ISSN 1831-9424

European Commission

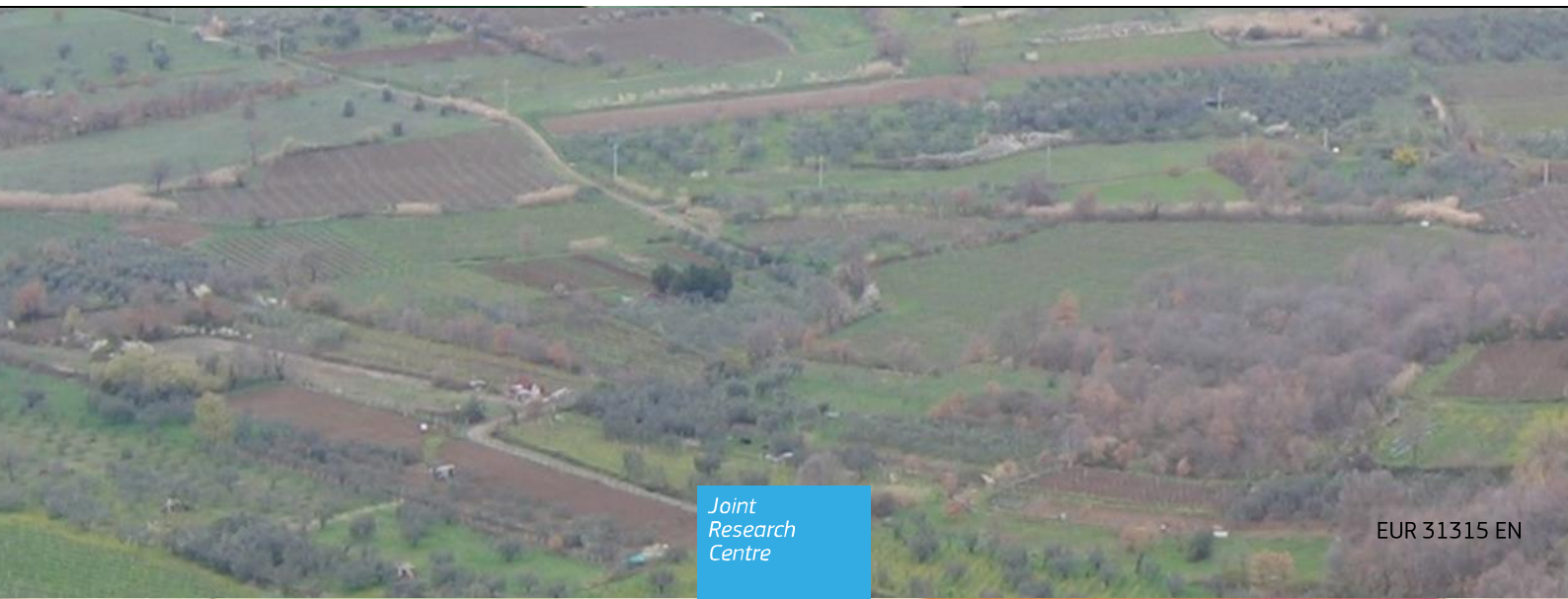
JRC TECHNICAL REPORT

Agroecological practices supporting food production and reducing food insecurity in developing countries
Volume 2

A study on scientific literature in nine countries

Paracchini M.L., Wezel A., Madsen S., Stewart B., Karuga J., Attard P., Rème L., Bezner Kerr R., Maes O., Zingari P.C.

2022



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JRC130395

EUR 31315 EN

PDF ISBN 978-92-76-59111-5 ISSN 1831-9424 doi:10.2760/059189 KJ-NA-31-315-EN-N

Luxembourg: Publications Office of the European Union, 2022

How to cite this report: Paracchini M.L., Wezel A., Madsen S., Stewart B., Karuga J., Attard P., Rème L., Bezner Kerr R., Maes O. , Zingari P.C., *Agroecological practices supporting food production and reducing food insecurity in developing countries - Volume 2*, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/059189, JRC130395.

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Abstract

This report is the second part of part of an effort to map existing knowledge on agroecological processes in 26 countries. Scientific literature has been screened, selected and synthesised for Bolivia, Burundi, Cameroon, Colombia, Cote d'Ivoire, Nigeria, Pakistan, The Gambia, Uganda, complementing the report "*Agroecological practices supporting food production and reducing food insecurity in developing countries*" (Paracchini et al., 2020[1]).

Approximately 50% of the analysed papers (278 documents in total for the two reports) reported a positive contribution of agroecological practices to food security, either direct or indirect, mostly due to improved yields, better economic situation of producers, improved resilience, enhanced diversification of production, availability of more nutritious food, diversified diet, and higher resilience to climate shocks. However, this contribution still needs to be quantified more precisely.

Agroecological approaches have the potential to make food systems more resilient to shocks. By improving soil fertility, agroecological farming is less dependent to chemical inputs. Many agroecological practices (e.g. agroforestry, intercropping, use of local varieties, etc.) contribute as well to climate change adaptation.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC121570

Acknowledgements

This report includes the results of studies carried out under the following contracts:

CT-EX2019D351242-102 (Agroecology for food insecure countries)

CT-EX2019D350866-102 (Agroecology for food insecure countries)

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1 Introduction

The Knowledge Centre for Global Food and Nutrition Security (KC FNS, https://ec.europa.eu/knowledge4policy/global-food-nutrition-security_en) supports the EU global commitment to end hunger, achieve food security and improve nutrition through a dedicated, reinforced science-policy interface and a fostered inter-policy dialogue.

Agroecology is one of the nine priority topics constituting the core activities of the KC FNS. This report represents the initial effort to map existing knowledge on agroecological processes in selected countries, chosen among the 60 developing countries in which food and nutrition security and sustainable agriculture represent a focal sector for EU intervention. The countries are: Bolivia, Burundi, Cameroon, Colombia, Cote d'Ivoire, Nigeria, Pakistan, The Gambia, Uganda. It complements the report "*Agroecological practices supporting food production and reducing food insecurity in developing countries*" (Paracchini et al., 2020[2]) in which scientific literature has been screened, selected and synthesised for 17 countries (Benin, Burkina Faso, Cuba, Ethiopia, Ghana, Guatemala, Kenya, Lao PDR, Madagascar, Malawi, Mali, Nicaragua, Niger, Senegal, Tanzania, Togo, Zimbabwe).

The report focuses on the identification and organization of existing scientific knowledge on the effectiveness of agroecology, in agronomic terms (e.g. effectiveness of individual farming practices), as well as by analysing agroecology as farming and food system. In particular, contribution to food and nutrition security and evidence of economic, social, environmental benefits are sought. Countries in Central and South America, Asia and Africa are represented in the two reports, with a majority of countries located in Africa. The reason why knowledge is synthesised per country is linked to a main characteristic of agroecology, which is by definition adapted to local conditions. By searching literature per country it is possible to draw a country profile, to link successful implementation to specific environmental and socio-economic conditions and provide thus useful information for the upscaling under similar conditions.

The definition of agroecology and its approaches adopted in this frame is the one proposed by the High Level Panel of Experts (HLPE) on Food Security and Nutrition in their Report 14 (HLPE, 2019)[3]:

"Agroecological approaches favour the use of natural processes, limit the use of purchased inputs, promote closed cycles with minimal negative externalities and stress the importance of local knowledge and participatory processes that develop knowledge and practice through experience, as well as more conventional scientific methods [...]. Agroecological approaches recognize that agrifood systems are coupled social–ecological systems from food production to consumption and involve science, practice and a social movement, as well as their holistic integration, to address food and nutrition security".

The identification of relevant scientific evidence is based on an adapted protocol for systematic literature review. The aim is not to have a comprehensive literature review of all the papers addressing agroecology, but to identify a set of papers that is able to provide information on the state of the art of knowledge in each country. Search and analysis were carried out individually on each of the selected countries.

The workflow adopted in the analysis is structured in four main steps, each one explained in detail in the following sections of the report:

Step 1. A common methodology was set up to allow the identification of a minimum number of relevant papers per country. Main scientific databases were screened, and grey literature repositories as well. The decision to include grey literature as additional source of information was taken due to the inhomogeneity of research results across the regions, with some countries being the object of extended scientific reporting and others lacking research efforts or not reported yet.

Step 2. Each selected paper was summarised in a table, structured in seven main themes and 38 sub-themes, spanning from the description of farming practices to that of economic benefits.

Step 3. The preparation of country briefs on agroecology for each of the analysed countries, synthesising available evidence.

[2] https://publications.jrc.ec.europa.eu/repository/handle/JRC121570

[3] HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

Step 4. General synthesis of main findings on the current status of scientific knowledge on agroecology in the analysed countries.

It is important to note that the country briefs presented in this report do not aim at describing the current state of implementation of agroecology in each country, but what is known about the effectiveness of such interventions at the scientific level. The fact that some positive (or negative) aspects are not addressed does not mean that they do not exist, but rather that they have not been the object of research. Overall the present study allows drawing some conclusions both on the benefits provided by the agroecological approach and on knowledge gaps, based on 106 documents (peer reviewed articles and grey literature) on a total of 2689 screened documents.

2 Methodology for document selection and analysis

2.1 Screening and sorting of scientific papers in the Web of Sciences database

The Web of Science (WoS) search engine was chosen as main source to build the database of scientific articles in the study.

For this purpose, three search strings, defined for the purpose of this study, were built:

- Search string 1: *(agroecolog* OR agro-ecolog* OR diversified farming systems OR ecological agriculture OR sustainable agriculture OR ecological intensification OR low input* OR organic farming) AND TS= (food security OR food insecur* OR food access* OR food sufficien* OR food insufficien*) AND CU=CountryName*
- Search string 2: *(agroecolog* OR agro-ecolog* OR diversified farming systems OR ecological agriculture OR sustainable agriculture OR ecological intensification OR intercrop* OR low input* OR agroforest* OR legume* OR green manure OR cover crop* OR no pesticides OR organic farming) AND TS=(food security OR food insecur* OR food access* OR food sufficien* OR food insufficien*) AND CU=CountryName*
- Search string 3: *(agroecolog* OR agro-ecolog* OR diversified farming systems OR ecological agriculture OR sustainable agriculture OR ecological intensification OR low input* OR organic farming) AND CU=CountryName*

Where: TS = Topic; CU=Country/Region

The search strings were applied for each concerned country (Bolivia, Burundi, Cameroon, Colombia, Cote d'Ivoire, The Gambia, Nigeria, Pakistan, Uganda), in addition to the Web of Science database, Search strings 1 and 2 were applied on the CAB Abstracts research database.

On the resulting set of articles, an additional criterion was applied: only articles published after the year 2000 were retained.

To identify the final selection of papers to be summarised, two procedures were possible:

1) A refined sorting was carried out on the basis of WoS study categories, since some documents retrieved by the search strings concerned topics not sufficiently related to agroecological practices. The keywords used were the following:

- *Agriculture multidisciplinary*
- *Agronomy*
- *Environmental sciences*
- *Water resources*
- *Ecology*
- *Green sustainable science technologies*
- *Multidisciplinary sciences*
- *Agriculture dairy animal science*
- *Nutrition dietetics*
- *Forestry*
- *Horticulture*

Papers resulting from this sorting were then screened according to the selection process described in 2.3.

2) After removing duplicates between the different equations and databases, each article was screened, reading the abstract and then «stoplighting» each article as either excluded (red), unsure if should be excluded (yellow) and green (include). This judgement was based on initial signs from the abstract that the research focused on some of the criteria outlined below in 2.3. After discussion between the team members, marginal articles were revisited to make a final call on exclusion or inclusion.

2.2 Grey literature screening

Articles from other sources (e.g. NGO reports, development project reports, consultancy studies, master student thesis) not listed in the WoS database were collected from databases hosted in research institutes

(e.g. CIRAD), from research partners, form NGOs working in the selected countries that were contacted by the authors, or identified from an internet research.

2.3 From screened papers to relevant literature selection

From the refined WoS list of documents and grey literature, a selection grid was elaborated to retain the most relevant documents only. In order to ensure the traceability of the information, the documents were labelled by name and type of document (provenance of WoS or grey literature) and a reference number was assigned to the article. In addition, for WoS papers, the number of search equation from which they originated (equation 1, 2 or 3) was reported. This made possible to identify the duplicates among the results of the three equations.

The relevance of the documents was based on several qualitative criteria including the presence of:

- *Data on food security*
- *Data on environmental aspects*
- *Economic data*
- *Social data*
- *Some information about the implementation of agroecological practices*
- *Elements of comparison between agroecological practices/conventional practices/traditional practices. This criterion also contains information on the notion of agroecological knowledge among farmers.*

These criteria were extracted from the summary of each document plus the materials and methods section when necessary.

The next step after this point could be option a) or b)

a) A scoring was set up to the selection grid to accept or reject documents. A score of 0, 1 or 2 was assigned to each of the 6 criteria listed above, and the sum of these scores gave a final score for each document. Empirically but consistently, when the final score was 6, the document was retained for full analysis. The selection threshold was reduced to 5 when number of selected documents was insufficient per country (less than 7).

If a document was scored 0 for one of the last two criteria, it was automatically rejected because it meant that it was not contributing to the subject or that no agroecological practice was reported. Overall, though, it had to be kept in mind that a selected article did not necessarily include relevant contributions on all criteria.

Finally, the database of selected articles resulting from this selection process was checked by specialists of partner institutions in the field. A file summing up the selected articles, according to the type of literature, was produced per country.

b) After two rounds of exclusion/inclusion based on abstract screening, included documents were summarised in the table as described in the next section. For each country, between 12-50 articles and grey literature documents were summarised. Through this process, the «best» 10-12 documents from each country could be identified. These were studies or reports that included information on food security and agroecological practices, making them relevant to KC FNS. A peer review process was used to check this selection process, with an expert external to the team of reviewers going through the initial summary table of grey and scientific literature to check that the final 10-12 documents were indeed the most relevant articles to be included in the country brief (Pakistan is an exception with 27 documents of grey literature identified as relevant for the analysis).

2.4 Summarising selected documents in a table

A table per country was set up to summarise each selected document. The structure of the table was made up of 7 groups of items elaborated by the authors:

- Source of information
- Contextualisation of the situation analysed
- Products/Inputs/Costs
- Multi-criteria assessment of agroecological production and services
- Quality of information for assessment
- Perception of the pros and cons
- Recommendation/advice

The reporting of quantitative data, where available, was essential. Cells were filled out as much as possible. If no information was available for some cells, they were filled with the mention “NA” (not applicable). The items included in the table are reported in Annex 1.

2.5 Preparation of country briefs

The knowledge acquired through the literature review was synthesised per country. Each synthesis included a general description of the agroclimatic profile of the country, a synthesis of agronomic practices described in literature, links to food security, a brief presentation of the agronomic practices covered in the relevant documents, the results regarding the effectiveness of implementation of agroecology in each country as reported by scientific literature, the contributions of agroecology to food security, relevant socio-economic aspects and relative environmental benefits. Finally, some conclusions were drawn.

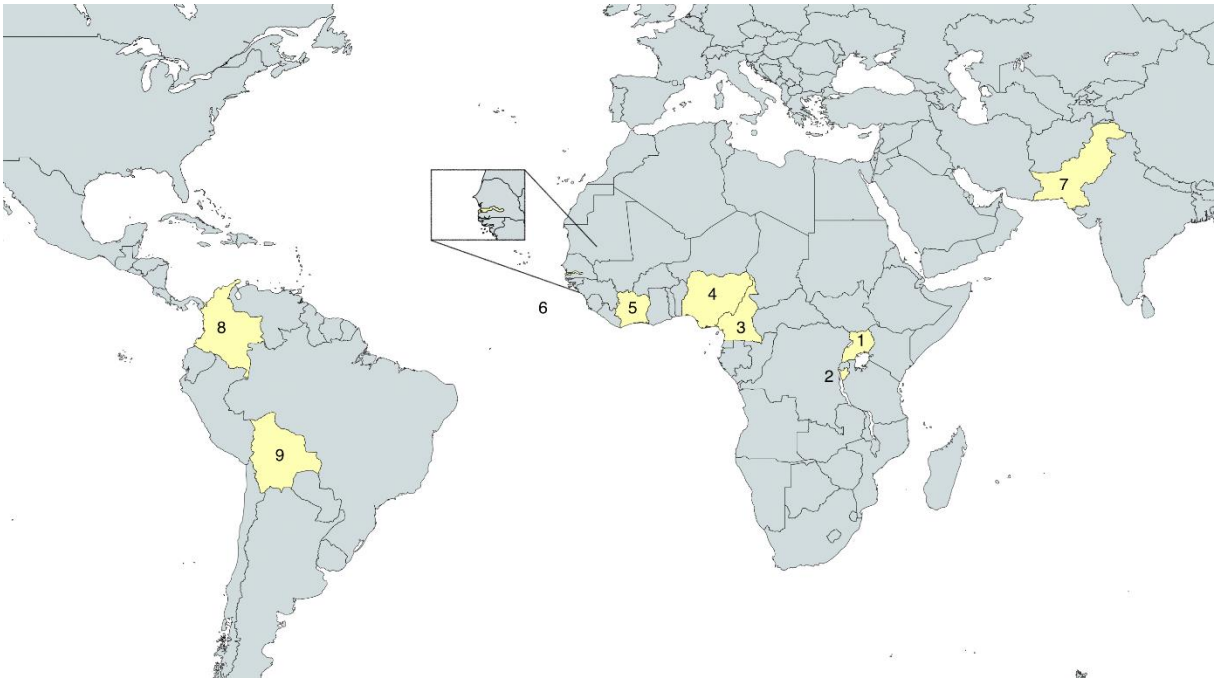
2.6 General synthesis

This sections contains the summary of the findings on the contribution of agroecological practices to food security in the nine selected countries (Figure 1), as resulting from the analysed literature, screened as described in chapter 2. Each profile contains the bibliographic references on which the profile is based.

3 Country briefs on agroecology

This section contains the summary of the findings on the effectiveness of agroecological practices in the seventeen selected countries (Figure 1) and four main geographical regions: West Africa, East Africa, South Asia, and South America, as resulting from the analysed literature, screened as described in chapter 2. Each profile contains the bibliographic references on which the profile is based.

Figure 1. Countries analysed in the present report[4]



1. Uganda
2. Burundi
3. Cameroon
4. Nigeria
5. Cote d'Ivoire
6. The Gambia
7. Pakistan
8. Colombia
9. Bolivia

[4] Copyright, European Union, 2022. Map created by EC-JRC. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.

3.1 Uganda

3.1.1 Country profile from the agro-environmental perspective[5]

Uganda is a landlocked country found on the eastern part of Africa with a total population of 34.9 million and a surface area of 241,000 km^2, of which 73% is arable land (World Bank 2020). About 72% of the population are peasant farmers cultivating an average less than 3 ha (NEMA 2014, UBOS 2020). Mean temperatures and rainfall in Uganda vary greatly based on elevation and landscape, ranging from 855-1703 mm/year of precipitation and 4-32° C respectively. Soils generally consist of a thin (20-30 cm) topsoil and a deep (5-10 m) subsoil, with organic matter and nutrients strongly concentrated in the topsoil. The favourable climate supports the common practice of rainfed agriculture, which influences agricultural productivity: extensive fields are found in low rainfall regions while fields in high rainfall regions are more productive.

The agriculture sector is the largest employer (81%) contributing 53% of Uganda total exports revenues, and 25% of total economic output (UBOS, 2020). 5.7 million ha are under food crops while 2.2 million ha are under permanent crops. Smallholder systems are mostly subsistence-oriented, growing maize, beans, groundnuts, cassava, millet, sorghum, sweet potato and banana. Farmers often allocate a smaller plot of land to cash crops, such as cotton, coffee, tea, cocoa tobacco, fruits and simsim. Local processing is minimal and marketing is widely done through farm gate traders and local marketplaces. Wood products such as timber and charcoal are also traded. Women and children are generally more involved in the production of foods crops, while men and hired labourers engage in commercial crop production.

3.1.2 Synthesis of agronomic practices

Selected studies focused mostly on small scale family farms in rural areas and intercropping was the most common agroecological practice examined. The majority of the studies focused on practices applied within field cropping systems, although livestock production was examined in relation to practices of agroecological management of manure, fodder and crop waste. These practices include intercropping, mixed cropping, integrated crop-livestock system, soil bunds, agroforestry, grass strips, water conservations practices (water harvesting equipment), integrated pest management, use of storage facilities for post-harvest practices and reduced tillage. Intercropping of banana-coffee followed by maize-beans or cassava were the most mentioned examples from the studies. Most practices mentioned were traditionally used in the study sites, although a few new practices had been introduced by NGOs or government agents.

3.1.3 Links to food security

The contribution of agroecological practices to household food security was measured using direct and indirect indicators. In most cases, total family income (farm and off-farm income) was used as a proxy for food security, although measurements such as staple and cash crops yield were also used as indicators of food security. The effectiveness of mixed cropping, crop rotations, and intercropping for combating food insecurity was the primary reason that farmers continued to use these agroecological practices (Mukadasi 2018). Substantial portions of farmers' fields were under staple crop cultivation, reducing the risk of having insufficient income for food purchasing (Karamura et al. 2013).

Intercropping and mixed cropping increased diversity and productivity of field cropping systems and traditional kitchen gardens (Jassonge et al. 2013a,b; Mubiru et al. 2018; Mukadasi 2018). Use of selected, improved and drought tolerant varieties of food security crops helped farmers to cope with the changing climate (Mubiru et al. 2018). Agroforestry system with fruit and nut trees on cropland and field boundaries contributed diversity to households' diets and supplied food during months of food scarcity (Ebifa-Othieno et al. 2017, Mukadasi 2018).

[5] UBOS, 2020. Uganda Annual Agricultural Survey 2018. Uganda Bureau of Statistics (UBOS), Kampala Uganda. https://www.ubos.org/wp-content/uploads/publications/AAS_2018_Report_Final_050620.pdf

NEMA, 2014. State of the Environment Report for Uganda 2014. National Environment Management Authority (NEMA), Kampal, https://nema.go.ug/sites/all/themes/nema/docs/FINAL%20NSOER%202014.pdf

World Bank, 2020. Agricultural land - Uganda.https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=UG

3.1.4 Sustainability assessment addressing the economic, environmental and social dimensions

The economic impact of agroecological practices was measured in four studies. Of these, three found that the use of agroecological practices was associated with positive benefits, measured as increased crop yields, product diversity, product quality and income. After diversifying their coffee plots, farmers found that intercropped banana plants generated income before coffee maturation and that, when coffee plants began to fruit, they earned income from both crops (Jassonge et al. 2013b). In addition, some farmers reported that the coffee produced was of better quality than that of the former (unshaded) systems. Further, the addition of a second crop added a secondary source of income for the farmer. Despite yield changes, overall farm income increased when Robusta and Arabica coffee varieties were intercropped with banana; in Robusta fields income increased $1400/ha/year (coffee monocrop) to $1900/ha/year (banana intercropping), and in Arabica fields from $2400/ha/year to $4400/ha/year (Jassogne et al. 2013a).

Other economic benefits mentioned included weed suppression through mulching with banana stalk, which lowered the labour cost of weeding. In another study, farmers mixed maize, beans and cassava, followed by maize and later cassava; this approach made staple foods available at different periods of the year (Mukadasi 2018). Ebifa-Othieno et al. (2017) found that, in tree-crop agroforestry system, diversifying yams or passion fruit production with *Tamaridus indica* tree species provided revenues from wood, food, medicinal leaves, fodder and charcoal, in addition to increasing the diversity of food diets. Agroecological soil management practices were used to reduce input costs, helping farmers to avoid the high costs associated with manure business and fertilizer (Karamura et al. 2013). No document addressed the cost of investing or transitioning to agroecological practices.

Farmers were knowledgeable about cropping diversity and soil conservation practices that improved landscape biodiversity and land management (Mukadasi 2018). Farmers explained that they continued to intercrop maize and beans, as they found that this traditional practice improved soil fertility (Fermont et al. 2009). Farmers used the soil fertility benefits of agroecological practices to reduce application of inorganic fertilizers and pesticides (Jassogne et al. 2013b), which can have negative environmental impacts. Indeed, the effectiveness of agroecological practices for sustaining soil health was given as a primary reason that farmers used traditional conservation methods like mixed farming, minimum tillage, agroforestry, soil bunds, water harvesting and manure application (Nyombi et al. 2006, Ebifa-Othieno et al. 2017, Mukadasi 2018). In one study, researchers found that practices of crop rotation, cover cropping, agroforestry, mulching, and manure/compost application did not have a measurable effect on soil fertility characteristics, although they acknowledged that their measurements might have failed to capture more localised effects of the practices (Nyombi et al. 2006). Another study found that agroecological practices of soil and water conservation, mulching and manure application, which modify nematode habitats, reduced nematode populations and subsequent crop damage (Karamura et al. 2013).

Regarding social aspects, Jassogne et al. (2013b) reported that intercropping coffee plantations gave women access to additional food and income sourced from banana plants. In another case, diversified agroforestry better met both men's and women's preferences, with men favouring those species with high economic value and women preferring those that met household consumption needs (Mukadasi 2018). Farmers were engaged in local, district and regional groups and marketing organizations (Mubiru et al. 2011, Jassonge et al. 2013b); in one study, 87% of farmers interviewed belonged to a local or district farmers group (Nyombi et al. 2010). Farmer networks provided financial loans and savings to members, and facilitated saving and exchanging of seeds/planting material with neighbours; these practices of social support lowered their input costs for packaging and transport logistics. Karamura et al. (2013) found that, based on generational knowledge, farmers could diagnose common crop diseases and pests and prepare organic treatments using local materials. Farmers acquired information on farming practices largely from neighbouring farmers and especially those from same organizations, NGOs and little from government agencies. Although the government does have a functioning agricultural extension agency, few farmers reported that they had received agricultural information or support from government agencies (Nyombi et al. 2010).

3.1.5 Promotion of agroecology in the country: evidence from the literature

No direct policy support to agroecology from the government appeared in the selected literature. Through government departments such as forest management department, promotion of agroforestry has been started (Mukadasi 2018). NGO support for community development and training programs has helped to disseminate agroecology, but most agroecological farming in-country is based on farmers' existing traditional

knowledge (Karamura et al. 2013, Ebifa-Othieno et al. 2017). Dissemination of agroecology has thus primarily been achieved through farmer-to-farmer exchange of knowledge and experience (Karamura et al. 2013).

3.1.6 Conclusion

Few articles examined the direct link between agroecological practices and food security; available evidence measured this relationship primarily in terms of staple or increased yields and diversified production. The lack of significant quantitative and qualitative data hinders the ability to make a clear statement about the food security outcomes of agroecology in Uganda. Many of the agroecological practices examined in the cases were not introduced, but reflected traditional farming approaches, of which some are under further development and expansion.

3.1.7 Number of analysed documents

The protocol for literature review applied in this study returned 527 scientific papers. Of these, 8 were considered matching the needs of the study. Grey literature screening returned 5 extra sources of information, but 0 were included after assessment.

3.1.8 References

3.1.8.1 Scientific papers

Ebifa-Othieno, E., Mugisha, A., Nyeko, P. and Kabasa, J. D., 'Knowledge, attitudes and practices in tamarind (Tamarindus indica L) use and conservation in Eastern Uganda', *Journal of Ethnobiology and Ethnomedicine*, 13. 2017 doi:10.1186/s13002-016-0133-8.

Fermont, A.M., Babirye, A., Obiero, H.M., Abele, S. and Giller, K.E., 'False beliefs on the socio-economic drivers of cassava cropping', *Agronomy for Sustainable Development*, 30, 2010, pp.433-444.

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Mukadasi, B., 'Mixed cropping systems for sustainable domestic food supply of the smallholder farming communities in Nakasongola District, Central Uganda', *Canadian Journal of Agriculture and Crops*, 3(1), 2018, pp.42-54.

Nyombi, K., Esser, B., Zake, J.Y.K., 'Efforts by Small-Scale Farmers to Maintain Soil Fertility and Their Impacts on Soil Properties, Luwero District, Uganda', *Journal of Sustainable Agriculture,* 27(4), 2006, pp.5-23.

3.2 Burundi

3.2.1 Country profile from the agro-environmental perspective

Burundi is a small, landlocked country situated in the Great Lakes Region of central Africa. The climate is tropical and humid, varying with altitudes and characterised by alternating rainy and dry seasons. Burundi contains five climatic and ecological areas, namely, the low Imbo flat country, the steep mountainous area of Mumirwa, the mountainous Congo-Nile watershed area, the Central plateau and the Kumoso and Bugesera depressions. Agriculture in Burundi composes 29% of GDP and employs 92% of the population (USAID 2020). Agriculture consists of mainly rain-fed cropping systems and production is largely subsistence-oriented. The major staple crops are cassava, bananas, maize, beans, rice, sorghum, and peanuts (Baramburiye et al. 2013, UN Comtrade 2021). Cash crops for export such as coffee, tea, and cotton play a large part in overall agriculture income. Of these, coffee commands the lion's share; in 2018, coffee accounted for 24% of agriculture export revenues, although in 2019 the percentage dropped to 20% (UN Comtrade 2021). Banana is a vital crop in Burundi both for the economy and food security. Banana is the second most produced crop in Burundi and, unlike coffee, much of the production of banana is consumed within Burundi; in 2019 Burundi exported just 0.05% of their 1.1 million tons harvest (FAO 2019). Burundi is often classified as a "low income country," where per capita GDP is 1.8% of the global average, and 10% of the regional average. Low income is linked to food security situation and Burundi scores a 35 on the global food security index (63 average globally; 43 average between other low income countries). 8% of children in Burundi are classified as 'severely underweight' (4% globally, 5% regionally) (USAID 2020). The food security and economic situation were made worse in the 1990s due to civil war. Several factors that contribute to food insecurity are lack of infrastructure in rural areas, climate change, soil erosion, and demographic pressure causing reduction of farm size.

The analysis that follows is based on the documents listed in the References, retrieved through the selection process described in chapter 2.

3.2.2 Synthesis of agronomic practices

There was very little literature that investigated agroecological practices in Burundi. Most research studies on agroecology were conducted on a sub-regional scale of the Great Lakes region of central Africa, which includes Burundi. Only three studies report specifically on agroecological practices: Banana-coffee intercropping (Jassogne et al. 2013), intercropping of avocado with other food crops (Hakizimana and May 2018), and a broad variety of practices used by farmers including some agroecological practices (Nyairo et al. 2014). Additionally, but not specifically on agroecological practices, strides have been made in Burundi to increase farmer access to knowledge exchange (Kessler et al. 2016) as these types of programmes have been shown to have the greatest effect on farmer income (Schut et al. 2016).

Jassogne et al. (2013) report on banana-coffee intercropping in Burundi, Uganda and Rwanda, though most information and more detailed studies comes from Uganda and Rwanda. Farmers increasingly resort to intercropping as a result of declining farm sizes, and in an effort to reduce risks related to income and food security. This practice was examined in the form of avocado intercropping within homestead crop production by Hakizimana and May (2018). Nyairo et al. (2014) investigated adaptations that farmers were making in two study regions as climate change began to pose a more serious threat to their production. Farmers were increasingly using practices of agroforestry (eg. fruit tree integration), composting, manure use, livestock integration, crop rotations, mulching, cover cropping, intercropping, and selecting improved and new varieties and crops.

3.2.3 Links to food security[6]

As food security (as rated by the 'food security index') in Burundi is critically low, the topic is at the forefront of any agricultural discussion. Therein, all agroecological practices studied are either directly or indirectly meant to address the issue of food security. Hakizimana and May (2018) investigated food security in the context of avocado production. While the study incompletely described specific growing practices, it relied on

[6] Niragira, S., D'Haese, M., D'Haese, L., Ndimubandi, J., Desiere, S., Buysse, J., 2015. Food for survival: diagnosing crop patterns to secure lower threshold food security levels in farm households of Burundi. Food and Nutrition Bulletin 36 (2), 196-210.

survey responses from 100 smallholder farmers, community workshops, and interviews to show that the practice of crop diversification with avocado trees generally improved food security. Avocados were a major subsistence crop for the surveyed smallholder farmers, which they consumed four times per week on average. In addition, avocados provided nutritionally important oils and fats that are expensive to purchase. The study concluded that, through direct consumption or agricultural income, children in households who diversified production with avocado trees were less likely to experience hunger.

More generally, by introducing diversification via intercropping, more food could be produced on the same amount of land. With land area in some regions becoming scarce, intercropping cash and food crops helped to manage risks linked to food insecurity (Jassogne et al. 2013). While yields of individual crops might reduce due to resource competition, the overall farm production increases brought by such systems were generally seen by farmers as a net benefit in terms of food security and income (Jassogne et al. 2013, Hakizimana and May 2018). Among the reasons farmers gave for intercropping coffee and banana were: the ability to harvest food from the banana plants throughout the year, as well as to generate a small continuous income from the surplus, both which benefit households' food security (Jassogne et al. 2013).

3.2.4 Sustainability assessment addressing the economic, environmental and social dimensions

Surveyed farmers reported multiple economic benefits of implementing coffee-banana intercropping, including increased income, drought resistance, coffee quality, and banana leaves as a source of free livestock fodder (Jassogne et al. 2013). When grown in the shade of banana plants, coffee is protected against climactic stressors such as intense heat waves or drought. Increased plant resilience reduced crop failure, leading to more reliable income in the long term. The micro-climatic benefits of banana-coffee intercropping improved water retention of the coffee plant, allowing coffee berries more time to fill and thereby increasing coffee bean quality and the potential to sell at a higher price (Jassogne et al. 2013). While intercropping creates resource competition between plants, potentially lowering yields, such systems improve the farm's overall resilience. Intercropped species were found to generate additional income and improve the farm's economic resilience to price volatility on markets for the primary crop (Jassogne et al. 2013, Hakizimana and May 2018).

While intercropping led to economic benefits in banana-coffee production systems, due to low financial capacity, not all farmers may be able to use certain agroecological practices or be able to guarantee sufficient quality and quantity of agricultural production (Schut et al. 2016). However, agroecological approaches also helped farmers to overcome financial constraints. Manure applications and livestock integration into cropping systems (especially agroforestry) were uniquely appealing agroecological techniques in Burundi as chemical fertilizers may be difficult to access either financially or physically. Therein, researchers found that 56% and 87% of respondents in their study area utilised manure fertilizer on the farm (Nyairo et al. 2014). Cost-saving benefits of agroecology were recognised by farmers in Burundi (also in Rwanda and Uganda), for whom mulching material had become increasingly scarce and expensive. Farmers reported that banana vegetation produced through intercropping banana with coffee served as in situ mulching material for the coffee (Jassogne et al. 2013). Environmental benefits of agroecological practices were most commonly examined in relation to climate change adaptation. In one study, farmers had begun to embrace diversity to mitigate the effects of climate change; 85% of respondents introduced a new crop into their systems, and farmers have begun to select more drought (water conservation) and disease resistant (less pesticide use) varieties, with implementation by 72% and 86% of farms respectively (Nyairo et al. 2014). Farmers implemented banana-coffee intercropping because they found that, when grown under banana shade and mulched with banana leaves, coffee was more resilient to drought (Jassogne et al. 2013). Other agroecological methods used in response to climate change include crop rotations, mulching, cover cropping, intercropping, contour ploughing, and limited irrigation although specific numbers were not given.

A new approach to knowledge dissemination based on cooperation among farmers' communities was found to effectively promote the implementation of ISFM (integrated soil fertility management) practices (Kessler et al 2016). Integrated soil fertility management is an agroecological practice which utilizes both organic and mineral fertilizers, which are then matched with appropriate germplasm and environmental conditions in order to maximise nutrient availability and reduce waste and input costs. The programme worked to organise farmers groups for the purpose of knowledge exchange to encourage experimentation and use of ISFM. Farmers involved in these knowledge exchange groups boosted vegetable production and diversification: for example, farmers were able to increase bean yields by 74%, gained access to new seeds selection, and learned new on-farm techniques such as creation of compost pits and use of organic fertilizer.

3.2.5 Promotion of agroecology in the country: evidence from literature

In this literature review, the lack of public financial investment or sensitive policy was identified as one of the main barriers to sustainable development of the agricultural sector. Schut et al. (2016) identified institutional and financial barriers to sustainable intensification, which often includes some agroecological practices, in the Central African Highlands of Burundi. These barriers included lack of adequate sensitization of the population for the adoption of innovation practices and absence of agricultural credit policies that can motivate the private sector to invest. Specifically, extension services are weakly spread over the territory, and thus farmers lacked information about key agricultural production techniques, such as diseases and pest management (for crops and livestock), and the use of insufficient improved varieties/breeds (Schut et al. 2016). For example, there were no banking services or insurance companies to provide access to credit in certain communes of the Giheta province in Burundi (Hakizimana and May 2018). Policies and research at a national level regarding implementation of agroecological practices were not documented in the literature. Although researchers identified the potential benefits of intercropping coffee and banana for smallholder farmers, many public and private development partners have not yet fully embraced this technology. National policies have historically favoured monoculture coffee production and intensification for making economic benefits from exports (Jassogne et al. 2013), and these policies are still dominant. Bottom-up approaches with the integrated farm plan approach have been effective for scaling-up sustainable agricultural practice, even if the future of those approaches depends greatly on the support at institutional and policy levels (Kessler et al. 2016).

3.2.6 Conclusions

Very little available literature investigated the use of agroecological practices in Burundi. Although some of the practices showed to have positive outcomes in terms of yield and thus influence positively income or self-consumption in households, no study measured direct evidence of food security outcomes. Indirect positive effects were reported in different studies but would need to be further verified. There is an absence of state support for agroecology promotion, and existing research and development efforts have been primarily promoted by organizations like FAO and CGIAR centres. The government seems to still support a more market-oriented sector, e.g. for coffee, and supporting specialization and higher levels of productivity.

3.2.7 Number of analysed documents

The application of the protocol for the literature review has returned 24 scientific papers from web of science, of which 5 were considered relevant. The grey literature provided no additional information.

3.2.8 References

3.2.8.1 Scientific papers

Hakizimana, C. and May, J., 'Can smallholder avocado production reduce poverty and improve food security through internal markets? The case of Giheta, Burundi', *Forests, Trees and Livelihoods*, 2018, DOI: 10.1080/14728028.2018.1515041

Jassogne, L., Nibasumba, A., Wairegi, L., Baret, P.V., Deraeck, J., Mukasa, D., Wanyama, I., Bongers, G. and van Asten, P.J.A., 'Coffee/Banana Intercropping as an opportunity for smallholder coffee farmers in Uganda, Rwanda and Burundi'. In: Blomme, G., van Asten, P., Vanlauwe, B. (eds.), *Banana Systems in the Humid Highlands of Sub-Saharan Africa*, CAB International, 2013, pp. 144-149.

Kessler, C. A., van Duivenbooden, N., Nsabimana, F. and van Beek, C.L., 'Bringing ISFM to scale through an integrated farm planning approach: a case study from Burundi', *Nutrient Cycling in Agroecosystems,* 105, 2016, pp. 249-261.

Nyairo, R., Onwonga, R., Cherogony, K. and Luedeling, E., 'Applicability of climate analogues for climate change adaptation planning in Bugabira Commune of Burundi', *Sustainable Agriculture Research,* 3 (4), 2014, pp. 46-62.

Schut, M., van Asten, P. Okafor, C., Hicintuka, C., Mapatano, S., Nabahungu, N.L., Kagabo, D. Muchunguzi, P., Njukwe, E., Dontsop-Nguezet, P.M., Sartas, M. and Vanlauwe, B., 'Sustainable intensification of agricultural systems in the Central African Highlands: The need for institutional innovation', *Agricultural Systems,* 145, 2016, pp. 165-176.

3.3 Cameroon

3.3.1 Country profile from the agro-environmental perspective[7]

Cameroon is often described as segmented into 5 major agro-ecological regions. In the South and Southwest, humid, hot, tropical forests provide good growing conditions for cocoa, coffee, and rubber while farmers in the semi-arid northern regions typically produce cotton and practice animal husbandry.

Like most African nations, agriculture is a major economic sector in Cameroon. While only 15% of the land in the country is arable, agriculture accounts for 44% of the nation's GDP and 70% of employment. About half of the country is covered by forests. Therein, agroforestry remains a cultural practice in some areas. Export productions include cocoa, coffee, cotton, rubber, sugar cane and lumber. Due to the high percentage of forests in the country, the timber industry accounts for one-tenth of export earnings despite the fact that only about one-third of the forests are accessible to lumber operations. Future development plans include expansion into new forested areas, worrying environmentalists.

While export agriculture provides 30% of total export revenue for the country, the percentage of crops exported is relatively low; 69% of agricultural production is used to meet national food consumption needs, while 7% is exported. Smallholder subsistence-oriented farmers produce most of the country's food crops, cultivating traditional regional crops such as millet, sorghum, peanuts, plantains, sweet potatoes, and manioc. Animal husbandry is also an important traditional farming practice and is often integrated into homegarden and agroforestry systems.

3.3.2 Synthesis of agronomic practices

Due to the high rate of forest cover in Cameroon, there exists a strong ethnic tradition of food sourcing from wild trees in forests and forests edges for a variety of products; food, fuel, fibre, fodder, and building material.

Figure 2. Example of homegarden agroforestry in Cameroon (erudef.org)

[7] Sources (in addition to those listed below):

Britannica, 2020. Agriculture, forestry, and fishing. https://www.britannica.com/place/Cameroon/Agriculture-forestry-and-fishing

FAO, 2020. Country profile Cameroon. http://www.fao.org/countryprofiles/index/en/?iso3=CMR&paia=2

MINADER, 2015. The State of Biodiversity for Food and Agriculture in the Republic of Cameroon. http://www.fao.org/3/CA3431EN/ca3431en.pdf

Agroforestry is thus an agroecological approach commonly practiced by farmers, and more than half of the included literature examined this practice. While there are different types of agroforestry, Cameroonian smallholders typically employ agroforestry within homegardens (Figure 1) integrated with livestock. This typically takes the form of intercropping food crops in aisles between trees and eventually some livestock is also fed in the homegarden area. The livestock fertilise the soil, control weeds, and can utilise the leaves of trees as fodder.

The cases also documented agroforestry practices applied in: home gardens without animals, trees on cropland, living fences, Taungya (planting food crops only while trees are young), and trees on grazing land (Awazi et al. 2020). Whether or not a farmer adopts agroforestry may depend on factors such as age, experience, family size, and access to extension services (Nkamleu and Manyong 2005). These results suggest that agroforestry may be most advantageous for subsistence farmers with homegardens, as it allows for intensive, diverse production in a small area.

Besides agroforestry, studies examined agroecological practices of intercropping (Nchanji et al. 2016, Singh et al. 2017) and no till (Brévault et al. 2007).

3.3.3 Links to food security

Although no article measured food security directly, all indicated that agroecological practices enhanced food security through increased yields or increased overall farm production diversity. Agroforestry, the most commonly studied agroecological practice, was found to improve food security in farming households by providing more diverse food sources via the introduction of new species of fruits and nut trees, the most common of which were *Persea americana, Psidium guajava,* and *Dacryodes edulis* (Awazi et al. 2020). Another food security benefit that farmers recognised in agroforestry systems was the ability to produce food, particularly fruit, during dry seasons, to fill nutritional gaps that occur after the main growing season has ended (Nchanji et al. 2016). Most subsistence crops were grown during the rainy season, therein, the dry season often corresponds to a lull in production.

Figure 3: Okra intercrop with a variety of crops (indiefarmer.com)

Intercropping is another method employed in agroecological farming systems in Cameroon. The primary food security benefits of intercropping include greater overall output per land area and improved yields through beneficial plant interactions, both of which increase yield and therefore food availability (Figures 3 and 4).

Figure 4: Oil palm intercropping with maize (opal-project.org)

For example, (Singh et al. 2017) examined different intercropping techniques on on-station field trails which are currently in use in Cameroon: Okra/bean, okra/maize, and okra/bean/maize. While decreased yields were observed when okra was intercropped with maize, intercropping of okra and beans led to a substantial yield increase in okra**,** providing farmers' access to a greater quantity and diversity of food. Another study documented the practice of intercropping food crops within young oil palm plantations (Nchanji et al. 2016) (Figure 3). The primary food crop intercropped with oil palm was plantain, but banana, cocoyam, yam, Egusi, groundnut, maize, vegetables, and cassava were also prevalent. While no industrial monoculture producers utilised the method, 90% of smallholders interviewed in Bamuso region of south-west Cameroon relied on these extra food crops during the unproductive, first 3-4 years of the plantation. Large producers feared that the intercropped species would increase competition over water and nutrients, although there was no conclusive evidence to suggest that intercropping in the early years of the plantation would affect palm oil yields (Nchanji et al. 2016).

While water and nutrient competition may adversely affect certain crops, if companion crops are well chosen, the inverse can be true and result in increased yields (Oakland Institute 2014; Nchanji et al. 2016).

3.3.4 Sustainability assessment addressing the environmental, social and economic dimensions

Several cases assessed how agroecological practices influenced farmers' financial viability (Oakland Institute 2014, Awazi et al. 2019; Awono et al. 2019). Awazi et al. (2019) and Awono et al. (2019) analysed survey information collected from farmers located throughout Cameroon and found that farmers valued agroforestry for the financial gains that on-farm diversification generated. Furthermore, Singh et al. (2017) found that overall profitability (revenue - costs) of diversified okra production with beans led to a 20% increase in profitability compared to okra monoculture. These financial gains resulted from the sale of novel crop varieties, which increased revenue sources. Diversifying production also reduced reliance on a single crop, mitigating the risk to food security and livelihood posed by a primary crop failure or a low market price for a single crop. Nchanji et al. (2016) found that food crop intercropping in oil palm plantations accounted for €1,297/year in income, €1,070 in labour returns (€247 in intensified production), and a net savings of €20 when seed cost was compared to the reduced weeding cost associated with intercropping.

In one study, smallholder farmers were well aware of threat posed to them by environmental changes (Awazi et al. 2019). Many farmers were gravitating toward agroecological methods (primarily agroforestry) to make their farms more resilient to drought and other climactic shocks. Agroforestry provides production during these times as deep tree roots are better able to locate ground water than seasonal food crops, enhancing resilience in the system. Indeed, Awazi et al. (2019) found that agroforestry was the favoured method farmers used to address climate change, with 28% of survey respondents choosing this method over alternative on-farm and off-farm adaptation options.

Most articles that examined agroforestry or intercropping measured species' biodiversity associated with the methods (Oakland Institute 2014, Nchanji et al. 2016, Singh et al. 2017, Sonwa et al. 2017, Awazi et al. 2020). One such example is that of agroforestry within cocoa plantations. Integrated trees provide shade to cocoa plants and habitats and nutrients for beneficial insect species. As a result, researchers found that tree diversity and density led to an increase in ant populations that provide a vital ecosystem service of soil aeration (Bisseleua et al. 2009). Biodiversity benefits were also documented in no-till production, which led to nearly a 70% increase in soil macrofauna, and up to a 180% increase when combined with mulching (Brévault et al. 2007). These numbers were species dependent. Soil macrofauna density can have direct links to plant health, long term yield, resilience, and reduced inputs.

While the literature search yielded few articles that examined the social implications of using agroecological practices, nearly all of the agroforestry articles discussed the benefits for family cohesion. Nchanji et al. (2016) argued that, in oil palm intercropping, the increased labour time required of such a system forces family and community members to work together more frequently and thus improved social interconnection. Increased income generated from these systems also translated into social benefits. For example, one study found that farmers were using revenues gained highest through agroforestry production to pay for children's education (30%), food (27%), medical expenses (25%), and household living expenses (12%) (Awono et al. 2010).

3.3.5 Promotion of agroecology in the country: evidence from literature

In general, agroecology in Cameroon is promoted by NGOs, non-profits, or multinational corporations. The primary goal of the Cameroonian government is economic development, and the country's policies favour capital-intensive cash crop monocultures over small-holder, diversified production. Of the studies referenced in this paper, nearly all of received partial or complete funding from an international research group, the most common being, CIRAD, IRAD-Cameroon, and IITA. Normally these research organizations are partnered with local and European universities for these projects. However, while the Cameroonian government does not actively implement projects in agroecology on the policy level, research institutions funded by the government still contribute substantial research to the field.

3.3.6 Conclusions

As global populations rise, food security has become a top priority, especially in Africa. Cameroon is one of the most vulnerable nations to climactic changes, which will affect agriculture more than most sectors. The majority of agroecological practices employed in Cameroon revolve around agroforestry and intercropping, strongly based on the principle of diversity and synergy in production systems. There is evidence that these practices have had positive economic and environmental outcomes, relevant to climate change adaptation. Indeed, several articles found that agroecological practices improved yields, although no articles provided evidence of direct linkages between agroecology and household food security and nutrition indicators.

3.3.7 Number of analysed documents

The application of the protocol for the literature review has identified 438 scientific papers from Web of Science, of these 9 were selected for further analysis. One grey literature source provided additional relevant information.

3.3.8 References

3.3.8.1 Scientific papers

Awazi, N.P., Tchamba, M.N. and Avana, T.M.L., ìClimate change resiliency choices of small-scale farmers in Cameroon: determinants and policy implications', *Journal of Environmental Management*, 250, 109560, 2019, https://doi.org/10.1016/j.jenvman.2019.109560

Awazi, N.P., Tchamba, M.N. and Temgoua, L.F., 'Climate-smart practices of smallholder farmers in Cameroon confronted with climate variability and change: The example of agroforestry', *Agricultural Research*, 2020, https://doi.org/10.1007/s40003-020-00477-0

Awono, A., Ndoye, O. and Preece, L., 'Empowering women's capacity for improved livelihoods in non-timber forest product trade in Cameroon', *International Journal of Social Forestry,* 3(2), 2010, pp.151-163.

Bisseleua, D.H.B., Missoup, A.D. and Vidal, S., 'Biodiversity conservation, ecosystem functioning, and economic incentives under cocoa agroforestry intensification', *Conservation Biology,* 23, 2009, pp.1176-1184.

Brévault, T., Bikay, S., Maldès, J.M. and Naudin, K., 'Impact of a no-till with mulch soil management strategy on soil macrofauna communities in a cotton cropping system', *Soil Tillage Research*, 97, 2007, pp.140–149.

Nchanji, Y.K., Nkongho, R.N., Mala, W.A. and Levang, P., 'Efficacy of oil palm intercropping by smallholders. Case study in South-West Cameroon', *Agroforestry Systems,* 90, 2016, pp.509–519.

Nkamleu, G.B. and Manyong, V.M., 'Factors affecting the adoption of agroforestry practices by farmers in Cameroon', *Small-scale Forest Economics, Management and Policy*, 4, 2005, pp.135-148.

Singh, A., Weisser, W.W., Hanna, R., Houmgny, R. and Zytynska, S.E., 'Reduce pests, enhance production: benefits of intercropping at high densities for okra farmers in Cameroon', *Pest Management Science,* 73, 2017, pp.2017-2027.

Sonwa, D.J., Weise, S.F., Nkongmeneck, B.A., Tchatat and M., Janssens, M.J.J., 'Structure and composition of cocoa agroforests in the humid forest zone of Southern Cameroon', *Agroforestry System*, 91, 2017, pp.451–470.

3.3.8.2 Grey literature

Oakland Institute, AFSA, *The agricultural and tree products program in Cameroon. Oakland Institute, Alliance for Food Sovereignty in Africa* (AFSA), 2014,
https://www.oaklandinstitute.org/sites/oaklandinstitute.org/files/Agroforestry_Cameroon.pdf

3.4 Nigeria

3.4.1 Country profile from an agro-environmental perspective[8]

Nigeria is a large country located in the tropical zone of West Africa. Three broad ecological zones are commonly distinguished in the country: i) the northern Sudan Savannah ii) the Guinea Savannah zone or Middle Belt, and iii) the southern rainforest zone (FAO 2016). The climate is semi-arid in the north and humid in the south and, except for an ultra-humid strip along the coast which experiences continuous rainfall, has distinct dry and wet seasons. Rainfall is concentrated in the period June-September and mean annual rainfall over the whole country is estimated at 1150 mm, ranging from 1000 mm in the centre of the country to 500 mm in the northeast. Low annual precipitation affects rainfed agriculture in northern areas, although in most agroecological zones it is the unpredictable spatial and temporal distribution of rainfall that negatively impacts agricultural production. Agricultural land makes up about 77 % of the total area of the country.

Nigeria's numerous agroecological zones accommodate a wide range of crop production: sorghum, millet, maize, groundnuts and cotton in the dry northern Sudan Savannah; cassava, yam, plantain, maize and sorghum in the Guinea Savannah; cash crop such as oil palm, cocoa and rubber in the south, and rice in the low-lying, seasonally flooded regions. The main exported agricultural commodities are cocoa, nuts and sesame, cocoa and cotton (FAO 2016, 2021). Agriculture remains the largest sector and employer of the Nigerian economy, employing 31 % of the economically active population (FAO 2016). Smallholder rural farmers still dominate the farming system, characterised by simple, low-input technology and low labour productivity. A typical Nigerian peasant farmer cultivates an average of 0.5 ha.

3.4.2 Synthesis of agronomic practices

Seven included case studies examined the application of agroecological practices on low input family farms and three case studies reported on-farm experiments often conducted in teaching and research farms (Ayoola and Adeniyan 2006, Oshunsanya 2013; Oku 2018). The most commonly studied agroecological practices were intercropping and mixed cropping strategies (Ayoola and Adeniyan 2006, Fawole and Oladele 2007, Oshunsanya 2013, Ifeanyi-Obi et al. 2017, Oku 2018, Adedapo et al. 2019, Okunlola et al. 2019). Depending on the study site, intercropping appeared in different forms. In the vetiver grass alley system described by Oshunsanya (2013), maize was intercropped with sweet potatoes and okra in mounds next to plantings of vetiver grass. In other cases, cassava was grown in a mixture with maize, cocoyam, okra and tomatoes (Fawole and Oladele 2007), or intercropped production systems included cassava-maize-melon (Ayoola and Adeniyan 2006). Intercropping was also practiced in agroforestry systems (Adedapo et al. 2019, Okunlola et al. 2019), in which annuals crops were grown with shade trees such as kola nut, orange, mango, and cocoa. Four types of common agroforestry systems are found in Nigeria[9]: scattered trees on farm land (parkland), row/hedges, trees on farmland, and wind breaks. Adedapo et al. (2019) found that most of the farmers practiced parkland, followed by windbreak/shelterbelt, live fencing systems, forest farming, alley cropping and riparian buffer systems. Two studies explored agroecological approaches to soil management (Ayoola and Adeniyan 2006, Oluwasusi 2014). Finally, no paper explored agroecological approaches to postharvest processing or reducing product losses. It is important to mention that the agroecological practices were never named as such, but often referred to as "climate-smart technology" or "strategies" to adapt to climate change.

3.4.3 Links to food security

In Nigeria, rainfed agriculture often fails to meet households' food requirements[1]. Five papers directly measured the contribution of the above-mentioned agroecological practices to food security in farming households: four found that agroecological practices contributed positively to food security (Fawole and Oladele 2007, Alao and Shuaibu 2011, Ifeanyi-Obi et al. 2017, Adedapo et al. 2019).

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[8] FAO, 2021. Nigeria at a glance. http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/
FAO, 2016. Country profile – Nigeria: AQUASTAT Report. FAO, Rome, Italy. http://www.fao.org/publications/card/en/c/I9807EN
FAO, 2014. World reference base for soil resources 2014: international soil classification system for naming soils and creating legends for soil maps. Rome: FAO.

[9] Shuaibu, B., 2013. Agroforestry practices and concepts in sustainable land use systems in Nigeria. Journal of Horticulture and Forestry 5, 156-159.

Fawole and Oladele (2007) found that family farmers' mixed-cropping systems reduced seasonal food insecurity, as it produced a variety of food all year long, even after the growing season ended. Cassava grown in mixture with maize, cocoyam, okra and tomatoes significantly increased yields, even as cassava served as an "insurance crop", available for harvest at any time to cover debt or any sudden needs (Fawole and Oladele 2007).

Compound farming, or producing a diversity of food crops and livestock on land located directly around the homestead, was a common practice farmers depended on to meet their household food security needs throughout the year (Ifeanyi-Obi et al. 2017). This diversified production of fruits provided a variety of food groups important to a healthy diet. Farmers harvested products from agroforestry systems that offered them food security benefits; these included food from fruit trees (mango, cashew, ornages, guava), and oil and soup condiments (oil palms, shea butter trees, African locust bean trees) (Alao and Shuaibu 2011, Adedapo et al. 2019). Agroecological practices of vetiver grass buffer strips were found to increase maize, sweet potato, and okra yields (Oshunsanya 2013, Oku 2018), but direct impact on food security was not measured.

3.4.4 Sustainability assessment addressing the economic, environmental, and social dimensions

Four studies investigated the potential of agroecological practices to generate higher income (Ifeanyi-Obi et al. 2017, Oluwasusi 2014, Okunlola et al. 2019, Adedapo et al. 2019). The soil and water conservation benefits derived from integrating yam, cocoyam or maize cultivation with trees led to better yields, which in turn resulted in higher incomes (Okunlola et al. 2019). Organic practices reduced the amount of production inputs needed to ensure crop productivity (Ayoola and Adeniyan 2006); farmers valued the cost saving that fewer inputs implied and found that these practice made farming more profitable (Oluwasusi 2014). In addition to avoiding food expenditures by producing their own food, compound farmers sold surplus to generate income that the family could then invest into purchasing other food items (Ifeanyi-Obi et al. 2017).

Seven studies documented ecological benefits derived from agroecological practices (Fawole and Oladele 2007, Alao and Shuaibu 2011, Oshunsanya 2013, Oluwasusi 2014, Oku 2018, Adedapo et al. 2019, Okunlola et al. 2019). Most found that agroecological approaches had positive effects on soil fertility and conservation (Fawole and Oladele 2007, Oshunsanya 2013, Oluwasusi 2014, Oku 2018, Adedapo et al. 2019). Practices of mixed-cropping and crop rotation improved soil health because crops with different nutrient demands were grown in sequence (Fawole and Oladele 2007), reducing the rate of fertility depletion. Vetiver grass alleys were associated with reduced water and nutrient runoff, and increased carbon and nitrogen sequestration, weed suppression and soil biodiversity (Oshunsanya 2013, Oku 2018). Similar benefits were found in agroforestry systems, which farmers perceived served to control soil erosion, regulate soil temperature, and allow the replenishment of nutrients (Alao and Shaibu 2011, Adedapo et al. 2019). Intercropping in agroforestry systems provided shade for associated crops and livestock, reducing crop damage from excessive sunlight and heat that is more prevalent due to climate change (Alao and Shuaibu 2011, Adedapo et al. 2019, Okunlola et al. 2019). Farmers reported that they used agroecological practices to mitigate the impacts of climate change (Okunlola et al. 2019).

Only one study investigated the direct link between agroecological practices and the social parameters. Oluwasusi (2014) observed that farmers favoured organic agricultural practices because they reinforced their knowledge of indigenous practices such as crop rotations, crop residues, animal manures, legumes, green manures, use of biological pest control to control insects, weeds, and other pests, and minimum tillage.

3.4.5 Promotion of agroecology in the country: evidence from the literature

There was little evidence of government support for the dissemination of agroecological practices or innovations. All scientific papers mentioned an obvious lack of extension agencies to train or educate farmers on sustainable practices. In addition, many papers observed that limited access to infrastructure (irrigation), affordable technologies to cope with climate change, and credit and insurance obstructed the adoption or further development of agroecological practices.

3.4.6 Conclusions

According to the selected literature, agroecological practices, in particular mixed/inter-cropping, agroforestry systems and organic agriculture, present considerable potential for providing economic, environmental and food security benefits. In particular, several studies emphasised the efficacy of agroecological practices for climate change adaptation, which was a primary driver behind farmers' decisions to use these approaches

(Oku 2018, Okunlola et al. 2019). While there are NGO initiatives to promote agroecological research and development projects, there is a lack of significant scientific data regarding agroecology's implementation and outcomes in Nigeria. There was consensus within all the included studies that more research programmes are needed to scale up agroecology in Nigeria.

3.4.7 Number of analysed documents

The protocol for literature review applied in this study returned 1257 scientific papers and 20 documents of grey literature. A final selection of 9 peer-reviewed papers has been included in the final analysis. No adequate grey literature was found.

3.4.8 References

3.4.8.1 Scientific papers

Adedapo, J.O., Zangina, A.S., Bolaji, O.W., 'Role of Agroforestry Practices in Sustainable Land Management in Rural Areas of Kaduna State, Nigeria', *African Journal of Earth and Environmental Sciences*, Maiden Edition, 2019, pp.13–21.

Alao, J.S. and Shuaibu, R.B., 'Agroforestry practices and preferential agroforestry trees among farmers in Lafia local government area, Nasarawa State, Nigeria', *Waste Management and Bioresource Technology*, 1, 2011, pp.12-20.

Ayoola, O.T. and Adeniyan, O.N., 'Influence of poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems in south west Nigeria'. *African Journal of Biotechnology*, 5 (15), 2006, pp.1386-1392.

Fawole, O.P. and Oladele, O.I., 'Sustainable food crop production through multiple cropping patterns among farmers in south western Nigeria', *Journal of Human Ecology*, 21 (4), 2007, pp.245–249.

Ifeanyi-Obi, C.C., Angba, A.O., Ajah, O.O. and Nnawuihe, P., 'Environmentally sustainable farm management strategies adopted by compound farmers in Mbaitoli Local Government Area, Imo State Nigeria', *Proceedings of the Annual Conference of the Agricultural Extension Society of Nigeria, Twenty-Second Annual Conference, 23rd -26th April, 2017*. Venue: University of Port Harcourt, River State, Nigeria.

Oku, EE.., 'Green farming practices for climate change mitigation and adaptation: A comparison of conventional practices and vetiver technology', in Saito, O., Kranjac-Berisavljevic, G. and Tekeuchi, K., *Strategies for Building Resilience against Climate and Ecosystem Changes in Sub-Saharan Africa*, Chapter 13, 2018, pp 237-246, DOI 10.1007/978-981-10-4796-1_13.

Okunlola, J.O., Oke, D.O., Adekunle, V.A.J. and Owolabi, K.E., 'Effects of climate change and coping strategies among crop farmers in South West, Nigeria', *Agroforestry Systems,* 93 (4), 2019, pp.1399-1408.

Oluwasusi, J.O., 'Vegetable farmers attitude towards organic agriculture practices in selected states of South West Nigeria', *Journal of Agricultural Extension and Rural Development,* 6 (7), 2014, pp.223-230.

Oshunsanya, S.O., 'Crop yields as influenced by land preparation methods established within Vetiver grass alleys for sustainable agriculture in southwest Nigeria', *Agroecology and Sustainable Food Systems*, 37 (5), 2013, pp.578-591.

3.5 Côte d'Ivoire

3.5.1 Country profile from the agro-environmental perspective[10]

Côte d'Ivoire is characterised by multiple regions segmented into four large agro-climatic zones based on biophysical and socioeconomic characteristics. They include the Sudan savannah, Guinea savannah, Western semi-mountainous forest zone, and forest zone in the south. The main cropping systems include food crop-based systems and perennial crop-based systems. The southern region near the Atlantic Ocean constitutes dense, tropical rainforests and experiences heavy rainfall in the rainy season. The Northern regions are classified as semi-arid and the midlands are primarily deciduous forest.

Agricultural production is one of the most important sectors of the Ivorian economy and politico-economic sphere. Agriculture constitutes 35% of GDP and 66% of exports. Production in Côte d'Ivoire is very specialised, with 55% of national export earnings arising from cocoa and coffee alone. The country is the world's largest producer of raw cocoa bean, generating 37% of global production. As such, the cocoa industry dominates agricultural policy and life within the country; it accounts for two-thirds of all employment, and is an income source for 800,000 cocoa farmers, 80-90% of whom are smallholder producers. Although the cocoa sector provides substantial employment opportunities, average income for cocoa farmers is very low.

3.5.2 Synthesis of Agronomic Practices

Six publications were selected that documented the use of agroecological practices in Côte d'Ivoire. Most dealt with agroforestry and intercropping in these systems (Gyau et al. 2014, Pye-Smith et al. 2016; Smith Dumont et al. 2014, Sanial and Ruf 2018). Other studies explored the agroecological practices of intercropping annual crops (Gnahoua et al. 2017) and crop rotations (Oka et al. 2018).

Figure 6: Cocoa with agroforestry (cirad.fr)

Figure 5: Cocoa with tree intercropping (pseudo-agroforestry) (cirad.fr)

Due to the socioeconomic importance of the cocoa sector, the most commonly examined agroecological practices were being applied to cocoa production and propagation. As the cocoa plant is naturally a shade tree, agroforestry has become an appealing agroecological method to increase both biodiversity and productive diversity (Figure 5). Intercropping food crops within cocoa fields (Figure 6) is another established practice. While intercropping other cash crops such as oil palm, kola nut, or coffee with cocoa is a common method for economic stability, much of cocoa intercropping takes place within agroforestry systems. For

[10] FAO, 2020. Country profile Cote d'Ivoire. http://www.fao.org/countryprofiles/index/en/?iso3=CIV
Malan, B.B., 2013. Volatility and stabilization of the price of coffee and cocoa in Côte d'Ivoire. Agricultural Economics 59, 333–340.

example Gyau et al. (2014), found that 80% of surveyed cocoa farmers in south-west region utilised agroforestry and 68% intercropped cocoa with food crops.

In the majority of the selected studies, local forms of agroecology were grounded in traditional methods. Agroforestry in itself is a cultural practice in Côte d'Ivoire, which stems from a long history of farmers harvesting forest products from nearby rainforests for increased production. Intercropping is also a traditional practice that farmers use to address the issue of low nutrient availability. Chemical and biological fertilizer are often too expensive or not physically available to farmers, and intercropping allows for fertilization through plants that fix nitrogen, such as cowpea (Gnahoua et al. 2017).

Some publications documented traditional agroecological practices, while others focused on improving upon them with scientific methods. Oka et al. (2018) surveyed Ivorian food crop farmers to identify traditional practices for producing yams, a vital staple crop. The authors found that many farmers utilised agroecological practices but lacked the scientific knowledge to make them as productive as possible. For example, the study recognised that the agroecological principle of crop rotation was already in use, but the selected rotation was sub-optimal; as such, the researchers recommended a more effective rotation for nutrient management. Yams are typically the first in crop rotation following a fallow/slash and burn. Rotations often include rice, maize, cotton ground nuts, or cashews. In some cases, yam is cultivated in mixed cropping, in particular with vegetable crops (e.g. tomatoes, chili pepper, eggplants) and cassava, and also intercropped with cashew trees when the intention is to turn the plot into a plantation.

3.5.3 Links to food security

None of the studies measured food security directly, but some discuss which practice could enhance food security and nutrition. Cocoa farmers who have integrated agroforestry into their systems have come to rely on these trees as vital aspects of their household food security and many farmers rate this as their top reason for employing this practice (Smith Dumont et al. 2014). Many of the trees used to diversify cocoa plantations produce fruits and nuts, the three most common being *Persea Americana, Citrus sinensis,* and *Cola nitida*. In the same study, 70% of farmers also intercropped their fields between trees and cocoa plants with food crops, further adding to their food security.

In another study, integrated soil fertility management (ISFM) strategies such as manure fertilizer and intercropping with cowpea produced higher cassava yields than local methods, providing greater availability of this important staple crop as well as additional food from legume crops (Gnahoua et al. 2017). Yam, a further vital staple food crop for Côte d'Ivoire that is also used in crop rotations, is seen as a major component of food security (Oka et al. 2018).

3.5.4 Sustainability assessment addressing the economic, environmental, and social dimensions

As a large proportion of farmers rely on cocoa for their primary income, they are vulnerable to the vast price fluctuations that characterise the cocoa market. It has been shown that the price of cocoa tends to vary 30% more than other agriculture products (Malan 2013) and that farmers bear the brunt of the consequences for this volatility (Fountain and Hütz-Adams 2018). Agroforestry and intercropping within cocoa fields can introduce novel crops that boost overall farm output and income, reducing farmers' vulnerability to low cocoa prices. Analysis of survey data found that diversified agroforestry systems increased farmers' income through improved cocoa yields and the sale of harvested products, such as fruit, nuts, and timber (Gyau et al. 2014). Cash crops such as kola nut are regularly intercropped to further bolster profits and such a combination is vital to the economic viability of many farmers (Sanial and Ruf 2018). Finally, in one study, practicing integrated soil fertility management and cassava-cowpea intercropping increased the economic profitability of this production system by a factor of 10 compared to local methods (Gnahoua et al. 2017).

To increase agricultural productivity, farmers in Côte d'Ivoire may deforest and plant new fields to increase production, rather than intensifying production on existing plots. The situation is linked to Côte d'Ivoire's rank as one of the most heavily deforested countries in the world[11], (Achard et al. 2002). Agroecological practices of agroforestry and intercropping have been introduced as methods with potential to sustain forested areas

[11] Achard, F., Eva, H.D., Stibig, H.J., Mayaux, P., Gallego, J., Richards, T., Malingreau, J.P., 2002. Determination of deforestation rates of the world's humid tropical forests. Science 297 (5583), 999-1002.

and farmers' livelihood through productive diversification. Diverse agroforestry systems create habitats for beneficial insects, and improve soil fertility, structure, and water retention. One study found that diversifying cocoa plantations with kola trees can provide ecosystem services, as the kola tree provided habitat to red ants that controlled populations of the devastating mirid pest (Sanial and Ruf 2018). In south-west Côte d'Ivoire, 70% of cocoa farmers utilising intercropping and agroforestry believed that the shade provided by trees reduced heat stress on cocoa plants and 53% saw benefits in soil fertility. Other environmental benefits recognised by farmers included the trees' ability to "bring rain," increase soil moisture, and control erosion at 28%, 24%, and 22% of respectively (Smith Dumont et al. 2014).

Only one study directly mentioned social implications of agroforestry systems. In farms that practice kola intercropping with cocoa trees, income from kola nuts was customarily controlled by women and often used to cover expenses for children, especially their school fees (Sanial and Ruf 2018).

3.5.5 Promotion of agroecology in the country: evidence from literature

National agricultural policies favour export-oriented intensive cocoa production over diversified farming systems that might better support smallholder subsistence farmers to access a greater variety of food and income sources. Policies also largely target large cocoa plantation production over smallholder production, despite the fact that the vast majority of the agricultural sector is composed of smallholder farmers. There is no evidence of national programs or policies that support the development and adoption of agroecological practices. Most programmes designed for the dissemination of agroecology are developed by NGOs and foreign multinationals, but many were found to insufficiently understand smallholder needs and rarely produce beneficial outcomes for farmers (Sanial and Ruf 2018).

3.5.6 Conclusions

The majority of studies examined agroecological practices of agroforestry and intercropping. Positive evidence of environmental and economic impacts was found for both diversification approaches, measured as improvements in yield or income, species diversity, and farmers' perceptions of climatic conditions. Although the literature indicated potential positive effects on food security and nutrition, none directly assessed agroecological practices' impact on households' access to stable and adequate diets.

3.5.7 Number of analysed documents

The application of the protocol for the literature review identified 252 scientific papers from Web of Science; of these 6 were selected for further analysis, as they contained valuable information about agroecological practices. Five grey literature documents were identified, of which one was selected for inclusion.

3.5.8 References

3.5.8.1 Scientific papers

Gnahoua, J.B.G., Ettien, D.J.B., N'Zué, B., Ebah, C., Koné, B., De Neve, S. and Boeckx, P., 'Intensification pathway for improvement of smallholder cassava production systems in southern Côte d'Ivoire', *Experimental Agriculture*, 53, 2017, pp. 44–58.

Gyau, A., Smoot, K., Kouame, C., Diby, L., Kahia, J. and Ofori, D., 'Farmer attitudes and intentions towards trees in cocoa (Theobroma cacao L.) farms in Côte d'Ivoire', *Agroforestry Systems*, 88, 2014, pp.1035-1045.

Oka, E. and Floquet, A., 'Local Dioscorea sp production systems and their potential for agroecological practices in the central part of Cote d'Ivoire', in: *13th European International Farming Systems Association (IFSA) Symposium, Farming Systems: Facing Uncertainties and Enhancing Opportunities*, 1-5 July 2018, Chania, Crete, Greece, 2018, pp. 1–18.

Sanial, E. and Ruf, F., 'Is kola tree the enemy of cocoa? A critical analysis of agroforestry recommendations made to Ivorian cocoa farmers', *Human Ecology*, 46, 2018, 159-170.

Smith Dumont, E., Gnahoua, G.M., Ohouo, L., Sinclair, F.L. and Vaast, P., 'Farmers in Côte d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services', *Agroforestry System*, 88, 2014, pp.1047-1066.

3.5.8.2 Grey literature

Pye-Smith C, Kouame C, Toledano Y. 'A brighter future for cocoa farmers: How the Vision for Change programme is raising productivity and improving rural livelihoods*', ICRAF Trees for Change no. 13*, World Agroforestry Centre, Nairobi, Kenia, 2016.

3.6 The Gambia

3.6.1 Country profile from the agro-environmental perspective[12]

The Gambia is a small West-African country, and among the poorest nations in the world, according to its Human Development Index rank. Agriculture is the largest sector of the economy, accounting for 33% of the national GDP, and involving 75% of the labour force, half of which are women. The country's population of approximately 1.9 million inhabitants skews younger and the majority resides in urban areas. The Gambia has three main agroecological zones that define its agricultural production systems: the Sudano-Sahelian zone or Riverine zone, the Sahel-Savana zone or semi-arid zone and the Guinea-Savana zone. The country has a tropical climate, alternating between dry and rainy seasons, and temperatures are higher inland than on the coast. Farming is primarily rainfed and subsistence-oriented. Smallholder farmers produce staple crops like millet, rice and sorghum, along with fruits and vegetables. The main cash crop is groundnut, which is exported either in shell or as oil. However, The Gambia depends on imports of staple foods, in part due to low agricultural productivity. Poverty in the country is high and will likely continue to be exacerbated by climate change, with extreme temperature, reduced rainfall and drought, and salinity intrusion impacting Gambian agriculture. Mean annual temperatures are expected to increase between 1.8 and 5.0°C, while sea level will rise between 0.4-0.7 m by the end of the century.

3.6.2 Synthesis of agronomic practices

Reflecting the country's small geographical area, there was little literature available that examined agroecological practices in smallholder or other farming systems in The Gambia. Those agroecological practices studied included the use of organic manure and crop residues, seed selection (Eldon et al. 2020), crop diversification and selection of drought-resistant or early maturing varieties (Kutir et al. 2015), mulching with tree leaves or integrating trees into cropping systems (Stoate and Jarju 2008). ActionAid (2017) examined climate smart agriculture projects that included some agroecological practices such as intercropping, mixed cropping, use composting, use of traditional, early maturing seed varieties, mulching, and the use of botanical pesticides.

3.6.3 Links to food security

All articles found positive, indirect links between agroecological practices and food security at the household or village scale (Stoate and Jarju 2008, Kutir et al. 2015, ActionAid 2017, Eldon et al. 2020). Reported outcomes were only assessed in terms of farmers' perceptions or yield increases, which can potentially lead to improvements in food security through direct consumption and agricultural income pathways. The application of organic manure or millet husk crop residues had positive effects on yields in 72% of cases, and when these practices were combined with lower rates of inorganic fertilizer application, yields improved for 84% or more of cases (Eldon et al. 2020). Farmer experimentation with tree integration with field crops identified that the mulch of one species, *Guiera senegalensis*, was particularly effective for increasing groundnut yields (Stoate and Jarju 2008). Finally, the majority of the farmers (88%) indicated that the climate change adaptation strategies they implemented, which included agroecological practices were effective, but no assessment of individual practices was provided (Kutir et al. 2015). Research conclusions are mostly based on the potential implementation of new practices according to farmer perceptions.

3.6.4 Sustainability assessment addressing the economic, environmental and social dimensions

Several studies reported that the use of agroecological practices was linked to yield improvements (Stoate and Jarju 2008, Kutir et al. 2015, Eldon et al. 2020), which can lead to improved earnings from crop sales. For example, Eldon et al. (2020) found that soil fertility management of different crops with organic amendments, combined with inorganic fertilizer and improved seed varieties, led to yield improvements for farmers in The Gambia and Senegal. A similar study found that millet yields were 37% higher on plots where tree leaf mulch and a half-rate of fertilizer had been applied than on plots where only fertilizer was applied

[12] FAO, 2010. Nutrition country profile republic of the Gambia. Nutrition and Consumer Protection Division. FAO, Rome, Italy, http://www.fao.org/3/a-bc628e.pdf

(Stoate and Jarju 2008). The literature also revealed that agroecological production was often associated with reduced expenditure on inputs, making these practices accessible to more farmers (Stoate and Jarju 2008, ActionAid 2017, Eldon et al. 2020). The practice of amending soil with millet husks might be particularly beneficial for the poorest households in the region with this crop, who are often highly dependent on millet production and can be expected to have difficulty purchasing commercial inputs (Eldon et al. 2020). The combination of these organic soil amendments with improved seed varieties were only found to increase yields for an additional 1-8 % cases compared to the use of local seed varieties, indicating that this agroecological approach provides suitable conditions for farmer-saved seed. This is an important characteristic, as seed saving was farmers' preferred seed sourcing method, and avoided the production cost of purchasing new certified seed stock. Based on these results, Eldon et al. (2020) concluded that there is not sufficient justification for the promotion of certified new cultivars and applying high rates of inorganic fertilizer as the single "best practice", which is still the leading recommendation from national governments.

Reported environmental benefits of agroecological farming included supporting ecosystem services, reduced pesticide application, and climate change adaptation. Stoate and Jarju (2008) found that the integration of indigenous trees on farmed land increased availability of mulching material from leaves, contributed to soil and water conservation; notably, soil organic matter was significantly higher on plots where tree leaf mulch had been applied compared to plots where it had not been used. These ecosystem services have benefited individual farmers and the wider community. As a result, more farmers value these species and plant them; for example, *Faidherbia albida,* an important and multi-purpose tree in many savannah areas in West Africa, has been increasingly planted on farmland. In another project, Action Aid (2017) reported a huge expansion in the application of botanical pesticides by smallholder farmers, who favoured this approach to pest management because, compared to chemical pesticides, it was more affordable and safer for people and the environment. Finally, Kutir et al. (2015) examined farmers' main climate adaptation strategies, which included a number of agroecological practices, such as crop diversification, crop rotations, soil and water conservation, in addition to other practices of using drought resistant cultivars and early maturing varieties, applying chemical fertilizers and prayer/ritual offerings. 61% of surveyed farmers reported that these strategies successfully mitigated the effects of climate change, either by increasing crop production, or ensuring that crops matured early. 7% of the respondents indicated that their response strategies were effective because crop diversification provided alternative food and income sources.

Research and discussion of social and gender dynamics of agroecological production was absent from all scientific articles (Stoate and Jarju 2008, Kutir et al. 2015, Eldon et al. 2020) and grey literature. This is a considerable knowledge gap, as women constitute about half of the agricultural labour force, particularly in horticulture and small- animal husbandry. Fields are managed by both men (53 %) and women (47%), with rice and horticulture areas mostly dominated by women. Overall, gender inequality remains in social recognition, land property and income[13].

3.6.5 Promotion of agroecology in the country: evidence from literature

No clear statements on agroecology were found in the literature regarding national policies or official state documents. Agroecology is primarily promoted through grassroots innovation and NGO-funded projects[14], which do not always provide clear evidence but just general descriptions of achievements.

3.6.6 Conclusions

Access to food is a major problem in The Gambia; the country produces a maximum of 50% of its national requirements of food staples. The new government aims to prioritise rural development, with goals of increasing overall productivity to feed the growing urban population, while stabilising the livelihoods of its rural population. Of the scarce available publications that examined agroecology within the country, all concluded that the agroecological approaches had the potential to improve food security or nutrition of

[13] FAO and ECOWAS Commission, 2019. National Gender Profile of Agriculture and Rural Livelihoods – The Gambia. FAO, Country Gender Assessment Series, Banjul, The Gambia. http://www.fao.org/3/ca3222en/ca3222en.pdf

[14] REAP (Resource Efficient Agricultural Production – Canada), 2006. The Gambia agro-ecological village development project. Final Report. Resource Efficient Agricultural Production, Sainte Anne de Bellevue, Quebec, Canada.
https://www.reap-canada.com/online_library/IntDev/id_gambia/Gambia%20-%20GAEV%20Final%20Project%20Report%20-%20(2006).pdf

farmers' households but performed no direct investigation of this outcome. The included literature primarily used qualitative research methods or on-farm experiment to assess the outcomes of agroecological practices and the only positive outcomes linked to food security were documented as yield increases.

3.6.7 Number of analysed documents

The application of the protocol for the literature review has identified 23 scientific papers from web of science, of these 3 could be selected for further analysis. One grey literature source provided additional information.

3.6.8 References

3.6.8.1 Scientific papers

Eldon, J., Baird, G., Sidibeh, S., Dobasin, D., Rapaport, P., Cheng, W. and Shennan, C., 'On-farm trials identify adaptive management options for rainfed agriculture in West Africa', *Agricultural systems*, 182, 2020, DOI: 10.1016/j.agsy.2020.102819.

Kutir, C., Baatuuwie, B.N., Keita, S. and Sowe, M., 'Farmers awareness and response to climate change: a case study of the North Bank Region, The Gambia', *Journal of Economics and Sustainable Development*, 6 (24), 2015, pp.32-41.

Stoate, C. and Jarju A.K., 'A participatory investigation into multifunctional benefits of indigenous trees in West African savanna farmland', *International Journal of Agricultural Sustainability,* 6 (2), 2008, pp.122-132, http://dx.doi.org/10.3763/ijas.2008.0299

3.6.8.2 Grey literature

ActionAid, 'Agroecology: Climate resilient sustainable agriculture for adaptation to climate change in The Gambia', *52 Profiles on Agroecology*, 2017, http://www.fao.org/3/a-bt150e.pdf

3.7 Pakistan

3.7.1 Country agro-environmental profile

According to the official UN data, the Islamic Republic of Pakistan land area covers 771,000 km^2. Arable lands cover 312,000 km^2 (40% of the total land area), permanent crops 7,900 km^2 (1%), and forests 14,700 km^2 (2%). With a population of 221 million in 2020, Pakistan is the fifth most populated country in the world with one of the highest growth rates varying from an annual 1.7 to 2.03%. The Human Development Index is 0.557 in 2019, scoring 152nd in the world list. Geographically Pakistan consists of four main areas: the northern Himalayan mountains (Karakoram, Hindu Kush, and Pamir), the large arid desert and mountainous Baluchistan (Balūchistān, also spelled Balochistan) Plateau in the south-west, the northern-eastern Potohar Plateau and the fertile Indus River basin one of the largest of the world with an estimated annual flow of 243 km^3 and a length of some 1,600 km^2 through the country most densely populated region of Punjab reaching half of total Pakistani population (110 Million in 2017) on an area of 205,000 km^2, almost one third of the total country. It is here that the agricultural lands of Punjab and Sindh along the alluvial plains are amongst the world largest producers of wheat, rice, sugarcane, cotton, potato, mango and onion. The climate varies from tropical to temperate, with arid conditions in the coastal south. There are four distinct seasons in Pakistan: a cool, dry winter from December through February; a hot, dry spring from March through May; the summer rainy season, or southwest monsoon period, from June through September; and the retreating monsoon period of October and November. Rainfall varies greatly from year to year, and patterns of alternate flooding and drought are common. Climate change is already influencing temperature and precipitation with vast consequences on ecosystems, water availability, and agricultural practices.

3.7.2 Links to food security

Agriculture - including crops, livestock, rangelands and forestry –, is the largest sector of Pakistan's economy, providing employment to 42% of the country's labour force and livelihood to 66% of the population while, at the same time, contributing to more than 23% of the Gross Domestic Product (GDP) and to an agro-based export reaching 65% of the total. All these contributions of the agricultural sector have been decreasing over the last two decades. Taking into account the rates of population growth, the sustainable enhancement of agricultural productivity has therefore become a major national challenge, which includes food security for a growing number of citizens. Moreover, a significant part of this sector is in the hands of rural landless smallholders. The rapidly growing population in recent years puts enormous pressure on natural resources; therefore, developing more sustainable and workable agricultural systems is an urgent matter (Ahmad et al. 2019). Following the Food Security Policy of 2017 "*Feeding the ever-growing population in the country means harnessing the food and agriculture system more effectively towards sustainable agriculture development imperatives*" (Government of Pakistan 2017). The importance of agro-biodiversity in Pakistan has been repeatedly raised as the country hosts has a large variety of ecosystems, habitats and species: some 6,000 species of plants out of which 7% are endemic) together with a history of one of the most ancient world civilisations, the Indus Valley Civilisation, built on a variety of plants domestication, cultivation and early irrigation, water storage and drainage systems dating back to 5 000 BCE. Nevertheless, few scientific studies on agro-biodiversity in Pakistan exist. "*For safeguarding national food security interest against erratic climate changes, it is crucial to invest in agriculture research for developing agro-ecology and farming system-specific climate-smart varietal and crop management related technologies*" (Green Climate Fund 2019). The latest available National Biodiversity Report for the Convention on Biological Diversity highlights some representative plants and animals species and varieties, e.g.: the wheat variety Saara Ghanum in Baluchistan, cold, disease and drought resistant. Wild olives are widely distributed in Baluchistan and primarily used for grazing of livestock. Beurekh, is a dual-purpose sheep breed. The most important characteristics of this breed include quick weight gain and long clean white wool, and disease resistance (Kakar 2009). So far agriculture has been based on five dominant crops: wheat, rice, sugarcane, maize, and cotton. The narrow choice of crops is due mainly to a lack of understanding about the scope of agro-biodiversity and a misallocation of resources. Taking advantage of the diversity of ecological conditions, climate and soils, cropping systems can reach sustainability. To this end, in 1980 the Government decided to implement a national ecological zoning for agricultural diversification based on local crop potential. An *ad hoc* assessment of the physical and biological potential of natural resources carried out by the Pakistan Agricultural Research Council - PARC in 1980 identified 10 Agro-Ecological Zones and 11 sub-zones, as a tool for farming diversification and adaptation to local ecological conditions. Considering rapid changes in land, water and climate at present a work on the redefinition of dynamic Agro-Ecological Zones is underway.

3.7.3 Sustainability assessment addressing the environmental, social and economic dimensions

In Pakistan, the sustainability of the agricultural sector is set as a priority by policies, strategies and planning that urge the overcoming of the stagnant outputs of the current agricultural model, unable to deal with the challenges of the Sustainable Development Goals. Two significant examples of the current efforts towards sustainability come from The National Food Security Policy 2017 of the Government of Pakistan and the Planning for Sustainable Agriculture in Pakistan of the University of Agriculture Faisalabad. The first aims at advancing beyond the agricultural sector towards a full achievement of sustainability, i.e., environmentally respectful, economically viable and socially acceptable, including nutrition, health, well-being and the full set of benefits represented by the so-called ecosystem services (Government of Pakistan 2017). The second focuses on the planning of an improved agriculture based on some key sustainability points:

- the sustainability of natural resources is essential to sustain agricultural activities;

- the lack of profitability is a persistent threat to the sustainability of agricultural systems, forcing migration and brain drain from rural economies;

- HLPE, 2019[15] recognises that there is a need to clarify, when using the term "sustainable intensification", on which principles it is founded and how it diverges from industrial agriculture. Khan, 2018 states that the key to sustainable agriculture lies in focusing on productivity without letting the natural resources decline. Stemming from this perspective, though most of the scientific and technical literature on agriculture in Pakistan does not show explicit efforts towards the use of the term agroecology as such, sustainability as the key feature of agroecology can be found under different materials and methods available on agriculture in Pakistan.

In Pakistan a number of field experiences of sustainable intensification are taking place. The common elements of sustainable intensification are summarised in the collected literature as:

- healthy plants with potential for root system growth;

- reduction in crop density giving each plant more room to grow above and below ground;

- enrichment of the soil with organic matter and keeping the soil well-aerated;

- application of water in ways that favour plant-root and soil-microbial growth.

An overall common denominator of such systems is their divergence from categories of agricultural intensification that have been prevalent over the past fifty years. Hence, sustainability in food production systems and food security is the target of research and policies in Pakistan (Abraham et al. 2014).

3.7.4 Promotion of agroecology in the country: evidences from literature

We have reviewed 55 papers, scientific articles, institutional reports and grey literature, following the overall agreed methodology on agroecology and food security. Seven have been selected as scientific and 28 as grey literature dealing with topics closely related to agroecology, although not all directly referring to this specific term. At the institutional level, several examples show that agriculture is a relevant part of the national political narrative in the latest two decades. Yet it is reported that "*Pakistan currently has over eight million private farms, on which over half the population of the country depends for income. About 90% of these farms are small farms (less than 5 ha), and in the livestock sector there are many landless farmers. A major failing of agricultural policy in Pakistan in recent decades has been the exclusive focus - in policy, financial support and even data collection - on the large-scale crop sector*" (Khan M.A. et al. 2019). Beside this lack of focus on some 90 million small family farmers, the investments on R&D in agriculture, including agroecology, are among the lowest in the whole Asian region. Consequently, also the agroecological experiences remain rather neglected by the scientific sector. On the other hand, we have found data on a number of practices of non-industrial agriculture which are close to the agroecology concept: e.g., the systems of crop intensification, sustainable agriculture, paradoxical agriculture, organic agriculture, conservation agriculture, integrated cropping, nature farming, agro-forestry, among others. Results of these practices in the field are sometimes

[15] HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

reported as encouraging: "*For wheat, maize, sugarcane, potatoes, and carrots, calculated from farmers' adaptations of systems of crop intensification (SCI) methodology in the Punjab province, from a unit of 144 ha under SCI, the average increase in yield/ha has been 62% over the intensive agriculture. It is conservatively calculated that with SCI management, the net economic returns/ha can be increased by at least 50%. An average of 38% reduction in costs per kg produced is reported*" (Adhikari et al. 2018). In another research the data collected show considerable variability; but overall, the impacts of SCI management are usually more than a doubling of yield: its increase range from 60% for sugarcane to 180% for wheat (International Network and Resources Center SRI-Rice, 2014). A special consideration deserves the mountain agro-silvo-pastoral systems of Pakistan covering 60% of total land area of the country and hosting 20% of the population, i.e., 40 million people. The mountain traditional agro-silvo-pastoral systems include a large variety of crops, fruits and other products (potato, wheat, barley, peas, faba bean, maize, vegetables, apple, apricot, cherry, fig, grapes, peach, pomegranate, plum, almond, loquat, pear, persimmon, walnut and mulberry, nuts, off-season vegetables, seeds, medicinal plants and livestock production.) close to the principles and practices of agroecology (Rasul 2015). Another example from mountain areas provides data specific to agro-forestry systems: the combination of trees with the annual crops increases the overall farm income of per unit land area of farmland, reduces the risks and broadens the sphere of alternatives (Essa 2011).

3.7.5 Conclusions, including limitations and obstacles

Pakistan is one of the largest agricultural economies of the world in a biodiversity rich country. Its large population with a high growth rate requires an adequate combination of agricultural production and conservation of biodiversity. As one of the oldest agricultural civilisations, based on ancient species, varieties and agricultural techniques (e.g., irrigation and drainage), this country shows today limitations and obstacles to meet sustainability standards, i.e., environmental, economic, social and cultural. One of the main limitations highlighted by literature is the low investment in agricultural research and development, including the involvement of international scientists, acting as promoters and "certifiers" of higher standards of materials, methods, practices, processes, and data. Agroecology research and comparative studies in particular are limited in a country that has a high potential and an already consolidated system of agro-ecological zoning. Based on this zoning exercise Pakistan is equipped with a good monitoring and evaluation system to provide sustainability in policies and practices at the different levels, with updated information on the wise use of agricultural resources (including the most adapted species in the right areas and habitats), on climate variability and change, and on agricultural markets development. The agro-ecological zoning reveals an enormous potential for crop diversification, resilience and productivity (Ahmad et al. 2019).

3.7.6 Number of documents analysed

Although Pakistan is a large country with a variety of ecosystems, habitats and species, there is no extensive research cooperation with international scientists. 55 papers were identified through the search string applied in the present study, of which 27 peer reviewed articles and 28 grey literature documents. After screening, 7 have been selected in scientific peer reviewed literature, 28 in grey literature.

3.7.7 References

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3.8 Colombia

3.8.1 Country agro-environmental profile

Colombia land area covers 1.1 million km^2 with a population of some 50 M people. The Human Development Index is 0.767 in 2019, scoring 83rd in the world list. Colombia is one of most "megadiverse" countries of the world, hosting some 10% of the planet's biodiversity, i.e. 53,812 species. Worldwide, it ranks first in bird with 1,800 species and orchid species and second in plants, butterflies, freshwater fishes and amphibians. With 314 types of ecosystems, Colombia possesses a rich complexity of ecological, climatic, biological and ecosystem components. For agro-environmental purposes, Colombia can be divided into four main geographical areas:

1) Andean region divided in three main chains: western, central and eastern cordilleras where high plateaus have moderate climates with pleasant living conditions and in many places enabling farmers two harvests per year;

2) Caribbean region with banana and cotton fields in the lowlands and small farming crops and cattle in altitude;

3) Pacific region, a major hotspot of tropical biodiversity;

4) Amazon region with its lowland rain forests.

Colombia is essentially a rural country. The Human Development Report of the United Nations Development Program - UNDP estimates that 75.5% of the municipalities are rural, occupying 94.4% of the national surface and are home to 31.6% of the population. Out of a total of 2.5 M agricultural production units, it is estimated that 80% are farms smaller than 10 ha. This proportion of the small farmers is the main provider of basic food for the Colombian population (Clavijo Ponce and Sánchez Gil, 2019).

3.8.2 Links to food security

In Colombia, the latest National Survey of Nutritional Situation of the Ministry of Health and Social Protection shows the prevalence of food insecurity and hunger up to more than a half of the population. Particularly, in the department of Boyacá (Andean region), considered the food pantry of Bogotá, the figure corresponds to 52% and around 37% of its municipalities present high levels of malnutrition (Clavijo Ponce and Sánchez Gil, 2019). The department of Boyacá hosts nearly 20% of the total species of the country. In Colombia, the Resolution 544 of 1995 of the Ministry of Agriculture, began the legitimisation of alternative agriculture by recognising the category of organic, biological and ecological primary or processed products without synthetic chemicals. In this Resolution "*organic farming is treated as an exclusive export issue, while power is handed over to the certifiers*". In the 80s, alternative agriculture started to be consolidated under one of its different names, including biological, ecological, organic, biodynamic, sustainable, conservationist and/or agroecological agriculture, which, directly or indirectly, involve the peasantry as an active category. The promotion of ecological agriculture is closely linked to the development of non-governmental organizations, which have influenced both the agricultural practice at the farm level, as well as the promotion and adoption of government policies, through the formalisation of the agro-environmental discourse by the academia. Most of these initiatives have been of urban origin, although their influence has motivated the formation of autonomous peasant organisations. The term ecological agriculture is fixed in 2006 by the Resolution 187 of the Ministry of Agriculture and Rural Development, defining the paradigm of "ecological production system" which combines the terms ecological, organic or biological as synonyms. In this way almost all agricultural systems that promote production in a healthy and safe way, from an environmental, social and economic point of view are included, while agroecology does not stand in its scientific place and role. Regardless of the school that is followed, all these systems coincide with the general principles of respect for biodiversity, ecosystem approach and recognition of agrobiodiversity. Nevertheless, there are a number of intrinsic elements threatening biodiversity in Colombia, including lack of political priority on environmental issues in national and sectorial policies, undesired effects of macroeconomic policies, conflicts with indigenous rights and disregard of their traditional knowledge, as well as a lack of coordination in land-use planning that takes place at various state levels.

3.8.3 Sustainability assessment addressing the environmental, social and economic dimensions

A number of analysed scientific articles are devoted to assess sustainability of agroecological practices in Colombia using methods based on the evaluation of criteria, indicators and indexes. The results from this variety of field study cases are showing a number of significant sustainability advantages of agroecology vs. conventional agriculture. Although the field assessments are providing clear environmental, social, cultural and economic evidences of the importance of agroecology for food security, the current agricultural policies and laws are not explicitly referring to and supporting it. Statistics show the severity not only of food insecurity, and of rural economy fragility, but of food-related health problems, such as obesity and diabetes, gaining large portions of the populations, including women and children. Traditional practices are highly valuable for the sustainable development of production systems in terms of local food provision, overall food sovereignty, risk minimization, erosion control, management of coverage and waste and saving of inputs. If not merely in terms of direct monetary benefits for access to "green markets", these practices represent, following different sustainability assessments, sound bases for addressing environmental, social, cultural and economic requirements for food health and security (Loaiza Cerón 2014). Among the variables that best explain the sustainability of the evaluated agro-ecosystems are dependence on supplies, management systems, fodder availability, number of products sold, plant diversity, production objective, application of acquired knowledge and local knowledge for animal production, distribution of income and decision-making, and plant genetic diversity (Vallejo Cabrera et al., 2020).

3.8.4 Promotion of agroecology in the country: evidences from literature

The literature review for Colombia shows a clear picture of the promotion of agroecology from scientific research, non-governmental organisation, private sector, and development cooperation. Much less support comes from government's policies, laws and in general from central institutions and administration. For example, already back in 1996, the central government promoted the Peasant Reserve Zone as a legal tool to protect the rights of access to land and the implementation of sustainable agricultural systems, basically with agroecology as a core theme of the initiative, but its practical implementation remained limited by the influence of the green revolution and agribusiness. In 2016 a law established the Zones for Rural Socio-Economic Development in a further attempt to promote rural development for smallholders based on practices closer to agroecology. The term agroecology is mentioned in Law 160 of 1994 but not as a science, practice nor social movement rather it denotes ecological characteristics or conditions. More specifically, the emergence of multiple agroecology experiences in Colombia ranges from the foundation of several initiatives by NGOs like the Major Peasant Institute (IMCA), the Center for the Research on Sustainable Systems for Agricultural Production (CIPAV), the Foundation for Science Teaching and Application (FUNDAEC), Ceiba and the Center for Health, Environment and Labor Studies (CENSAT) to the convergence of academic groups, peasants and consumers, who were inspired by old-new ways to implement and develop agriculture. It is at the end of the 80s that some pioneering initiatives in the field of biological agriculture took place as the Colombian Association of Biological Agriculture and Eco-development (ACABYE), which later became the Colombian Network of Biological Agriculture (RECAB), the Colombian Association of Organic Coffee Producers (ACOC), the Association of Agroecological Peasants of Páramo del Duente Natural Park's buffer zone (Asoduende) and the Association of the Agroecology Group of Colombian South-western Zone (ACASOC). Concerning non-formal education, in 2009, several community-based organisations created Alimentos de Vida (Food for Life), the network of agroecological markets of Valle del Cauca (REDMAC). Over 100 agroecology Peasant Schools were founded at the beginning of the second decade of the 21st century. As far as the academy is concerned, the Agroecological Engineering Program in the Corporación Universitaria Minuto de Dios (UNIMINUTO) offers since 2001 agroecological training to a large group of professionals by placing special emphasis on social inclusion. The Universities of Antioquia and the National University of Colombia provide doctoral programmes with the support of SOCLA, the Latin American Scientific Society of Agroecology, a network of researchers, professors, extentionists and other professionals that promotes agroecological alternatives to confront the crisis of industrial agriculture in the region. Other agroecological-related academic activities are carried on by the Faculty of Agroecological Engineering of the Universidad de la Amazonia, and the University of Santa Rosa de Cabal (UNISARC).

3.8.5 Conclusions, including limitations and obstacles

Agroecology in Colombia appears to be slowly developing thanks to academia and social movements, which benefit, in the first case, from contributions of the international research and, in the second case, from the sustainable basis of the traditional knowledge and agricultural systems of the 1.9 million small production

units (< 10h) of a large and diversified country. There is a key role played, during four decades now, by the many non-governmental organisations supporting small farmers through training and capacity-building programmes and projects. In Colombia the rapid decline of indigenous peoples - 35 ethnic groups surviving out of 102 still existing at the beginning of twenty-first century – brought to a significant loss of traditional knowledge and practices associated with food production. This loss is one of the main challenges to be solved in relation to food sovereignty. This limitation can be partly compensated by the inputs of research institutions in terms of knowledge, principles and practices and by the field training activities of the NGOs. In the big picture of the Colombian agroecology the central institutions and governments are still missing explicit and effective strategies, juridical tools, and economic planning supporting small farmers and their food security.

3.8.6 Number of documents analysed and topics dealt

A total of 23 papers were identified through the search string applied in this study; of these, 12 are scientific papers and 11 have been considered as grey literature or reports of meetings. The majority of scientific papers are in Spanish. Eight scientific papers have been selected as relevant for this study. Six mention agroecology in their titles. Seven documents have been selected as pertinent in grey literature.

3.8.7 References

3.8.7.1 Scientific papers

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3.9 Bolivia

3.9.1 Country agro-environmental profile

The Plurinational State of Bolivia is a highly diversified country, geographically, environmentally and culturally, where the Constitution acknowledges thirty-three official languages for thirty-six ethnic groups. The land area covers 1.1 M km², with a current population over 11 M people across three main geographical regions (tropics, valleys and highlands) this country is the second poorest in South America, after Paraguay. The Human Development Index is 0.718 in 2019, scoring 107th in the world list. With its 14 eco-regions Bolivia is one of the mega-biodiverse countries of the world with some 20,000 plant species and more than 2,600 vertebrate species, many of these groups with high rates of endemism. Bolivia is also one of the main centres of origin for domesticated plants and their wild relatives. Together with Peru, it is the centre of origin of potatoes, with some 4,300 native varieties. Reports since 2010 show a net increase in trade of products derived from biodiversity. Chestnut and quinoa make up most of these exports however in recent years wild cacao, maca (*Lepidium peruvianum*), caiman leather, vicuña fibre, copaiba (*Copaifera sp.*), almond, cusi (*Attalea speciosa* or *Orbignya phalerata*) and acai (*Euterpe oleracea*) have also become important export products. 3,000 plant species are used for medicinal purposes at local or regional levels. A collection of some 16,000 seeds is preserved, e.g.: beans, quinoa, lupine, cañahua (*Chenopodium pallidicaule*), amaranth, potatoes, peppers, achojchas (*Cyclanthera pedata*). The Bolivian Government is committed to conserve biodiversity and developing sustainable production systems through the implementation of non-market-based approaches and integrated community-based management by indigenous peoples, campesino communities and small-scale producers. Bolivia is currently carrying out a pilot project to record traditional knowledge associated with genetic resources (Catacora-Vargas 2015).

3.9.2 Links to food security

The Bolivian Constitution of 2009 puts food sovereignty as a constitutional principle (Art. 255/8, 309/4 and 405). Accordingly, the country's national development plans, including the "Agenda Patriótica 2025" (Patriotic Agenda), promote food sovereignty and hunger eradication. Yet Bolivia faces today a number of food- and nutrition-related challenges, including high chronic malnutrition in rural areas, increasing rates of overweight and obesity, especially among women, and alarming levels of child anaemia. Since the early 2000s the overall agricultural production increased significantly, mostly by well organised agribusiness in the area of Santa Cruz. Although proven to provide vital benefits, including food security, for the vast majority of small farmers and local communities, the development of sustainable agriculture and agroecology is still limited. Small-scale community-based agriculture tends to be largely managed by women, although they have limited access to and control over productive resources and markets. With the creation in 1991 of the Association of Organizations of Ecological Producers of Bolivia (AOPEB), small farmers slowly started to organise themselves in groups, associations, cooperatives, companies and NGOs, distributed in different ecoregions of the country (Catacora-Vargas 2015). A growing concern for food security in this country, as in many others in Latin America and worldwide, is the number of people, mostly poorer groups, affected by health problems such as obesity and diabetes. This problem is leading the World Food Program to concentrate strategic plans on measures to reduce the dimension of the problem. Traditional and agroecological practices could significantly contribute in this direction. Nevertheless, the great number of traditional practices in Bolivia are basically local and agroecology should be always considered as the scientific catalyst to expand the local traditional systems to larger production contexts.

3.9.3 Sustainability assessment addressing the environmental, social and economic dimensions

While scientific evidences and data on agroecology in Bolivia are still lagging behind for insufficient and comparative research, the available literature, both scientific and grey, systematically offers insights on the potential of traditional practices of the many ethnic groups and, in particular, of the considerable amount of agro-biodiversity of this country. Even from a limited assessment, there are clear evidences on the sustainability imbalance of agro-industry vs. agro-ecology, as in the case of pest management avoiding chemical inputs or in soil conservation. Sustainability should be always considered on the long term and agro-ecology compared to intensive agriculture shows environmental, economic, social and cultural advantages in this sense (Donaire Eguívar 2006). Traditional and agroecological practices indeed include all the aspects of sustainability, including climate variability and change, and not forgetting the cultural acceptability by a vast

majority of the population (Comunidad Andina, Agencia Española de Cooperación Internacional para el Desarrollo 2011).

3.9.4 Promotion of agroecology in the country: evidences from literature

The new Constitution of 2009 explicitly refers to the "*promotion of production and trade of agroecological products*" (art. 407/3) and declares that "*natural resources are the inalienable and indivisible property and direct dominion of the Bolivian people and will be administrated, in the collective interest, by the State*" (art. 349). In 2010, Bolivia adopted the Law on the Rights of Mother Earth, followed in 2012 by the Framework Law on Mother Earth and Integral Development for Living Well, both focused primarily on climate change mitigation and adaptation stressing the importance of measures for biodiversity and cultural conservation. The National Development Plan "Bolivia Dignified, Sovereign, Productive and Democratic to Live Well" of 2010 (Decree n° 29272), promotes organic production at the national level, establishing that "*The Agricultural Development program with food sovereignty and national identity will work to promote ecological agriculture in its different components (seed management, biological control of pests, elimination of the use of agrochemicals and fertilization with organic fertilizers), oriented to native crops of high nutritional value at the level of family and community agriculture*" (Catacora-Vargas 2015, 2016).

3.9.5 Conclusions, including limitations and obstacles

Bolivia stands as one of the countries in Latin America, and possibly worldwide, with the highest potential for food varieties and traditional background that both could concur to food security and market development. Political commitments exist, but the actual implementation of strategies, plans, programmes and projects is still limited, while agro-industry advances with the support, and interests, of national and multinational companies. Small and family farming play a central role in many areas for food security and some steps are being developed to create synergies between the traditional and agroecological practices via associative and cooperation organization. At the same time this biologically and culturally highly diversified country confirms the lack of scientific field research on the links between traditional farming and agroecology taking into account the many different aspects in a balanced and interdisciplinary way. Social aspects are mostly covered by surveys that do not take into sufficient account the agronomic figures in quantitative terms. Consequently, it is also difficult to have the full economic pictures of production. Analysed literature also shows gaps between the farming aspects (production) and the overall food supply chains (transformation and marketing), either in the contexts of local rural development or in larger marketing contexts (and even export). One main obstacle to report for Bolivia, as for other countries, agroecology is not yet standing as a full-fledged concept, which includes scientific ecology; in many cases traditional, small-farmers, family farming, organic, ecological agriculture or agroforestry (Calicho, Escalera 2019) are mentioned as corresponding to agroecological principles and practices, along with others definitions (Centro de Investigación y Promoción del Campesinado CIPCA, Alianza por la Agroecología 2017). Further clarifications and a sound communication are required to bring agroecology to its right place and role in policies, economy and society.

3.9.6 Number of documents analysed and topics dealt

A total of 58 papers were identified through the search string applied in this study; 43 are scientific papers and 15 have been considered as grey literature or reports of meetings. The majority of scientific papers are in Spanish. All of them have been analysed, and 7 scientific papers selected as relevant for this study. Of these, four mention agroecology in their titles. Seven documents have been selected as pertinent in grey literature.

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4 Conclusions: what science is telling us on agroecology, and benefits deriving from agroecological practices on food security

Agroecology designs sustainable agroecosystems by applying ecological and agronomic concepts and principles. It includes a wide range of agricultural practices, all based on a sustainable use of natural resources, enhancement of ecosystem services (e.g. pollination, natural pest control, decomposition and fixing processes in the soil) and recycling of biomass and nutrients, which substitute the use of chemical inputs. Available literature on agroecology has been analysed in this report for nine countries (Bolivia, Burundi, Cameroon, Colombia, Cote d'Ivoire, Nigeria, Pakistan, The Gambia, Uganda). A total of 106 documents, including scientific and grey literature, have been synthesised to provide information on characteristics of existing research and available scientific results addressing the agroecological transitions and implementation of agroecological practices. A summary of selected literature per country is shown in Table 1.

Table 1. Number of documents screened and selected per country

	Peer-reviewed literature		Grey literature	
	Retrieved from search	Selected	Retrieved from search	Selected
Bolivia	43	5	15	9
Burundi	24	5	0	0
Cameroon	438	9	1	1
Colombia	12	8	11	7
Cote d'Ivoire	252	6	5	1
Nigeria	1257	9	20	0
Pakistan	27	6	28	27
The Gambia	23	4	1	1
Uganda	527	8	5	0
Total	2603	60	86	46

Moreover, the results of the analysis presented in this report can be combined with a similar analysis carried out on 17 countries and described in the report "*Agroecological practices supporting food production and reducing food insecurity in developing countries*" (Paracchini et al., 2020[16]), to provide general conclusions on the basis of 26 country reports, available at the end of this chapter.

In African countries (Burundi, Cameroon, Cote d'Ivoire, Nigeria, The Gambia, Uganda) the analysed literature mostly concerned small scale, extensive farming systems and food production for subsistence levels and sale on local or regional markets. Most of the crops grown were staple crops and, particularly in agroforestry systems, cash crops. In these systems, cocoa and coffee production was important for international markets. The application of agroecological practices for vegetable production and livestock rearing was rarely studied. Due to the predominantly tropical nature of these regions, the majority of production challenges related to climate change and soil problems. Soil fertility, soil erosion, and recycling of nutrients were among the prominent constraints noted, as well as drought and temperature stress for certain crops. These problems were noted as the reasons why most agroecological practices were implemented. Some practices like intercropping, use of organic fertilizers, crop residue management, mulching, crop diversification and rotation as well as agroforestry were used in the various farming systems. Intercropping and agroforestry were the most important practices in the relevant literature analysed.

In the investigated Latin American countries (Bolivia and Colombia), beside the high biological and cultural diversity, some common features appear as most relevant to the current development of agroecological systems. In many cases local groups and communities are organised or supported on the production and marketing on a small-scale and family farming base. Communities in these countries show a consistent degree of attachment to traditional agricultural systems which are adapted to not only to the local conditions but also to the cultural and traditional knowledge and patterns. One of the common features reported by the literature is the resilience of agroecological systems to climate variability, pests and soil erosion or low

[16] https://publications.jrc.ec.europa.eu/repository/handle/JRC121570

fertility. Most of the common traditional production system are based on maize intercropped with other species, such as beans, squashes or potatoes (known as "milpa" in the Mexican and Central American area). The system is integrated by a great diversity of crop, trees (e.g. agroforestry), and animal breeding, providing a potential full ecological picture. There is growing awareness and practice of key aspects of agroecology in these countries, such as local seed management, biological control of pests, decrease in the use of agrochemicals and increase of fertilization with organic fertilizers, oriented to native crops of high nutritional value at the level of family and community.

In Pakistan, policy and financial support focus mainly on the large-scale crop sector and investments on R&D in agriculture, including agroecology, are among the lowest in the whole Asian region. Consequently, also the term "agroecology" is seldom used by the scientific sector. Though agroecology is not explicitly mentioned as term, practices of non-industrial agriculture which are close to the agroecology concept can be found in literature, e.g. the systems of crop intensification (SCI), sustainable agriculture, paradoxical agriculture, organic agriculture, conservation agriculture, integrated cropping, nature farming, and agroforestry.

Overall, the literature found for the different countries indicated some notable contributions of the practices implemented to household food security. In fact, approximately 50% of the analysed papers reported a positive contribution of agroecological practices to food security, either direct or indirect, mostly due to improved yields, better economic situation of producers, improved resilience, enhanced diversification of production. However, most country reports indicated the lack of quantifiable data and direct measurement of the relationship between the use of agroecological practices and food security. Many studies found that, based on improvements in yield and income, agroecological practices positively impacted food security by providing a larger amount and greater diversity of food to households, often during critical periods in the year. A limited number of publications assessed environmental health and social benefits of agroecological practices. The identification of linked ecosystem services was not systematically made, and it was not following international standards.

There was a clear lack of quantifiable data related to parameters regarding food security and nutrition in the available publications, which limited proper analysis and conclusive results in all countries. Also, there was almost no information on post-harvest practices, and government policies or promotion of agroecology in these countries, making it very difficult to assess the role of organizations in the promotion and support of agroecology. In the few instances when the promotion of agroecology was mentioned, these initiatives were mainly supported by NGOs and research centres, and seldom by traditional and local authorities. Only in Bolivia is agroecology promoted in national law, while in Colombia agroecology is promoted in University curricula.

In the review and synthesis of available literature few studies were found that documented a systemic approach that covered all facets of agroecology. Furthermore, while literature provided evidence that farmers are using agroecological practices, there is room for improved assessment of the outcomes of these practices, as indicated by the lack of literature and direct assessments of the contribution of agroecology to food security. In order to properly assess agroecology and food security, there is a need for further research on the direct links between agroecological practices and household outcomes of different food security and nutrition parameters. Moreover, improved research must be carried out that evaluates the development and impact of a more comprehensive set of agroecological practices using selected social, economic, and environmental indicators for global outcomes assessment.

For broader implementation and use of agroecological practices in the studied countries, there is a need for national policies to support farmers by providing extension resources and facilitating knowledge sharing between farmers. Involvement of NGO, national and regional public authorities, together with knowledge sharing among farmers and researchers can further support the scaling up process. The benefits, but also constraints, of some agroecological practices should be made more widely known to stimulate farmers' interest in the implementation of these practices in different farming systems. In the landscape of analysed countries, Bolivia stands out as the only one where agroecology and ecological farming are promoted in the law.

In several countries, the availability of relevant publications was limited. In particular, few resources were available to evaluate the impact of agroecology on food security and nutrition in The Gambia (4 publications) and Burundi (5 publications). More pertinent literature was available to feed the analysis for the other countries. Agroecology implementation and its contribution to food security in these regions is not well documented and/or not common. For some countries, such as Nigeria, Uganda, and Cameroon, the high number of irrelevant articles found in the Web of Science with the search string complicated the process of

selecting suitable publications. Although sometimes many papers were found, only few indications provided direct or indirect links to food security and nutrition in relation to agroecological practices.

Overall, in the frame of the two reports on "Agroecological practices supporting food production and reducing food insecurity in developing countries" scientific literature on 27 countries and for a total of 278 papers and reports has been synthesised. The general conclusions that can be drawn are the following:

- The vast majority of synthesised documents focus on small scale farming, on staple crops cultivation and much less on cash crops. Overall, a positive contribution to food security, whether quantitative or qualitative, is reported in at least 50% of the analysed literature. This is linked to improved yields, availability of more nutritious food, diversified diet, higher resilience to climate shocks, higher income. Information is mostly qualitative than quantitative;
- Overall, there is a lack of a systemic approach in the analysis of agroecology, available information appears to be scattered across different aspects, when not lacking. Most studies describe agroecological farming practices rather than the agroecological approach, and highlight the agronomic aspects more than economic and especially social aspects;
- The improvement of soil fertility is a major need across the regions, and this directly links to the management of nutrients and organic matter;
- There is a general lack of reporting on post-harvest practices, and in some countries there is a lack of literature on the links between agroecology or agroecological practices and food security and nutrition, with only few publications available;
- Dissemination of knowledge is an issue, the need for an improvement of extension services and of farmer-to farmer exchanges are repeatedly reported. This reflects as well the lack of political support to agroecology evidenced in most of the analysed countries;
- There is a need for more structured research providing a solid scientific basis for agroecology as well as practical solutions;
- Finally, in relation to major crises the world is facing, and namely conflicts and climate change, agroecological approaches offer substantial solutions in making agriculture systems more reliant on local natural resources and therefore less dependent from external purchased inputs; agroecology is also regarded as an option for climate change adaptation, through specific practices such as agroforestry, crop rotations, intercropping, and selection of local adapted and resistant varieties.

List of abbreviations and definitions

CGIAR	Consultative Group for International Agricultural Research
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross domestic product
HLPE	High Level Panel of Experts
ISFM	Integrated soil fertility management
JRC	Joint Research Centre
KC FNS	Knowledge Centre for Global Food and Nutrition Security
NGO	Non-governmental organization
UN	United Nations
WoS	Web of Science

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