Sustainable intensification of food production through resilient farming systems in West & North Africa

Deliverable D1.3
Farming practices overview

Due date of deliverable: M14
Actual submission date: 31st October 2021

GENERAL DATA

Grant Agreement: 861924
Project acronym: SustInAfrica
Project title: Sustainable intensification of food production through resilient farming systems in West & North Africa
Project website: www.sustinafrica.com

Start date of the project: September 1st, 2020
Project duration: 60 months
Organisation name of lead contractor: Luke

Funding source: SFS-35-2019-2020 - Sustainable Intensification in Africa
Type of action: Research and Innovation Action

DELIVERABLE NUMBER:	D1.3
DELIVERABLE TITLE:	Farming practices overview
DELIVERABLE TYPE:	Other
WORK PACKAGE:	WP1
WORK PACKAGE TITLE:	Baseline analysis and monitoring systems design of W. and N. African farming systems
DELIVERABLE LEADER:	Luke/BOKU
AUTHOR: CONTRIBUTORS:	Pierre Ellssel Nils Borchard, Bernhard Freyer
DISSEMINATION LEVEL:	CO

ABSTRACT

Deliverable D1.3 'Farming practices overview' presents an overview and information on agroecological farming practices (AEP) and the effects on productivity, farm economic and ecosystem service indicators. A systematic literature was conducted to collect and retrieve respective information. The search yielded more than 4,000 articles of which 99 were selected for a full text review after a thorough screening process. The report presents the results on various single agroecological practices such as diversified crop rotations, and on combined agroecological practices such as conservation agriculture and organic farming.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Table of contents

Tables

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 861924

Figures

List of abbreviations and acronyms

AE	Agroecology
AEP	Agroecological practices
ATB	Leibniz Institute for Agricultural Engineering & Bioeconomy
BF	Burkina Faso
BOKU	University of Natural Resources & Life Sciences Vienna
EG	Egypt
FAO	Food and Agriculture Organisation of the United Nations
GH	Ghana
Ibid	Ibidem
LUKE	Natural Resources Institute Finland
NI	Niger
OA	Organic Agriculture
TU	Tunisia
UN	United Nations
WP	Work package

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

1 Introduction

1.1 Deliverable 1.2

The following document represents **Deliverable 1.3 - Farming practices overview** - which is part of **Task 1.2.a - Screening of agricultural practices and technologies for improving productivity, preservation of ecosystem services, resilience, and sustainability –** as part of work package 1. The Task 1.2.a is shared by BOKU/Luke and ATB/Luke.
According to the **SustInAfrica** proposal: "This task will gather information and knowledge on **traditional** (coordinated by BOKU/Luke), **agroecological** (coordinated by BOKU/Luke), and smart farming practices and monitoring technologies (coordinated by ATB/Luke) from literature (e.g. reviews and meta-analyses) and of selected communities in targeted agro-ecological zones and assess their **efficiency on improving agricultural productivity** while reducing **environmental impacts** of agricultural activities. Findings and criteria are defined by the needs of WP 2 and 3 (e.g., history, present, future potential, transition). This task will conduct literature review and/or meta-analysis to elucidate information about existing agricultural practices and smart farming and monitoring technologies, along their effects on productivity and delivery of ecosystem services. The literature review and/or meta-analysis[1] will be done in accordance to gathered data and information collected from the ISI Web of Science, Scopus, data from Ministries in Charge of Agriculture in the 5 countries, and UN FAO database, etc. Screening of smart, open, and affordable monitoring technologies for farmers will be coordinated by ATB and Luke and conducted in collaboration with local experts mentioned in the Grant Agreement of this proposal for plant health (GH, NI, EG, TU), water, and soil management (GH, BF, NI, EG, TU). The screening will search for tools and solutions in previous and current research activities, businesses, research projects, and initiatives as well as already available technologies. A data base will be built, stored at the project`s SharePoint (Tiimeri operated by Luke) and made available in Farmerline`s Mergdata platform (www.mergdata.com). The database can be easily browsed from the web to provide a systematic summary of the findings with access to freely available tools and solutions. The database will be filtered to extract relevant future-oriented technologies that have potential to be tailored to the needs of smallholder farmers in Africa. Each sorted out technology will be ranked for their suitability of practical implementation for smallholder farming in African agriculture. The ranking will take into account the current situation but also the future development in African agriculture" (Source: H2020 Proposal **SustInAfrica**, p. 34)

According to **Task 1.2.a** the following (research) framework guides the **Deliverable 1.3**:

- **Objective:**

To provide evidence from on-farm experiments on how agroecological farming practices impact on productivity, farm economies and ecosystem services in the semi-arid and sub-humid tropics and subtropics.

- **Research question:**

What is the effect of on-farm interventions in the form of agroecological farming practices on productivity, farm economies and ecosystem services in semi-arid and sub-humid tropics and subtropics?

- **Expected output:**

A database with an overview of agroecological practices and their effects on the efficacy and efficiency of farm economies and ecosystem services for the semi-arid and sub-humid tropics and subtropics will be made available open access via the **SustInAfrica** partner FARMERLINE and mergedata platform.

---

[1] *Uman, L. S.* (2011): Systematic reviews and meta-analyses. *J. Can. Acad. Child Adolesc. Psychiatry* 20, 57–59.

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 861924

1.2 Agroecological farming practices

The concept of Agroecology (AE) has received increased attention during the last two decades on the political, scientific, and civil society level as it is perceived a systemic and holistic approach to the various challenges agriculture and food systems face on a global level (HLPE, 2019; IAASTD, 2009; IFAD, 2021), and henceforth, an approach aiding in achieving the United Nations Sustainable Development Goals (HLPE, 2019). The concept of AE has many similarities in its principles and practices with organic agriculture (OA), as both approaches have similar goals and follow a systems approach (Migliorini & Wezel, 2017). The main difference is that OA is more prescriptive as it is officially regulated, certified, and labelled, while AE is more practiced informally with certain practices and principles differing (ibid). Furthermore, synthetic fertilizers and pesticides are not generally excluded in AE in contrast to OA, although AE aims to reduce or phase out its use (HLPE, 2019; Wezel et al., 2015).

The concept of AE contains multiple definitions due to the various places and times where it evolved as well as the different stakeholders who apply it according to their specific circumstances and priorities (FAO, 2021). Broadly AE is defined as i) a scientific discipline, ii) a set of practices, and iii) as a social movement (HLPE, 2019), although here we will mainly set a focus on the practices.

Yet, there is no clear definition of what is an agroecological practice and what is not (ibid). However, all practices and approaches that enhance or foster biological processes and ecosystem services, which on the other hand support and enhance agricultural production may be considered "agroecological". These approaches or practices use ecological intensification[2] on the field (e.g., intercropping), farm (e.g., agroforestry), and landscape level (e.g., landscape elements, natural habitats) by fostering and enhancing biological processes. Thus, ecological principles are used and applied to agriculture, with the central aim to increase diversity, recycling, and resource use efficiency. Diversification of crops and the integration of animals is a key feature to improve the (re)cycling of nutrients, water, biomass, and energy, but also to increase resilience of farming systems, biodiversity, and ecosystem service delivery. The enhanced biological processes and (re)cycling of nutrients also aims at significantly reducing or phasing out external inputs such as mineral fertilizers, synthetic pesticides, antibiotics, and growth promoters which is beneficial for human health and the environment (HLPE, 2019).

HLPE (2019) refer in their report to certain practices that enhance the above-mentioned processes which include: **Diversification, mixed cultivation, intercropping and relay intercropping, cultivar mixtures, crop-animal integration, habitat management techniques for crop-associated biodiversity, biological pest control, improvement of soil structure and health, biological nitrogen fixation, recycling of nutrients, energy and waste, organic fertilization, split fertilization, reduced tillage, drip irrigation, integrated pest management, choice of cultivars resistant/tolerant to biotic stresses (diseases, insect pests and parasitic weeds), biofertilizers, natural pesticides and biopesticides, diversified crop rotations, agroforestry, allelopathic plants, direct seeding into living cover crops or mulch, integration of semi-natural landscape elements at field, farm and landscape scale.**

Hence, AEP can comprise single practices (e.g., intercropping) or combined practices (e.g., crop-livestock integration, agroforestry, conservation agriculture) or systems approaches such as organic farming and permaculture. Several studies show that combined practices and practices combined in whole systems maximize ecological benefits instead of just applying single practices (Rosa-Schleich et al., 2019; Schader et al., 2021).

With respect to traditional and agroecological farming practices, a clear differentiation can usually not be made. Oftentimes agroecological practices build on traditional practices and knowledge, often added by scientific findings and knowledge (HLPE, 2019). Some of the aforementioned AEP such as multiple species management (e.g., agroforestry, intercropping) can be viewed as traditional (Berkes

[2] Ecological intensification: „Ecological intensification is defined as using natural processes to replace human-produced inputs like pesticides and fertilizers, while maintaining or increasing food production per unit area." (Kremen, 2020)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

et al., 2000) while they are at the time agroecological as they enhance biological processes, recycling and resource use efficiency (Singh & Singh, 2017).

2 Methodological approach

2.1 Agroecological practices, farm economic and environmental indicators

The systematic review aims to examine evidence of the effects of agroecological practices on farm economics and ecosystem services. The analysis focuses mainly on the results of on-farm trials, thus of main interest are publications that refer to the plot / field scale and on the household / farm scale. Viable practices and indicators that may be included and analysed are listed in Table 1.

Table 1. Agroecological practices, components, and indicators

Agroecology components	Practice or indicator	
	Plot/field scale	Household / farm scale
Production		
Soil management	▪ Cover crops ▪ Mulching ▪ Green manure ▪ Legume integration (nitrogen fixing crops) ▪ Compost, animal manure ▪ Reduced or no-tillage	▪ Soil and water conservation (terracing, ridging, swales, or contour bunds/depressions to capture rainwater)
Crop diversification	▪ Diversified crop rotations ▪ (Relay) Intercropping ▪ Cultivar mixtures	▪ Organic production ▪ Agroforestry
Pest management	▪ Botanical/natural pesticides ▪ Insectary plantings (i.e., strategic planting of species for the attraction of beneficial insects)	▪ Border plantings/flower strips
Livestock integration		▪ Mixed crop-livestock
Productivity and economy		
Productivity	▪ Yield per hectare ▪ Land equivalent ratio	
Profitability	▪ Agricultural income: gross margin	
Labour savings	▪ Labour reduction/less costs for labour (reduction in overall time needed for agricultural activities)	
Synthetic fertilizer savings	▪ Fertilizer costs (amount) can be reduced	
Synthetic pesticide savings	▪ Pesticide costs (amount) can be reduced	
Synthetic herbicide savings	▪ Herbicide costs (amount) can be reduced	
Ecosystem services		
Biodiversity	▪ Increased abundance and richness of plant and animal species including above- and belowground communities	
Pollination	▪ Enhanced pollinator richness and abundance for improved crop pollination quality and quantity	
Pest control	▪ Enhanced biological regulation of pests, pest resistance or tolerance	
Disease incidence	▪ Lower disease and pathogen infestation	
Weed control	▪ Less crop competition with weeds, increased allelopathic interactions, enhancement of weed seed decay	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Soil health	▪ Improved soil fertility, soil physical properties such as reduced soil compaction, and higher soil microbial biomass
Erosion control	▪ Reduced loss by soil or wind
Nutrient availability	▪ Higher nutrient efficiency (faster mineralization rates, reduced N leaching, better nutrient cycling and nitrogen fixation)
Water regulation	▪ Better water-holding capacity, water-use efficiency and water infiltration into the soil
Carbon sequestration	▪ Increased soil organic carbon content

Source: D'Annolfo et al. (2017); (HLPE, 2019; Kerr et al., 2021; Mottet et al., 2020; Rosa-Schleich et al., 2019; Smith et al., 2017)

2.2 Systematic literature review

The systematic review was conducted according to the Cochrane guidelines as described in Deliverable 6.2 and supplemented by the PRISMA guidelines (Page et al., 2021). The systematic review differs from merely descriptive reviews by its systematic search of the literature and respective reporting procedures (Uman, 2011).

2.2.1 Eligibility criteria

The following inclusion and exclusion criteria have been defined in order to focus the analysis (Table 1). Farmer-led research may not be fully randomised but was still included although it will be marked and mentioned in the report narrative. Furthermore, studies that report physical crop (yield) measurements and studies reporting farmer recall will be included, although the latter is sometimes regarded as varying and less valid due various social and cultural reasons.

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
▪ Published between 1990-2021	▪ Not published between 1990-2021
▪ Reports empirical data (data on AEP, economic data, environmental/ecosystem services data) ▪ Data from trials can be physically measured or data from farmer recall (the latter will be made explicit in the analysis)	▪ Non-empirical data, modelling studies ▪ No AEP data or AEP not clearly defined: sources that only talk about vague "agro-ecological practices" are excluded
▪ Randomised on-farm trials, non-randomised farmer lead research, intervention studies	▪ On-station trials ▪ Reviews ▪ Observational studies
▪ Studies using a control	▪ Studies without a control
▪ Agroecological zones (sub-humid & semi-arid tropics, subtropics) according to the Köppen-Geiger climate classification[3]	▪ Studies/experiments conducted outside sub humid & semi-arid tropics/subtropics
▪ Cropping systems	▪ Grassland/grazing practices, studies on breeding/new breeds, greenhouse, or pot experiments, irrigation studies
▪ Peer reviewed, dissertation / thesis, academic book	▪ Non-peer reviewed studies ▪ Methods of poor quality ▪ Inappropriate study design/ unclear study design
▪ In case of grey literature (institution with relevant expertise and track record)	▪ Institutions with no relevant expertise and track record

[3] https://www.nature.com/articles/sdata2018214

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

▪ Information on location, rainfall during cropping season, crop variety, soil type must be provided by the study	▪ Lack of fundamental information in the methodology section: location, rainfall during the cropping season, crop variety, soil type

Source: own

2.2.2 Information sources and literature search strategy

The search for scientific literature was conducted in the database of the Web of Science Core Collection in August 2021, limited to English language publications. The search was restricted to a screening of title, abstract content, and author keywords, excluding reviews, proceedings, editorials, opinions, commentaries, and perspectives. The results were downloaded from the database in the form of an Excel database.

For the search of relevant literature, search terms and respective search strings were developed. The terms were developed through a pre-screening of relevant papers, abstracts and testing in databases. Wildcards such as asterisk (*) were used to also retrieve variations of search terms. It was decided to use country names to cover the envisaged geographic area (developing countries in semi-arid and subhumid tropics and subtropics) as studies usually report in their title or abstract where the research was conducted, especially in the case of on-farm trials and experiments (Table 3).

Table 3. Search string and keywords

Search string and keywords (20.08.2021)
TS=(productivity OR "gross margin" OR profit* OR benefit* OR revenue OR cost* OR labour OR labor OR yield OR income OR economic* OR "ecosystem service*") AND TS=("Sustainable intensification" OR "Ecologcial intensification" OR "Agroecological intensification" OR "Agro-ecological intensification" OR "Eco-functional intensification" OR "Sustainable land management" OR "SLM" OR "Climate smart agriculture" OR "climate resilient agriculture" OR "Conservation agriculture" OR "conservation farm*" OR "regenerative agriculture" OR "Agroecology" OR "agro-ecology" OR "agroecological practice*" OR "agro-ecological practice*" OR "Organic agriculture" OR "Organic farm*" OR "organic production" OR "Organic management" OR "organic agriculture practice*" OR "organic farming practice*" OR "organic management practice*" OR "biodynamic agric*" OR "biodynamic farm*" OR "biodynamic product*"OR "ecological agriculture" OR "ecological farm*" OR "ecological production" OR "ecoagriculture" OR "ecofarm*" OR "ecoproduction" OR "Sustainable agriculture" OR "sustainable farm*" OR "sustainable production" OR "Sustainable cropping systems" OR "sustainable cropping practices" OR "natural agriculture" OR "natural farm*" OR "natural production" OR "multifunctional agriculture" OR "multifunctional farm*" OR "multifunctional production" OR "integrated agriculture" OR "integrated farming" OR "integrated production" OR "diversified agriculture" OR "diversified farm*" OR "diversified production" OR permaculture OR "low external input agriculture" OR "low input agriculture" OR "low input farm*" OR "low input production") AND TS=(Mexico OR Belize OR Costa Rica OR El Salvador OR Guatemala OR Honduras OR Nicaragua OR Panama OR Bolivia OR Brazil OR Colombia OR Ecuador OR French Guiana OR Galápagos Islands OR Guyana OR Paraguay OR Peru OR Suriname OR Venezuela OR Suriname OR Venezuela OR Uruguay OR Anguilla OR Antigua and Barbuda OR Aruba OR Bahamas OR Barbados OR "British Virgin Islands" OR "Cayman Islands" OR Cuba OR Dominica OR "Dominican Republic" OR Grenada OR Guadeloupe OR Haiti OR Jamaica OR Martinique OR Montserrat OR "Netherlands Antilles" OR "Puerto Rico" OR "Saint Barthélemy" OR "Saint Kits and Nevis" OR "Saint Lucia" OR "Saint Martin" OR "Saint Vincent and the Grenadines" OR "Trinidad and Tobago" OR "Turks and Cacaos Islands" OR "United States Virgin Islands" OR Angola OR Cameroon OR "Central African Republic" OR Chad OR Congo OR "Democratic Republic of Congo" OR Zaire OR "Equatorial Guinea" OR Gabon OR Sudan OR Zambia OR Burundi OR Comoros OR Djibouti OR Eritrea OR Ethiopia OR Kenya OR Madagascar OR Malawi OR Mauritius OR Mayotte OR Mozambique OR Reunion OR Rwanda OR Seychelles OR Somalia OR Tanzania OR Uganda OR Benin OR "Burkina Faso" OR "Côte d'Ivoire" OR "Ivory Coast" OR Gambia OR Ghana OR Guinea OR Guinea-Bissau OR Liberia OR Mali OR Mauritania OR Niger OR Nigeria OR "Saint Helena" OR "São tomé and Principe" OR Senegal OR Sierra Leone OR Togo OR Brunei OR Burma OR Myanmar OR Cambodia OR East Timor OR Indonesia OR Laos OR Malaysia OR Philippines OR Singapore OR Thailand OR Vietnam OR India OR Algeria OR Egypt OR Tunisia OR Morocco OR Botswana OR "Cape Verde" OR Lesotho OR Mauritania OR Namibia OR "South Africa" OR Zambia OR Zimbabwe OR "Western Sahara" OR Bhutan OR Bangladesh OR Philippines OR "Sri Lanka" OR China)

Source: own

2.2.3 Screening process

The screening of the retrieved articles from Web of Science was conducted in Microsoft Excel. In a first step the duplicates were removed. In the second step the titles and/or abstracts were screened, and colour coded during a first screening process according to defined categories such as "probably of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

interest" or "of high interest" or not coloured "of no interest" and therefore removed. According to this screening process in total 99 Abstracts were selected for a full text review. In case studies were excluded during the full text review, an explanation for the exclusion was given in the Excel database at the end of each line.
The screening was conducted by one reviewer. In case of doubt a second reviewer was consulted for a final decision of inclusion or exclusion.
For the full text review selected studies were sorted in Microsoft Excel according to following information: **Author, publication year, title, study country, climate, altitude, rainfall type (uni/bimodal), rainfall during cropping season, soil type, soil texture, crop variety, farm type, farm size, plot size, type of AEP, number of observations, type of yield measurement (physical or farmer recall), control (yes/no), years of study duration, treatments**, and in Table 1 listed farm economic and ecosystem service indicators.

2.2.4 Data extraction and study quality assessment

The relevant data was manually extracted and transferred to the Excel database and sorted according to the demanded information as stated under 2.2.3 (e.g., rainfall type, soil type etc). The study quality was assessed during the full-text review with the help of the defined inclusion and exclusion criteria (see Table 2). Studies were for example excluded if fundamental information was not provided such as location, soil type or rainfall during the implementation and assessment of on-farm experiments or if the study design was unclear.
In many cases studies report results for various treatments including purely agronomic and for example synthetic fertilization treatments. In such cases only data were extracted for treatments that were considered as agroecological practices (see Table 1). For example, if a study included a control (e.g., farmers practice/no fertilization), a treatment with recommended synthetic fertilizer application, and a treatment with compost application, then only data was extracted for the comparison of the compost with the control treatment as the latter can be considered an AEP.

2.2.5 Data analysis

For the deliverable and the time being we conducted a simplified analysis sorting the selected studies and the reported on-farm trials according to the agroecological practices and the significance of the results. Therefore, studies and their on-farm trial results have been classified according to: i) significant increase compared to a control; ii) neutral or no significant increases or decreases compared to a control; iii) inconclusive; or iv) significant decreases compared to a control.
Some of the retrieved studies reported only on one or two on-farm trials, while others on many different trials. We considered each on-farm trial as a single trial for analysis, when trials were conducted for example in different agroecological zones, on different soil types or with different crop sequences in a rotation. When on-farm trials were conducted across different seasons/years and no averages/means were reported in studies across seasons, then each season was included for analysis as a separated on-farm trial, for example, as in the case of Ojiem et al. (2014).

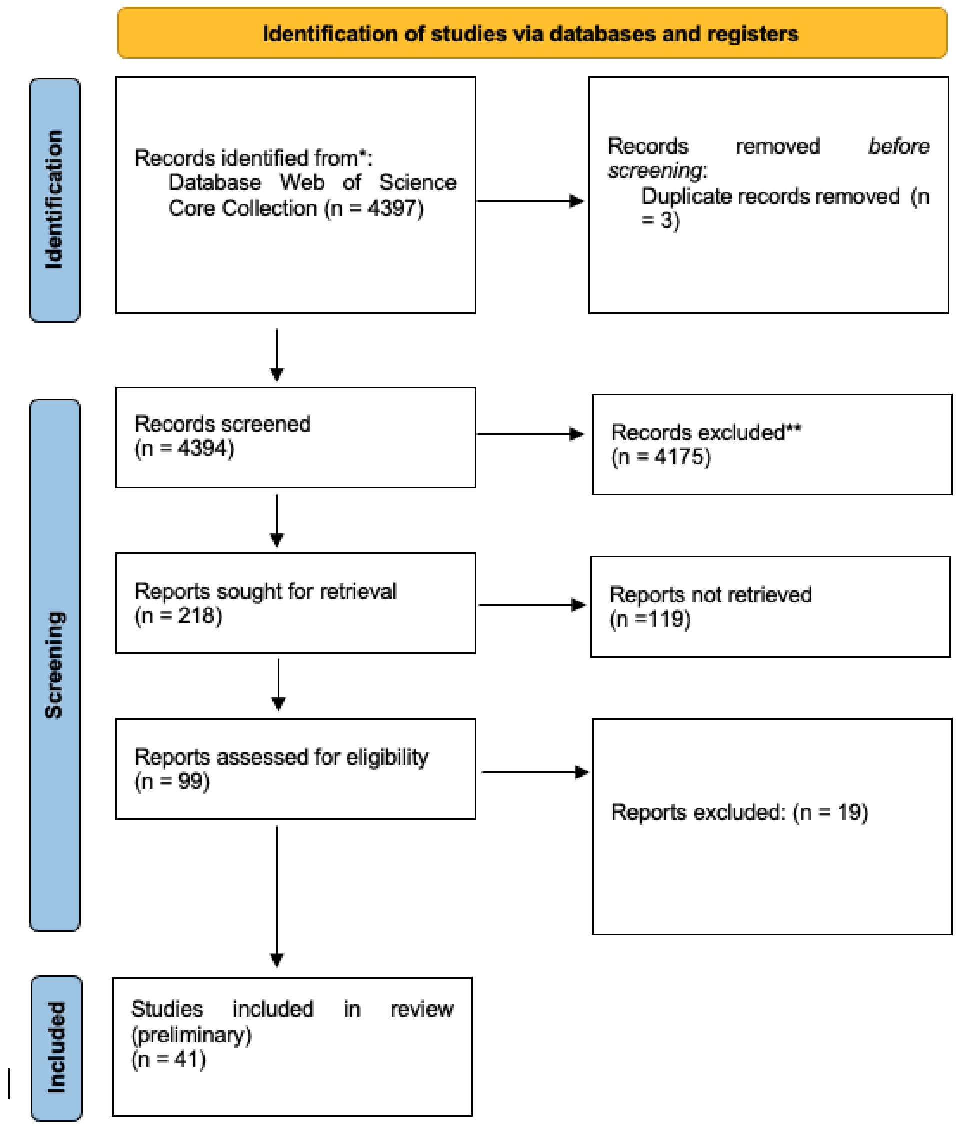
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

3 Results - Farming practices

3.1 Screening process

The initial inquiry of the screening yielded in sum 4,397 documents which were published between 1990 and 2021. In a first step the duplicates were removed (n=3). In the second step the titles and/or abstracts were screened (n=4,394), of which 4,175 were excluded as they did not meet the basic inclusion criteria such as no agroecological practices reported, no on-farm trials etc. (see Table 2). In sum 218 reports were sought for retrieval. These reports were checked for the methods section to determine if studies meet the inclusion criteria such as on-farm trials (see inclusion criteria Table 2). In sum 119 reports were not retrieved while of 99 documents the full text was assessed. In sum 19 studies were excluded thus far as they did not meet criteria such as reporting on the location and soil type of trials, AEP were not reported, studies were conducted in arid zones etc. To current, from the full text assessment 41 documents were included in the review. In sum 37 documents still need to be assessed. Therefore, the results are preliminary.

Figure 1. Screening process and identification of studies



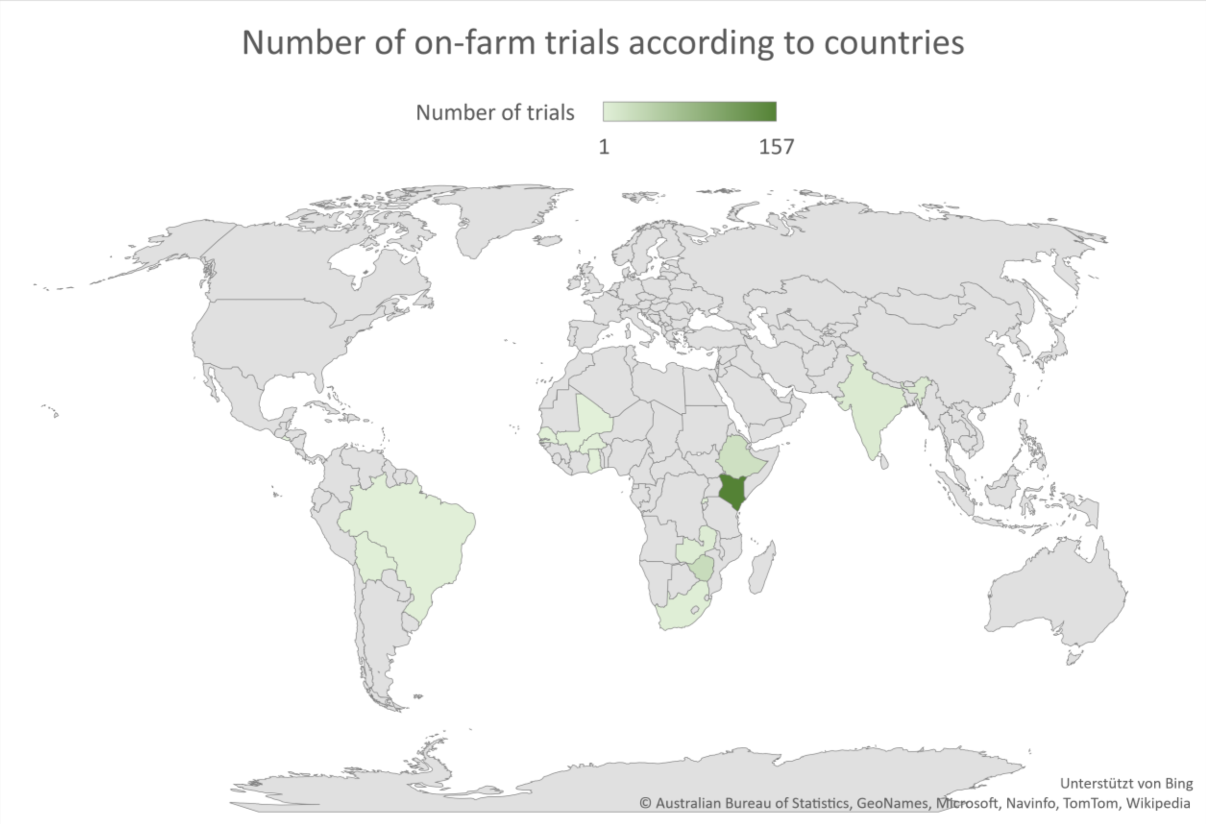
Source: PRISMA reporting items, Page et al. (2021)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

3.2 General results

In sum 41 studies were included which reported on on-farm trials in 15 different countries (Figure 2). Most studies were conducted in countries in sub-Saharan Africa (10), Latin-America (3), and Asia (2). The studies reported in sum on 246 on-farm trials. For example, some studies conducted on-farm trials in different agroecological zones, texting different crops, crop rotations or tillage technologies. Most of the trials were conducted in Kenya (157), followed by Zimbabwe (29), and Ethiopia (23). All other countries hosted below 10 trials.

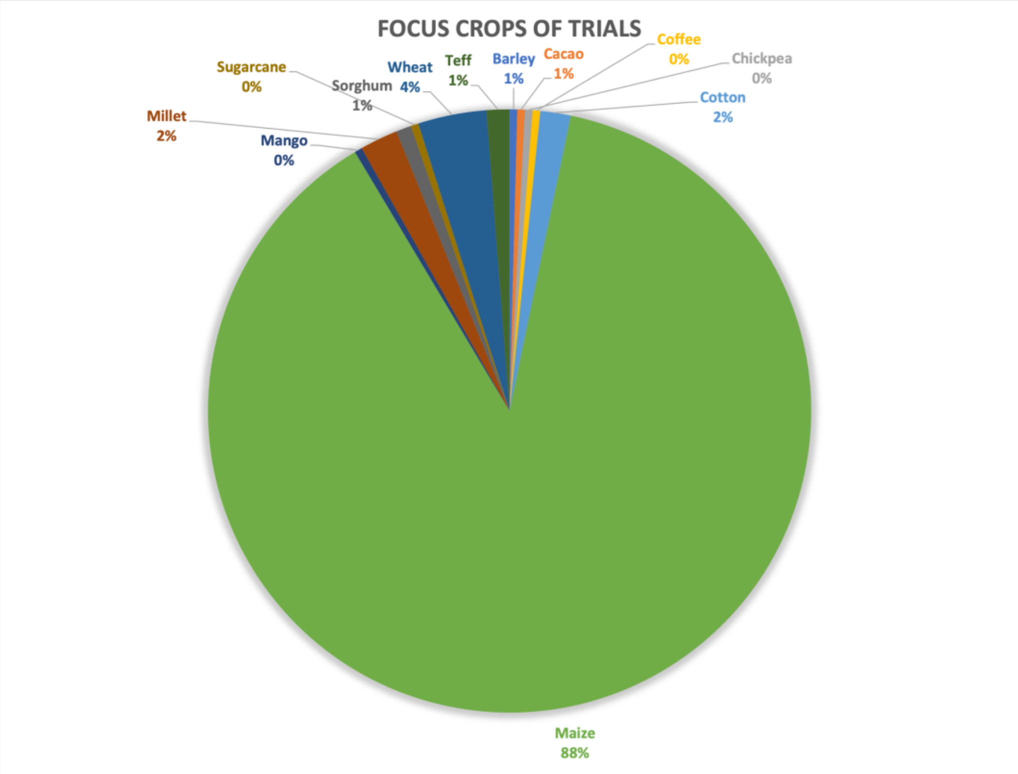
Figure 2. Number of on-farm trials according to countries



Source: own/BING

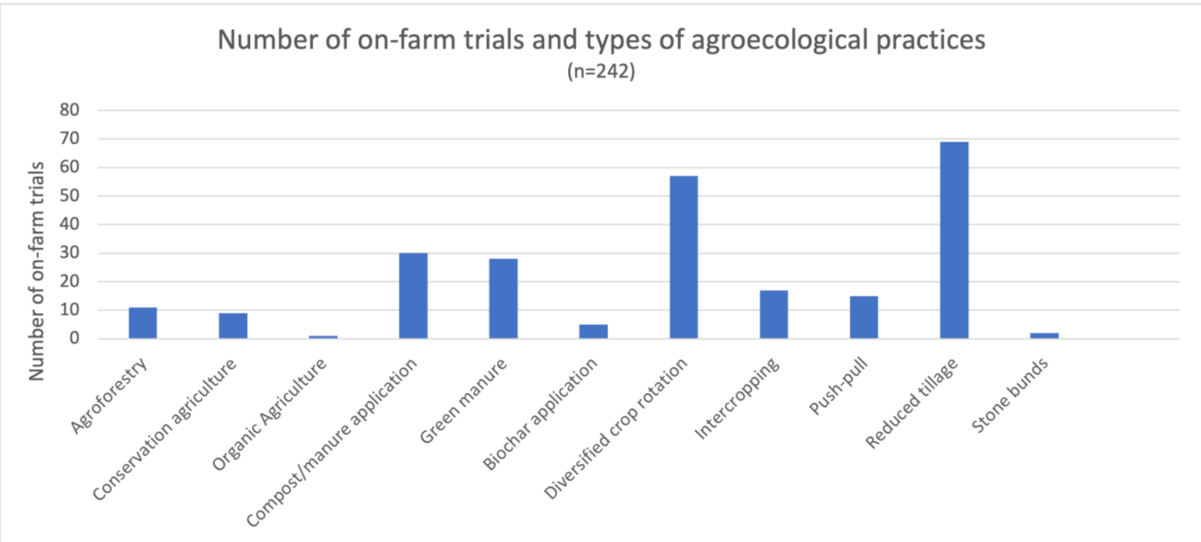
Most trials tested agroecological practices aiming at the target crop maize (88%), followed by wheat (4%), Millet and Cotton (2%), and by all other crops with about 1% (Figure 3). The high share of studies and respective on-farm trials researching and reporting on maize is coherent with importance of maize as a staple food crop. Maize can be considered the most important cereal crop in sub-Saharan Africa (Grote et al., 2021), where most of on-farm trials were conducted (Figure 2).

Figure 3. Target crops of on-farm trials



Source: own

Figure 4. Agroecological practices and number of on-farm trials



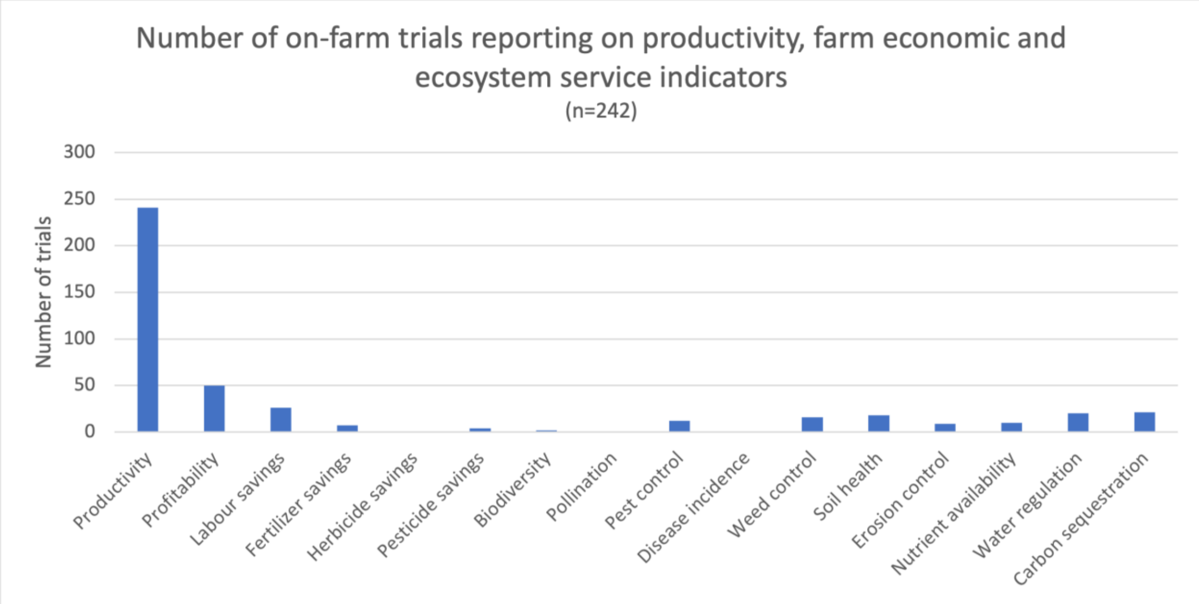
Source: own

Most of the on-farm trials among the included studies experimented with reduced tillage (including no-tillage), followed by diversified crop rotations, usually by integrating grain legumes and to lesser extent fodder legumes. Compost and/or manure application as well as the cultivation and integration of green manure crops was among the most frequent agroecological practices tested, followed by

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

intercropping practices, and push-pull. On-farm trials testing stone bunds, organic agriculture systems, or agroforestry were less prevalent among the retrieved studies (Figure 4).[4]

Figure 5. Number of trials reporting on productivity, farm economic and ecosystem service indicators



Source: own

The most important indicator all studies reported on was productivity (yield per hectare). Some studies on intercropping reported the land equivalent ratio[5], although not all (see 3.3.2). The farm economic indicator 'profitability' was the second most reported item, followed by all other indicators, including those for ecosystem services (Figure 5). However, not all ecosystem service indicators are relevant for each agroecological practice (e.g., erosion control is of less relevance when testing natural pesticides).

3.3 Single agroecological practices

3.3.1 Diversified crop rotation

Diversified crop rotations can be defined as the integration of various crops in a sequence of time (temporal diversification), usually compared to sole or monocropping in most of the on-farm trials. In sum, four studies were retrieved for the review (Chikowo et al., 2004; K. Choudhary et al., 2018; M. Choudhary et al., 2018; Ojiem et al., 2014), reporting and researching in total 57 on-farm trials. For all trials the effect of diversification on productivity was reported, with most of them indicating increases in productivity (54), and three with a neutral effect. In sum 16 trials showed an increase in profitability, 1 neutral, and 2 decreasing profitability. For only one on-farm trial on the indicators 'fertilizer savings', 'soil health', and 'carbon sequestration' was reported, all indicating increases (Table 4).

Table 4. Effect of diversified crop rotations

Number of trials reporting:	Productivity	Profitability	Fertilizer savings	Soil health	Carbon sequestration
Increase	54	16	1	1	1

[4] Among the full text that have not yet been assessed, 26 of these studies conduct research on conservation agriculture. Therefore, the number of on-farm trials for CA will likely increase.

[5] LAND EQUIVALENT RATIO (LER): "the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of the fractions of the intercropped yields divided by the sole-crop yields". Source: https://www.fao.org/3/x5648e/x5648e0m.htm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Neutral	3	1	-	-	-
Decrease	-	2	-	-	-
Inconclusive	-	-	-	-	-

Source: own

3.3.2 Intercropping

The practice of intercropping combines different crop species and/or cultivar mixtures in the same space (spatial diversification). Different types of intercropping can be distinguished such as relay intercropping[6], strip intercropping[7], and mixed intercropping[8]. In sum, seven studies were retrieved for the review (Balde et al., 2020; Bhaskar et al., 2018; Bucagu et al., 2013; Falconnier et al., 2016; Madembo et al., 2020; Masvaya et al., 2017; Mthembu et al., 2018), reporting and researching in total 17 on-farm trials.

Nearly all on-farm trials report on the effect of intercropping on productivity, with an equal distribution among increases (5), neutral (5), and decreases (4). For five on-farm trials the land equivalent ratio is reported with an increase for all five. For four on-farm trials outcomes on 'profitability' are reported with an increase for all four, as well as for labour and pesticides savings, one and three, and three for pest and weed control, respectively (Table 5).

Table 5. Effect of intercropping

Number of trials reporting:	Pro-ductivity	LER[6]	Profit-ability	Labour savings	Pesticide savings	Pest control	Weed control
Increase	5	5	4	1	3	3	3
Neutral	5	-	-	-	-	-	-
Decrease	4	-	-	-	-	-	-
Inconclusive	1	-	-	-	-	-	-

Source: own

3.3.3 Agroforestry

Agroforestry can be defined as the spatial and temporal integration of crops and trees, although a wide variety of agroforestry system exists, differing in the composition of species, the spatial density, hight of trees and arrangement, the integration of livestock etc. Thus, the integration of shade trees (e.g., coffee) as well as the integration of hedgerows and alleys with trees or shrubs could be considered as agroforestry practices.

In sum, five studies were retrieved for the review (Blaser et al., 2017; Kearney et al., 2019; Lenka et al., 2012; Ndoli et al., 2018; Sow et al., 2020), reporting and researching in total 11 on-farm trials. For most trials productivity is reported, indicating increases (4), decreases (4), and neutral effects (1) (Table 6). The on-farm trials as reported by Kearney et al. (2019) resulted mostly in inconclusive results for most of the ecosystem service indicators due to high variability of data when they were analysed separately. But when analysed simultaneously by creating composite indices, the effect became pronounced. Furthermore, the effect on productivity on single crops is often reduced when cultivated in agroforestry systems, and in the case of Ndoli et al. (2018) additionally negative effected by the reduced tillage system. Therefore, productivity is highly depended on the type of crops cultivated as well as on the measurement of productivity. In many cases the land equivalent ratio reports higher total productivity compared to monocropping, although the retrieved studies did not report on LER in the specific cases. Several global studies highlight the importance of agroforestry for the sustainability of agricultural systems (e.g., Kremen, 2020; Rosa-Schleich et al., 2019).

[6] Relay intercropping: two crops or more are grown for part of the season at the same time.

[7] Strip intercropping: two or more crops are grown in adjacent strips at the same time.

[8] Mixed intercropping: two or more crops are grown in the same space, at the same time without a distinct arrangement of rows.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Table 6. Effect of agroforestry

Number of trials reporting:	Productivity	Biodiversity	Pest control	Disease incidence	Weed control	Soil health	Erosion control	Nutrient availability	Water regulation	Carbon sequestration
Increase	4	-	-	-	1	-	4	4	-	4
Neutral	1	-	1	1	-	1	-	-	-	1
Decrease	4	-	-	-	-	-	-	-	-	-
Inconclusive	-	1	1	-	-	1	1	-	1	1

Source: own

3.3.4 Reduced tillage / no-tillage

This section combines studies and on-farm trials reporting on reduced tillage, no-tillage, and direct seeding, which are all characterized by a reduced disturbance and non-turning of soil.
In sum, ten studies were retrieved for the review (Araya et al., 2016; Barbosa et al., 2019; Gathala et al., 2016; Gathala et al., 2015; Guto et al., 2012; Kiboi et al., 2017; Kosgei et al., 2007; Mavunganidze et al., 2020; Mutuku et al., 2020; Rusinamhodzi, 2015), reporting and researching in total 69 on-farm trials.
Productivity was among the most reported indicators (66). Out of these 50 indicate increases, 15 neutral, and 1 decreasing effects. For fewer on-farm trials profitability was reported (14), indicating increases (8), neutral (3), and decreasing effects (3). Increases in labour savings were reported for 13 trials, while 8 indicated increased labour demands (Table 7). However, in those 8 eight cases as reported by Rusinamhodzi (2015), planting basins were created which increased the amount of labour significantly as well as increased weeding requirements. An increasing demand for the latter is often reported, due to the non-inversion of soil, often leading to increased labour demand or herbicide applications (Derpsch et al., 2010). Thus, an adapted crop rotation (e.g., inclusion of forage legumes) becomes even more important as well as the inclusion of green mulch cover crops (Freyer & Bingen, 2020).
For only six on-farm trials effects on soil health were reported (6 neutral). However, an increased soil health due to minimal soil disturbance as well as reduced soil erosion is one of the major benefits of reduced tillage practices (Derpsch et al., 2010).

Table 7. Effect of reduced tillage

Number of trials reporting:	Productivity	Profitability	Labour savings	Weed control	Soil health
Increase	50	8	13	-	-
Neutral	15	3	-	-	6
Decrease	1	3	8	-	-
Inconclusive	-	-	-	3	-

Source: own

3.3.5 Cover crops / green manure

The cultivation of cover crops aims first and foremost on the covering of the soil between the cultivation of the main crops in a rotation. The cover crops can serve as a green manure in the form of mulch or when incorporated into the soil or they can be harvested and function as fodder for livestock.
In sum, one study was retrieved for the review (Ojiem et al., 2014), reporting and researching in total 28 on-farm trials, reporting on increases in productivity (28), and profitability (9) (Table 8).
Ojiem et al. (2014) incorporated green manure legumes in a rotation with maize which doubled maize yields compared to continuous maize. The return to labour was in most cases higher, in some cases equal, and in only a few cases lower. The fixation of nitrogen by the legumes reduces the costs for synthetic fertilizers. Although not reported by the retrieved study, cover crops and green manures can increase carbon sequestration through below- and aboveground biomass, especially when combined

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

with reduced tillage practices, and significantly decrease soil erosion. The increased soil health and thus water holding capacity of soils may increase yield stability under increased climate variability (Delgado et al., 2021; Erenstein, 2003; Freyer & Bingen, 2020).

Table 8. Effects of green manure / cover crops

Number of trials reporting:	Productivity	Profitability
Increase	28	9
Neutral	-	-
Decrease	-	-
Inconclusive	-	-

Source: own

3.3.6 Compost / animal manure application

Compost consists of decayed organic material which can be of plant and/or animal origin. In sum, four studies were retrieved for the review (Bedada et al., 2014; Chikowo et al., 2004; Kafesu et al., 2018; Ouédraogo et al., 2001), reporting and researching in total 30 on-farm trials.
All on the included on-farm trials report on productivity, showing increasing productivity for all reported cases (30). For two trials fertilizer savings are reported (increase), three trials report on soil health (increase), and one trial on carbon sequestration (1) (Table 9).
The positive effect of compost / manure application on productivity as well as soil health, nutrient availability and carbon sequestration is well studied and can especially beneficial for smallholder farmers as reported by other reviews (e.g, Ndambi et al., 2019). Declining soil fertility is a major constraint for many smallholder farmers in the tropics and subtropics due to various biophysical and socio-economic reasons. However, feed quality as well as storage and application techniques have important implications for the quality of the manure (ibid).

Table 9. Effect of compost / animal manure application

Number of trials reporting:	Productivity	Fertilizer savings	Soil health	Carbon sequestration
Increase	30	2	3	1
Neutral	-	-	-	-
Decrease	-	-	-	-
Inconclusive	-	-	-	-

Source: own

3.3.7 Biochar

Biochar is produced by pyrolysis from biomass such as plant organic matter. In sum, two studies were retrieved for the review (Martinsen et al., 2014; Obia et al., 2016), reporting and researching in total 5 on-farm trials. For the five trials in total three reported on productivity effects (neutral), soil health (2 increases), for nutrient availability one trial result was inconclusive, while two were neutral. Five results indicate increased water regulation. In none of the on-farm trials impacts on carbon sequestration was reported. However, carbon sequestration is viewed as one of the main potentials of biochar application to soil, apart from improving other soil health indicators (Nair et al., 2017), especially for highly weathered tropical soils and their inherent low fertility (ibid).

Number of trials reporting:	Productivity	Soil health	Nutrient availability	Water regulation
Increase	-	2	-	5
Neutral	3	-	2	-
Decrease	-	-	-	-
Inconclusive	-	-	1	-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Source: own

3.3.8 Insectary plantings / flower strips / push-pull

The search yielded no specific studies that met the inclusion criteria with specific regard to the effect of insectary plantings or flower strips. However, in sum two studies were retrieved studying the effect of the push-pull system[9] in 15 on-farm trials (Kebede et al., 2018; Ndayisaba et al., 2020). All 15 studies reported on productivity outcomes, showing three increases, 11 neutral effects, and one decrease. The effect of pest control was increasing in two cases, and neutral in four. Soil health was reported in six cases (Table 11). Push-pull is widely viewed as a promising strategy, especially in low input smallholder farming, to sustainably increase productivity and profitability (Pickett et al., 2014).

Table 10. Effect of insectary plantings / flower strips / push-pull

Number of trials reporting:	Productivity	Pest control	Soil health
Increase	3	2	3
Neutral	11	4	3
Decrease	1	-	-
Inconclusive	-	-	-

Source: own

3.3.9 Soil and water conservation techniques

Soil and water conservation techniques comprise various technologies such as terracing, stone bunds, contour bunds, swales etc. All these techniques intend to keep the water in the landscape, foster infiltration, and hinder runoff and thus soil erosion. In sum, two studies were retrieved for the review (Guadie et al., 2020; Vancampenhout et al., 2006), reporting and researching in total two on-farm trials stone bunds.

Productivity was reported two times (1 increase, 1 neutral), while soil health also one time (increase), erosion control two times (increases), as well as nutrient availability (Table 11). Although not reported here, but water conservation measures such stone bunds and terraces do need a high amount of labour input, albeit rather at the implementation phase with some maintenance work throughout time (De Graaff et al., 2008).

Table 11. Effect of stone bunds

Number of trials reporting:	Productivity	Soil health	Erosion control	Nutrient availability
Increase	1	1	2	1
Neutral	1	-	-	-
Decrease	-	-	-	-
Inconclusive	-	-	-	-

Source: own

3.4 Combined agroecological practices

3.4.1 Conservation agriculture

Conservation agriculture combines reduced or no-tillage and/or direct seeding with diversified crop rotations and the cultivation of cover crops / mulching for a permanent soil cover. In sum, three studies were retrieved for the review (Araya et al., 2021; Gatere et al., 2013; Micheni et al., 2016), reporting and researching nine on-farm trials, although as mentioned under 3.1, further full texts will be assessed which mainly research conservation agriculture.

[9] For the push-pull system see: Pickett et al. (2014)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Among the current on-farm trials all report on productivity (8 increase, 1 neutral), four report on profitability (increase) as well as labour savings. For the ecosystem service indicators two trials report increases, one neutral results, for nutrient availability one increase and 1 neutral, four report increases in water regulation, and three in carbon sequestration.
The retrieved studies and respective on-farm trials indicate increase in productivity and profitability as well as labour savings. However, as mentioned under the section Reduced tillage / no-tillage, labour can increase due to increased weeding requirements, especially if crop rotations and cover cropping is not optimally realized. Furthermore, there are also reviews indicating that crop yield increases cannot be generalized, specifically referring to smallholder farming in sub-Saharan Africa (Corbeels et al., 2020). Additionally, the authors state that specifically for maize, larger yield responses can be attributed to mulching and crop rotation adaptations.

Table 12. Effect of conservation agriculture

Number of trials reporting:	Productivity	Profit-ability	Labour savings	Soil health	Nutrient availability	Water regulation	Carbon sequestration
Increase	8	4	4	2	1	4	3
Neutral	1	-	-	1	1	-	-
Decrease	-	-	-	-	-	-	-
Inconclusive	-	-	-	-	-	-	-

Source: own

3.4.2 Crop-livestock integration

There have been no studies retrieved specifically comparing crop-livestock systems in on-farm trials to non-integrated farms. However, some of the benefits do relate to the application of manure as described in section 3.3.6. However, various reviews provide evidence that diversified crop-livestock systems provide numerous advantages in terms of ecological and economic benefits such as higher yields, savings in inputs, and increases in economic returns and profitability (Rosa-Schleich et al., 2019).

3.4.3 Organic agriculture

Organic agriculture (OA) can be defined as a system approach combining various agroecological practices that aim to enhance ecological processes and nutrient cycling. OA is specifically dependent on AEP as agrochemical inputs are not allowed in certified OA.
The search yielded only one study which contained on-farm trials in the envisaged geographic area. The retrieved study by Carvalheiro et al. (2010) researched in on-farm trials in South Africa the effect of pollination services in relation to the distance of natural habitats. More indirectly the effect of organic versus conventional cultivation on biodiversity and pollination was studied, although the results found no significant effect in differences among the two systems on the studied parameters.
The overall search results indicate a lack of primary studies and/or insufficient keywords. And indeed, many studies on organic farming are conducted on-station and most publications relate to temperate regions (Schader et al., 2021). However, a few long-term studies have been initiated researching the effect of organic farming on various indicators compared to a control in India, Kenya, and Bolivia (Adamtey et al., 2016; Armengot et al., 2016; Armengot et al., 2020), indicating that agroecological system approaches can be as productive as conventional systems, although depending on crop and management practices, while reducing synthetic pesticides and enhancing ecosystem services such as soil health.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

4 References

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K., . . . Berset, E. (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. *Agriculture, ecosystems & environment, 235*, 61-79.

Araya, T., Gebremedhin, A., Baudron, F., Hailemariam, M., Birhane, E., Nyssen, J., . . . Cornelis, W. (2021). Influence of 9 years of permanent raised beds and contour furrowing on soil health in conservation agriculture based systems in Tigray region, Ethiopia. *Land Degradation & Development, 32*(3), 1525-1539.

Araya, T., Nyssen, J., Govaerts, B., Deckers, J., Sommer, R., Bauer, H., . . . Cornelis, W. M. (2016). Seven years resource-conserving agriculture effect on soil quality and crop productivity in the Ethiopian drylands. *Soil and Tillage Research, 163*, 99-109.

Armengot, L., Barbieri, P., Andres, C., Milz, J., & Schneider, M. (2016). Cacao agroforestry systems have higher return on labor compared to full-sun monocultures. *Agronomy for sustainable development, 36*(4), 1-10.

Armengot, L., Ferrari, L., Milz, J., Velásquez, F., Hohmann, P., & Schneider, M. (2020). Cacao agroforestry systems do not increase pest and disease incidence compared with monocultures under good cultural management practices. *Crop Protection, 130*, 105047.

Balde, A., Scopel, E., Affholder, F., Da Silva, F., Wery, J., & Corbeels, M. (2020). Maize relay intercropping with fodder crops for small-scale farmers in central Brazil.

Barbosa, L. C., Magalhães, P. S. G., Bordonal, R. O., Cherubin, M. R., Castioni, G. A. F., Tenelli, S., . . . Carvalho, J. L. N. (2019). Soil physical quality associated with tillage practices during sugarcane planting in south-central Brazil. *Soil and Tillage Research, 195*, 104383.

Bedada, W., Karltun, E., Lemenih, M., & Tolera, M. (2014). Long-term addition of compost and NP fertilizer increases crop yield and improves soil quality in experiments on smallholder farms. *Agriculture, ecosystems & environment, 195*, 193-201.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications, 10*(5), 1251-1262.

Bhaskar, V., Bellinder, R. R., DiTommaso, A., & Walter, M. F. (2018). Living mulch performance in a tropical cotton system and impact on yield and weed control. *Agriculture, 8*(2), 19.

Blaser, W. J., Oppong, J., Yeboah, E., & Six, J. (2017). Shade trees have limited benefits for soil fertility in cocoa agroforests. *Agriculture, ecosystems & environment, 243*, 83-91.

Bucagu, C., Vanlauwe, B., & Giller, K. E. (2013). Managing Tephrosia mulch and fertilizer to enhance coffee productivity on smallholder farms in the Eastern African Highlands. *European Journal of Agronomy, 48*, 19-29.

Carvalheiro, L. G., Seymour, C. L., Veldtman, R., & Nicolson, S. W. (2010). Pollination services decline with distance from natural habitat even in biodiversity-rich areas. *Journal of Applied Ecology, 47*(4), 810-820.

Chikowo, R., Mapfumo, P., Nyamugafata, P., & Giller, K. E. (2004). Maize productivity and mineral N dynamics following different soil fertility management practices on a depleted sandy soil in Zimbabwe. *Agriculture, ecosystems & environment, 102*(2), 119-131.

Choudhary, K., Jat, H., Nandal, D., Bishnoi, D., Sutaliya, J., Choudhary, M., . . . Jat, M. (2018). Evaluating alternatives to rice-wheat system in western Indo-Gangetic Plains: crop yields, water productivity and economic profitability. *Field Crops Research, 218*, 1-10.

Choudhary, M., Jat, H. S., Datta, A., Yadav, A. K., Sapkota, T. B., Mondal, S., . . . Jat, M. L. (2018). Sustainable intensification influences soil quality, biota, and productivity in cereal-based agroecosystems. *Applied Soil Ecology, 126*, 189-198.

Corbeels, M., Naudin, K., Whitbread, A. M., Kühne, R., & Letourmy, P. (2020). Limits of conservation agriculture to overcome low crop yields in sub-Saharan Africa. *Nature Food, 1*(7), 447-454.

D'Annolfo, R., Gemmill-Herren, B., Graeub, B., & Garibaldi, L. A. (2017). A review of social and economic performance of agroecology. *International Journal of Agricultural Sustainability, 15*(6), 632-644.

De Graaff, J., Amsalu, A., Bodnar, F., Kessler, A., Posthumus, H., & Tenge, A. (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography, 28*(4), 271-280.

Delgado, J. A., Mosquera, V. H. B., Alwang, J. R., Aveiga, A., Ayala, Y. E. C., Neer, D., . . . López, L. O. E. (2021). Potential use of cover crops for soil and water conservation, nutrient management, and climate change adaptation across the tropics. *Adv. Agron, 165*, 175-247.

Derpsch, R., Friedrich, T., Kassam, A., & Li, H. (2010). Current status of adoption of no-till farming in the world and some of its main benefits. *International journal of agricultural and biological engineering, 3*(1), 1-25.

Erenstein, O. (2003). Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. *Agriculture, ecosystems & environment, 100*(1), 17-37.

Falconnier, G. N., Descheemaeker, K., Van Mourik, T. A., & Giller, K. E. (2016). Unravelling the causes of variability in crop yields and treatment responses for better tailoring of options for sustainable intensification in southern Mali. *Field Crops Research, 187*, 113-126.

FAO. (2021). Agroecology Knowledge Hub. Food and Agriculture Organization of the United Nations (FAO), Rome. Assessed on 24/08/2021: http://www.fao.org/agroecology/knowledge/definitions/en/.

Freyer, B., & Bingen, J. (2020). Resetting the African Smallholder Farming System: Potentials to Cope with Climate Change. *African Handbook of Climate Change Adaptation*, 1-27.

Gatere, L., Lehmann, J., DeGloria, S., Hobbs, P., Delve, R., & Travis, A. (2013). One size does not fit all: Conservation farming success in Africa more dependent on management than on location. *Agriculture, ecosystems & environment, 179*, 200-207.

Gathala, M. K., Timsina, J., Islam, M. S., Krupnik, T. J., Bose, T. R., Islam, N., . . . Ghosh, A. K. (2016). Productivity, profitability, and energetics: a multi-criteria assessment of farmers' tillage and crop establishment options for maize in intensively cultivated environments of South Asia. *Field Crops Research, 186*, 32-46.

Gathala, M. K., Timsina, J., Islam, M. S., Rahman, M. M., Hossain, M. I., Harun-Ar-Rashid, M., . . . McDonald, A. (2015). Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems: Evidence from Bangladesh. *Field Crops Research, 172*, 85-98.

Grote, U., Fasse, A., Nguyen, T. T., & Erenstein, O. (2021). Food security and the dynamics of wheat and maize value chains in Africa and Asia. *Frontiers in Sustainable Food Systems, 4*, 317.

Guadie, M., Molla, E., Mekonnen, M., & Cerdà, A. (2020). Effects of soil bund and stone-faced soil bund on soil physicochemical properties and crop yield under rain-fed conditions of Northwest Ethiopia. *Land, 9*(1), 13.

Guto, S., Pypers, P., Vanlauwe, B., De Ridder, N., & Giller*, K. E. (2012). Socio-Ecological Niches for Minimum Tillage and Crop-Residue Retention in Continuous Maize Cropping Systems in Smallholder Farms of Central Kenya. *Agronomy Journal, 104*(1), 188-198.

HLPE. (2019). Other Innovative Approaches for Sustainable Agriculture and Food Systems that Enhance Food Security and Nutrition. *High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security: Rome, Italy*.

IAASTD. (2009). Agriculture at a crossroads: Sub-Saharan Africa (SSA) report (Vol. V). International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). Washington, DC: Island Press.

IFAD. (2021). Stock-take report on agroecology in IFAD operations: An integrated approach to sustainable food systems. International Fund for Agricultural Development (IFAD), Rome, 112 p.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Kafesu, N., Chikowo, R., Mazarura, U., Gwenzi, W., Snapp, S., & Zingore, S. (2018). Comparative fertilization effects on maize productivity under conservation and conventional tillage on sandy soils in a smallholder cropping system in Zimbabwe. *Field Crops Research, 218*, 106-114.

Kearney, S. P., Fonte, S. J., García, E., Siles, P., Chan, K., & Smukler, S. M. (2019). Evaluating ecosystem service trade-offs and synergies from slash-and-mulch agroforestry systems in El Salvador. *Ecological indicators, 105*, 264-278.

Kebede, Y., Baudron, F., Bianchi, F., & Tittonell, P. (2018). Unpacking the push-pull system: Assessing the contribution of companion crops along a gradient of landscape complexity. *Agriculture, ecosystems & environment, 268*, 115-123.

Kerr, R. B., Madsen, S., Stüber, M., Liebert, J., Enloe, S., Borghino, N., . . . Wezel, A. (2021). Can agroecology improve food security and nutrition? A review. *Global Food Security, 29*, 100540.

Kiboi, M., Ngetich, K., Diels, J., Mucheru-Muna, M., Mugwe, J., & Mugendi, D. N. (2017). Minimum tillage, tied ridging and mulching for better maize yield and yield stability in the Central Highlands of Kenya. *Soil and Tillage Research, 170*, 157-166.

Kosgei, J. R., Jewitt, G., Kongo, V., & Lorentz, S. (2007). The influence of tillage on field scale water fluxes and maize yields in semi-arid environments: A case study of Potshini catchment, South Africa. *Physics and Chemistry of the Earth, Parts A/B/C, 32*(15-18), 1117-1126.

Kremen, C. (2020). Ecological intensification and diversification approaches to maintain biodiversity, ecosystem services and food production in a changing world. *Emerging Topics in Life Sciences, 4*(2), 229-240.

Lenka, N. K., Dass, A., Sudhishri, S., & Patnaik, U. (2012). Soil carbon sequestration and erosion control potential of hedgerows and grass filter strips in sloping agricultural lands of eastern India. *Agriculture, ecosystems & environment, 158*, 31-40.

Madembo, C., Mhlanga, B., & Thierfelder, C. (2020). Productivity or stability? Exploring maize-legume intercropping strategies for smallholder Conservation Agriculture farmers in Zimbabwe. *Agricultural Systems, 185*, 102921.

Martinsen, V., Mulder, J., Shitumbanuma, V., Sparrevik, M., Børresen, T., & Cornelissen, G. (2014). Farmer-led maize biochar trials: Effect on crop yield and soil nutrients under conservation farming. *Journal of Plant Nutrition and Soil Science, 177*(5), 681-695.

Masvaya, E. N., Nyamangara, J., Descheemaeker, K., & Giller, K. E. (2017). Is maize-cowpea intercropping a viable option for smallholder farms in the risky environments of semi-arid southern Africa? *Field Crops Research, 209*, 73-87.

Mavunganidze, Z., Madakadze, I. C., Nyamangara, J., Mafongoya, P., & Mashingaidze, N. (2020). Weed community responses to soil type during transition to no-till practice on smallholder farms in Zimbabwe. *Weed Research, 60*(5), 334-342.

Micheni, A., Kanampiu, F., Kitonyo, O., Mburu, D., Mugai, E., Makumbi, D., & Kassie, M. (2016). On-farm experimentation on conservation agriculture in maize-legume based cropping systems in Kenya: water use efficiency and economic impacts. *Experimental Agriculture, 52*(1), 51-68.

Migliorini, P., & Wezel, A. (2017). Converging and diverging principles and practices of organic agriculture regulations and agroecology. A review. *Agronomy for sustainable development, 37*(6), 1-18.

Mottet, A., Bicksler, A., Lucantoni, D., De Rosa, F., Scherf, B., Scopel, E., . . . Sourisseau, J.-M. (2020). Assessing transitions to sustainable agricultural and food systems: a Tool for Agroecology Performance Evaluation (TAPE). *Frontiers in Sustainable Food Systems, 4*, 252.

Mthembu, B. E., Everson, T. M., & Everson, C. S. (2018). Intercropping maize (Zea mays L.) with lablab (Lablab purpureus L.) for sustainable fodder production and quality in smallholder rural farming systems in South Africa. *Agroecology and Sustainable Food Systems, 42*(4), 362-382.

Mutuku, E. A., Roobroeck, D., Vanlauwe, B., Boeckx, P., & Cornelis, W. M. (2020). Maize production under combined Conservation Agriculture and Integrated Soil Fertility Management in the sub-humid and semi-arid regions of Kenya. *Field Crops Research, 254*, 107833.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924

Nair, V. D., Nair, P., Dari, B., Freitas, A. M., Chatterjee, N., & Pinheiro, F. M. (2017). Biochar in the agroecosystem–climate-change–sustainability nexus. *Frontiers in plant science, 8*, 2051.

Ndambi, O. A., Pelster, D. E., Owino, J. O., De Buisonje, F., & Vellinga, T. (2019). Manure management practices and policies in sub-Saharan Africa: implications on manure quality as a fertilizer. *Frontiers in Sustainable Food Systems, 3*, 29.

Ndayisaba, P. C., Kuyah, S., Midega, C. A. O., Mwangi, P. N., & Khan, Z. R. (2020). Push-pull technology improves maize grain yield and total aboveground biomass in maize-based systems in Western Kenya. *Field Crops Research, 256*, 107911.

Ndoli, A., Baudron, F., Sida, T. S., Schut, A. G., van Heerwaarden, J., & Giller, K. E. (2018). Conservation agriculture with trees amplifies negative effects of reduced tillage on maize performance in East Africa. *Field Crops Research, 221*, 238-244.

Obia, A., Mulder, J., Martinsen, V., Cornelissen, G., & Børresen, T. (2016). In situ effects of biochar on aggregation, water retention and porosity in light-textured tropical soils. *Soil and Tillage Research, 155*, 35-44.

Ojiem, J., Franke, A., Vanlauwe, B., De Ridder, N., & Giller, K. E. (2014). Benefits of legume–maize rotations: Assessing the impact of diversity on the productivity of smallholders in Western Kenya. *Field Crops Research, 168*, 75-85.

Ouédraogo, E., Mando, A., & Zombré, N. (2001). Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agriculture, ecosystems & environment, 84*(3), 259-266.

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., . . . Brennan, S. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *bmj, 372*.

Pickett, J. A., Woodcock, C. M., Midega, C. A., & Khan, Z. R. (2014). Push–pull farming systems. *Current opinion in biotechnology, 26*, 125-132.

Rosa-Schleich, J., Loos, J., Mußhoff, O., & Tscharntke, T. (2019). Ecological-economic trade-offs of diversified farming systems–a review. *Ecological Economics, 160*, 251-263.

Rusinamhodzi, L. (2015). Tinkering on the periphery: labour burden not crop productivity increased under no-till planting basins on smallholder farms in Murehwa district, Zimbabwe. *Field Crops Research, 170*, 66-75.

Schader, C., Heidenreich, A., Kadzere, I., Egyir, I., Muriuki, A., Bandanaa, J., . . . Lazzarini, G. (2021). How is organic farming performing agronomically and economically in sub-Saharan Africa? *Global Environmental Change, 70*, 102325.

Singh, R., & Singh, G. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energy, Ecology and Environment, 2*(5), 296-316.

Smith, A., Snapp, S., Chikowo, R., Thorne, P., Bekunda, M., & Glover, J. (2017). Measuring sustainable intensification in smallholder agroecosystems: A review. *Global Food Security, 12*, 127-138.

Sow, A., Seye, D., Faye, E., Benoit, L., Galan, M., Haran, J., & Brévault, T. (2020). Birds and bats contribute to natural regulation of the millet head miner in tree-crop agroforestry systems. *Crop Protection, 132*, 105127.

Uman, L. S. (2011). Systematic reviews and meta-analyses. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 20*(1), 57.

Vancampenhout, K., Nyssen, J., Gebremichael, D., Deckers, J., Poesen, J., Haile, M., & Moeyersons, J. (2006). Stone bunds for soil conservation in the northern Ethiopian highlands: Impacts on soil fertility and crop yield. *Soil and Tillage Research, 90*(1-2), 1-15.

Wezel, A., Soboksa, G., McClelland, S., Delespesse, F., & Boissau, A. (2015). The blurred boundaries of ecological, sustainable, and agroecological intensification: a review. *Agronomy for sustainable development, 35*(4), 1283-1295.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 861924