2017	67	Mengistu & Assefa, 2019	92	Tsige et al., 2020
18	Asnake & Elias, 2017	43	Gebremeskel et al., 2018	68	Miheretu, 2014	93	Urgessa Waktola & Fekadu, 2021
19	Asrat & Babiso, 2020	44	Gebru et al., 2019	69	Miheretu & Yimer, 2017	94	Urgessa and Amsalu, 2014
20	Asrat & Simane, 2018	45	Gebru et al., 2021	70	Mohammed & Takel, 2018	95	Wale & Chianu, 2015
21	Aweke et al., 2021	46	Gedefaw et al., 2018	71	Mulu et al., 2016	96	Wolancho, 2015
22	Ayalneh et al., 2007	47	Goshu et al., 2012	72	Nurie et al., 2013	97	Wolka et al., 2013
23	Ayichew, 2019	48	Guteta & Abegaz, 2016a	73	Saguye, 2017	98	Wordofa et al., 2020
24	Bacha et al., 2011	49	Guteta & Abegaz, 2016b	74	Sani et al., 2016	99	Yaebiyo et al., 2015
25	Bedeke et al., 2019	50	Horamo et al., 2020	75	Shako et al., 2021	100	Yihdego et al., 2015

Declarations

Conflict of interest. The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.