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

A study on scientific literature in 17 countries

Paracchini M.L., Justes E., Wezel A., Zingari P.C., Kahane R., Madsen S., Scopel E., Héraut A. Bhérer-Breton P., Buckley R., Colbert E., Kapalla D., Sorge M., Adu Asieduwaa G., Bezner Kerr R., Maes O., Negre T.

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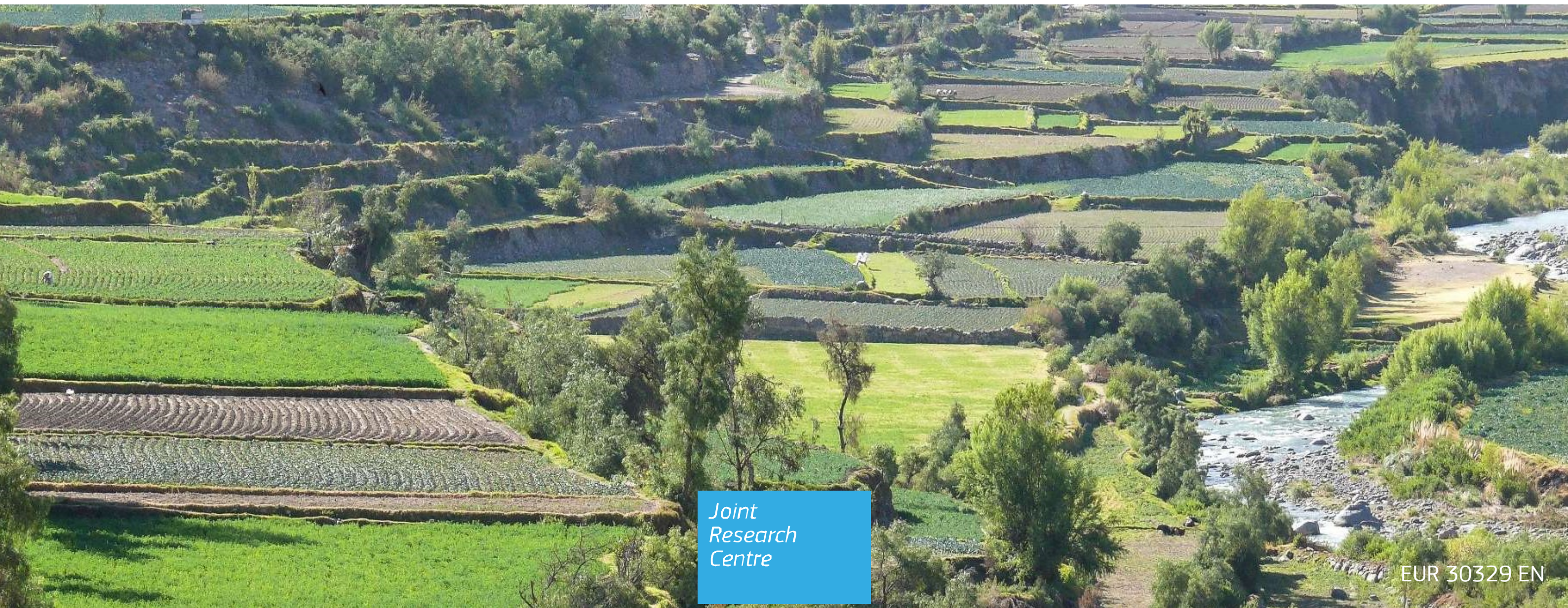

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Abstract

This report represents the initial effort to structure existing knowledge about agroecology as farming and food system in support of the EC Knowledge Centre on Food and Nutrition Security (https://ec.europa.eu/knowledge4policy/global-food-nutrition-security_en). Scientific literature has been screened on a selection of developing countries in which food and nutrition security and sustainable agriculture represent a focal sector for EU intervention (Benin, Burkina Faso, Cuba, Ethiopia, Ghana, Guatemala, Kenya, Lao PDR, Madagascar, Malawi, Mali, Nicaragua, Niger, Senegal, Tanzania, Togo, Zimbabwe). In total, 172 documents have been synthesised, a country brief has been prepared for each investigated country, and some general conclusions have been drawn.

Overall, the majority of analysed publications focuses on small scale, extensive farming systems that produce food at subsistence levels and for sale on local markets. This includes smallholder farming producing staple crops (millet, sorghum, yam, etc.) or vegetable gardening for local markets. The agroecological practices that are mostly studied are: agroforestry, intercropping (or mixed cropping), introduction of legumes in rotations, soil and water conservation practices (mulching, return of crop residues, zaï holes etc.), use of animal manure, biocontrol methods to mitigate chemical pesticide use.

At least 50% of the analysed papers report a positive contribution of agroecological practices to food security, mostly due to improved yields and/or a better economic situation of producers. The improvement of soil quality is key to improve yields and consequently income and food security; this can be achieved using various practices including the use of residue mulch from tree leaves in agroforestry, as well as crop mixtures or intercropping and longer more diversified crop rotations. Moreover, higher on-farm crop species diversity often results in more diversified diets. Diversified crop systems, including the introduction of agroforestry, improve household nutritional status and have positive links to better health conditions. On the other hand, the lack of access to inputs is an important limitation to the improvement of soil fertility (manure, mineral fertilizer, leaf litter, etc.), which remains a major hindrance for food security.

The agroecological cultivation of cash crops, post-harvest practices and crop-livestock integration were overall lacking in the scientific analyses, as well as the assessments of fully agroecological systems compared to individual agroecological practices or groups of practices.

The report identifies three factors required for the substantial development of agroecology at the farm level: more financial support from the government, greater scientific knowledge on novel agroecological practices, and a higher market value for agroecological products.

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: Benin, Burkina Faso, Cuba, Ethiopia, Ghana, Guatemala, Kenya, Lao PDR, Madagascar, Malawi, Mali, Nicaragua, Niger, Senegal, Tanzania, Togo[1], 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 analyzing agroecology as farming and food system. In particular, contribution to food and nutrition security and evidence of economic, social, environmental benefits are sought.

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)[2]:

"*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 dishomogeneity 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 summarized 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, synthetizing available evidence.

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 study allows drawing some conclusions both on the benefits provided by the agroecological approach and on knowledge gaps.

[1] Togo is included as country where food security and rural development are target sectors of the European Development Fund (https://ec.europa.eu/international-partnerships/where-we-work/togo_en)

[2] 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.

2 Methodology for document selection and analysis

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

The Web of Sciences (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 applies for each concerned country (Benin, Burkina Faso, Mali, Senegal, Ghana, Niger, Togo, Kenya, Ethiopia, Zimbabwe, Malawi, Madagascar, Tanzania, Lao PDR, Cuba, Guatemala, Nicaragua), though for the countries of Malawi, Kenya, Madagascar, Tanzania, Congo, Ghana, Niger, Togo, and Zimbabwe, only Search string1 and Search string 2 were applied, as Search string 3 was found to be too broad, including a large number of articles, of which many irrelevant for the scope of the analysis, and some overlapping substantially with the returns of the other search strings. Instead, 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 summarized, 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 summarized in the table as described in the next section. For each country, between 12-50 articles and gray 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.

2.4 Summarizing selected documents in a table

A table per country was set up to summarize 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 synthesized 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 17 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 sections contains the summary of the findings on the effectiveness of agroecological practices in the seventeen selected countries (Figure 1) and four main geographicl regions: West Africa, East and Southern Africa, Asia, Central America and the Caribbean, as resulting from the analysed literature, screened as described in chapter 2. Each profile contains the bibliographic references on which the profile is based.

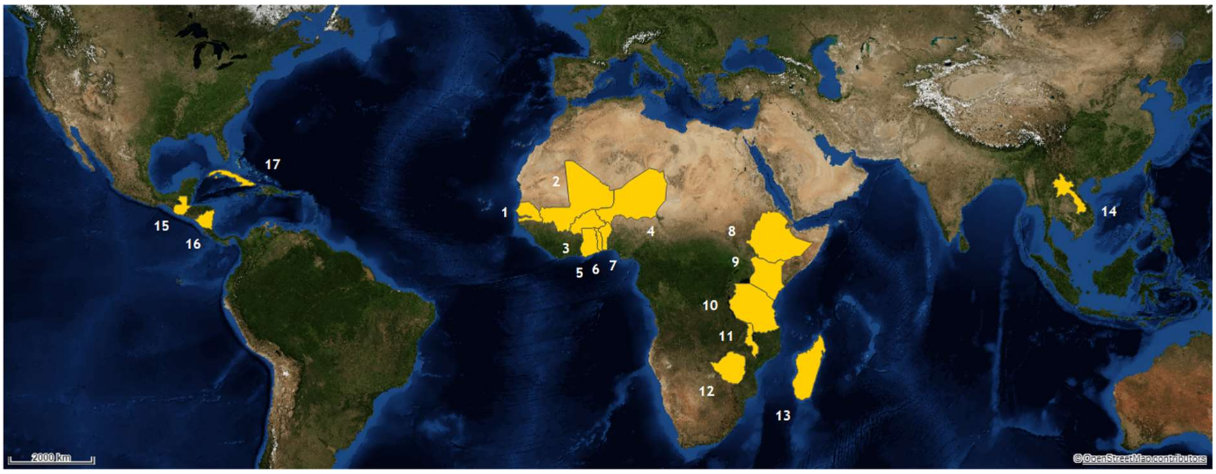

Figure 1. Countries analysed in the present report[3]:

West Africa

1 - Senegal

2 - Mali

3 - Burkina Faso

4 - Niger

5 -Ghana

6 - Togo[4]

7 – Benin

East and Southern Africa

8 - Ethiopia

9 - Kenya

10 - Tanzania

11 - Malawi

12 - Zimbabwe

13 – Madagascar

Asia

14 - Lao PDR

Central America and the Caribbean

15 - Guatemala

16 - Nicaragua

17 - Cuba

[3] Copyright, European Union, 2020. Map created by EC-JRC. The boundaries and names shown on this map do not imply official endorsement or acceptance by the European Union.

[4] Togo is included as country where food security and rural development are target sectors of the European Development Fund (https://ec.europa.eu/international-partnerships/where-we-work/togo_en)

3.1 Senegal

3.1.1 Country profile from the agro-environmental perspective

Located on the western edge of Africa's vast Sahel region, Senegal environment is mostly arid, with five tropical climatic zones, from shrub steppes of the Sahelian zone, through the dry steppes of the Sudano-Sahelian zone and the savanna landscapes and forests of respectively the Sudanian and Sudano-Guinean zones.

Most farmers practice small-scale rainfed subsistence agriculture. They experience harsh cropping conditions, low rainfall and are adversely affected by soil degradation, frequent dry spells and increasing population5. Staple crops are rice, millet, sorghum and maize, while cash crops are mainly cotton, groundnuts, fruits and vegetables. Senegal imports a considerable amount of its food, like rice, and agriculture accounts for around 10% of national Gross Domestic Product, which is low compared to other West African countries. Despite a significant livestock population, Senegal also remains a net importer of meat and milk powder.

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

3.1.2 Topics covered by the selected literature

Most systems encountered in this literature review are organic farming home gardening, agroforestry systems, or annual crops such as millet or groundnut (Figure 1 and Figure 2). The reported agroecological practices encompass crop mixtures and crop rotations, the use of residue mulching, compost-based organic fertilization, or biocontrol methods; no postharvest management was recorded among them. The studies focused on smallholder family farming, with some publications establishing a farm typology according to acreage and market orientation.

About half of the relevant documents deal with experimental results, while the others are mainly based on surveys and interviews of farmers in the field, sometimes in a combination with participatory approaches and experiments carried out at the farmers' plots.

Figure 1. Agroforestry in the groundnut basin, Caroline Dangleant © Cirad

Figure 2.: Vegetable crops in the Niayes region, Pierre Silvie © Cirad

3.1.3 Links to food security

The contribution of agroecological practices to improve food security was mainly evaluated indirectly through crop yields or livelihood evolution, i.e. income change. Only one paper directly assessed the impact on food security through direct survey of farmer's income. The effect on nutrition security was barely reported, besides some organic farming products.

[5] Sources (in addition to the references below):

http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/5999762-1242914244952/Senegal_Report_Final_EN.pdf , https://www.ifad.org/en/web/operations/country/id/senegal

A positive contribution of agroecology can be noticed, since all 4 articles assessing these practices (i.e., agroforestry, traditional plant associations, mulching and natural fertilization) in experimental settings found higher yields of millet and groundnuts. The highest yields were obtained in one experiment combining local trees (i.e., Piliostigma reticulata) with traditional plant associations (millet, groundnut). When including those trees, additional fertilization did not increase further the yields (Bright et al. 2017). In the remaining experiments closer to conventional agriculture without trees, combinations of natural and synthetic fertilizers yielded the best results (Badiane et al. 2001, Stoate et al. 2008, Trail et al. 2016). A second group of articles, typically compared conventional versus organic farming in observational settings. These articles consistently showed lower yields in organic farming and lower profitability as the market does not offer higher prices for these products (Binta et al. 2015, Adramiampianina et al. 2018, de Bon et al. 2019). Another article shows contrasting effects depending on the type of farm, i.e. subsistence or extensive farms will have more difficulties to improve their food security than more intensive and more market-oriented systems due to a lack of added value price. But this study did not really look clearly into agroecological practices, besides farms where livestock (ie. small ruminants) were used to increase soil fertility (Douxchamps et al 2016). One of the most important factors affecting food security seems the management of soil fertility thanks to soil conservation practices, such as the use of residue mulch from tree leaves in agroforestry, crop mixtures or intercropping and rotations studied and found usually relevant in the twelve articles.

3.1.4 Sustainability assessment addressing the environmental, social and economic dimensions

With regard to productivity, the species Piliostigma reticulatum, Faidherbia albida and Guiera senegalensis were found particularly suitable for increasing groundnut and millet yields in intercropping/agroforestry systems compared to plots without these shrubs. For example, millet grain yield was increased by a third in intercropping, as it ranged from 1248-1606 kg/ha in the plots with shrubs and application of leaf mulch compared to 894-1236 kg/ha in the plots without shrubs (Stoate and al. 2008). Likewise, intercropping of millet with legumes significantly increased millet production by 55% for millet-cowpea intercrop compared to millet sole crop (Trail et al. 2016) (Figure 3 and Figure 4). The same applies for compost fertilizer in combination with intercropping, which led to higher crop performances compared to compost or fertilizer applied alone (Badiane et al 2001). On the other hand, studies regarding organic farming point out significant lower yields than for conventional production, even if the order of magnitude of yield gap varies according to crops tested (de Bon et al. 2019). Another type of agroecological practice has being studied, such as the use of neem leaves as biopesticide, and has been characterized as efficient to control a cabbage pest, the white fly (Plutella xylostella), leading to significantly improved yields (Sow 2013). It demonstrated that some solutions exist to substitute chemical by natural products to control some pests or diseases.

From an economic point of view, a number of agroecological practices having improved farmer's livelihoods can be emphasized. For agroforestry systems, the multiple uses of trees, such as e.g. wood for energy, fodder for breeding, medicinal use, and organic fertilization with falling leaves, can allow an external input saving for households (Bright et al. 2017). When yield is increased, it can raise income, only if the cost generated by the agroecological practice does not exceed the resulting surplus income, since no price valuation exists. Note that this cost of transition or cost benefit analysis is usually missing in most articles since they are focused solely on productivity. In organic farming, the gross margins assessed on various vegetable productions led to lower economic net returns compared to conventional production, especially due to the absence of local market and certification for organic products, which guarantees premium prices for covering reduced yields (Binta et al., 2015).

Some articles point out that the needed investment is a barrier to adopting agroecological practices, especially when economic returns occur only in the long term thanks to soil fertility increase, and that farms have significant cash issues (Douxchamps et al. 2016, Bright et al. 2017). Little data on the cost of labour are available, even if the surplus of working time in agroecology and organic farming is demonstrated (Binta et al. 2015, Ba Bah 2016), and that farms are mainly based on family labour.

Regarding environmental benefits, trees in agroforestry can provide significant ecosystem services, such as i) reducing soil erosion, ii) allow nutrients recycling, iii) increasing soil organic matter and iv) carbon sequestration, therefore v) increasing water retention, vi) enhancing soil fertility and vii) increasing biodiversity (Bright et al. 2017, Stoate et al. 2008). By increasing soil cover, intercropping and residue mulching can reduce the splash effect of raindrops resulting in higher infiltration and reduced erosion (Trail et al. 2016), while improved soil quality can also be obtained through the return of crop residues to the soil in order to maintain organic matter levels in sandy soils (Badiane et al. 2001). Moreover, neem-based pest management methods decrease chemical pesticide use and could therefore result in a decrease in health hazards and biodiversity loss (Sow 2013). Additionally, one of the documents suggests lower carbon emissions in organic farming systems than in conventional systems (Binta et al. 2015), as a way to mitigate climate change.

No noteworthy elements were pointed out on the social level in the documents, except the social value of some tree species (Stoate et al. 2008), or the social benefits from improved income, which enables better access to ecosystem services (Douxchamps et al. 2016).

Figure 3. Millet field manual weeding, Caroline Dangleant © Cirad

Figure 4. Crop association: cowpea, groundnut and millet, Caroline Dangleant © Cirad

3.1.5 Promotion of agroecology in the Country: evidence from literature

No government policy supporting agroecology has been mentioned in the articles analyzed. Agroecological practices seem to be mainly disseminated by local associations or NGOs, which promote and lead several development projects in agroecology in West Africa. For example, the ENDA PRONAT NGO has created a certification of healthy and sustainable agriculture, with specifications similar to organic farming, and developed its local markets, which however struggles to ensure stable prices to farmers and sell sufficient volumes (Ba Bah 2016).

Overall, the level of dissemination and adoption of agroecological practices by farmers is rarely analyzed in scientific papers. Then there is probably a significant gap between practices experimented through researchers and implementation on a larger scale with farmers.

3.1.6 Conclusions

Agroecology has an encouraging potential to improve food security in Senegal by increasing yields and soil fertility, if not to be substantially convincing through this analysis due to some lack in published economic studies. Some practices, such as agroforestry, crop mixtures of cereal and legume, residue mulching and compost use, are studied in Senegal and results indicated that they can improve soil properties and therefore productivity at lower costs. In studies dealing with organic farming, however, the lack of premium price valuation is really an issue, as demonstrated in market gardening where organic farming production is characterized by lower yields than in conventional practices, as well as income due to the absence of a specific market for this type of production, despite positive environmental externalities. Given the lack of exhaustiveness in the themes covered, there is a significant need both for research and development project to have a more accurate evaluation of the contribution of agroecology in this country for improving food security, livelihood, social and environmental benefits. Results from experimental studies are promising though contributing as to provide a stronger base for deciding on the adoption by farmers of agroecology.

3.1.7 Number of analyzed documents

For this study, and in comparison with other reviewed countries, Senegal presents a significant number of documents published, in fact the applied protocol for literature screening returned 112 publications and 65 others documents. Of these, only 8 scientific papers and 4 documents from the grey literature were found relevant for the scope of this study.

3.1.8 References

Scientific papers

Andriamampianina, L., Temple, L., de Bon, H., Malezieux, E., Makowski, D., 2018. *Multi-criteria evaluation of organic agriculture in sub-Saharan Africa using probabilistic elicitation of expert knowledge*. CAHIERS AGRICULTURES 27. https://doi.org/10.1051/cagri/2018030

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Grey literature

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Ba Bah, A.B., 2016. *Changements climatiques et Intensification Durable au Sénégal*. https://bibnum.ucad.sn/viewer.php?c=thd&d=thd_2016_0025

Ketteka, V., 2016. *Dynamique de transition agroécologique du maraîchage dans la zone Sud des Niayes, Sénégal.* http://agritrop.cirad.fr/592403/

Sow, G., 2013. *Gestion intégrée des populations de Plutella xylostella L. (Lepidoptera: Plutellidae), principal ravageur du chou au Sénégal*. http://agritrop.cirad.fr/569799/

3.2 Mali

3.2.1 Country profile from the agro-environmental perspective

Mali is a large, land-locked country at the heart of the West African Sahel spanning the latitudinal transition from desert in the north (Saharan zone, with less than 200mm of annual rainfall), through semiarid grassland in the center (Sahelian zone), to wooded savanna in the south (Sudanian and Sudano-Guinean zones with average annual rainfall ranging from 600 to 1200 mm).

The Malian economy is largely dependent on agriculture, measured by a contribution of agriculture to national gross domestic product of more than a third. Most of the population engages in subsistence agriculture (around 75%). An agricultural area of major importance is the inland Niger delta. Millet, sorghum, and maize as well as yams and cassava are the main subsistence crops, mostly grown in northern and central regions, while cotton is an important commercial crop, primarily in Southern Mali. Rice, groundnut, sugarcane, tobacco, and tea are also grown for market. Market gardens produce a variety of vegetables and fruits, including cabbages, turnips, carrots, beans, tomatoes, bananas, mangoes, and oranges. Livestock is commercially important; the major area for livestock raising (cattle, sheep, and goats) is the Sahel.

The agricultural production is highly dependent on variable rainfall and vulnerable to frequent dry spells. There is an alternation of dry and rainy season. It is clear that cash crops (cotton and rice) have received more attention than staple rainfed food crops in terms of research and support.

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 Topics covered by the selected literature

The main systems encountered in the literature are family farms, producing staple crops for self-consumption such as millet, maize, sorghum or cassava. Farms with more means can grow cash crops such as cotton and rice. There are also studies focusing on vegetable crops and a paper deals with the relationships between farmers and agro-pastoralists. Surprisingly, only few documents dealing with cash crops and horticultural production were found despite their importance in the country.

Agronomic practices studied include crop residue management, cereal-legume cropping rotations and intercropping, biological pest control through predator rearing, agroforestry, and the use of trees as fences. One of the papers addresses the conditions of land access for women, who are allocated the least fertile plots, and discusses the potential benefits of agroecological intensification on these lands with the development of perennial crops. No post-harvest agroecological practice was found.

Only one research experiment was carried out in an experimental plot, the other experiments having been set up on farm fields, as found in three articles. The other three papers result from interviews with actors in the field. Most of the studies were conducted in Central and southern Mali, within a 300 km radius from Bamako.

3.2.3 Links to food security

The contribution to food security was only mentioned in three documents (Payne et al 2011, Roge et al 2017, Sidibe et al 2017), and evaluated on the basis of the yields obtained or the nutritional value of products. Agroecological practices were found positive in each of these three cases, either with improved yields due to some better management of agricultural resources.

3.2.4 Sustainability assessment addressing the environmental, social and economic dimensions

Regarding the productivity of the agroecological systems, few articles present significant results. In mixed crop-livestock systems, Dongmo and al. (2012) point out that the most productive plots are those that are richer in organic matter and mineral elements due to effective biomass recycling, using organic fertilizer produced from crop residues which are preserved from free grazing for example. Sidibé and al. (2017) showed that the intercropping of planted Ber with sorghum and eggplant did not have a negative effect on the production of these two latter crops. In addition, the on-farm biological control of the millet head miner can be effective through rearing and releasing the parasite Habrobracon hebetor, the results of which suggest millet yields increased by 40% (Payne et al., 2011).

The economic data related to agroecological practices are quite poor for Mali. In agroforestry systems, the economic value of trees is often mentioned in the documents, whether for the sale of wood, fruit, or leaves with medicinal properties, but a wide quantification is lacking. However, it has been shown that the high level of fruit production of an improved variety of Ber intercropped with eggplant and sorghum on farms under rain-fed conditions may be a source of additional income and diversification of diet for rural communities in West Africa (Sidibé and al. 2017). Moreover, Roge et al. (2017) evoke the savings in inputs and labour induced by perennial crops. Note that no document addresses the cost of investing or transitioning to agroecological practices.

Regarding environmental benefits, most authors point out the improved soil properties due to agroecological practices. For example, in the case of cereal-legume intercropping, it was suggested that cowpea creates a "live mulch" that lowers surface soil temperature and evaporation, thus improving water conservation compared with sole cropping. Thanks to extensive root systems, perennial crops can increase nutrient use efficiency and can store carbon according to Roge and al. (2017). The soil improving properties and low water requirement of some trees have also been reported as a benefit in agroforestry systems (Sidibe and al. 2017, programme Mali-UAVES 2014). Moreover, the application of biocontrol methods to manage pests allows avoiding to use pesticides, which can pose risks to human health and the environment and were reported as efficient (Payne and al. 2011).

On the social level, the development of perennial crops could benefit women farmers and pastoralists who are often marginalized by the development of cash crops. They may result in a better access to land and resources for these two groups (Roge and al. 2017). The model of crop residues management proposed by Dongmo et al. (2012), which aims at improving biomass recycling and crop livestock integration compared to traditional use of crop residues by herders and farmers, can be a relevant solution to solve conflicts and tensions between crop farmers and pastoralists in the Sudano-Sahelian region. Finally, live fences with trees have been identified as effective by farmers to protect livestock access to land and to mark properties. Some trees have a cultural value and the owners are not the only ones to reap the reward from having trees since members of the village can benefit from the products of the live fence (Levasseur and al 2004).

3.2.5 Promotion of agroecology in the Country: evidences from literature

The lack of support from the government to develop agroecological innovations can be pointed out. For example, Roge et al. (2012) indicate that, on the contrary, policies subsidise the purchase of synthetic fertilizers and aim to develop cash crops (cotton, rice). Agroecology is supported by some associations and NGOs, such as Agroecology and Solidarity with the Sahelian People, UAVES (Union for a Future Ecological and Solidarity) which have implemented several agricultural development projects, but few reports and quantitative results are available. Cooperation between farmers at the community level appears to be fundamental for the diffusion of new practices.

3.2.6 Conclusions

According to the documents found and studied, it is mentioned that some agroecological practices, in particular agroforestry, present considerable potential at the economic, environmental and food security levels. However, there is a lack of significant scientific data regarding agroecology for this country, as well as results from development projects. Obviously, there are projects that are being set up according to NGOs, and the agroecological transition is "gaining ground", but the results of these projects are missing in the grey literature. There is therefore a need to capitalize all available information to have a more precise idea of the potential and state of development of agroecology in Mali.

3.2.7 Number of analyzed documents

Mali is characterized by modest reporting of relevant scientific knowledge on agroecology, since of the 98 papers initially identified through the applied protocol, only 6 documents were retained. The grey literature is very modest as well, with only 14 documents initially identified, and almost no appropriate document apt to be evaluated, except one.

3.2.8 References

Scientific papers

Dongmo, A.-L., Vall, E., Dugue, P., Njoya, A., Lossouarn, J., 2012. *Designing a Process of Co-Management of Crop Residues for Forage and Soil Conservation in Sudano-Sahel*. Journal of Sustainable Agriculture, 36, 106–126. https://doi.org/10.1080/10440046.2011.620232

Falconnier, G.N., Descheemaeker, K., Van Mourik, T.A., Giller, K.E., 2016. *Unravelling the causes of variability in crop yields and treatment responses for better tailoring of options for sustainable intensification in southern Mali.* FIELD CROPS RESEARCH 187, 113–126. https://doi.org/10.1016/j.fcr.2015.12.015

Levasseur, V., Djimde, M., Olivier, A., 2004. Live fences in Segou, Mali: an evaluation by their early users. AGROFORESTRY SYSTEMS 60, 131–136. https://doi.org/10.1023/B:AGFO.0000013268.44627.2f

Payne, W., Tapsoba, H., Baoua, I.B., Malick, B.N., N'Diaye, M., Dabire-Binso, C., 2011. On-farm biological control of the pearl millet head miner: realization of 35 years of unsteady progress in Mali, Burkina Faso and Niger. INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY 9, 186–193. https://doi.org/10.3763/ijas.2010.0560

Roge, P., Diarisso, T., Diallo, F., Boire, Y., Goita, D., Peter, B., Macalou, M., Weltzien, E., Snapp, S., 2017. Perennial grain crops in the West Soudanian Savanna of Mali: perspectives from agroecology and gendered spaces. INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY 15, 555–574. https://doi.org/10.1080/14735903.2017.1372850

Sidibe, D., Sanou, H., Bayala, J., Teklehaimanot, Z., 2017. Yield and biomass production by African eggplant (Solanum aethiopicum) and sorghum (Sorghum bicolor) intercropped with planted Ber (Ziziphus mauritiana) in Mali (West Africa). AGROFORESTRY SYSTEMS 91, 1031–1042. https://doi.org/10.1007/s10457-016-9978-z

Grey literature

Agroécologie et Solidarité avec les peuples du Sahel, 2014, Programme Mali-UAVES, http://agrosol-sahel.org/nos-actions/nos-programmes/mali/

3.3 Burkina Faso

3.3.1 Country profile from the agro-environmental perspective[6]

Burkina Faso is a Sahelian country that faces low and variable rainfalls, land degradation, deforestation and desertification. Despite the harsh climate, Burkina Faso's agriculture sector generates roughly a third of the country's GDP and involves 80 percent of the population. Agriculture production is generally characterized by low crop and livestock productivity and is dominated by subsistence farming. According to US Aid, more than 3.5 million people, roughly 20 percent of the population, are food insecure.

The country has a semi-arid tropical climate. The dry season, from October to March, is characterized by the harsh harmattan wind, while the rainy season, from May or June to September, is marked by humid winds. From South to North, three agro-climatic zones can be identified: the south Sudanese zone, with an average annual rainfall between 900 and 1200 mm; the Sudano-sahelian region in the central zone of the country, which has an average annual rainfall of between 800 and 900 mm; and the Sahelian zone in northern Burkina Faso, with an average annual rainfall between 300 and 600 mm over only three months. In the latter zone, the vegetation consists of steppes with trees, shrubs and thick bushes while denser forest formations may be found in the other two zones. The northern zone is characterised by the most degraded soils of the country and frequent dry spells that may result into subsequent yield declines and food shortages in this region.

The main crops grown are millet, sorghum, maize, and cotton. The latter, which is primarily grown in western and eastern regions of Burkina Faso, is the most important in terms of economic value and accounted for 60% of the country's export before the gold mining boom.

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

3.3.2 Main topics addressed by the selected literature

Most of systems encountered in the literature review are family farming systems characterised by a low level of inputs use, except for cotton planters' farms, the major cash crop in this country. Staple crops grown encompass sorghum, millet, maize, groundnut or maize (Figure 5 and Figure 6). There are also studies focusing on vegetable cropping systems and on mixed farming and breeding systems. Moreover, agroecological practices studied refer to crop-livestock integration, the use of organic manure, conservation agriculture, the use of neem-based biopesticides, agroforestry, and Zaï holes. No paper on postharvest agroecological practice for reducing product losses or wastes has been identified. It should be noted that only two documents deal with cotton production, which indicates that, for the moment, more agroecological activities have been developed on staple crops than on cash crops in this country.

Three studies are based on farmers interviews, the remaining refer equally to on-farm experiments and station experimental sites. Likewise, research activities took place in several regions across the territory, with 4 studies in Northern Burkina Faso (BF) and Central plateau, 3 studies in Western BF, and 2 studies in Eastern and Southern BF.

[6] Sources (in addition to the references below):
https://agriculture.gouv.fr/burkina-faso
https://www.usaid.gov/burkina-faso/agriculture-and-food-security
http://www.fao.org/3/i3760e/i3760e.pdf

Figure 5. Half-moons to restore soil fertility, Patrick Dugué © Cirad

Figure 6. Stocking cereal straw (sorghum and millet) for livestock, Patrick Dugué © Cirad

3.3.3 Links to food security

Several documents highlight a positive contribution of agroecological practices to food security. It was mainly evaluated by assessing food availability or livelihood evolution. For example, the application of compost appears as a sound technology for alleviating food shortage and poverty, as it results in a significant increase in crop production and mitigated the negative effect of a delay in sowing, although there are some socio-economic constraints to its adoption (Ouedraogo and al. 2001). Similarly, Vall et al. (2017) showed that food security is higher in mixed crop-breeding systems than in farms with a low level of crop-livestock integration, with more than 200 kg of cereals per year per capita because of a better use of cattle manures. According to Bambara and al. (2008), sorghum and cowpea intercropping with improved varieties may resolve issues of food insecurity by increasing total grain production and decreasing food shortage when compared to the inefficient traditional practices of intercropping. In the grey literature, the increase in crop production and food security allowed by Zaï holes technic (small planting holes where water and manure are concentrated) is largely reported, especially in most degraded lands (Ouedraogo and al. 2005, Billaz 2012). Moreover, the potential of overall agroecological practices to increase food security by increasing yields and resiliency is suggested by the CALAO report (2018), although this document lacks quantitative data.

3.3.4 Sustainability assessment addressing the environmental, social and economic dimensions

The potential impact on productivity of some agroecological cropping systems are well illustrated through these publications. For instance, the application of compost (5t/ha) increased sorghum grain yields by 45% in southern Burkina Faso compared to no-compost plots (Ouedraogo and al. 2001). Likewise, the use of compost in combination with mineral fertilizers resulted in higher cotton yields compared to the application of fertilizers alone in Central and Western Burkina Faso, but differences were not significant (Pouya and al. 2013). In northern Burkina Faso, Bambara and al. (2008) showed that improved varieties and rational relative densities of intercropping led to an increase of grain yield of 34% for sorghum and 26% for cowpea compared to the traditional system of intercropping. Similarly, in the grey literature, Sermé (2007) reported that sorghum-cowpea rotation resulted in sorghum grain and biomass yield increases of 31 and 40 % respectively when compared to pure sorghum crop rotation, while Zida (2011) highlighted similar benefits. Billaz (2012) references other studies suggesting substantial sorghum yield increases (from 70 kg/ha to 300 kg/ha) with Zaï holes compared to cropping systems without Zaï. In addition, with better recycling, crop livestock-integration practices can improve crop productivity. For example, Vall et al. (2017) showed that maize yield was higher (+36%) in farms with high level of integration between crop and livestock than in farms with lower levels of integration. Finally, several conservation agricultural practices combining trees can improve staple crops yields on unfertile soils (Bayala and al. 2011). Coppicing trees and rotations appeared to be better adapted for zones with an annual rainfall of over 800 mm, while residue mulching seemed to improve crops yields when the rainfall is less than 600 mm (Bayala and al. 2011).

From an economic point of view, gross margins or incomes appear to be considerably higher in farms with high level of crop-livestock integration in comparison to farms with low level of association (CALAO report 2018). For example, Vall and al. (2017) suggested gross margins 57% higher for maize in this type of farming system. Moreover, Zaï holes technique can improve farmers' production and benefits. Indeed, the cereal surplus can be sold or used to feed poultry and small ruminants, covering economic investment with sufficient margin (Billaz, 2012). The production of good quality local seeds can enable farmers to achieve a satisfactory level of production while saving the purchase of seeds and other inputs. Consequently, the decrease of these expenses improves farm profitability and income (Comité Français pour la Solidarité Internationale). In addition, Millogo (2007) pointed out higher economic gains in certified organic cotton production than in conventional one despite lower yields, because of higher price for the product and lower production costs.

In many documents, the cost of agroecological transition is outlined as a limit to its potential development. Indeed, some farmers cannot afford equipment such as pickaxes, wheelbarrows and carts, which are of tremendous importance in compost production and crop livestock integration (Ouedraogo and al. 2001, Millogo and al., Vall and al. 2017, CALAO report 2018 etc.). Thus, these innovations could be only adopted by producers owning animal power and sufficient labour.

In terms of environmental benefits, many documents emphasize the improvement of soil fertility or water conservation brought about by agroecological practices (Figure 7 and Figure 8). For instance, soil structure and cation-exchange capacity was improved by applying compost (Ouedraogo and al 2001), or through the use of cowpea as a cover crop (Sermé, 2007). Likewise, crop-livestock integration contributes positively to soil fertility and carbon sequestration by retaining the largest amount of carbon on the farm (Vall and al., 2017). Moreover, according to Billaz (2012), Zaï holes regenerate soil fertility and increase water infiltration, while stones retaining barriers are efficient to stop water runoff. These benefits are of paramount importance as water runoff is the most impacting factor on the water balance during dry spells in the region. Soil conservation practices can also enhance the abundance of macrofauna (Ouedraogo, 2009) or increase soil carbon content (CALAO report 2018). Assisted natural regeneration (ANR) also contributes to soil rehabilitation (Billaz, 2012).

Some social benefits are pointed out in the documents, in addition to the improvements of food security or farmer livelihoods mentioned above. The development of Zaï holes technique tends to decrease rural exodus and strengthen the fight against poverty (Billaz 2012). Zaï holes or organic cotton production can also improve women's status as well as the one of young farmers because they acquire better autonomy than in conventional production (Millogo, 2007). According to the CALAO report, agroecological practices lead to a recovery of local know-how. Moreover, in a context of limited access to inputs, crop-livestock integration reinforces autonomy and sufficiency of farms. However, it is combined with the development of commercial exchanges between farms (e.g. manure, fodder, carts) and could enhance some conflicts between communities to have access to these resources. (Vall and al. 2017). Finally, according to farmers, cotton organic production can reduce health hazards (Millogo, 2007).

It should be outlined that some results from the grey literature must be analyzed carefully as they do not rely on scientific or accurate observations, and there is no evident comparison with conventional practices. These results should therefore be used cautiously.

Figure 7. Sorghum-cowpea association, Jacques Chantereau, © Cirad

Figure 8. Sorghum in zai holes, © X. N. Gnoumou, from httpswww.researchgate.netfigureSorgho-dans-les-poquets-de-zai-eau-Cliche-X-N-Gnoumou-2013-23-COLLECTE-DES-DONNEES_fig1_315615098

3.3.5 Promotion of agroecology in the Country: evidences from literature

Agroecology is promoted by local or regional union of producers, Non-Governmental Organizations (NGOs) such as Fert, Accir, Gret and sometimes in collaboration with ministries or research institutions, by implementing on farm plots to diffuse innovations to producers and train them (Morin-Kasprzyk and al 2015). However, several documents mention the lack of policies supporting the development of agroecology practices (CALAO report 2018, Bambara 2008, Ouedraogo 2005, etc). Levard and Mathieu (2018) point out that adoption of agroecological practices is higher in Senegal than in Burkina Faso especially because there are more NGOs promoting their diffusion. According to the CALAO report (2018), conservation practices do not exceed 25% of farmers in Burkina Faso despite the training of many of them.

Moreover, many constraints are to be overcome to upscale the diffusion of agroecological innovations. The main limiting factors are available labour and its remuneration, equipment requirements, and organic manure availability (Vall 2017, Ouedraogo 2001). For example, Zaï without mechanization requires approximatively 300 hours of work per ha (Billaz 2012). The lack of cash flow to invest in practices that pay off in the long run is also a barrier, as well as some land access issues (CALAO report 2018). The different organizations promoting agroecology must cooperate with other private actors and policy makers to overcome the above constraints.

3.3.6 Conclusions

This brief report highlights some positive contributions of agroecology especially in terms of food security and environmental impacts. Some practices even seem critical to restore soil fertility and productivity in most degraded lands. However, in view of the lack of scientific papers, agroecology research activity should be intensified in Burkina Faso, these results need to be confirmed by additional studies.

3.3.7 Number of analyzed documents

A small number of relevant scientific papers was found for Burkina Faso, as from 152 papers returned by the application of the protocol for literature review used in this study, only 5 were considered relevant for the goal of this study. However, three papers referring to studies in Burkina Faso among other ones (Senegal, Mali) were analysed. In contrast, a considerable amount of grey literature was found to be relevant, as 10 documents were selected among 90 initially identified.

3.3.8 References

Scientific papers

Bambara, D., Zoundi, J.S., Tiendrebeogo, J.-P., 2008. *Sorghum Sorghum bicolor (L.) Moench and cowpea Vigna unguiculata (L.) Walp intercropping for crop-livestock integration in the Sudano-Sahelian area*. Cahiers Agricultures 17, 297–301.

Bénagabou, O.I., Blanchard, M., Bougouma Yaméogo, V.M.C., Vayssières, J., Vigne, M., Vall, E., Lecomte, P., Nacro, H.B., 2017. *L'intégration agriculture-élevage améliore-t-elle l'efficience, le recyclage et l'autonomie énergétique brute des exploitations familiales mixtes au Burkina Faso ?* Rev. Elev. Med. Vet. Pays Trop., 70, 31. https://doi.org/10.19182/remvt.31479

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Pouya, M.B., Bonzi, M., Gnankambary, Z., Traore, K., Ouedraogo, J.S., Some, A.N., Sedogo, M.P., 2013. Current soil fertility management practices and their effects on the cotton production and soil on the cotton farms of Central and Western Burkina Faso. Cahiers Agricultures 22, 282–292. https://doi.org/10.1684/agr.2013.0643

Vall, E., Marre-Cast, L., Kamgang, H.J., 2017. Intensification pathways and sustainability of crop-livestock systems in Sub-Saharan Africa: crop-livestock interaction contribution. Cahiers Agricultures 26. https://doi.org/10.1051/cagri/2017011

Grey literature

Bayala, J., World Agroforestry Centre (Eds.), 2011. *Conservation agriculture with trees in the West African Sahel: a review*, ICRAF occasional paper. World Agroforestry Centre, Nairobi.

Billaz, R., 2012. *La lutte contre les aléas climatiques au Burkina Faso Acquis et défis de l'agro-écologie: le cas de la région Nord.* https://www.avsf.org/public/posts/914/la-lutte-contre-les-aleas-climatiques-au-burkina-faso-acquis-et-defis-de-l-agroecologie-dans-la-region-nord.pdf

Comité Français pour la Solidarité Internationale, n.d. Ferme Agroécologique et Autonomie Semencière Paysanne. FICHE CAPI PAFAO #87. https://www.alimenterre.org/system/files/ressources/pdf/1115-entretien-jafowa-aidmr-bacye-sam-tokoro-cdr.pdf

Levard, L., Mathieu, B., 2018. *CALAO report, agroécologie: capitalisation d'expériences en Afrique de l'Ouest*, Projet CALAO. https://www.gret.org/wp-content/uploads/rapport_etude_calao_2018-web_avsf_gret_cedeao.pdf

Millogo, J., 2007. *Perception paysanne du coton biologique: cas de la zone de Fada*.

Morin-Kasprzyk, M., Sankara, R., Garnotel, J.-L., 2015. *Quel accompagnement des producteurs sur la voie de l'agroecologie*. Fert, ACCIR, UDPN Dablo. https://www.alimenterre.org/system/files/ressources/pdf/954-fert-accir-udpn-capitalisation-agro-ecologie-burkina-2015.pdf

Ouédraogo, A., Sawadogo, H., 2005. *Innovation locale au Burkina Faso dans la vulgarisation agriculteur-à-agriculteur*.

Ouédraogo, J., 2009. *Evaluation de la contribution de la macrofaune du sol sur la performance des mesures de conservation des eaux et des sols*.

Sermé, I., 2007. *Agriculture de conservation dans les systèmes de culture à Base de sorgho dans les zones centre et sud-ouest du Burkina Faso*.

Zida, Z., 2011. *Long-term effects of conservation soil management in Saria, Burkina Faso,* West Africa. s.n., S.l. https://library.wur.nl/WebQuery/wurpubs/fulltext/180894

3.4 Niger

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

Niger is a country located in the Sahel region of West Africa. It is land-locked, and the majority of its area is located in the Sahara Desert, with the southernmost part of the country being savannah, therefore it is covered by Saharan, Sahelian and Sudanian agroecological zones. It has a population of more than 19 million people and it is growing at an estimated 3.2% per year, one of the highest rates in the world.

Its agricultural sector is characterised by livestock herding and smallholder field cropping. Its major staple crops are millet, sorghum, cowpea, groundnut, cassava and rice. Agricultural productivity is generally low due to persistent drought conditions, soil infertility, and desertification. Food security is affected by these factors, as well as regional epidemics and conflicts.

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

3.4.2 Synthesis of agronomic practices

Agri-food systems covered in the analysis included subsistence and entrepreneurial field cropping (extensive and low-level intensive), market gardening systems, agroforestry, home gardening, and mixed cropping systems. Practices demonstrated were farmer managed natural regeneration (FMNR), micro-dosing of fertiliser, biological pest control, intercropping, market-based diversification, demi-lunes and tassa (planting pits), organic fertilisation and natural seed treatments. No post-harvest practices were described in the literature. Factors influencing farmers and other stakeholders to adopt various agroecological practices included pests, low incomes, soil infertility, erosion, diminishing yields, chronic food insecurity, high input prices, low seed survival rates, increasingly erratic rainfall, and limited access to land.

3.4.3 Links to food security

The analysed literature detailed exclusively indirect contributions to food security through increases of generated income, increased access to land or production gains (yield)/increase of food availability. Of the eight total sources, four presented positive correlations between the activities presented and project participant food security. All sources addressed food security at the household or village scale.

3.4.4 Sustainability assessment addressing the environmental, social and economic dimensions

From the selected literature, yield increases were the only described indicator of productivity improvements through agroecological practices. In a study highlighting the use of biological controls against pearl millet head miner, farmers observed increases in yield of up to 40% (Payne et al, 2001). In a large-scale study on the use of farmer managed natural regeneration (FMNR), some farmers observed a doubling of their yield (WRI et al, 2008). A project investigating micro-dosing of fertiliser (precision application of 40-60 kg NPK/ha) saw average yields increase 44%, with some increases as high as 89% (Tabo et al., 2011). In a smaller study where farmers applied manure to fields in tandem with integration of agroforestry systems, yield increases of 48-240% were observed (AFSA, 2015).

Increase in income was the most highlighted economic benefit within the studies. The use of FMNR resulted in farmers and farmer families having their incomes doubled or tripled as a result of sales of fuelwood, forage and leaves for human consumption (WRI et al., 2008). A study combining the use of micro-dosing and of a "warrantage" system (a community-based credit system where farmers sell their harvest to a community organisation for immediate income, then the harvest is stored and sold when market prices increase, and the extra income is shared with farmers and fed back into the organisation) showed incomes increasing 44-121% during the study (Tabo et al., 2011). Farmers who planted Moringa oleifera for human consumption recorded higher opportunity costs than those cultivating staple crops in a small study (Larwanou et al., 2003). A study of an initiative to improve women's access to land saw the participating women increase their household incomes through increased market sales (Mamadou & Salaou, 2013). Peri-urban gardeners around Niamey observed

[7] Sources (in addition to those listed below):
Image by Marcos Elias de Oliveira Júnior - Own work, Public Domain
https://www.cia.gov/library/publications/the-world-factbook/geos/ng.html
https://www.wfp.org/countries/niger

higher gross margins in their operations by serving niche markets and producing vegetables during seasons of low availability (Andres and Philippe, 2011).

In addition to increase in income, there were three other economic benefits observed in the literature. As a result of the increased efficiency of the micro-dosing regimen, farmers' expenditure for inputs were reduced (Tabo et al, 2011). Rehabilitation of degraded lands and improved water conservation practices through the practice of FMNR saw land values increased for farmers (WRI et al, 2008). In a study of a farmers federation, members created a market for improved millet seed, which saw seed vendors rise from 8 to 200 in one year (UNDP, 2015).

There were limited environmental benefits observed in the literature. Biodiversity was enhanced in two studies. In the case of using biological control of the pearl millet head miner, chemical pesticide use was either reduced or eliminated. This led to an increase in beneficial insect populations (Payne et al, 2011). In another study (WRI et al, 2008), where FMNR was practiced, a return of local fauna was observed. In addition to this biodiversity enhancement, farmers and landowners observed increased soil fertility, reduced erosion and improved groundwater stores through practicing FMNR. During this study, which covered 5 million ha, tree cover increase by 10-20 times. In one study, where communities established tree nurseries to support agroforestry efforts, discarded plastic bags were gathered and used (AFSA, 2015).

The literature demonstrated a wide array of realised social benefits, which are categorised as empowerment of farmers or community, policy and social changes. Farmer field schools (FFS) and farmer to farmer knowledge exchange was seen in a study where an NGO was promoting the use of agroforestry practices. Through these trainings and exchanges, farmers established or improved their social network for technical support and knowledge sharing (AFSA, 2015). In the study of the application of biological controls, the project resulted in the training of farmers, extension agents, and village-based animators (Payne et al., 2011). In the study of the farmers' federation, trainings targeted specifically for women and promoted financial independence (UNDP, 2015). One project which was studied resulted in the mobilisation of women groups to create and maintain tree nurseries, which were either used themselves or sold to the villages (AFSA, 2015). A project which focused on providing women with better access to land, employment and market opportunities were improved for participants (Mamadou & Salou, 2013). The "warrantage" system, where farmers were able to store harvest and sell at more opportunistic times of the year, also yielded increased self-reliance on the village scale and stimulated farmer-based organisations and cooperative organisations in the area (Tabo et al., 2011). In the case of moringa production, employment opportunities increased for villagers during harvest times, as a result of moringa higher opportunity cost (Larwanou et al., 2003).

As a result of the practice of FMNR, there was an observed increase in the availability of productive lands which led to a decreasing trend of rural exodus (WRI et al, 2008). Through the support of the farmer federation, some funds which were generated were fed back in to the community to support public health facilities and schools. In addition to this community level benefit, the actions of the farmers' federation resulted in improved support from national and regional governments for farmer organisations (UNDP, 2015).

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

The literature did not mention specific policies promoting agroecology; however, the Nigerien government was highly supportive in the scaling-out of FMNR practices (WRI et al, 2008). Farmers organisations were key in the promotion of village and regional scale initiatives centred around agroecological practices (UNDP, 2015). Most support for agroecology described in the literature was provided by international development agencies or national academic centres. For some studies, it was local village committees who promoted such practices.

3.4.6 Conclusions

Overall, few examples were reported of observed benefits deriving from agroecological practices. Economic indicators were generally measured as income gains at the household level, although input cost reductions and increased land prices were also observed. The environmental benefits that were observed generally dealt with the protection, conservation and management of soil, as well as the promotion of natural biodiversity within agricultural systems. Social benefits included the empowerment of women with access to land and more broadly the empowerment of villages.

Agroecological practices, as represented in the summary above, have a mostly scattered presence in the Nigerian agriculture. The harsh conditions in the country provide little opportunity to farmers for experimentation, although certain agroecological practices could hold the potential to make the agricultural sector more resilient in the face of a changing and unpredictable climate. Therefore, more presence of the national government and NGOs in supporting farmers to research the implementation and dissemination of such practices could prove invaluable to the country. Additionally, most research efforts focus on productivity and/or economic benefits of certain practices. Results fail to quantify the actual effects that these benefits have on food security.

3.4.7 Number of analysed documents

The protocol for literature review applied in this study returned 106 scientific papers, and no grey literature documents. Of these, three were considered matching the needs of the study. In addition, grey literature was further searched to highlight research, projects or initiatives in the area which were not represented in journal articles. Five documents were retained. Overall, of the total amount of articles found, very few represented agroecological practices or transitions in the "real" world.

3.4.8 References

Scientific Literature

Andres, L., Philippe, L. 2011. Peri-urban Agriculture: The Case of Market Gardening in Niamey, Niger. African Review of Economics and Finance, 3(1), 69–81.

Payne, W., Tapsoba, H., Baoua, I.B., Malick, B.N., N'Diaye, M., Dabire-Binso, C. 2011. On-farm biological control of the pearl millet head miner: realization of 35 years of unsteady progress in Mali, Burkina Faso and Niger. International Journal of Agricultural Sustainability, 9(1), 186–193.

Tabo, R. Bationo, A., Amadou, B., Marchal, D., Lompo, F., Gandah, M., Hassane, O., Diallo, M.K., Ndjeunga, J., Fatondji, D., Gerard, B., Sogodogo, D., Taonda, J.B.S., Sako, K., Boubacar, S., Abdou, A., Koala, S. 2011. Fertilizer Microdosing and "Warrantage" or Inventory Credit System to Improve Food Security and Farmers' Income in West Africa. In: Bationo A., Waswa B., Okeyo J., Maina F., Kihara J. (eds), Innovations as Key to the Green Revolution in Africa. Springer, Dordrecht, pp 113–121.

Grey Literature

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Mamadou, A., Salaou, A., 2013. Women's land rights in a changing climate: a case study from Maradi, Niger. In A New Dialogue: Putting People at the Heart of Global Development. Dublin.

United Nations Development Programme (UNDP). 2015. Gaskiya Federation of Maradi Farmers Unions, Niger. Equator Initiative Case Study Series. New York, NY.

World Resources Institute (WRI) et al., 2008. Roots of Resilience—Growing the Wealth of the Poor. World Resources 2008. Available at: https://www.wri.org/publication/world-resources-2008 [Accessed November 23, 2019].

3.5 Ghana

3.5.1 Country profile from the agro-environmental perspective[8]

Ghana is a country in West Africa situated along the Gulf of Guinea and the Atlantic Ocean with a population of approximately 30 million. The region is characterized by grasslands mixed with coastal shrublands and forests. The climate is distinguished by a wet and dry season. About 65% of Ghana's total land area is agricultural land, of which 30% is arable (47000 km^2). Overall there are 11,000 irrigated hectares. Small and medium size farms make up 95% of cultivated land, with most farms less than 1.2 hectares. Agriculture in Ghana is mostly traditional, smallholder and rainfed. More than half of the labour force is in agriculture and women are the majority of workers. The agricultural sector contributes to 54 % of Ghana's GDP, and accounts for over 40 % of export earnings, while at the same time providing over 90 % of the food needs of the country. Ghana also produces high-quality cocoa and is the 2nd largest producer of cocoa in the world.

Each agroecological zone within Ghana is characterised by a unique farming system. Tree crops are vital in the forest zones (coffee, cocoa, rubber and oil palm) and are usually intercropped with maize, plantain, cocoyam and cassava (MOFA 2001). In the middle belt, mixed or single cropping of maize, legumes, cocoyam or yam are commonly grown with cash crops like tobacco and cotton. However, in the northern regions, where sorghum, maize, millet, cowpea, groundnut and yam are the main food crops, cotton and tobacco are also grown. Rice cultivation is also essential in all zones. Moreover, livestock farming is second to arable crop production (e.g. most rural households' rear livestock). Cattle production dominates the Savannah zones whereas poultry is more common in the south. However, sheep and goat production is a common practise all over the entire country.

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

3.5.2 Synthesis of agronomic practices

In the analysed literature most farms were smallholdings, with farmers usually practising subsistence farming. Crops cultivated on these farms included food crops (maize, sweet potato, cowpea, groundnuts, cocoyam), cash crops (cocoa and cocoyam) and vegetables. Cocoa plantation systems were also studied in one article and this production was done on small-scale, family farming. All projects and studies included in were performed on-farm. Most practices in these production systems were either traditional (shifting cultivation, bush fallow system, use of inorganic fertilizers) or adapted with some agroecological practices (crop rotation with legumes, using organic fertilizers, intercropping) and what was mentioned as climate-smart practices (intercropping, minimal tillage, residue management, manure application, contour ploughing, crop rotation, manure management and rainwater harvesting).

3.5.3 Links to food security

Four cases recorded positive outcomes to household food security with the agroecological practices they used. The studies used indirect and direct measurements of food security to assess the impact of agroecological practices, noting positive impacts of agroecology through improved yields, food availability, increased incomes and improved wellbeing. Organic cocoa farmers had a greater diversity of tree, shrub, and herb diversity on their plots, giving them greater access to these resources for consumption and medicinal purposes compared to conventional farmers (Bandanaa et al. 2016). In another study, farmers implementing intercropping, minimum tillage, residue management, manure application, contour ploughing, crop rotation, and manure management, for the production of vegetables, maize, millet, and sorghum had no noticeable improvement in food security or well-being associated with using these agroecological practices (Alare et al. 2018).

3.5.4 Sustainability assessment addressing the environmental, social and economic dimensions

From the point of view of productivity, the practices used had a positive effect with the exception of two case studies (Alare et al. 2018; Boakye-Achampong et al. 2017), which documented no change or a slight reduction in crop yield. The use of new crop varieties, intercropping of maize, cassava, cowpeas, and vegetables, crop rotation, and extensification of agricultural production through introduction of rice farming within the crop's

[8] FAOSTAT, 2019

“agroecological niche” (eg. along rivers and swamps), farmers were able to reduce risk of crop failure and increase the diversity and duration of food availability (Ayivor et al. 2016). When rotated with maize, groundnut yields doubled for 75% of farmers and increased maize yields as well, although intercropping of maize and groundnuts reduced groundnut yields. For this reason, farmers preferred a monoculture rotation of maize and groundnuts (Clottey et al. 2006). Farmers trained in minimum-tillage, compost and manure application, crop residue incorporation and crop diversification with the orange-fleshed sweet potato reported that their sweet potato yield was double that before adoption (Venhoeven 2014).

The economic impact of practices was reported in four documents. For the cocoa farms study, organic farmers, whose use manure and no chemical additives was associated with higher flora diversity on the cocoa plot compared to conventional farmers. Agro-diversity practices allowed farmers to stabilize and improve income despite adverse climatic, market, and political conditions; for example, mixed-cropping of grain, legume, and vegetables provided food for consumption and cowpea that could be sold for income (Ayivor et al. 2016). Farms who engaged in both crop and livestock production benefited from increased income through livestock sales (Alare et al. 2018). Farmers benefited from the flora diversity through the sale of herbs, shrubs, and tree products found on the cocoa farm and recorded 25% higher income from flora sale than conventional farmers (Bandanaa et al. 2016). Farmers who had adopted a new variety of sweet potatoes reported that the associated increase in crop yields led to surplus harvest that they could sell, increasing their income (Venhoeven 2014). However, in one study intercropping of cocoyam with plantain, cassava and cocoa was less profitable than monocropping cocoyam, although the researchers recommended that a diversity of food crops continue to be cultivated because of the related food security benefits of this diversity (Boakye-Achampong et al. 2017).

With respect to environmental benefits, agroecological practices improved agrobiodiversity and landscape diversity, reduced synthetic input application, and improved soil management. Farmers applied local indigenous knowledge of their biophysical environment to select cropping systems more adapted to agroecological niches, and thus more efficiently using water and nutrient availability for crop production (Ayivor et al. 2016). Organic cocoa production was associated to greater biodiversity conservation, with a higher species abundance of flora than conventional farms (Bandanaa et al. 2016). In one project, farmers were trained in Low External Input Sustainable Agriculture (LEISA) techniques (reduced tillage, zero tillage, crop residue incorporation, use of compost and manure) in an effort to reduce soil erosion and increase soil fertility (Venhoeven 2014). Farmers learned about alternatives to pesticide use, using instead locally available materials such as animal manure to prepare bio-pesticides and thus reducing the application of synthetic pesticides (Mwinsigten et al. 2013); farmers were able to use compost as fertilizer application without experiencing yield loss. In the same study, farmers reported that the application of compost increased soil moisture and reduced weed abundance in maize-legume intercropped fields compared to fields where they had not applied compost (Clottey et al. 2006).

Three cases noted an impact of the agroecological practices used on the social benefits, while one article reported that while dry season farming increased household well-being, the implementation of agroecological practices did not overcome the main constraint to dry season farming, which was access to a water reservoir (Alare et al. 2018). In a project that encouraged biopesticides as a substitute for pesticide, women’s groups participated in food fairs to display alternatives to conventionally-produced and processed vegetables and foods and reported a visible increase in the availability of traditional food and crops at markets (Mwinsigten et al. 2013). Cultivation of orange-fleshed sweet potato using LEISA was accompanied by training in financial resource mobilisation in order to establish a culture of saving and to develop competence in setting up, expanding and diversifying commercial enterprises (Venhoeven 2014). Farmer field schools proved effective for building on indigenous knowledge to adapt and disseminate practices of intercropping and compost-making (Clottey et al. 2006).

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

No policies supporting agroecology in Ghana are reported in the literature studied. All but one study had no policies in place to support their practices and this exception was recorded in the smallholder, extensive production of rice in irrigated lowlands cultivation and rain fed lowlands cultivation. In most of the cases, the promotion of agroecology has been done by local and traditional authorities and some extension officers. In some instances, national organizations like the Ministry of Food and Agriculture (MOFA) and other public institutions have been involved. Nevertheless, some NGOs and private organizations have promoted agroecology. In the orange-fleshed sweet potato research, agroecology was promoted by the TRAX Program Support and Self Help Africa, United Kingdom (Venhoeven 2014). This promotion was done by teaching farmers about compost pits; including how to construct these pits, how to improve animal pens for effective dropping collection, and providing financial assistance to farmers during the training programme.

3.5.6 Conclusion

In Ghana, due to the development of agroecology, several traditional practices are being replaced or enhanced by agroecological practices regardless of the type of farm system; family farms, commercial farms, and extensive/intensive production. Practices like intercropping, lowland rice cultivation, LEISA, organic production contributed to increased yields, food availability, enhanced income diversification, and improved environmental health. This reflects a positive impact of agroecological practices on household food security. However, several cases reported that agroecological practices were insufficient in themselves to increase productivity of a single crop, or to cope with dry spells, and that policies that support farmers' access to rainwater harvesting, protect farmers' land rights, and disseminate appropriate technology are necessary for agroecological practices to effectively address food insecurity.

3.5.7 Number of analysed documents

The protocol for literature review applied in this study returned a total of 200 scientific papers and 8 documents of grey literature. These articles were then shortlisted by briefly reading through their abstracts to determine their connection to the topic; this step returned 5 scientific papers and 2 documents of grey literature. Overall, Ghana has limited relevant articles on this study topic, especially for grey literature.

3.5.8 References

Scientific papers

Alare, R.S., Owusu, E.H., Owusu, K. 2018. *Climate Smart Agriculture Practices in semi-arid Northern Ghana: implications for sustainable livelihoods*. Journal of Sustainable Development, 11, 5, 57-70.

Ayivor, J.S., Pabi, O., Ofori, B.D., Yirenya-Taiwiah, D.R., Gordon, C. 2016. *Agro-diversity in the forest-savannah transition zone of Ghana: a strategy for food security against climatic and socio-economic stressors*. Environment and Natural Resources Research, 6(1), 1-12.

Bandanaa, J., Egyir, I. S., Asante, I. 2016. *Cocoa farming households in Ghana consider organic practices as climate smart and livelihoods enhancer*. Agriculture & Food Security, 5, 29, 1-9.

Boakye-Achampong, S., Ohene-Yankyera, K., Aidoo, R., Sørensen, O. J. 2017. *Is there any economics in smallholder cocoyam production? Evidence from the forest agro-ecological zone of Ghana*. Agriculture & Food Security, 6, 44, 1-16.

Clottey, V. A., Agyare, W. A., Gyasi, K. O., Schreurs, M., Maatman, A., Abdulai, H., Dinku, R. K. 2006. *Composting to ensure food security: learning by doing*. Livestock Research for Rural Development, 18, 137. www.lrrd.org/lrrd18/10/clot18137.htm

Grey Literature

Mwinsigten, M. A., Dianon, P. P., Sabri, R. A. 2013. Indigenous foods for food sovereignty of women in Northern Ghana. Agroecology Fund.

Venhoeven, D. TRAX Program Support, 2014. *Orange-fleshed sweet potato brings health and livelihood to Pelungu, Ghana*, in: AFSA 2016. Agroecology: The Bold Future of Farming in Africa. AFSA & TOAM. Dar es Salaam. Tanzania.

Other literature

FAO. *Ghana at a Glance*. http://www.fao.org/ghana/fao-in-ghana/ghana-at-a-glance/en/ . Accessed December 2019.

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3.6 Togo

3.6.1 Country profile from the agro-environmental perspective[9]

Located on Africa's West Coast, Togo is one of the smallest countries in the continent. The narrow strip of land is located between Ghana and Benin, and has a population of 7.6 million inhabitants. Since gaining independence from France in 1960, Togo has struggled to maintain political stability and to build a strong economy. The agricultural sector employs more than two thirds of Togo's active population and accounts for 41% of GDP. The country's main cash crops are cocoa, coffee and cotton. It is also one of the largest producers of phosphorus in the world, a frequently used fertilizer in the national agricultural sector. Togo is included in this study as country where food security and rural development are target sectors of the European Development Fund[10].

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

3.6.2 Synthesis of agronomic practices

Family farming is the main farming system described in the analysed literature. It includes both extensive rainfed crops and off-season small scale irrigated home-garden cropping. Production from these systems is both for self-consumption and marketing on local and national markets. Crops cultivated include horticultural products (e.g. tomatoes and onions) and cereals (e.g. sorghum, millet and maize). The main agricultural practices mentioned in the articles concern crop diversification and rotation, agroforestry and fertilization (mainly manure and organic compost). Factors influencing the adoption of these practices include soil fertility degradation and persistent economic, social and ecological challenges farming communities have to face. Among the latter, access to transport equipment is particularly relevant, especially for the use and recycling of organic matter. None of the articles mentioned post-harvest practices. Two studies focused on on-farm trials (Mackiewickz, 2016; Rossel, 2019), of which one (Mackiewickz, 2016) was related to a farmer field school approach (FFS).

3.6.3 Links to food security

Out of the five articles selected, two articles (Rossel, 2019; Levard et al., 2018) mentioned a positive contribution of agroecological practices to food and nutrition security. This contribution was indirectly evaluated based on increased household income, higher yields, diversified agricultural production and increased food availability. In addition, Rossel (2019) reported a link between improved food security and the development of agroecosystems that are more resilient to climate change.

3.6.4 Sustainability assessment addressing the environmental, social and economic dimensions

From an economic perspective, the adoption of agroecological practices can lead to increased and stabilised income for farmers. Yield improvements of subsistence crops (e.g. sorghum and millet) after adopting sound agroecological practices (e.g. composting and minimum tillage) were associated with increased income at the household level (Rossel 2019). Levard and Mathieu (2018) note income stability as a positive economic impact of agroecological practices (e.g. use of manure and more generally integration between crop and livestock activities) at the household level, and increased employment opportunity and value added at a national level.

In terms of production, all the articles selected indicate an increase or stabilization of yield after implementation of a single fertilizing practice or multiple practices. Mackiewickz (2016) noted that the reduction of mineral fertilizer replaced by organic compost or manure did not negatively affect the yield of maize crops. Rossel (2019) noted a rise in yield of 140% within the first three years of use of organic fertilizer on subsistence agriculture crops. Levard and Mathieu (2018) have shown that when combining anti-erosion practises and organic fertilizer with a supplement of mineral fertilizer the yield of sorghum and millet are 50% higher on average (from 0.4 to 0.7 t per ha to 1.0 to 1.2 t per ha). In the case of maize in northern Togo, the use of mineral fertilizers was on average 38% lower in plots where compost was combined with soil and water conservation measures, compared to plots where such measures were not applied (Levard and Mathieu, 2018).

[9] Sources (in addition to those listed below)
https://www.bbc.com/news/world-africa-14106781
https://www.nationsencyclopedia.com/economies/Africa/Togo-AGRICULTURE.html
https://www.gafspfund.org/projects/togo-agriculture-sector-support-project-pasa
[10] https://ec.europa.eu/international-partnerships/where-we-work/togo_en

Finally, a project conducted by the Alliance for Food Sovereignty in Africa (2019) found that associating composting and soil conservation practises made productivity rise to 3 t per ha.

As for the environmental benefits associated with the implementation of agroecological practices, Bakker et al. (2017) noted that market garden improves water conservation through the use of compost, effective soil preparation and the optimization of plant density.

Lastly, four cases studies recorded positive social impacts related to agroecological practices. Two studies showed that increasing participation of women in the implementation of agroecological practices improved regional gender equity (Mackiewickz 2016, Rossel 2019). Furthermore, a study recording an increase of income at a household level was directly linked to increased access to public healthcare (65% of the participants) and access to schooling (50% of beneficiaries) (Rossel 2019). A pilot experience report from Agronomes et Vétérinaires Sans Frontières (AVSF) (Bakker et al. 2017) also highlighted the importance of creating conditions for the development of agroecological practices. In that case by supporting access to donkey cart equipment for the transport of biomass, to enable its use and recycling in crop production, as well as to facilitate transport of tree seedlings and stones for the improvement of soil and water conservation measures.

3.6.5 Level of promotion of agroecology in the country: evidence from literature

No regional or national policies supporting agroecology have been recorded in the articles selected, except the National Institute of Technical support and Advisory (ICAT) in partnership with Agronomes et Vétérinaires Sans Frontières (AVSF) in northern Togo. However, the promotion of agroecology and diffusion of agroecological practices were initiated by various organization from the civil society: local NGOs RAFIA, CARTO and international NGOs, such as AVSF and INADES.

3.6.6 Conclusions

Overall, the studies analyzed suggest that agroecological practices can improve food and nutrition security in Togo. Crop diversification and rotation as well as various fertilisation practices have been shown to increase food availability, yield and income. However, no study assessed food security based on distribution and access to food resources. The studies also showed that there is a lack of participation from state actors in the promotion of agroecology and diffusion of agroecological practices. Furthermore, due to the exhaustive lack of available research and documentation (from the limited results of the search protocol and presence of multi-country studies, e.g. Levard and Mathieu 2018, Rossel 2019), a considerable need for research in this field is required, in order to gain clarity on the actual impact of agroecological practices on food and nutrition security.

3.6.7 Number of analysed documents

The protocol for literature review used in this study returned 11 scientific papers and no returns for grey literature. On the basis of a preliminary screening for exclusion, none of those articles were deemed suitable for the purpose of this research. Hence, the articles selected for this report were found outside the search protocol – in grey literature.

3.6.8 References

Alliance for Food Sovereignty in Africa (AFSA) 2019. *Improving traditional systems of soil fertility*. https://afsafrica.org/wp-content/uploads/2019/04/improving-traditional-systems-of-soil-fertility-.pdf?fbclid=IwAR0GcpKxaIAjFvtoqPTYEwZ1gUYb3QHSCwcw8IB2FWRtBK8fO1zqMAhqzHo

Bakker, T., Kambogue, F., Makenou, R., Lamboni, A. 2017. *Guide méthodologique pour l'équipement de petits groupes de producteurs en charrettes asines au Togo*. AVSF, ICAT, TOGO, I., RAFIA, UROPC-S. https://www.avsf.org/public/posts/2136/avsf_guide_charettes_asines_togo.pdf

Mackiewickz, M, 2016. *Des champs-école pour l'agroécologie au Togo*. Fiche expérience innovante. Ruralter. AVSF.

Levard, L., Mathieu, B. 2018. *CALAO Project: Agro-ecology: capitalization of experiences in West Africa; Factors that further or limit the development of agro-ecological practices; Evaluation of the socio-economic and agro-environmental effects*. AVSF-Gret. https://www.avsf.org/fr/posts/2217/full/calao-project-capitalization-of-experiences-in-west-africa-factors-that-further-or-limit-the-development-of-agro-ecological-practices-evaluation-of-the-socio-economic-and-agro-environmental-effects

Rossel, T. 2019. *Un réseau de fermes agroécologiques pour autonomiser des femmes au Togo et au Bénin*. Dakar, Sénégal: Innovation, environnement et développement (IED) en Afrique. http://www.iedafrique.org/Un-reseau-de-fermes-agroecologiques-pour-autonomiser-les-femmes-au-Togo-et-au.html

3.7 Benin

3.7.1 Country profile from the agro-environmental perspective[11]

Located in West Africa, Benin is characterized by a climate system dominated by the alternation of a rainy season and a dry season (harmattan wind) and a rainfall pattern with regional disparities. Agriculture plays an important role in the economy, as it accounts for roughly 30% of the GDP and generates around 70% of employment. 550,000 smallholdings are estimated, averaging 1.7 ha each where subsistence farming of cereals and tubers dominates, and which are characterized by low inputs, low productivity and high vulnerability to climatic variations.

Crop production encompasses cotton – which is the main export crop –, pineapple, oil palm, cashew, and staple crops such as maize, cassava, sorghum, yam, cowpea and groundnut. Livestock, mainly in northern Benin, is characterized by traditional systems and animal production is insufficient to meet national demand – 58% for meat, 37% for milk[12] . As a result, the country's food situation is highly dependent on imports.

Though the food crops overall cover food requirements, they still fall short of the potential offered by the country's agroclimatic conditions[13]. Indeed, Benin has a large river system and only 11% of low-lying lands are exploited. However, the agricultural sector faces several constraints such as degradation of land fertility, climatic conditions, lack of knowledge and skills regarding water management and organic input production.

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

3.7.2 Synthesis of agronomic practices

The types of cropping systems addressed by the analysed documents are mainly small-scale family farming, growing staple food crops (yam, millet, sorghum) and vegetable gardening for local markets. One article is also dealing with mango production. Cotton, as one of the major products of the country, did not appear in the documents analysed, as well as other cash crops such as pineapple, cashew or oil palm. Moreover, no study on crop-livestock integration appeared in the scientific literature whereas most of smallholder farms have mixed crop and livestock systems in the country.

The studied agronomic practices include crop rotations with legumes, the return of crop residues, insect netting, crop associations in market gardening, and the use of organic insecticide to combat fruit flies in mango orchards. Most experiments were conducted on-farm.

3.7.3 Links to food security

The effects of agroecological practices on food security were mentioned in four of the seven selected documents, and were perceived as positive, notably due to improved yields and/or a better economic situation of producers.

3.7.4 Sustainability assessment addressing the environmental, social and economic dimensions

In terms of productivity associated with agroecological practices, the use of legumes (Aeschynomene histrix and Mucuna pruriens) intercropping with maize significantly increased yam yields in cropping sequences (average 14.5 and 16.0 t/ha) in comparison with traditional yam-based system maize or one-year fallow of Andropogon gayanus (average 9.0 and 7.5 t/ha). Yet, these cropping sequences with herbaceous leguminous plants decreased maize yields, probably due to competition for nutrients and light (Maliki et al. 2012). Integrated soil-crop management practice, combining the recommended mineral fertilizer dose to farmers and return of crop residues led to equivalent yields to those obtained with a high mineral fertilizer use (almost double the recommended dose) (Amouzou et al. 2018). Moreover, the use of netting protection led to considerably lower cabbage pest populations compared with foliar insecticide sprays. The study showed a significant two-fold higher production of marketable cabbages with netting protection compared with foliar insecticide sprays (Martin et al. 2006). The use of GF-120, an organic bait spray, reduced fruit flies infestation by more than 80% in mango orchards compared to untreated plots (Vayssières et al. 2009).

[11] DOI: 10.1016/j.agrformet.2016.01.143
[12] http://www.fao.org/3/a-i4401f.pdf
[13] https://agriculture.gouv.fr/benin, https://www.ifad.org/en/web/operations/country/id/benin

From an economic point of view, the cropping sequences with herbaceous leguminous plants preceding yam led to an at least two-fold higher net revenue in comparison with traditional cropping sequences, in spite of 35% higher labour costs (Maliki et al. 2012). Regarding mosquito netting, net returns were higher with this practice (247 US$/100 m^2) than using insecticides (149 US$/100 m^2) (Martin and al. 2006).

Regarding environmental benefits, soil fertility was improved in legume-based cropping sequences, with greater biomass dry matter and recycled nitrogen compared with traditional cropping sequences (Maliki et al. 2012). Amouzou et al. (2018) came to similar conclusions, as integrated soil-crop management practice resulted in lower nutrient losses and positive nitrogen and phosphorus partial balances compared to the use of chemical fertilizers alone. Moreover, Dassou et al. (2019) indicated that the abundance of generalist predators and omnivores was significantly higher in tomato mixed-crop fields than in mono-crop fields. As a result, mixed-crop fields significantly reduced the abundance of Helicoverpa armigera, a major tomato pest, compared with mono-crop fields. In addition, the use of insect netting was effective in protecting human health by reducing hazardous insecticide spray and reducing environmental pollution from insecticide residues (Martin et al. 2006).

No noteworthy social elements were pointed out in the selected documents.

3.7.5 Level of promotion of agroecology in the country

No policy support to agroecology has been mentioned in the analyzed literature, and relatively few organizations implementing agroecology in development projects have been identified in the Benin gray literature compared to Senegal and Burkina Faso, for example.

Two analyzed articles discussed the factors influencing the adoption of new practices by farmers. Zoundji et al. (2018) reported that learning videos could effectively convince farmers to adopt sustainable agricultural practices and to change their behaviour with agrochemicals. It was shown an excellent way to encourage farmers to come up with their own innovation. Likewise, a study assessing cabbage farmers' opinions about the use of eco-friendly nets as an alternative to exclusive use of synthetic pesticides in Benin showed that external support was the main incentive toward their use, as farmers need easy access to knowledge and finance. For example, farmers members of a farmer association had more positive attitudes toward netting performances than those not members (Vidogbena et al. 2016). Higher costs and investments were also pointed out as barriers to the adoption of agroecological practices in several documents. More emphasis should therefore be put on technical and financial issues to upscale agroecological innovations.

3.7.6 Conclusions

Despite encouraging results from agroecological experiments in Benin, research activities or capitalization work are quite poor in regard of this review, notably about the main crops grown in the country (millet, sorghum, cotton). The present bibliographic study highlights the absence of a significant potential of agroecology for improving food security and farmer livelihoods in a sustainable way in the country. Particularly, few scientific evidences of farm development projects conducted by associations was found in the literature, despite studies on the adoption factors of agroecological practices. As a result, research and development focusing on agroecology need to be intensified in Benin.

3.7.7 Number of analysed documents

The applied protocol returned 115 documents, of these only 5 were considered matching the needs of this study. Two of the articles are based on results from the same study, and do not differ fundamentally (considered as a duplicate). Other three scientific papers were identified in a further step, providing a significant complement on pest control and insect diversity. In parallel, no usable data was found in the grey literature from 27 documents initially identified.

3.7.8 References

Scientific papers

Amouzou, K.A., Naab, J.B., Lamers, J.P.A., Becker, M., 2018. Productivity and nutrient use efficiency of maize, sorghum, and cotton in the West African Dry Savanna. Journal of Plant Nutrition and Soil Science, 181, 261–274. https://doi.org/10.1002/jpln.201700139

Dassou, A.G., Vodouhè, S.D., Bokonon-Ganta, A., Goergen, G., Chailleux, A., Dansi, A., Carval, D., Tixier, P., 2019. Associated cultivated plants in tomato cropping systems structure arthropod communities and increase the Helicoverpa armigera regulation. Bull. Entomol. Res. 1–8. https://doi.org/10.1017/S0007485319000117

Maliki, R., Sinsin, B., Floquet, A., 2012. Evaluating Yam-Based Cropping Systems Using Herbaceous Leguminous Plants in the Savannah Transitional Agroecological Zone of Benin. Journal of Sustainable Agriculture, 36, 440–460. https://doi.org/10.1080/10440046.2011.646352

Maliki, R., Sinsin, B., Floquet, A., Cornet, D., Lancon, J., 2017. Sedentary yam-based cropping systems in West Africa: Benefits of the use of herbaceous cover-crop legumes and rotation-lessons and challenges. Agroecology and Sustainable Food Systems, 41, 450–486. https://doi.org/10.1080/21683565.2017.1279252

Martin, T., Assogba-Komlan, F., Houndete, T., Hougard, J.M., Chandre, F., 2006. Efficacy of Mosquito Netting for Sustainable Small Holders' Cabbage Production in Africa. Journal of Economic Entomology, 99, 5.

Vayssieres, J.-F., Sinzogan, A., Korie, S., Ouagoussounon, I., Thomas-Odjo, A., 2009. Effectiveness of Spinosad Bait Sprays (GF-120) in Controlling Mango-Infesting Fruit Flies (Diptera: Tephritidae) in Benin. ec 102, 515–521. https://doi.org/10.1603/029.102.0208

Vidogbena, F., Adegbidi, A., Tossou, R., Assogba-Komlan, F., Martin, T., Ngouajio, M., Simon, S., Parrot, L., Garnett, S.T., Zander, K.K., 2016. Exploring factors that shape small-scale farmers' opinions on the adoption of eco-friendly nets for vegetable production. Environment Development and Sustainability, 18, 1749–1770. https://doi.org/10.1007/s10668-015-9717-z

Zoundji, G.C., Okry, F., Vodouhe, S.D., Bentley, J.W., 2018. Towards sustainable vegetable growing with farmer learning videos in Benin. International Journal of Agricultural Sustainability, 16, 54–63. https://doi.org/10.1080/14735903.2018.1428393

3.8 Ethiopia

3.8.1 Country profile from the agro-environmental perspective

Ethiopia covers roughly 1.1 million km^2 and is an immensely diverse landscape. To the north and west are the high plateaus of the Simien Mountains characterised by deep gorges and valleys. Running through the center of the country is the Great Rift Valley. To the east and far north, lie the Ogaden and Danakil deserts respectively. Ethiopia is characterised by tropical monsoons with local precipitation highly dependent on elevation. The highlands are typically cool and wet while the lowlands to the east are arid and hot. Average annual rainfall in Ethiopia is around 900 mm, but varies immensely from year to year. Ethiopia has over 109 million inhabitants (second largest country in Africa), with the majority of the workforce currently employed in agriculture. Agriculture accounts for 50% of the country's GDP and grows a variety of crops including wheat, coffee, barley, sorghum, beans, teff, noug, and rapeseed (IFAD 2013). Moreover, Ethiopia hosts an impressive intra-crop diversity (varieties) as one of the eight centres of origin and diversity of agricultural products (Hadgu et al. 2009b). However, the cultural and natural heritage of Ethiopia is threatened by several factors including global climate change, overpopulation, and land degradation.

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

3.8.2 Synthesis of agronomic practices

Selected studies focused on the effects of agroecological practices on family farms at the household level. Farms tended to be small-scale, extensive plots that were either subsistence or sold predominantly to local markets. Practices were implemented across Ethiopia from Amhara province in the west to Somali in the east. However, the majority of analysed projects was developed in the highlands and was targeting mostly arable crops, livestock, and/or agroforestry system. Additionally, the type of crops grown and their particular use varied greatly depending on the site. Crops that were often mentioned include tef, maize, barley, eucalyptus, wheat, beans, and sorghum. These crops were produced by applying at least one agroecological practice. Agroecological practices mentioned include intercropping, soil bunds, grass strips, agroforestry systems, diverse polycultures (inter and intra species diversity), water conservation practices (water harvesters), integrated crop livestock systems, integrated pest management, and direct seeding.

3.8.3 Links to food security

The effects of agroecological practices on food security within households were determined using either indirect or direct indicators. Studies frequently used household income to infer improved food security, assuming a direct (positive) link between income and food security (Ayalew 2011, Hadgu et al. 2009b, Meaza and Dimssie 2015, Feyisa et al. 2018, IFAD 2013). In several cases, studies claimed that as the soil fertility improved, crop yields would rise, and farmers would increase their income (Ayalew 2011, Hadgu et al. 2009b, IFAD 2015). Additionally, farmers would increase their income by selling new products such as eucalyptus (Meaza and Dimssie 2015, Feyisa et al. 2018). For example, 98% of households in one study in Tigray province were dependent to some extent on woodlots for income (Meaze and Dimisse 2015). Another community in Somali regional state found that by collectively removing the invasive plant prosopis and producing charcoal they would be able to generate enough income to feed their children three meals a day (IFAD 2013).

Other studies provided indicators that directly measured food security through changes in caloric consumption, the duration of food insecure periods, changes in the nutritional quality of the crop, and changes in dietary diversity (Hadgu et al. 2009a, Regassa 2016, Bond et al. 2014). High crop diversity was often related to reduced periods of food insecurity and higher calorie consumption (Hadgu et al. 2009a, Bond et al. 2014). For example in Hawassa city, 40% of home gardeners were dependent on their urban garden for income, 25% were food secure for the entire year and 15% were food insecure for six months (Regassa 2016).

3.8.4 Sustainability assessment addressing environmental, social and economic dimensions

Productivity is quantified in terms of yields (kg/ha, quintals, or total crop calories) and income (% of income or in Ethiopian Birr - ETB). Some studies compared former yields/income to new yields/income under agroecological practices (Ayalew 2011, IFAD 2013, Bond et al. 2014, Balehegn 2018). Ayalew (2011) noted a fourfold increase in maize yields, from 400 kg/ha to 1600 kg/ha after implementing soil conservation measures. Additionally, direct seeding of finger millet in a system of crop intensification resulted in yields that were 7.6 tons/ha (2.8

tons/ha in traditional fields) (Araya et al. 2018). Communities in the region of Somali found that by removing the invasive plant prosopis and using it to produce charcoal, they could increase their monthly income from 500 Birr (15.8 USD) to an average of 1,100 ETB (±35 USD) (IFAD 2013).

A few studies focused on an entirely new source of revenue, such as the additional income gained per tree (Meaza and Dimssie 2015, Regassa 2016). The majority of the studies looked at the productivity at different levels of adoption (Hadgu et al. 2009b, Feyisa et al. 2018, Araya et al. 2018). For example, Hadgu et al. (2009a) examined the total caloric crop yield according to varying degrees of biodiversity, in terms of species richness. High diversity farms had a 19% higher caloric crop yield than low diversity farms. Although studies vary greatly in the way they measure and compare productivity, none of the studies suggested a decrease in yields or income due to the implementation of agroecological practices.

Several studies looked at the additional economic effects of adopting agroecological practices. Potential economic benefits of agroecology include increased access to property, tools, expertise, influence, etc. The majority of studies discussed access to additional revenue sources (Meaza and Dimssie 2015, Regassa 2016, Feyisa et al. 2018, Bond et al. 2014, IFAD 2013). In agroforestry systems, smallholders were able to sell tree products such as fruits, firewood, charcoal, and fodder to generate additional income (Meaza and Dimssie 2015, IFAD 2013, Feyisa et al. 2018). One study found that average annual income from selling eucalyptus ranged from 11,000 to 15,000 ETB/ha for smallholders (Feyisa et al. 2018).

Additionally, increased access to livestock or urban garden space, allowed smallholders to diversify their income source (Regassa 2016, Bond et al. 2014). Agroecological practices were sometimes able to reduce input costs and thus improve the economic situation of the farmer (Hadgu et al. 2009a, Araya et al. 2018). For example, increased on farm-diversity and crop productivity reduced inorganic fertilizer costs (Hadgu et al. 2009a). Additionally, direct seeding of millet helped reduce the labour requirement (compared to broadcast seeding) by 75%, while also making it easier to weed (Araya et al. 2018). Finally, one study mentioned using nutrient rich tree fodder to improve the nutritional quality of milk to generate a higher price premium (Balehegn 2018).

The environmental benefit of agroecological practices was typically a secondary priority for most studies and usually followed a larger discussion on productivity. Environmental benefits include increasing biodiversity, reducing pollution, promoting soil health, and improving water management. Although different practices were used, such as grass strips, terraces, and polycultures, they focused on two services (Ayalew 2011, Meaza and Dimssie 2015, Balehegn 2018). The environmental impacts of agroecological practices centered on promoting soil health and biodiversity (Hadgu et al. 2009a, Hadgu et al. 2009b, Ayalew 2011, IFAD 2013, Meaza and Dimssie 2015, Araya et al. 2018, Feyisa et al. 2018, Balehegn 2018). In Eucalyptus woodlots, soil organic matter increased, reduced erosion and lowered bulk density (Hadgu et al. 2009, Feyisa et al. 2018). Moreover, soil conservation measures such as bunds, terraces, and grass strips helped lower erosion, increase organic matter and raise available nitrogen (Hadgu et al. 2009b, Ayalew 2011, Feyisa et al. 2018, Balehegn 2018).

Additionally, some soil conservation practices also helped to increase biodiversity. For example, re-greening measures provided habitat for threatened mammals and birds such as the White-Billed Starling (Balehegn 2018). Studies also investigated how other agroecological practices affect biodiversity. For example, the effect of adopting diversified woodlots on homestead biodiversity and invasive species removal to native seed bank regeneration (Meaza and Dimssie 2015, IFAD 2013). Finally, two studies addressed climate adaptation and mitigation by promoting carbon sequestration and planting strategies to promote drought resiliency (Araya et al. 2018, IFAD 2013).

Studies were least likely to investigate social benefits of agroecological practices than other indicators in their analysis. Social indicators and measures differed greatly depending on the particular study and did not follow any clear trends. The social benefits in this overview include increased social cohesion, greater access to services, and protecting traditional practices (Ayalew 2011, IFAD 2013, Bond et al. 2014, Meaza and Dimmssie 2015, Regassa 2016, Araya et al. 2018). In other examples, households reported being able to afford school fees, access to bank services, and purchasing mobile phones (Meaza and Dimssie 2015, IFAD 2013).

3.8.5 Level of promotion of agroecology in the country: evidence from the literature

No study mentioned nation-wide policies or projects to scale up agroecological practices. However, Ethiopian universities, foundations, nurseries, regional governments, and institutes actively supported, in some form, the studies included in this brief (Ayalew 2011, Bond et al. 2014, Meaza and Dimssie 2015, Regassa 2016, Araya et al. 2018, Feyisa et al. 2018, Balehegn 2018). Additionally, international institutes, NGOs, and foreign governments commonly funded or supported agroecological research or projects (Hadgu et al. 2009a, Hadgu et al. 2009b, IFAD 2013, Bond et al. 2015, Araya et al. 2018, Balehegn 2018). Academic articles typically involved international and Ethiopian researchers working with local farmers through universities and research institutes (Ayalew 2011, Meaza and Dmisse 2015, Regassa 2016, Feyisa et al. 2018). Case studies in grey literature were more likely to include NGOs, institutes, and state government in the project (IFAD 2013, Bond et al. 2014, Araya et al. 2018, Balehegn 2018).

3.8.6 Conclusions

Agroecological practices included in these studies had a slightly larger focus on agroforestry (eucalyptus woodlots) and soil conservation measures (bunds, grass strips, and terraces). Researchers typically indirectly infer the link between yields, income, and improved food security. However, several studies look at indicators such as caloric yield or food insecure periods. Studies that included economic measurements discussed how agroecological practices could generate new revenue sources, reduce input costs, and improve product quality. Environmental benefits tended to overlap with other effects but focused on promoting soil health and biodiversity. Social benefits were less likely to be included and varied depending on the study.

Although these studies have demonstrated the potential success of agroecological practices at the household level, there are several notable limitations and obstacles: these initiatives are very context specific and implementation in a different location could yield completely different results; market access is a major limitation when farmers do not have a market for new products, and may not be able to explore new revenue sources. Moreover, the initial cost of investment is extremely high in terms of both time and capital. Farmers often do not have the time to learn complicated practices nor the capital to purchase expensive new equipment or inputs. It is precisely because of these limitations that studies that could document successful practices were focusing on agroforestry and soil conservation measures. These measures are low-input, adaptable, and generate quick results.

3.8.7 Number of analysed documents

The protocol for literature review applied in this study returned 50 scientific papers, and no grey literature documents. Of these, 6 were considered matching the needs of the study. Grey literature was further screened by reviewing the work of several organizations implementing agroecological practices within the country (McKnight Foundation, World Agroforestry Centre, AFSA, etc.) and 4 relevant documents were identified.

3.8.8 References

Scientific papers

Ayalew, A. (2011). Construction of Soil Conservation Structures for improvement of crops and soil productivity in the Southern Ethiopia. Journal of Environment and Earth Science, 1(1). https://www.iiste.org/Journals/index.php/JEES/article/view/763

Feyisa, D., Kissi, E., Floe, Z.K. (2018). Rethinking Eucalyptus globulus Labill. Based Land Use Systems in Smallholder Farmers Livelihoods: A Case of Kolobo Watershed, West Shewa, Ethiopia. Ekológia (Bratislava) 37. 10.2478/eko-2018-0006.

Hadgu, K.M., Kooistra, L., Rossing, W.A.H. (2009a). Spatial variation in biodiversity, soil degradationand productivity in agricultural landscapes in the highlands of Tigray, northern Ethiopia. Food Security 1: 83. https://doi.org/10.1007/s12571-008-0008-5

Hadgu, K.M., Kooistra, L., Rossing, W.A.H. (2009b). Assessing the effect of Faidherbia albida based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia. Food Security, 1(3), 337-350.

Meaza, H., Demssie, B. (2015). Managing fragile homestead trees to improve livelihoods of land-poor farmers in the Northern Highlands of Ethiopia. Singapore Journal of Tropical Geography, 36(1), 57–66.

Regassa, R. (2016). Useful plant species diversity in home gardens and its contribution to household food security in Hawassa city, Ethiopia. African Journal of Plant Science. 10. 211-233. 10.5897/AJPS2016.1439.

Grey Literature

Araya, H., Asmelash, A., Misgina, S., Legesse, H., Zibelo, H., Woreda, T., Assefa, T. Mohammad, E. (2013). SCI: Planting with Space, AFSA. https://afsafrica.org/wp-content/uploads/2019/04/sci-planting-with-space.pdf

Balehegn, M. (2018). Drought tolerant Ficus thonningii silvopastures sustain livestock and crops in Northern Ethiopia. AFSA. https://afsafrica.org/wp-content/uploads/2019/07/ficus-thonningi-eng-online.pdf

Bond, V., Amedeivand, T.,Mangiest, F. (2014). Securing the livelihoods of small-scale farmers in Ethiopia, AFSA. https://afsafrica.org/wp-content/uploads/2019/04/azgo-ethiopia.pdf

IFAD. (2013). Learning for rural change 14 stories from Ethiopia, International Fund for

Agricultural Development (IFAD), www.ileia.org/wp-content/uploads/2016/11/Learning-for-rural-change-Ethiopia.pdf

Supplementary literature

FAO. (2016). AQUASTAT Country Profile-Ethiopia. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy.

Peterson, A. 2018. Koppen Climate Types of Ethiopia, Wikimedia Commons. https://commons.wikimedia.org/wiki/File:K%C3%B6ppen_climate_types_of_Ethiopia.svg

3.9 Kenya

3.9.1 Country profile from the agro-environmental perspective[14]

Arid and semi-arid landscapes dominate great part of Kenya (83-89%) (GoK 2018). The majority of Kenya's agriculture is therefore in areas of high and medium potential in the central and western regions (Biovision 2019).

98% of agriculture is rainfed, represented in great part by small-scale farming systems (GoK 2018). 60% of Kenya's income is derived from the agricultural sector, which also provides 60% of total employment (UNEP, 2015).

Staple crops include maize, cassava, rice, wheat, arrowroot, millet, potatoes and sorghum. A number of horticultural products are produced for own-consumption and local markets. Horticultural produce, fruits and floriculture are important subsectors for the export market. Additional cash crops such as cotton, sugar, coffee, tea and chat are also important for the sector. Dairy production is central to many small-scale mixed farming systems.

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

3.9.2 Synthesis of agronomic practices

The selected studies concerned mostly small-scale agriculture, typically focusing on family farms at the household and farm level. Examples of extensive and intensive farming systems were found as well as homegardens. No information was provided regarding land ownership or average farm size. However, one paper reported that one million farmers are farming 0.5 million hectares of land using organic methods in Kenya (UNEP 2008). A wide variety of food crops are grown in Kenya, but only a selected group were observed in the reviewed studies. These included food crops such as maize, sorghum, arrow root, rice, vegetables (unspecified), kale, beans, and coffee. Fodder crops included napier grass, Brachiaria grass and Desmodium.

A range of agroecological practices were described in the analysed cases. Some cases specifically focused on one practice, for example push-pull and climate adapted push-pull farming; sustainable rice intensification (SRI); improved maize fallows with Hyptis spicigera; agroforestry. Other cases reported the outcomes of training programmes that promoted an integrated approach to farming (UNEP 2008). These programmes included the following agroecological practices: diversified crop production, biointensive agriculture (organic farming method that focuses on maximising yields from very small spaces with practices including compost production, raised beds, dense plant spacing, and companion planting), natural soil fertility management, integrated pest management, soil and water conservation techniques, seed saving, organic farming methods, cover-cropping; and green manures. One paper (Wainaina et al. 2017) examined the impact of a suite of practices in isolation and combination, including: terracing, soil bunds, crop residue management, manure use, zero tillage, and use of improved maize seeds. No information was provided on post-harvest techniques for storage or loss prevention.

Reason for implementing agroecological practices varied between practices. In general farmers aimed to improve yields and to increase or diversify income. For some farmers there was also a desire to reduce costs associated with inputs. Maize farmers used push-pull farming and improved fallows to combat yield losses from Striga weed parasitism and stem borer moth (Khan et al. 2011; Othira et al. 2013; Midega et al. 2015). SRI was interesting for some farmers as it helps with resistance to wind lodging of rice (Niidiri, 2013). Agroforestry offered potential for improving climate resilience for farmers in drier regions (Quandt et al. 2017).

3.9.3 Links to food security

One study reviewed specifically linked agroecological practices to measurable improvements in food security. Farming training in IPM, cover cropping and green manures has resulted in the average number of food secure months increasing from 1-3 to 3-6 in over 2000 households (MEFE, in UNEP 2008). Despite limited direct evidence, the increased or diversified yields and increased income reported in the other studies may have led to improved household food security. Food security at community, regional, and national scales was not mentioned in any article. Assessment of the nutritional security agroecological practices provided was limited to four cases. Increased legume production improved protein intake amongst children (MEFE, in UNEP 2008).

[14] References used here are additional to the literature review sources for the purpose of context

Agroforestry diversified household diets through increased on-farm availability of fruits (Quandt et al. 2017). Crop diversification in general had the same effect (EAT, in UNEP 2008) as did the specific reintroduction of traditional African leafy vegetables to farming systems (AFSA 2016). Planting of fruit trees and inclusion of other diversified crop systems improved household nutritional status (C-MAD, in UNEP 2018).

3.9.4 Sustainability assessment addressing the environmental, social and economic dimensions

Economic benefits were generated by a number of agroecological practices either by increasing or stabilizing income, reducing costs, or a combination of all three. Wainaina et al. (2017) studied the effects of three conservation agriculture practices on maize farmers' incomes across Kenya. They found that zero tillage, amending soil with manure and using improved maize varieties increased income by 16%, 14% and 15% respectively. However, when these three practices were combined incomes increased by 35% on average. Terracing, soil bunds, crop residue management and use of chemical fertilizers had no impact on income (Wainaina et al. 2017). Farmers training on natural soil fertility management, integrated weed, pest and disease management, soil and water conservation, and seed saving led to an increase in farmer income of 40% (SACDEP, in UNEP 2008). In some cases, only qualitative statements were provided regarding changes to income. Biointensive agriculture has increased farmer incomes allowing them to invest in capital assets and pay for school fees (Oakland Institute 2015). Diversifying production led to farmers earning a premium price in the case of growing traditional African leafy vegetables (AFSA 2016) or increased income stability in the case of agroforestry (Quandt et al. 2017; C-MAD, in UNEP 2018). Some farmers have been able to generate income from selling Desmodium seeds under the push-pull farming system (Khan et al 2011). Several practices have reduced the use of synthetic fertilizer, pesticides and herbicides, thereby reducing farmers' costs (Othira et al. 2008; UNEP 2008; Khan et al. 2011; Ndiiri et al 2013; Midega et al. 2015). However, levels of inputs or transition costs were not quantified in any of the cases.

Farm productivity was enhanced by agroecological practices in all cases. Nine cases reported quantifiable yield increases. Push-pull Farming has increased maize yields from 1 to 3.5 t/ha and sorghum yields from 1 to 2 t/ha compared to monocultures (Khan et al 2011). A climate-adapted variation of this system (which utilizes drought resistant crops in place of the usual crops, e.g. drought resistant maize or sorghum in place of maize; Brachiaria grass instead of napier; and greenleaf Desmodium in place of silverleaf Desmodium) has increased maize yields by 105-333% compared to monocultures (Midega et al. 2015). Rotating maize cultivation with improved fallows of H. spicigera increased yields by 55% compared to normal fallows and 90% compared to continued cultivation (Othira et al. 2008). Sustainable Rice Intensification increased rice yields by 33% to 1.6 tons per ha compared to traditional methods (Ndiiri et al. 2013). Biointensive agriculture increased maize yields by 150% and kale yields by 300% (Oakland Institute 2015). Organic farming methods were reported to have increased yields by 179% on average for 1 million farmers in Kenya compared to yields before these practices had been used (UNEP 2008). A number of training programs reported increases in crop yields, although the causal relationship between specific practices and yield increases was unclear. Training on tree planting, organic farming methods and soil conservation was linked to two times higher maize yields, increasing from an average of 2 t/ha to 4 t/ha on 500 farms (C-MAD, in UNEP 2008). Integrated training on crop diversification, reducing pesticide use, soil conservation techniques and application of organic manure has increased maize yields by 71% and bean yields by 158% compared to traditional practices (EAT, in UNEP 2008). Another training programme that focused on IPM, cover cropping, and green manures, was shown to double bean and groundnut yields (MEFE, in UNEP 2008). Diversification of crop production also increased farm productivity (Quandt et al 2017; AFSA 2016; UNEP 2015).

Ecological benefits were reported qualitatively in terms of improved soil fertility, water retention and chemical input reduction. The four training programmes reviewed described increases in soil fertility as a result of their integrated approach to farming (UNEP 2008). Push-pull farming (and the climate-adapted variant) highlighted increased soil organic matter content, and soil nitrogen content as a result of biological fixation from Desmodium (Khan 2011 et al 2011; Midega et al. 2015). Push-pull farming (Khan et al. 2011; Midega et al. 2015), agroforestry (UNEP 2008), double digging (a technique that require a deep digging of soil for initial cultivation of land) (Oakland Institute 2015), and integrated farmer training programmes (SACDEP & C-MAD, in UNEP 2008) were all reported to enhance soil water retention. SRI reduced overall water requirements by 28% (Ndiiri et al. 2013). Reductions in chemical fertilizers, pesticides and herbicides were also recorded but not quantified in terms of quantity or wider life cycle impact. Push-pull farming reduced the use of all three inputs (Khan et al. 2011; Midega et al. 2015). SRI reduced fertilizer use and farmers opted for manure instead (Niidiri et al. 2013). Maize rotations with improved fallows reduced herbicide requirements (Othira et al. 2008). IPM led to reductions in pesticide use (MEFE program, in UNEP 2008).

Agroecological practices generated social benefits beyond increased income and food security. Push-pull farming has increased farmers' social capital through the development of farmer-led networks and farmer field schools (Khan et al. 2011). Biointensive farming led to enhanced community cohesion, the development of partnerships between farmers, and improved access to health and education (Oakland Institute 2015). Community farmer training programmes led to greater cooperation between farmers and improved community cohesion (UNEP 2008). Reduced pesticide use was linked to improved farmer health (EAT, in UNEP 2008). The use of a mechanical weeder in SRI led to better gender equality as men were more likely to share the task of weeding compared to when manual weeding was the only option. This enabled children to spend more time at school (Niidiri 2013).

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

The cases reviewed showed how agroecological practices are being promoted by local community groups and research institutes. Local community groups tended to take a more holistic approach to agricultural development, offering technical advice for the implementation of a range of practices relating to soil health, water conservation, crop diversification, and input reduction or substitution (UNEP 2008). Research institutes, on the other hand, tended to focus their efforts on single practices, for example, push-pull farming, SRI, or improved fallows (Othira 2008; Khan et al 2011; Ndiiri et al. 2013; Midega et al. 2015). No government policies were mentioned to be supporting agroecology in any of the literature. However, the Kenya Government is currently in the early stages of implementing a framework for Climate Smart Agriculture (GoK 2018). No certification is presently available that reflects the use of the agroecological practices analysed. However, organic certification is available in Kenya and organic farmers are represented by the Kenya Organic Agriculture Network (KOAN) (UNEP 2008).

3.9.6 Conclusions

The impact of agroecological practices is likely to be highly context dependent, and so the cases presented here should be viewed within their specific settings. Furthermore, each practice has its own purpose related to particular crops and farming contexts. Despite this caveat, it is clear that a number of practices are already being scaled out, in particular push-pull farming which has been adopted by tens of thousands of farmers in East Africa (Khan et al. 2011) and organic farming which is used by a million farmers in Kenya (UNEP 2008). Training programmes conducted at the community level also show promise in helping farmers move toward a range of integrated practices that foster ecological resource management, good yields, and improved livelihoods. Taken together, the practices presented in this country profile demonstrate potential for improving economic, social and ecological aspects of smallholder farming in Kenya.

The economic benefits of agroecological practices in the literature analysed were primarily assessed at the household level. There was a lack of information about transition costs or labour and input requirements for the adoption of agroecological practices. From an agronomic perspective, agroecological practices appear to offer great potential for improving yields for a range of crops. More research is needed to understand under what conditions such improvements can be achieved, so as to understand the applicability of these practices to regions with different soil, weather or other factors. Cases that reported environmental impacts, primarily focused on the benefits of agroecology on soil and water conservation as well as reduced input use. However, there is a lack of measurable data regarding this impact. The community promotion of agroecological practices has been demonstrated to lead to social benefits such as improved community cohesion.

There is a shortage of studies that specifically link agroecological practices to changes in food security status of farmers or communities in Kenya. In particular, there is a lack of long-term studies assessing adoption of practices against a baseline or control group. As a result, there are very limited sources of quantifiable data available. This shortcoming may be a result of the literature review method chosen. This seems likely when the limited results found relating to agroforestry is considered, given the location of The World Agroforestry Centre in Nairobi. Nonetheless, it is clear that more research is needed to assess which practices are being adopted by farmers and which of these effectively improve food security at household, community or national levels.

3.9.7 Number of analyzed documents

The protocol for literature review applied in this study returned 592 scientific papers and 22 documents of grey literature. A final selection of six peer-reviewed papers has been included in the final analysis. In addition, three pieces of grey literature were analysed. One grey literature source (UNEP 2008) provided 4 useful case studies and hence 13 cases are referred to in the profile.

3.9.8 References

Scientific papers

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Ndiiri, J., Mati, B., Home, P., Odongo, B., Uphoff, N. 2013. *Adoption, constraints and economic returns of paddy rice under the system of rice intensification in Mwea, Kenya*. Agricultural Water Management 129, 44-55.

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Quandt, A., Neufeldt H., McCabe J. T. 2017. *The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya*. Ecology and Society 22(3), 10.

Wainaina, P., Tongruksawattana, S., Qaim, M. 2017. *Synergies between Different Types of Agricultural Technologies in the Kenyan Small Farm Sector*. The Journal Of Development Studies 53, 1974-1990.

Grey Literature

AFSA. 2016. *African leafy vegetable enterprise boosts livelihood of rural communities in Kenya. In Agroecology: The Bold Future of Farming in Africa*. AFSA & TOAM: Dar es Salaam. Tanzania.

Oakland Institute. 2015. *Biointensive Agriculture training program in Kenya*. Accessed on 31/10/19. Available from: https://www.oaklandinstitute.org/biointensive-agriculture-training

UNEP-UNCTAD Capacity Building Task Force on Trade, Environment and Development (CBTF). 2008. *Organic Agriculture and Food Security in Africa*. United Nations: New York & Geneva

Additional literature used for context

Biovision. 2019. *AEZs:Kenya System*. Accessed on 9th December 2019. Available from: https://www.infonet-biovision.org/EnvironmentalHealth/AEZs-Kenya-System

Government of the Republic of Kenya (GoK). 2018. *Kenya Climate Smart Agriculture Implementation Framework-2018-2027*.

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UNEP. 2015. *Green Economy Sector Study on Agriculture in Kenya*. United Nations Environment Programme.

3.10 Tanzania

3.10.1 Country profile from the agro-environmental perspective[15]

Tanzania is located in East Africa, with varied terrain including plains, plateaus, and highlands. Agricultural land represents 42% of total land area and 77% of the population is employed in the agricultural sector. Rainfall in the central and southern highlands occurs during one growing season from November to April, while rain falls over two periods in the northeastern highlands and coastal regions. Temperature also varies regionally, with hotter daily temperatures around 30°C in the coastal areas and cooler temperatures (15-22°C) in the highlands. Agricultural production is affected by unreliable rainfall and droughts, with rainfed maize, beans, rice, sunflower, and cassava among the main food crops cultivated by smallholder farmers.

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

3.10.2 Synthesis of agronomic practices

Selected research studies and projects were targeting primarily smallholder farms and investigated a variety of agroecological practices. These practices include livelihood diversification (fish farming, livestock integration), crop diversification (vegetable production, legumes, pumpkins, local varieties), no-till, maize-legume intercropping, crop rotation, cover cropping, mulching, terracing and contour ridges, and incorporation of organic fertilizers. Crop diversification and intercropping in maize-based cropping systems were the practices most commonly examined.

3.10.3 Links to food security

Only one empirical study directly measured food security; this study found that diversifying farming with integrated vegetable and fish production increased the diversity and quantity of food items available for consumption (Limbu et al. 2017). Indirect measurements of crop yields and farmers income indicated improvements in food security in all scientific studies, while all grey literature documents reported that adoption of agroecological practices led to better food security. In particular, better food security was achieved after soil management practices increased crop yields, especially for maize, which is the dietary staple of farm households.

3.10.4 Sustainability assessment addressing the environmental, social and economic dimensions

All analysed cases claimed that agroecological practices had improved agricultural productivity. In one scientific study, a suite of soil management practices (cover crops, terracing, mulching, crop rotation, intercropping and organic fertilizer) led to improvements in yields for all cultivated crops, with 11% higher maize yields, 11% higher cow pea yields, and 56% higher pumpkin yields compared to crops under conventional production (Miyashita 2006). Soil conservation practices doubled maize yields from 1.3 to 2.6 t/ha and bean yields from 0.7 to 1.7 t/ha over a sample of 6,000 participants of a conservation agriculture project (Oakland Institute 2014). Farmer participants in a different conservation agriculture project reported 50% higher yields in fields where they had used practices of legume diversification, crop rotation, no-till, and agroforestry, compared to fields where they had not applied these practices (Oakland Institute 2001). The addition of more of the aforementioned agroecological practices to a farming system was associated with greater yield increases (Arslan et al. 2017).

Scientific studies examined the impact of legume diversification and intercropping on crop yields. One study found that maize yields were up to five times higher, with average yields between 0.75-1.25 t/ha before adoption compared to 1.88 to 3.75 t/ha after several years of legume intercropping (Marietha et al. 2011); intercropping also resulted in 20% higher productivity for pigeonpea adopters compared to non-adopters (Asfaw et al. 2012). Finally, an innovative study integrating aquaculture with vegetable production found that irrigating vegetable plots with nutrient-rich water from fish ponds resulted in yield increase (2.5 to 3 times higher than conventional system) (Limbu et al. 2017).

All cases reported improvements in economic indicators linked to implementation of agroecological practices. In several studies and reports, a higher farmer's income resulted from increased crop yields leading to an

[15] Sources (in addition to the references below): http://www.fao.org/3/i9836en/I9836EN.pdf

increase in sales (Oakland Institute 2001; Marietha et al. 2011; Arslan et al. 2017; Limbu et al. 2017). Diversification at field and farm-level led to greater profits: net-income for pigeonpea adopters was 21% higher than that of farmers who only cultivated maize (Asfaw et al. 2012), while farmers reported that intercropping lablab bean (Lablab purpureus) helped them accessing additional income through crop sales. As a result, some families were able to purchase livestock assets (Oakland Institute 2001). Integrating livestock into their farming systems provided families with a source of income (European Commission 2015). Price premiums related to agroecological practices increased the price farmers received for their products, positively impacting household income. A survey of 326 families found that farmers with organic certification had an eleven times higher annual mean profit, compared to conventional/traditional farmers (Miyashita et al. 2011). The higher quality milk a farmer obtained through strip grass animal fodder resulted in higher market prices (Oakland Institute 2014). Finally, farmers reported a reduction in costs by substituting synthetic fertilizer with agroecological practices enhancing soil fertility (Oakland Institute 2001).

Soil conservation practices such as terracing, contour-ridges, no-till, grass strips, and intercropping were found to reduce soil erosion and improve drought tolerance by increasing water availability (Oakland Institute 2001; Oakland Institute 2014; European Commission 2015), which was particularly valued in areas with variable rainfall (Arslan et al. 2017). In one village, a project implementing a suite of soil management practices combined with the construction of solar lamps led to a reduction in deforestation, and an increase in soil organic matter (European Commission 2015). Finally, substituting locally available inputs reduced reliance on fossil-fuel based synthetic fertilizers; examples include irrigating vegetable plots with fish pond water (Limbu et al. 2017) and intercropping with nitrogen-rich legume crops (Oakland Institute 2001).

Only a few documents assessed the social impact of agroecology. In three cases, households achieved social outcomes through improved incomes associated with adopting agroecological practices. In a scientific study, households reported they were now able to pay for school fees and thereby access education for their children (Marietha et al. 2011). In a project report, the economic benefits of conservation agriculture allowed families to strategically reinvest earnings in their community and household in a way that reduced their own poverty (Oakland Institute 2001). Another report explained that greater agricultural earnings increased women's access to disposable income and thus improved their independence (European Commission 2015). Other social outcomes resulted from village participation in project activities that catalyzed change and self-organization of community members, gave villagers more job opportunities, and trained farmers in financial management (Oakland Institute 2001; Oakland Institute 2014). Labour requirements of agroecological practices were examined; organic agriculture required more hours of labour (Miyashita et al. 2014), while no-till conservation agriculture reduced labour because the task of plowing was avoided (Oakland Institute 2001). This gave household members more time to conduct other activities and socialize (Marietha et al. 2011).

3.10.5 Level of promotion of agroecology in the Country: Evidence from the literature

Most studies acknowledged that farmers would need institutional support to implement agroecological practices, in the form of training and access to seeds. Implied in this statement is that these services are not currently provided by Tanzanian agricultural extension agents. Most existing efforts of agroecological project implementation and research are funded by international institutions or governments, such as the European Union. The sizeable body of grey literature on agroecological practices in Tanzania indicates substantial NGO support for these initiatives.

3.10.6 Conclusions

Nearly all studies found that agroecology was linked to a positive impact on food security; in particular, all cases reported improved crop yields and economic benefits from the adoption of agroecological practices. While some of these studies were conducted with a small sample size and were dependent on certain conditions for implementation (e.g. fish ponds require access to water), similar results were found for studies with very large sample sizes. Some of the analysed projects have already been scaled up to a regional level, but replication would require assistance through field schools or other technical support. Farmers' access to technologies and resources might limit the potential of some approaches to alleviate poverty for the poorest; for example, fish ponds and organic certification require high upfront costs. There was a noticeable lack of research examining whether agroecology can effectively address social equity issues, delivering food security benefits to the most vulnerable households.

3.10.7 Number of analysed documents

The applied protocol for literature review allowed identifying eight documents: four grey literature reports and four scientific peer-reviewed articles.

3.10.8 References

Scientific papers

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Grey literature

European Commission. (2015). *Chololo Ecovillage: a model of good practice in climate change adaptation and mitigation*, AFSA. https://afsafrica.org/wp-content/uploads/2019/04/03_chololo-book-final-lowres.pdf

Miyashita, C. (2016*). Can organic farming be an alternative to improve well-being of smallholder farmers in disadvantaged areas? A case study of Morogoro region, Tanzania*. International Journal of Environmental and Rural Development 2016 Vol.7 No.1 pp.160-166, Sokoine University of Agriculture, Master's Thesis. http://www.suaire.sua.ac.tz:8080/xmlui/bitstream/handle/123456789/1191/CHIE%20MIYASHITA.pdf?sequence=1&isAllowed=y

Oakland Institute. (2001). *Conservation Agriculture in Tanzania*. Oakland Institute. https://www.oaklandinstitute.org/sites/oaklandinstitute.org/files/Conservation_Agriculture_Tanzania.pdf

Oakland Institute. (2014). *Soil and Water Conservation on the Slopes of Kilimanjaro*, Oakland Institute. https://afsafrica.org/wp-content/uploads/2019/04/soil_water_conservation_kilimanjaro_tanzania.pdf

3.11 Malawi

3.11.1 Country profile from the agro-environmental perspective[16]

Malawi is a land-locked country located in Eastern Sub-Saharan Africa. The agricultural sector is the most important in Malawi's economy; 83% of the population lives in rural areas, most of whom are smallholder farmers who depend on rainfed agriculture for their livelihoods. Malawi has a tropical continental climate, although highland areas in Northern Malawi have more temperate conditions. Climate is greatly influenced by the large mass of Lake Malawi, which extends along two-thirds of Malawi's border. The agricultural growing season occurs during the rainy season from November to April. Malawi is prone to climate-related natural disasters, such as drought and flooding, which have increased in frequency and intensity during the past two decades.

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

3.11.2 Synthesis of agronomic practices

Smallholder farmers were primarily cultivating maize and legume crops (primarily groundnuts and soybean) intended to meet household consumption. Consequently, the majority of studies focused on agroecological practices connected to maize-based systems. Intercropping was the most common agroecological practice investigated, with 9 out of 14 studies including this practice. Due to the soil fertility benefits of nitrogen-fixing legumes, the introduction of intercropping was accompanied by a reduction in synthetic fertilizer inputs. Intercropping precludes monocultures, so in fields that had previously been maize monocultures, crop diversification was implemented. Crop diversification was also assessed at the farm-level, with more diversified farms including fruit trees, cereal crops (sorghum, millet), vegetable crops, and legume crops, both annual (cow pea, bambara nut, groundnut) and semi-perennial (pigeonpea, mucuna). The impact of crop residue management was also frequently examined, with 6 of 14 studies incorporating this practice. The focus on intercropping, diversification and crop residue practices is perhaps unsurprising, as these are techniques traditionally used in some regions of Malawi. A few papers investigated the impact of agroforestry practices; in particular, planting fertilizer trees and fruit trees. Finally, soil management practices of compost-manure application, mulching, and crop rotation were also included in several studies. Detail on these studies is provided in the next chapters.

3.11.3 Links to food security

Nearly all studies (11/12) found that agroecological practices had a positive impact on indicators of food security. Indeed, the effectiveness of agroecological practices to combat food insecurity is a primary reason that some farmers continue to use traditional agroecological practices of soil management, crop diversification, and local varieties of maize (Briggs and Moyo 2012). Eight studies measured crop yield as an indicator of food security, while four studies used direct indicators of food security. Agroecological practices served to improve the food security for a range of populations. Analysis of nationally-representative survey data showed a positive correlation between diverse diets and on-farm crop species diversity (Jones et al. 2016). In another study, village-level adoption of legume intercropping and crop rotation was linked to improved child nutrition over time using anthropometric data (Bezner Kerr et al. 2010). In a related study, HIV-affected households who implemented a number of agroecological practices (compost manure application, crop-residue incorporation, legume-maize intercropping and rotation), reported that these practices had led to better food security, despite their more vulnerable socio-economic position (Nyantaki-Frimpong et al. 2016). These agroecological practices, in addition to mulching and botanical pesticide application, were scaled-up in a five-year district-level study, which found that farmers who had adopted the agroecological practices were significantly more likely than non-adopters to transition from food insecurity to food security during the study period (Kangmennaang et al. 2017).

3.11.4 Sustainability assessment addressing the environmental, social and economic dimensions

Several studies found significant increases in crop yields through the implementation of agroecological practices. Farmers who planted fertilizer trees had maize yields 1.4 times greater (Beedy et al. 2013) and 57%

[16] Sources (in addition to the references below): http://www.fao.org/3/i9753en/I9753EN.pdf

higher than a control group (Coulibaly et al. 2017). In two studies, intercropping legumes with maize resulted in increased overall crop yields, with farmers maintaining or improving maize yields while producing additional legume crops on the same area of land (Snapp et al. 2010, Snapp et al. 2018).

Increases in maize yield due to adoption of agroecological practices boosted farmers' potential crop sales and thus overall income. Adoption of fertilizer-trees was found to increase potential income from crop sales by 35% (Coulibaly et al. 2016), while intercropping pigeon pea, groundnuts, and maize resulted in the highest net income for farmers (Snapp et al. 2010, Snapp et al. 2018). In particular, semi-perennial legume rotations led to two times greater profits than maize monoculture (Snapp et al., 2018). In one study, farmers explained that legume crops had a higher market value than maize, leading to improved income (Nyantaki-Frimpong et al. 2016). In the nationally-representative survey, the one third of households who cultivated the highest number of crop species sold a greater proportion of their crops, thus earning more from agricultural sales (Jones et al. 2016). Farmers who implemented agroecological practices of crop diversification and soil management had significantly higher incomes after 3-5 years of adoption (Kangmennaang et al. 2017). Several studies found that agroecological practices reduced expenditure on food and agricultural inputs (Beedy et al. 2013, Conrad 2014), giving them greater financial stability. About 67% of adopters reported that they spent less money purchasing food, since they now grew a greater diversity and quantity of food products (Conrad 2014). In addition, in cash-strapped smallholder households, farmers deliberately use agroecological soil fertility management practices to avoid spending too much on fertilizer (Briggs and Moyo 2013).

Half of the selected articles reported that agroecological practices were implemented in tandem with low fertilizer usage, contributing to environmental benefits, as well as the aforementioned economic benefits (Myaka et al. 2006, Snapp et al. 2010, Beedy et al. 2013, Conrad 2014, Coulibaly et al. 2016, Snapp et al. 2018). Instead, farmers relied on legume nitrogen-fixation, incorporation of compost-manure, and crop residue management to improve soil fertility. Pigeon pea-maize intercropping added up to 60 kg/ha of nitrogen, with most of this left in the soil (Myaka et al. 2006); in the same system, there was a slight increase in soil carbon-but the brevity of the study meant that there were no significant findings regarding soil carbon. Compared to monoculture maize production, pigeon pea and/or groundnut-maize intercropping stabilized or increased soil organic matter (Snapp et al. 2010). Maize intercropping with annual and semi-perennial legumes also increased fertilizer efficiency significantly; compared to a maize monoculture, this cropping system produced greater overall crop yields with only one-quarter of the fertilizer (Snapp et al., 2018). This practice also led to increased vegetative cover of the soil during the year, reducing soil erosion.

Several articles found that the studied agroecological practices or agroecological interventions resulted in socio-cultural benefits. In some situations, the delivery of the intervention mattered for these social outcomes. For example, using a participatory, farmer-to-farmer approach, facilitated knowledge sharing between farmers and inclusion of marginalized groups, such as HIV-affected households and women (Nyantaki-Frimpong et al. 2016). Women preferred legume-maize intercropping to monoculture maize cultivation, which is significant as women are primarily responsible for growing nutritionally-valuable crops in Malawi (Snapp et al. 2018). A few studies examined the labour requirements of agroecological practices (Myaka et al. 2006, Briggs and Moyo 2012, Nyantaki-Frimpong et al. 2016, Snapp et al. 2018); all found that agroecology either reduced or maintained labour inputs. This was especially important for HIV-affected households, who found that legumes require less labour, and thus reduces the workload for family members occupied with seeking healthcare, caring for sick family members, and farming (Nyantaki-Frimpong et al. 2018).

3.11.5 Level of promotion of agroecology in the country: Evidence from the literature

A few articles described the context of agroecology in Malawi. The most pertinent policy is a government subsidy for legume crop seeds, although this initiative is relatively underfunded compared to the Fertilizer Input Subsidy Program (FISP) which provides farmers with vouchers for synthetic fertilizer and hybrid seeds and has been correlated with lower on-farm crop diversity. The majority of studies included in this brief were initiated by internationally-based research teams and research centers, although there is agroecological research performed by Malawian universities. Finally, there are a number of NGOs and community-based organizations that are actively promoting agroecology; the low-input and non-mechanized form of Malawian agriculture has made agroecology attractive for smallholder farmers with severe resource constraints.

3.11.6 Conclusions

Agroecological practices of legume intercropping, crop diversification, and soil management through agroforestry, crop rotations, crop residue incorporation and compost-manure amendments were effective for directly and indirectly improving household food security in Malawi. Studies documented how agroecological practices improved crop yield, leading to higher income from crop sales, while reducing expenditure on agricultural inputs. Better soil health and fertilizer efficiency were documented environmental outcomes of adoption of agroecological practices. Diverse and marginalized groups benefited from the food security and economic outcomes of agroecology, in particular- women and HIV-affected households preferred agroecological practices and crops. Scientific evidence from longitudinal studies provided empirical information to gain an overview of agroecology in Malawi, capturing environmental, social, and economic aspects of adoption. More research on the implementation of several agroecological practices and expand to farm-level practices, such as livestock integration, would help to understand how practices studied individually can work synergistically.

3.11.7 Number of analysed documents

This brief is based on thirteen selected documents: two grey literature reports and eleven referenced articles, selected among the 122 papers initially retrieved through the protocol for literature review applied in this study.

3.11.8 References

Scientific papers

Beedy, T.L., Ajayi, O.C., Sileshi, G.W., Kundhlande, G., Chiundu G., Simons, A.J., 2013. *Scaling up agroforestry to achieve food security and environmental protection among smallholder farmers in Malawi*. Journal of field actions: Special Issue 7; Agroforestry for food security.

Bezner Kerr, R., Berti, P., Shumba, L. 2010. *Effects of a participatory agriculture and nutrition education project on child growth in northern Malawi*. Public Health Nutrition, 14(8), 1466-1472

Briggs, J., Moyo, B. (2012) *The Resilience of Indigenous Knowledge in Small-scale African Agriculture: Key Drivers*, Scottish Geographical Journal, 128:1, 64-80, DOI:10.1080/14702541.2012.694703

Coulibaly, J., Chiputwa, B., Nakelse, T., Kundhlande, G. 2017. *Adoption of agroforestry and the impact on household food security among farmers in Malawi*. Agricultural Systems: 155, 52-69.

Jones, AD. 2017. *On-Farm Crop Species Richness Is Associated with Household Diet Diversity and Quality in Subsistence- and Market-Oriented Farming Households in Malawi*. Journal of Nutrition. 147: 86-96.

Kangmennaang, J., Bezner Kerr, R., Lupafya, E., Dakishoni, L., Katundu, M., Luginaah, I. 2017. *Impact of a participatory agroecological development project on household wealth and food security in Malawi*. Food Security. 9:561-576

Kassie, M. Teklewold, H., Marenya, P., Jaleta, M., Erenstein, O. 2015. *Production risks and food security under alternative technology choices in Malawi: Application of a multinomial endogenous switching regression*. Journal of Agricultural Economics, 66:3, 640-659.

Myaka., F., Sakala, W., Adu-Gyamfi, J., Kamalongo, D., Ngwira, A., Odgaard, R., Nielsen, N., Hogh-Jensen, H. 2006. *Yields and accumulations of N and P in farmer-managed intercrops of maize-pigeonpea in semi-arid Africa*. Plant Soil, 285: 207-220

Nyantaki-Frimpong, H., Mambulu, F., Bezner Kerr, R., Luginaah, I., Lupafya, E. 2016. *Agroecology and sustainable food systems: Participatory research to improve food security among HIG-affected households in northern Malawi*. Social Science and Medicine, 194: 89-99

Snapp, S., Blackie, M., Gilbert, R., Bezner Kerr, R., Kanyama-Phiri, G. 2010. *Biodiversity can support a greener revolution in Africa*. Proc Natl Acad Sci USA, 107(48): 20840-20845

Snapp, S., Grabowski, P., Chikowo, R., Smith, A., Anders, E., Sirrine, S., Chimonyo, V., Bekunda, M. 2018. *Maize yield and profitability tradeoffs with social, human and environmental performance: Is sustainable intensification feasible?* Agricultural Systems, 162: 77-88

Grey literature

Conrad, A. 2014. *We are farmers: Agriculture, food security, and adaptive capacity among permaculture and conventional farmers in Central Malawi. American University*, Department of Anthropology.

Oakland Institute. 2014. *Agroforestry for Food Security*. Oakland Institute.

3.12 Zimbabwe

3.12.1 Country profile from the agro-environmental perspective[17]

Located in Southern Africa, Zimbabwe is a landlocked country, in which the agricultural sector provides employment and income for 60-70% of the population, however only contributes to roughly 17% of GDP. Overall, 33.3 million of the 39 million ha of total land area is used for agriculture. Farmers are subject to poor and declining soil fertility, insufficient and irregular rainfall with periodic drought, low investment, shortage of labour and electricity, lack of infrastructure, and limited access to irrigation.

Climate type varies by region, with a predominantly Humid Subtropical climate in the North and warm semi-arid in the South. The country has varying rainfall levels with alternating dry and rainy seasons.

Production by smallholder farmers accounts for 70% of staple foods, largely focusing on maize, sorghum, millet, and groundnuts. Cattle production is also widespread, as nearly 60% of rural households own cattle. Cotton, coffee, tea, and sugar are produced for export[18].

Rural populations and smallholder farmers are largely impoverished and considered food insecure. Malnutrition due to lack of access to food and poor agricultural performance is widespread and has long lasting effects, particularly for children.

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

3.12.2 Synthesis of agronomic practices

Analysed studies focused mainly on smallholder or family farms. However, several articles used a further grouping system based on the level of resource endowment of the farmers, developed by Mtambanengwe and Mapfumo (2005)[19]. Farming systems included conservation agriculture, various alternative methods for soil fertility and efficiency, organic production, urban farming, and a collection of agroecological practices. Practices investigated included planting basins, intercropping, crop rotation and diversification, reduced tillage, mulching and use of leguminous species, wastewater, and combinations of organic and inorganic fertilizers for soil fertility. Three articles grouped several agroecological practices and reported on their cumulative effect, these practices included crop diversification, composting and compost use, agroforestry, water harvesting, mulching, integrated pest management, and livestock integration, these will be referred to as a collection of agroecological practices. One article looked at a post-harvest preservation technique, the use of diatomaceous earth on stored maize. Three articles were based on on-farm experiments while the remaining nine were based on interviews and farm sampling, with several being the result of interventions/ development projects. Details are explained in the coming paragraphs.

3.12.3 Links to food security

The relationship between agroecological practices and food security was discussed in seven out of the twelve articles; five reported positive effects, one reported a null effect and one reported a negative effect. In addition, one article discussed nutrient availability of a key micronutrient (Zinc), reporting null to positive results for utilizing leaf litter for mulch, drawing a link with nutrient security rather than food security (Manzeke et. al. 2012). Three of the twelve articles used defined indexes to assess food security. Makate et al. (2016) used the food consumption score (FCS), household food insecurity access score (HFIAS), and household dietary diversity score (HDDS) to assess the impact of crop diversification (intercropping and crop rotation) on food insecurity, finding the practice to have a positive impact on the FCS and HDDS indexes. In their research on urban agriculture in Harare, Kutiwa et. al. (2010) applied the HDDS to understand dietary diversity in the given population. The results indicate a positive correlation between the raising of livestock and household dietary diversity. Lastly, Mango et. al. (2017) used the FCS to evaluate the impact of conservation agriculture on food security, finding a negative correlation with adoption of practices of food security through a reduction in the FCS of participants. This was attributed to the small percentage of land devoted to conservation agriculture and inability to implement "*the full complement of practices necessary to set off the biophysical process that are*

[17] http://www.fao.org/zimbabwe/fao-in-zimbabwe/zimbabwe-at-a-glance/en/
[18] http://exploringafrica.matrix.msu.edu/module-thirty-activity-one/
[19] Mtambanengwe, F., Mapfumo, P. (2005). Organic Matter Management as an Underlying Cause for Soil Fertility Gradients on Smallholder Farms in Zimbabwe. Nutrient Cycling in Agroecosystems, 73(2), 227–243. https://doi.org/10.1007/s10705-005-2652-x

expected to drive yield increases". Two additional articles used the number of daily meals consumed by participants as a method for assessment of practices on food security. One did not find a positive correlation with increased daily number of meals (United Nations Development Programme 2017) and the second a positive correlation but only in some regions and only when best conservation agriculture practice was applied (Hove and Gweme 2018). Two articles had no defined method of assessment, making associations between increased income as well as resilience to extreme weather events and increased food security (Stathers et. al. 2002, La Via Campesina 2016). Finally, four articles did not mention either food or nutrient security but rather focused on yields (Kanonge et. al. 2009, Mtambanengwe et. al. 2009, AFSA and Garden Africa 2016, Makate et. al. 2019).

Practices having a positive impact on food - and to some extent nutrition - security include crop diversification, wastewater use for soil fertility (as it is easily accessible, inexpensive, and increases yields and therefore income), and use of leaf litter mulch (for nutrient- Zinc availability) (Kutiwa et. al. 2010, Manzeke et. al. 2012, Makate et. al. 2016). Conservation agriculture practices also showed some positive results for food security through yield increase but only when the full set of practices could be implemented, which was often not the case (Mango et. al. 2017, Hove and Gweme 2018). However, Hove and Gweme (2018) found notable improvements in grain harvests from the women's conservation agriculture plots. During the years when poor rains were received these plots became the major food security plots for the families since nothing was harvested from conventional plots which only augmented during years with good rains.

Throughout different articles, a trend can be observed as lack of access to inputs, particularly for soil fertility management (manure, mineral fertilizer, leaf litter, etc.), is a major hindrance for food security.

3.12.4 Sustainability assessment addressing the environmental, social and economic dimensions

In terms of productivity, the collection of agroecological practices increased maize yields for farmers using organic methods, reaching at the highest maximum the equivalent of 8 tons per ha, as compared to the national average of 850 kg per ha which was at below subsistence productivity levels in 2012 (AFSA and Garden Africa 2016). A study showed that combining organic and inorganic fertilizers led to an increase in maize and legume yields between 189-350% (Manseke et. al. 2012). In addition, this practice has yielded an increase in Zinc concentrations (with leaf litter and inorganic fertilizer), nearly doubling its concentration as compared to sole mineral fertilizer. Furthermore, the integration of leguminous species tends to only have significant impact on crop yield when combined with other practices (i.e. mulching with leaf litter, application of mineral Phosphorus, strategic crop rotations) (Kanonge et. al. 2009, Mtambanengwe et. al. 2009). A study on conservation agriculture reported an increase in maize yield from 0.53 MT to 0.97 MT (Hove and Gweme 2018). However, labour and time restraints were a hindering factor for successful adoption of conservation agriculture practices, especially for women who often have other responsibilities aside from farming, and therefore these results varied.

Combining agroecological practices appeared to have a positive economic impact. Under a United Nations Development Programme (2017), the adoption of various agroecological practices (e.g. conservation agriculture, crop diversification, agroforestry, composting and compost use, water harvesting, integrated pest management, and livestock integration) generated sales worth US$167,908 at local markets. Another program integrating agroecological practices resulted in a 265% increase in farmer income for its 591 participants by the final phase of the program, with US$132,000 worth of sales by participants (AFSA and Garden Africa 2016). This increase was partly attributed to the ability of selling products at higher prices under an organic label. However, it is noted that the higher prices for organic products is dependent on the market. The use of diatomaceous earths for post-harvest preservation increased the value of maize and sorghum as compared to typical grain preservation techniques through effective repellence of insects and rot, among other parameters (Stathers et. al. 2002).

Environmental benefits of the different agroecological practices are numerous. A study concluded that conservation agriculture improves soil fertility, soil moisture conservation and soil temperature regulation (Makate et. al. 2018). A scientific study on crop diversification found that this practice increases the potential to harbour biodiversity, which is beneficial for pest, disease, and weed management (Makate et. al. 2016). In addition, the integration of indigenous crops can contribute to the preservation of local biodiversity (Makate et. al. 2016). Collectively agroecological practices improved soil moisture and biodiversity conservation (United Nations Development Programme 2017). For example, one study found an increase in agrobiodiversity by 122% after 18 months (AFSA and Garden Africa 2016). Moreover, practices that focus on building soil organic matter and augmenting organic fertilizers reduced the potential for nitrate leaching when compared to inorganic fertilizer (La Via Campesina 2016).

In terms of social impacts, a study focusing on women and adoption of conservation agriculture concluded that participants felt more confident and respected after partaking in a training program (Hove and Gweme 2018).

3.12.5 Level of promotion of agroecology in the country: evidence from literature

There was no mention of government policy supporting agroecology in the selected literature. However, the existence of extension services and consortium initiatives (ie. Soil Fertility Consortium of Southern Africa) showed positive effects on the adoption of some agroecological practices; for example, adoption of crop diversification was seen to increase by 38% due to extension service access, and similar trends were seen for leguminous species integration and combinations of organic and inorganic fertilizers (Manseke et. al. 2012, Makate et. al. 2016). One farmer field school, the Shashe Agroecology School, founded for the promotion of agroecological practices showed potential for positive impact on practice adoption of smallholder farmers (La Via Campesina 2016). Otherwise, agroecological practices appear to be largely promoted by NGOs or international development agencies through training programs.

3.12.6 Conclusions

The state of agroecology in Zimbabwe appears to be fragmented with a few cases showing potential for agroecological practices to address food insecurity. However, generally there is a lack of data, use of food security indexes, and literature on the topic. Within the literature reviewed, there were several trends that spanned across the different practices, for instance soil fertility and the build-up of soil organic matter were important areas of focus. Access to inputs and resource endowment also appear to be highly influential factors for successful implementation, particularly for those related to soil fertility. Lastly, combining agroecological practices appears to yield better results. In conclusion, results from the literature are very promising, but more research is needed to clearly connect agroecological practices and food security in Zimbabwe.

3.12.7 Number of analysed articles

The search for scientific articles for Zimbabwe yielded adequate results for number of articles available. The application of the protocol for literature review used in this study, returned 169 articles. Additionally, three relevant scientific articles were found outside of the search protocol. In total, 9 articles were selected to compile this brief. For grey literature, 5 relevant articles were identified, of which 3 were used for this brief.

3.12.8 References

Scientific Papers

Hove, M., Gweme, T. (2018). Women's food security and conservation farming in Zaka District-Zimbabwe. Journal of Arid Environments, 149, 18–29. https://doi.org/10.1016/j.jaridenv.2017.10.010

Kanonge, G., Nezomba, H., Chikowo, R., Mtambanengwe, F., Mapfumo, P. (2009). Assessing the potential benefits of organic and mineral fertiliser combinations on legume productivity under smallholder management in Zimbabwe. South African Journal of Plant and Soil, 32(4). https://doi.org/10.1080/02571862.2015.1053156

Kutiwa, S., Boon, E., & Devuyst, D. (2010). Urban Agriculture in Low Income Households of Harare: An Adaptive Response to Economic Crisis. Journal of Human Ecology, 32(2), 85–96. https://doi.org/10.1080/09709274.2010.11906325

Makate, C., Wang, R., Makate, M., Mango, N. (2016). Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. SpringerPlus, 5(1), 1135. https://doi.org/10.1186/s40064-016-2802-4

Makate, C., Makate, M., Mango, N., Siziba, S. (2019). Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa | Elsevier Enhanced Reader. Journal of Environmental Management, 231, 858–868. https://doi.org/10.1016/j.jenvman.2018.10.069

Mango, N., Siziba, S., Makate, C. (2017). The impact of adoption of conservation agriculture on smallholder farmers' food security in semi-arid zones of southern Africa. Agriculture and Food Security, 6(1). https://doi.org/10.1186/s40066-017-0109-5

Manzeke, G., Mapfumo, P., Mtambanengwe, F., Chikowo, R., Tendayi, T., Cakmak, I. (2012). Soil fertility management effects on maize productivity and grain zinc content in smallholder farming systems of Zimbabwe. Plant and Soil, 361(1–2), 57–69. https://doi.org/10.1007/s11104-012-1332-2

Mtambanengwe, F., & Mapfumo, P. (2009). Combating food insecurity on sandy soils in Zimbabwe: The legume challenge. Symbiosis, 48(1), 25–36. https://doi.org/10.1007/BF03179982

Stathers, T. E., Chigariro, J., Mudiwa, M., Mvumi, B. M., Golob, P. (2002). Small-scale farmer perceptions of diatomaceous earth products as potential stored grain protectants in Zimbabwe. Crop Protection, 21(10), 1049–1060. https://doi.org/10.1016/S0261-2194(02)00089-3

Grey Literature

Alliance for Food Sovereignty in Africa (AFSA) and Garden Africa (2016). Agroecology for home and market: A winning combination for rural communities in Mashonaland East, Zimbabwe. Retrieved from http://www.fao.org/3/a-be864e.pdf

La Via Campesina Africa (2016). Shashe Agroecology School: A true centre of Agroecology and practical food Sovereignty. Retrieved from http://www.fao.org/3/a-bl921e.pdf

United Nations Development Programme (2017). Community Approaches to Sustainable Land Management and Agroecology Practices. Retrieved from https://www.thegef.org/sites/default/files/publications/SGP-Agroecology%20Publication-Digital.pdf

Other Literature

Module Thirty, Activity One – Exploring Africa. (n.d.). Retrieved December 11, 2019, from http://exploringafrica.matrix.msu.edu/module-thirty-activity-one/

3.13 Madagascar

3.13.1 Country profile from the agro-environmental perspective[20]

Madagascar is the fourth largest island in the world. It is located off the coast of Mozambique in South-East Africa. It is comprised of tropical climates along the coast, temperate, mountainous regions inland, and arid conditions in the south. It has a population of more than 25 million people that is growing at an estimated 2.5% per year. The island is known for its unique biodiversity, of which 90% of all species are endemic.

Its agricultural sector is characterized by its major staple crops: rice, cassava, beans, groundnuts and bananas. Agricultural productivity and food security are challenged by erosion and soil degradation, desertification, wildfires, water pollution, drought and natural disasters such as cyclones and locust infestations.

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

3.13.2 Synthesis of agronomic practices

Agri-food systems covered in the literature included family farming, entrepreneurial enterprises, agroforestry systems, livestock systems (including integrated systems), and aquaculture. All of the systems are considered to be extensive, or in a few cases intensive. Agroecological practices included: composting; integration of trees; system of rice intensification (SRI); crop rotation; cover cropping (seasonal + semi-permanent); organic fertilization; crop diversification; integration of livestock; use of grass strips; and integration of fish within rice paddy systems. None of the reviewed literature detail post-harvest practices. Factors influencing farmers and other stakeholders to adopt various agroecological practices include: climate change; low yields; low or no access to inputs; low availability of arable land; soil infertility; soil erosion and degradation; high labour requirements; and low incomes.

3.13.3 Links to food security

The contribution of agroecological practices to food and nutrition security was assessed indirectly on a household level. Many articles reported indirect positive contributions at the household level (Razafimbelo et al. 2018, Violas et al. 2018; Randrianarison et al. 2017; Rerolle and Andriamampionona, 2017, ADRA 2016) as the implementation of certain practices led to increased income, yield and/or food availability.

3.13.4 Sustainability assessment addressing the environmental, social and economic dimensions

The literature provided minimal data (quantitative or qualitative) regarding productivity indicators. Those that did offer data showed productivity increases through yield (Violas et al. 2018, Naudin et al. 2018, Rerolle and Andriamampionona 2017). Two studies showed that farmers who had implemented the practice of SRI observed average rice yields increasing from 2 t/ha to 5 t/ha (Dupin 2011, Rakotovao et al. 2017). In one study, farmers saw their vegetable (unspecified types) yields increase by 1 t/ha when using composted manure mixed with other organic matter as opposed to simple manure in their fields (Naudin et al. 2018). An action research experience dealing with planting of Cassava in the south of Madagascar, reported an important yield increase using compost and ridging with draught power to reduce the workload of this agroecological practice (Rerolle and Andriamampionona 2017).

In semi-arid area (Region of Androy) agroecological sites, based on Cajanus cajan cultivation, have increased from 457 ha in 2014 to 2.434 ha in 2018 (Violas et al. 2018) (note: 4.395 ha in 2019). This agroforestry approach permits a great environmental and nutritional impact by: (i) decreasing soil erosion due to heavy rain and strong wind, (ii) increasing soil fertility (mulch, nitrogen), (ii) reducing logging by providing fuelwood, (iv) increasing biodiversity and (v) increasing food availability thanks to Cajanus cajan grains harvested two times a year.

[20] Sources (in addition to those below)
Image from https://commons.wikimedia.org/w/index.php?curid=6701154
https://www.cia.gov/library/publications/the-world-factbook/geos/ma.html
https://www.wfp.org/countries/madagascar

Lastly, in a study of different strawberry production systems, it was observed that organic producers observed higher yields (13 t/ha as opposed to 9.8 for vegetable growers and 11 for combination growers) than those practicing conventional strawberry cultivation (Randrianarison et al. 2017).

Economic outcomes of the implementation of agroecological practices were variable between cases. On the one hand, Randrianarison et al. (2017) observed low income in organic producers due to expensive land rental required outside labour. On the other hand, the adoption of better adapted paddy rice varieties allowed farmers greater production stability and hence more stable income (Naudin et al. 2018). Finally, a single farmer case study showed how the association of paddy rice and fish production in the same field optimized land use and enabled continuous production throughout the year, allowing the farmer a consistent source of income (ADRA 2016).

Through incorporation of agroecological practices, some studies showed environmental benefits. In the study of strawberry producers, organic farmers experienced improved soil fertility as a result of organic fertilizer and management practices (Randrianarison et al., 2017). In a study of smallholder farmers' carbon footprints (CFP), it was shown that by incorporating agroforestry practices, composting of organic matter, and SRI, farmers were able to significantly reduce their CFP (Rakotovao et al. 2017). In another study about agroforestry, it was observed that biodiversity was enhanced through reforestation, and suggestions were made that these practices also increased on-farm carbon storage (Razafimbelo et al. 2018).

The analysed literature reported a limited range of social benefits. Only L'Agence Française du Développement recorded an increase of extension and support services for local farmers (AFD 2016).

3.13.5 Promotion of Agroecology in the Country: Evidence from Literature

There was no mention in the literature of government organizations promoting agroecology. A report from the Centre De Coopération Internationale En Recherche Agronomique Pour Le Développement (CIRAD) highlighted a number of regional, national, and international NGOs working in tandem to promote such practices as conservation agriculture, vermicomposting, agroforestry, and improved water management (Naudin et al., 2018). In another study, the Malagasy Department of Agriculture participated in the distribution of improved lima bean seeds in cooperation with a research team to study the adoption trends with new varieties (Rakotovao et al., 2017).

Overall, the promotion of agroecology and agroecological practices appeared low based on the resulting literature search. Where specific practices were being promoted, it was generally initiated by development organizations or research institutions.

3.13.6 Conclusions

In conclusion, the literature on agroecological practices in Madagascar included family and entrepreneurial farming systems, covering extensive aquaculture, livestock, agroforestry and cropping agroecosystems. The main agroecological practices included composting, SRI, organic fertilizer, crop rotation, protection against erosion and diversification. Reasons to adopt these practices included climate change resilience, soil health and low or no access to inputs. Literature has shown that agroecological practices can improve food and nutrition security in Madagascar, as they contribute to increased income, yield and/or food availability. The main observed benefits from the literature were yield increases, improved incomes, and reduction of environmental impacts. The studies analysed showed that there is a lack of participation from state actors in the promotion of agroecology and diffusion of agroecological practices.

The analysed literature neglected to assess food security based on distribution and access to food resources. There was also poor differentiation between realized benefits and the hypothetical potentials of agroecological practices with regards to food security. The lack of research of agroecological practices and their relationship to food security suggests a greater need to explore the potential of agroecology in Madagascar.

3.13.7 Number of analysed documents

The selection process returned 85 scientific articles and no documents of grey literature. Three scientific papers were found to match the aim of the study, in addition grey literature was further screened to highlight research, projects or initiatives not represented in journal articles. Six documents were identified.

3.13.8 References

Peer Reviewed Literature

Rakotovao, N.H., Razafimbelo, T.M., Rakotosamimanana, S., Randrianasolo, Z., Randriamalala, J.R., Albrecht, A. (2017). *Carbon footprint of smallholder farms in Central Madagascar: The integration of agroecological practices*. Journal of Cleaner Production, 140, 1165–1175.

Randrianarison, R., Ranaivoarisoa, H.F., Rabibisoa, N.L., Rasamimanana, L.A., Ramananarivo, S., Ramananarivo, R. (2017). *Smallholder farmers' logic to promote strawberry value chain in the rural Commune of Tsiafahy, Analamanga Régions, Antananarivo*. Acta Horticulturae, (1156), 929–936.

Razafimbelo, T.M., Andriamananjara, A., Rafolisy, T., Razakamanarivo, H., Masse, D., Blanchart, E., Falinirina, M.-V., Bernard, L., Ravonjiarison, N., Albrecht, A. (2018). *Impact de l'agriculture climato-intelligente sur les stocks de carbone organique du sol à Madagascar*. Cahiers Agricultures, 27(3), 35001.

Grey Literature

ADRA 2016. *L'innovation paysanne. Le journal de la pisciculture à Madagascar*. Vol 33. http://www.apdra.org/IMG/file/voix_rizipisciculture/LVRP%2033%20VF.pdf

Agence Français de Development (AFD) (2016). *Améliorer la productivité agricole à Madagascar (PAPAM) | AFD - Agence Française de Développement*. www.afd.fr/fr/ameliorer-la-productivite-agricole-madagascar-papam.

Dupin, B. (2011). *Analyse des conditions d'adoption paysanne de diverses techniques agro-écologiques à partir des expériences de coopération d'AVSF*. www.avsf.org/public/posts/667/l-agroecologie-a-madagascar-analyse-des-conditions-d-adoption-paysanne-de-differentes-techniques-a-partir-de-l-experience-d-avsf.pdf

Naudin, K., Autfray, P., Dusserre, J., Penot, E., Raboin, L.-M., Raharison, T., Rakotoarisoa, J., Ramanantsoanirina, A., Randrianjafizanaka, M.T., Rasolofo, L.I., Raveloson, H., Razafimahatratra, H.M., Salgado, P., Sester, M., Vom Brocke, K., Scopel, E. (2018). *L'agro-écologie à Madagascar : de la plante au paysage.* http://agritrop.cirad.fr/590486/

Rerolle, J., Andriamampionona L.L.R., 2017. *D'une innovation à une pratique paysanne améliorée: Cas de la culture de manioc sur "billan amélioré" dans le Sud de Madagascar*. ASARA. Agronomes et vétérinaires sans frontières. http://asara-aina.eu/wp-content/uploads/2015/12/2-AVSF-MANIOC.pdf

Violas, D., Maharetse, J., Sandratriniaina, R., Lhériteau, F. 2018. *Document de capitalisation sur les blocs agroécologiques. Région Androy. ASARA*. Gret. https://docplayer.fr/129433601-Document-de-capitalisation-sur-l-experience-des-blocs-agroecologiques.html

3.14 Lao People's Democratic Republic

3.14.1 Country profile from the agro-environmental perspective[21]

Agriculture is a key sector for Lao PDR economy, it accounts for nearly half the country's GDP and employs around 75% of the population. The sector is dominated by small-scale subsistence farmers, depending on rice-based agriculture and livestock. The country is rich in biodiversity, consequently used also as an important source of food and nutrition for rural people.

Principal crops other than rice include sweet potatoes, sugarcane, corn (maize), assorted vegetables, fruits in smaller quantities, tobacco and coffee, which is the main exported crop. The country is characterized by a low agricultural productivity which can generate food security issues. Agriculture is also vulnerable to weather events like flooding, droughts or typhoons.

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

3.14.2 Main topics addressed in the selected documents

All documents focus on smallholder farming systems. The main crops studied are rice and maize, which are grown both for as staple food and cash crops. Some farms also own livestock as assets to finance monetary costs including ceremonies, healthcare and education, even though animals are also used to generate power and manure. The agronomic practices studied include conservation agriculture, which requires no-till, permanent soil cover (mulch), and diversified crops rotations; maize/rice bean cropping system; organic farming rice and growing forage to feed livestock.

On the other hand, documents from the grey literature deal mainly with organic farming vegetable production based on principles in accordance with the belief of nurturing nature, traditional customary law and local ethnic knowledge in a village community; sustainable rice systems with single seedling transplanting, manual weeding and no chemical inputs; as well as organic rice under contract.

3.14.3 Links to food security

No scientific document specifically addresses the question of food security and only one evokes the nutritional qualities of rice beans as a source of protein while another suggests production in marginal lands through conservation agriculture may improve food security, but these documents do not really develop thoroughgoing the notion. Yet, no document mentions an adverse effect of agroecology on food security. On the contrary, two documents from the grey literature highlight the benefits of organic farming vegetable production that enable villagers to be in a position of self-reliance while ensuring the long-term sustainability of natural resources (SPERI 2017). Another report of the Sustainable Agriculture and Environment Development Association (SAEDA) claims that organic vegetable production enables to improve food security at the family level due to satisfactory food production with low cost, though this argument is not supported by scientific data. In addition, organic vegetables provide families with healthy food.

3.14.4 Sustainability assessment addressing the environmental, social and economic dimensions

Regarding productivity, no-till systems may increase maize yields under certain conditions. For example an experiment observed an increase of 16% for grain yield and 34% for crop residues, under no-till compared to conventional tillage from the third year onward (de Rouw and al. 2010). Likewise, Lienhard and al. (2014) suggested that total grain production of maize, rice and soybean was similar or even higher under conservation agriculture systems than under conventional tillage systems. The use of cover crops under conservation agriculture prior to or intercropped with main crops increased significantly total biomass production, of 50% higher, under all conservation agriculture systems as compared with conventional tillage. Besides, the maize / rice bean cropping system resulted in lower or equivalent maize yields in respectively intercropping and relay cropping in comparison with sole maize (Yap and al. 2019). This later study identified a number of challenges

[21] Sources (in addition to the references below): https://www.agropolis.fr/formation/pdf/2009-politique-agricole-monde-laos.pdf , https://www.britannica.com/place/Laos/Agriculture-forestry-and-fishing

associated with intercropping systems with rice bean. On the other hand, rice yields were estimated as equivalent in organic and conventional farming in Sangthong District, due to the closeness between the two systems, because conventional farmers are cropping in low-input systems in this region (Phranakhone and al. 2017). Rice farmers in organic farming obtained higher yield than conventional farmers (3272 kg/ha vs 2603 kg/ha), as farmers have better access to seeds, organic fertilizer and technical assistance facilitated by the contracting firm (Setboonsarng and al. 2008). In addition, according to a literature review carried out by Philp and al. (2019), the expansion of forage production can result in successful cattle fattening in Lao PDR.

From an economic point of view, crop diversification may generate additional income, such as maize / rice bean cropping system or cover crops in conservation agriculture for example, but the lack of local markets in some rural areas can hinder the selling of these crops (Yap and al. 2019). In conservation agriculture, total net incomes can be similar (without cover crop value) or even higher (with cover crop additional value as forage) than conventional tillage systems. This can be explained by higher grain production and lower annual variable costs for land preparation and weed management, despite higher initial investments (Lienhard and al. 2014). On the other hand, growing forages in a sustainable way may provide households with a general increase in the quantity and quality of feeds available for animal production that can generate greater returns from livestock than would be attainable under traditional smallholder farming practices (Philp and al. 2019). Besides, organic rice farmers can achieve a higher profit from their rice production, due to higher selling price of certified organic rice. For example, Phranakhone and al. (2017) reported a 50% increase of profit with organic rice farming compared to conventional farming in Sangthong District. The development of local or export organic markets to increase the selling price compared to conventional farming also resulted in better farmer incomes in two other cases study (SAEDA, Setboonsarng and al. 2008).

Regarding environmental benefits, some papers suggest that agroecological practices can contribute to improving soil fertility, for example in the case of rice bean production by farmers (Yap and al. 2019). However, no-till systems have been shown to improve soil structure, leading to more water availability (de Rouw and al. 2010). The recycling of biomass in conservation agriculture systems can considerably contribute to enhancing soil chemical, physical and biological properties and to producing various ecosystem services (Lienhard and al. 2014). However, a study found a loss of carbon in a no-till system while conventional tillage system significantly stored carbon. The authors argued that this can be due to the slowness of biomass transformation into organic matter from the soil surface compared to direct carbon losses, while ploughing plant residues into the soil enable to capture them more efficiently. However, the authors highlighted the fact that no-till system depended heavily on fertilizers and herbicides (de Rouw and al. 2010), which cannot be consider as agroecology. Besides, Philp and al. (2019) referenced similar ecological benefits that can be attained by growing forages, such as limiting soil erosion, sequestrating carbon, or fixing nitrogen through leguminous forages.

No noticeable social benefits were pointed out in the selected scientific papers, except the positive effect of increase income on households' livelihoods. In the grey literature documents, organic production of vegetables was mentioned as suitable for women in two articles as it is less labour intensive (SPERI 2017, SAEDA). In addition, the agroecological system production of Long-Lan village is a relevant example of agricultural system where the village elders, heads of families, prestigious villagers and key farmers are playing a decisive role in maintaining the traditional values, structures and regulation of relations amongst families and clans, and ensuring the sustainable management of natural resources.

3.14.5 Promotion of agroecology in the Country: evidences from literature

The agricultural development policies of Lao PDR are aiming at intensifying the production system and forcing out the traditional shifting cultivation practices. However, there is a series of research and development projects that are testing and promoting alternative low input cropping in various places of the country. For example, the Eco-Friendly Intensification and Climate Resilient Agricultural Systems in Lao PDR (EFICAS) and Forestry and Agro-Ecology in Lao PDR Rural Uplands (FORAE) projects can be mentioned. These projects are mainly led by NGOs, as Agrisud which supported the development of rice bean cropping system for example. Besides, organic rice farming can be promoted by farmer associations, as the Sangthong Organic Farmers Association, which developed organic rice markets (Figure 9 and Figure 10).

Figure 9. Rice parcel © Agrisud

Figure 10. Rice harvest, F Grunewald, © Cirad

Several NGO lead agroecological development projects in Lao PDR, mainly at the village community level. The ALiSEA database (Agroecology Learning Alliance in South East Asia) has capitalized a significant amount of these projects. ALiSEA is "an innovative regional platform to network all initiatives supporting the agroecology movement, to feed public policies and to support wider dissemination of successful alternative agricultural practices". These development projects can effectively promote transition from conventional to agroecology farming in Lao PDR. However, as for West African countries, they do not result in scientific publications, neither in quantitative database allowing verifying narratives about agroecology.

Several impediments need still to be overcome to upscale agroecological production. Economic difficulties to invest in new practices, commitment to traditional practices, lack of knowledge regarding agroecological practices and high labour requirements are cited as the main barriers to adoption. Financial support to implement agroecological practices and development of markets for new agroecological products are needed. Farmer-led organizations can provide a strong basis for the promotion of agroecology, as they can enhance access to information and market channels and provide farmers with technical mentoring. According to documents from the grey literature, farmer to farmer learning is a very effective extension methodology. Factors of success for promoting agroecology farming include simple and low investment techniques. The development of organic farming markets is also essential, provided that consumers are aware of benefits of organic products.

3.14.6 Conclusions

This literature review of agroecological research experiences in Lao PDR highlights some considerable environmental and economic benefits that could be brought about by agroecological practices. However, the amount of relevant scientific literature is relatively poor, there is therefore a need to enhance active research in these topics. On the other hand, development projects are quite active in some areas, and the capitalization of agroecological experiences through the creation of ALiSEA database shows that agroecological awareness is growing. Even if the development projects need to be supported, the publication of exploitable reports must be encouraged, as most of documents on ALiSEA were not relevant to provide a scientific insight of agroecology practices.

3.14.7 Number of analysed documents

The analysis highlights a weak amount of relevant scientific literature concerning agroecology in Lao PDR, with only 5 papers found relevant among the 60 papers returned by the application of the search protocol. Regarding grey literature documents, they were retrieved from ALiSEA (Agroecology Learning Alliance in South East Asia). However, they are mostly based on empirical knowledge. Thus, only three documents were relevant among 226 available found in ALiSEA for Lao PDR.

3.14.8 References

Scientific papers

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Grey literature

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3.15 Guatemala

3.15.1 Country agro-environmental profile

The total land area of Guatemala is 109,000 km^2 with 39,000 km^2 devoted to agriculture and 35,000 km^2 to forests. The country is mostly mountainous with two major chains from west to east, while lowlands are limited to the southern coastal area and in the northern Petén department. Consequently, the climate varies with elevation, from the hot and humid tropical lowlands and to the temperate and even cold highland peaks and valleys. Guatemala, like other central American and Caribbean countries, is seasonally hit by hurricanes causing floods and landslides with serious consequences to agriculture and its rural population. The country is considered a biodiversity hot spot with seven main biomes (tropical humid forest, tropical rainforest, cloud forest, montane forest, dry scrub, sub-tropical humid forest, and tropical humid savannah) which are home to 1,246 known species of amphibians, birds, mammals and reptiles (7% endemic), 8,680 vascular plants (13.5% endemic). This is the land where corn was domesticated with other major plants (squash, beans, avocados, cacao, tomatoes, zapotes, jocotes, chicle, amaranth, chilis, among others) and animals such as the turkey. Notwithstanding its high rate of endemisms, however, biodiversity in general is being degraded through unsustainable land uses. Traditional practices and knowledge associated with the use of biological resources are threatened, as well as the cultural and ethnic diversity with its traditional knowledge, skills and timeless practices. Between 1999 and 2003, the extent of forests, agricultural lands and wetlands was reduced while the cover of natural pastures and shrubs increased. The agricultural and livestock sector is promoting sustainable practices and market competition, with a view towards high aggregated value in volume and quality in the national and international markets. As such, the country recognises the importance of considering ecosystem conservation, genetic diversity, traditional knowledge related to the cultivation and use of native species, among other factors, in the development of sectoral policy to deal with present and future challenges. Certain institutions are undertaking activities to compile and record traditional knowledge but this is hampered by the absence of baseline information. The prevailing economic model of agriculture threatens biodiversity and traditional practices with moving towards packaged food and drinks, large-scale monoculture farming (e.g. sugar cane, African palm) for export purposes. The loss of traditional practices as a result of the exodus of the rural populations to the urban centres poses another threat. Indigenous Guatemalans are close to 50% of the national population, which is among one of the largest percentages in Latin America, behind only Peru and Bolivia. Most indigenous Guatemalans are of the Maya people with a large cultural diversity of ethnic groups. They often speak almost exclusively their native languages. This is raised as an obstacle in scientific agroecology investigation.

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

3.15.2 Links to food security

Taking into account that Guatemala is a country suffering from decades-long armed conflicts with devastating consequences on rural people and family farming systems, food insecurity in Guatemala is an access-related problem given that most rural households are net consumers of food, which means that they buy more food in the market than what they produce. Widespread malnutrition is, consequently, to be expected in a country where more than half of total households live in poverty. Despite its wealth of natural resources, nearly half the children under 5 years of age suffer from malnutrition. Nearly 60% of the national population lives under the poverty line with two towns in the San Marcos Department, Tacaná and Sibinal, reaching 84% and 90% respectively. Agroecology-based farmers have higher levels of food availability than semi-conventional ones during both dry and rainy seasons. The former produce 27% more plant varieties during the dry season and 62% more so during the rainy season than the latter. In fact, agroecological farmers make also more agricultural income during both seasons (46% in the dry season and 78% in the rainy one) than their semi-conventional peers. Agricultural production is irregular in Guatemalan households throughout the year, reaching minimum levels during water-shortage periods. Farmers explain scarcity periods as the result of a number of factors, namely: (i) limited areas for production; (ii) lack of irrigation systems during the dry season; (iii) climate-related limitations such as frosts, droughts, excess of rainfall, and hail; and (iv) plant disease out-breaks during the rainy season. Seed storage is, for the most part, artisanal which can entail health-related risks and jeopardize food security, moreover agroecology-based farming provides grounds for more resilient livelihoods among smallholders in Western Guatemala (Calderón et al. 2018).

3.15.3 Sustainability assessment addressing the environmental, social and economic dimensions

While agroecological produce is commercialised at the municipal level, semi-conventional products seem to stay within the realm of the village. Agroecological producers are better suited to local markets than their semi-conventional peers. The households engaged in commercialising their produce made an average USD PPP 766.43 over a 6-month recall period. This means that each month these households made around USD PPP 127.74 or USD PPP 4.26 per day for the whole family. As for semi-conventional households, this figure drops to USD PPP 2.06 per day for the entire family. These numbers suggest that both, semi-conventional and agroecological farmers do not align perfectly with regional market systems. Agroecological producers, however, claim to generate enough income to live off the land throughout the year, which suggests that even if weakly suited to the market-based economy, they meet their needs with a combination of self-consumption and a limited share of cash-income generating produce. Semi-conventional producers, conversely, contend that agriculture is not enough and many among them seek job opportunities overseas, notably in Mexico and the USA. Despite widespread concerns among agroecological producers regarding marketing and income-generating strategies, our analysis suggests that they have better market integration levels than their semi-conventional peers, which on its own is no guarantee for long-lasting poverty alleviation but indicates a trend. In addition, agroecological farmers seem to be better organized and have access to stronger solidarity networks. With agroecological practices they provide soil conservation and erosion control and plant diversity. This means that agroecological fields harbour a larger amount of plant species which brings about structural advantages given, for example, a more diversified root system and therefore a more even absorption of soil resources. A cohesive social fabric is instrumental in providing community members with a sense of belonging and enables a number of solidarity networks to grow. This is particularly relevant under challenging circumstances such as climate-related catastrophes when social bonds allow victims to endure hardship and uncertainty. Organisational capacities provide community members with a safety net and it seems to be working for both agroecology-based and semi-conventional farmers. Agroecological families seem to distribute schooling opportunities more evenly (15 girls and 15 boys) than their semi-conventional peers (15 girls and 23 boys). Agroecological groups have had more chances of being trained by a number of organisations which seems to have deepened their gender-related sensitivity. Even so, agroecological female producers still face major challenges as to health, nutrition, education, access to credits, access to water, work, migration, and organisation (Calderón et al. 2018).

3.15.4 Promotion of agroecology in the country: evidence from literature

Guatemala is noted for its deep connections to the agroecological movement, the social and political actions propelling the spread of sustainable/ancestral agricultural practices and principles, often connected to larger territorial struggles. Throughout the 70s and 80s thousands of peasant farmers reclaimed autonomy at the family and community level through the horizontal exchange of agroecological knowledge and practices: the methodological process of learning by doing, largely successfully widespread in Latin America and the Caribbean, now commonly referred to as Campesino a Campesino, in English Farmer to Farmer (Einbinder et al. 2019). The grassroots approaches to collective action have provided opportunities to foster community-level climate adaptation strategies despite long-running social, economic, and political divisions (Hellin, J. et al. 2018))). In 2007 Guatemala established a National Commission on Ecological Agriculture (Comisión Nacional de Agricultura Ecológica – CNAE) as a public-private organisation that, under the auspices of the government and international partners, has been developing synergies with the different institutions and member sectors of the country's organic production chain, making the best efforts to become a collegiate body representing the organic and/or agroecological sector of Guatemala. Its purpose is to "promote and regulate organic and/or agroecological production at the national level, whose development is based on the sustainable management of natural resources, avoiding pollution and degradation of the environment, protecting human and animal health, properly manage water, soil and biodiversity".

In 2010 CNAE starts the consultations and definition of the "National Strategy for the Development of Organic and Agroecological Production of the Republic of Guatemala 2013-2023" as a working tool for the promotion, improvement and strengthening of production, transformation, marketing, regulation, and prioritisation of food and agricultural products consumption in general from organic and/or agro-ecological production systems using natural resources efficiently and sustainably. The National Strategy states that "organic and agroecological agricultural production systems are alternative and differentiated, capable of generating various income in family and subsistence farming, and guarantees food security, contributing to improve the quality of life of those who are part of this important productive segment. The principles of organic and agro-ecological agricultural production are in accordance with the requirements necessary to comply with the Hunger Pact of the Government of Guatemala and the Millennium Development Goals, considering this type of production a tool for sustainable rural development and poverty reduction" (Estrategia Nacional para el Desarrollo de la Producción Orgánica y Agroecológica de la República de Guatemala 2013-2023 https://visar.maga.gob.gt/visar/eao13.pdf).

3.15.5 Conclusions

The Guatemala National Strategy for Organic and Agroecological Production, based on the actor consultation at the regional and national levels, identifies and synthetises the following main limitations by thematic areas:

- primary production: • limited quantity of seeds produced organically or agroecologically • soils with a high degree of degradation and low fertility • plants with a high degree of infection by diseases and insects • little control over irrigation water quality • minimum crop diversification • limited available productive infrastructure • poor planning and management of production activity records • limited production experiences and lack of knowledge of them to encourage new ones;
- transformation of primary production: • limited infrastructure in the regions, centralized in the capital of the country • little development of machinery and industrial equipment • limited network of services for the transformation of products • low availability of packaging for processed products because of its high price • production volumes dispersed in the territories that raise transportation costs • little knowledge of good manufacturing practices and quality regulations • poor product design and marketing development • high degree of bureaucracy in the procedures of brand, label, sanitary registration, etc. • shortage of some organic or agroecological inputs for the transformation;
- commercialisation: • ignorance of the term “organic” • limited knowledge of national organic production regulations • consumers with little or no knowledge of what organic products are • lack of advertising and dissemination of organic products and where they are sold locally and nationally • strong competition from the non-regulated advertising industry of conventional products • for the national and local market there is no type of certification that guarantees organic product or ecological quality • organic and agroecological production, as it does not have a differentiation or distinction, competes with conventional products in local markets • no records of production marketed in the national market; • limited storage and market place infrastructure • few fairs or places of sale of organic and organic products • a large majority of peasant production lacks a trade patent, tax identification number and/or legal quality records • consumers prioritise the purchase of agricultural products accordingly at a lower price than quality;
- Institutionally: • poor organization of the sector in general and more specifically by region • limited union association • consumers not organised to demand and monitor quality • no government programmes and/or policies aimed at promoting, strengthening and encouraging the organic and agroecological sector • limited recognition of producers as economic actors by the central government and municipal • international cooperation supports actors in a dispersed way, without a strategic approach to coordination and development of the sector • great ignorance of the ministerial agreement that conforms to the NACE, which sectors participate and their functions • limited inter-institutional coordination of the CNAE; • poor representation of the regions on the board of directors of the CNAE • little investment of the state for the promotion of organic and agroecological agriculture • little regulation and public supervision of the health quality of the pro conventional agricultural pipeline (use of sewage, prohibited agrochemicals, etc.) • segregation of members of the board of directors of the CNAE at the end of its management period; • CNAE lacks self-sustainability plans

(Estrategia Nacional para el Desarrollo de la Producción Orgánica y Agroecológica de la República de Guatemala 2013-2023 https://visar.maga.gob.gt/visar/eao13.pdf).

3.15.6 Number of analysed documents

The scientific and grey literature of Guatemala is mostly based on social, historical, political and cultural reviews and qualitative assessments rather than quantitative agronomic or production figures, like many countries in Latin America and the Caribbean. Two related questions raise for agroecology: how to identify and quantify the different components – agronomic, ecological, economic, social and, last but not least, cultural (so often forgotten and so clearly evident in the case of Guatemala)? And once identified and quantified a set of criteria and indicators, how and what scale to compare inputs and outputs in relation to industrial agriculture? Most papers show that agroecology runs all along the food chain, the different levels, and all the components of sustainability including cultural diversity and heritage.

The literature review returned 14 scientific publications 12 grey literature documents. Of these, 8 scientific papers and 6 documents from the grey literature were found relevant for the scope of this study.

3.15.7 References

Scientific papers

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Grey literature

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Estrategia Nacional para el Desarrollo de la Producción Orgánica y Agroecológica de la República de Guatemala 2013-2023 https://visar.maga.gob.gt/visar/eao13.pdf

Convention on Biological Diversity, Guatemala Country Profile https://www.cbd.int/countries/profile/?country=gt

Delegation of the European Union to Guatemala, 2018. Proyecto agroecología, economía solidaria, y espacios de diálogo, en el manejo de la conflictividad económica y ambiental, a través de redes, en la Costa Sur y en los departamentos de Huehuetenango, Sololá, y Chimaltenango, Guatemala. https://eeas.europa.eu/delegations/guatemala_pt/38964/Proyecto%20agroecologi%CC%81a,%20economi%CC%81a%20solidaria,%20y%20espacios%20de%20dia%CC%81logo,%20en%20el%20manejo%20de%20la%20conflictividad%20econo%CC%81mica%20y%20ambiental,%20a%20trave%CC%81s%20de%20redes,%20en%20la%20Costa%20Sur%20y%20en%20los%20departamentos%20de%20Huehuetenango,%20Solola%CC%81,%20y%20Chimaltenango,%20Guatemala

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3.16 Nicaragua

3.16.1 Country agro-environmental profile

The total land area of Nicaragua is 130,000 km2 with an agricultural area of 51,000 km2 and 31,000 km2 of forest cover[22]. Nicaragua hosts 68 ecosystems, a figure that represents 60% of the 114 ecosystems that are identified in the Central American isthmus. The biological wealth of Nicaragua is 20,485 species distributed as follows: 29.35% corresponds to flora, 9.75% vertebrates, 59.98% invertebrates and 0.89% fungi. The genetic resources of Nicaragua are important elements for the food security and sovereignty of the country, mainly those originating in the biogeographic region (corn, beans, cocoa, cucurbitaceae, capsicum spp, among others). It is significant to mention that Nicaragua is home to a population of teocintle corn (Zea nicaraguensis Iltis & Benz), ancestor of corn, located in the Department of Chinandega. This genetic wealth is being managed by both government institutions and by peasant families, who are working for the recovery and conservation of genetic resources of ancestral origin. A good part of the conservation of this genetic heritage is carried out by peasant families who have organized to rescue the knowledge associated with creole seeds. Today in the country there are 342 community banks of creole seeds, distributed in the different departments of the country. For its part, the Government, through the Nicaraguan Institute of Agricultural Technology (INTA), has rescued 403 creole varieties of basic grains (rice, beans, corn and sorghum) with the objective of conserving and using genetic resources for improved yields, disease tolerance and adaptation to adverse climatic conditions. Nicaragua has planned to achieve the following strategic goals and actions in its Biodiversity Strategy by 2020: - design and promote food security and sovereignty-oriented programmes, based on the principles of agroecology; - promote healthy production, making use of the ancestral knowledge of the communities, for example, the inclusion of native species of high nutritional value; - diversify agricultural, forestry, livestock and aquaculture production, in order to obtain locally the necessary products for the food security of the communities; - promote family gardens to improve the diet of families; - develop recovery programmes and promote ancestral practices and traditional sustainable use of biodiversity; - implement procedures and technical standards to support agroecological production based on human health[23].

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

3.16.2 Synthesis of agronomic practices

There are limited data available from field research in Nicaragua on the purely "agronomic" aspects of agroecology practices. In the perspective of food security, most of the agri-food system in Nicaragua is structured around families and cooperatives. Most often small holders rely on coffee, milpa (the traditional Mesoamerican family agricultural practice combining maize, beans and squash as core crops for daily food requirements along the year), home gardens, fruit trees and animals (mostly pigs and chickens). Since the '90 coffee production turns to agro-ecological practices to meet market quality standards. Today some 10% of the country farming is considered as agroecological. After the devastating Hurricane Mitch in 1998 a comparative study on agroecological and conventional plots (Holt-Giménez 2002) showed the advantages of practices such as rock bunds, contour ditches, live barriers, green manures and cover crops (e.g. the legumes Mucuna spp, Canavalia ensiformis) to conserve water, protect soil and supply organic nitrogen, crop rotation and stubble incorporation. As in other Mesoamerican countries, agroecological practices in Nicaragua developed from bottom-up adaptations to unfavourable climatic, economic, market and political trends.

3.16.3 Links to food security

In Nicaragua, bottom-up (lead by grassroots organisations) and top-down (lead by national government) processes are in play, an element which several authors have identified as critical to the diffusion of agroecology. The national legislation on agroecology and related topics since 2007 is the following:

2007 n° 620: Regulation of national water sources;

2008 n° 648: Equal rights and opportunities for all citizens;

2009 n° 693: Food and nutrition security and sovereignty;

2010 n° 705: Regulating the use of biotechnology;

[22] http://www.fao.org/countryprofiles/index/en/?iso3=NIC
[23] https://www.cbd.int/doc/world/ni/ni-nbsap-v2-es.pdf

2011 n° 747: Animal rights;

2011 n° 765: Agroecological and organic production: The purpose of this law is to promote the development of agroecological or organic production systems, through regulation and promotion of production activities, practices and processes with environmental, economic, social and cultural sustainability that contribute to the restoration and conservation of ecosystems, agroecosystems, as well as sustainable land management. The definition of agroecological production in this law is: "*production process where local resources are used to the maximum and the synergy of the processes at the agroecosystem level, uses practices that favor its complexity, adopting biological control and organic nutrition optimally in the management of the production system or the farm*";

2012 n° 807: Conservation of biodiversity.

In 2013 the technical norm 11 037 regulates the characterisation, regulation and certification of the production units in agroecology. Other steps in the adoption of agroecology as a major option for food security and sovereignty in Nicaragua are the Creation of the Agroecological and Organic Producers and Producers Movement of Nicaragua (MAONIC/2009), an arena that aims at contributing to the improvement of the quality of life of farming families through the positioning of agroecological and organic production on the national agenda and the creation of the Alliance for Agroecology in 2014.

3.16.4 Sustainability assessment addressing the environmental, social and economic dimensions

Evidences show that Nicaragua is well in advance on agroecology within the Latin American and Caribbean countries. The number of agroecological farmers in Nicaragua is rapidly growing, as is their social prestige and, importantly, their capacity to innovate and generate solutions from below. Agroecological organizational structures in the rural territories of Nicaragua are also generating secondary benefits, such as massive processes of education, prevention of mosquito-borne epidemics, and greater levels of citizen security. Agroecology has important synergies with the food sovereignty paradigm, including its focus on local resources and knowledge, women's participation in food systems, and long-term economic, ecological, and social sustainability. (McCune 2016).

3.16.5 Promotion of agroecology in the country: evidence from literature

There is a surprising degree of overlap among the visions of rural communities, territorial government institutions, and social movements in promoting agroecological farming as a way to reduce dependence on farm inputs and food imports, conserve agrobiodiversity and maintain food production levels during long-lasting droughts that afflicts the country. The number of agroecological farmers in Nicaragua is rapidly growing, as is their social prestige and, importantly, their capacity to innovate and generate solutions from below. Agroecological organisational structures in the rural territories of Nicaragua are also generating secondary benefits, such as massive processes of education, prevention of mosquito-borne epidemics, and greater levels of citizen security. Some historical conjectures are more propitious to scaling-up agroecology than others, and in the case of Nicaragua, post-neoliberal development under the leadership of a national unity and reconciliation government is creating a fertile medium for agroecological transition at the national scale (McCune 2016).

3.16.6 Conclusions

Analysing the situation in Nicaragua, some central mechanisms blocking the agroecological transition have been identified: policy mismatches, inadequate mobilization of resources, and insufficient market development, which weaken entrepreneurial opportunities and experimentation. Although these blocking mechanisms hindering the diffusion of agroecology are strongly interlinked, the analysis allowed to pinpoint specific factors break down these barriers. The results of this research highlight the coupled innovations that are necessary to drive agri-food systems sustainability transitions. A central factor is the fragmented institutional framework concerning agroecology, which inhibits a wide-spread perception of agroecology as a viable alternative to conventional agriculture, as well as hinders concrete actions that could incentivize stakeholders in the agroecological innovation system. Two other strongly interlinked factors are the lack of a common definition of agroecology, and the lack of a common vision amongst stakeholders for the development of agroecology vis-à-vis conventional agriculture. These factors open interesting avenues for future research, particularly concerning the power struggles during the development of common definitions of agroecology and vision for contested processes such as agri-food system sustainability transitions, the role of politics and the state in transition processes, and the role of individual and organizational agency in such transitions (Schiller 2019)

3.16.7 Number of analysed documents

As for Cuba, and among other countries in Latin America and the Caribbean, most of the scientific papers and the grey literature describing agroecology in Nicaragua stresses the social and socio-economic aspects also in relation to the national and international historical developments of the latest four decades. Little is still available on pure agronomic terms, given the fact that agroecology is a complex combination of traditional knowledge, innovation, skills that embrace a large agrobiodiversity, a diversity of soil conditions, and the changing patterns of climate. Of the 15 scientific papers returned by the applied protocol for literature review, 10 were selected as relevant for this brief. 20 documents of grey literature were returned and 5 selected.

3.16.8 References

Scientific papers

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3.17 Cuba

3.17.1 Country agro-environmental profile

The total land area of Cuba is 111,000 km2 with an agricultural area of 62,000 km2 and 32,000 km2 of forest cover[24]. The country hosts 42 types of ecosystems, ranging from arid and semi-arid land to humid tropical forests and mountains. Plains cover 75% of the territory, while mountains cover 18% (in the southeast and south-central area) and humid coastal lands cover the remaining areas[25]. The country is divided into seven agro-ecological zones. The Cuban flora is one the richest in the world and an important source of domestication and diversified agro-ecosystems. The forests cover was 14% in 1959 and reached 32% in 2015 (FAO data). Plant and seeds collections are organised in germplasm banks, genetic resources for food and agriculture in 14 conservation centres, which store 17,773 samples or accessions of 844 species, without considering forest resources[26]. The climate of Cuba is tropical, with a dry and relatively cool season from November to April, and rainy the rest of the year. Annual precipitation is between 1,000 and 1,500 mm. The wettest month is August (58 mm), the driest month is December (17 mm). Average temperature in July is 27°C and in December 21°C. Hurricanes in Cuba are frequent and often severe.

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

3.17.2 Links to food security

In Cuba, after thirty years of the Green Revolution, since the beginning of the 1990s, work has been carried out on the transition to organic and agroecological agriculture (N.B. in Cuba it is common to use 'organic farming' to refer to any kind of sustainable agriculture, agroecology, ecological farming, etc.). Agroecology has played a key role in helping Cuba survive the crisis caused by the collapse of the socialist bloc in Europe and the tightening of the US trade embargo. Cuban peasants have been able to boost food production without scarce and expensive imported agricultural chemicals by first substituting more ecological inputs for the no longer available imports, and then by making a transition to more agroecologically integrated and diverse farming systems. This was possible not so much because appropriate alternatives were made available, but rather because of the Campesino-a-Campesino (Farmer to Farmer) Agroecology Movement (MACAC), a social process methodology that the National Association of Small Farmers (ANAP) used to build a grassroots agroecology movement. The method, successful in other Latin American countries, significantly increased agro-ecological practices, contributing to increase relative and absolute food production and security, social movement dynamics, diversification, ecosystem services, including resilience to climate change (Rosset, 2011). In 2019 the Ministry of Agriculture and the European Union (EU) agreed on the Programme "Strategic Support for Sustainable Food Security in Cuba" (SAS), with the main goal of efficient and sustainable increase local level production of diversified and healthy food in six municipalities and the Integrated knowledge management system for food security in the country. The Programme includes aspects related to climate change adaptation, agroecology and exchange of experiences with other countries [27]. Since the 90s, Cuba has been working on the transition to organic and agroecological agriculture with a number of cross-sectoral policies, as a way to achieve food security and sovereignty, and nutritional sustainability of the population[28]. The 2019 Report of the High-Level Panel of Experts on Food Security-HLPE reports on Cuba as a case study, summarising critical aspects of agroecology in the country as related to food security: - over 300000 farmers use agroecological practices; - over half of all vegetables, maize, beans, fruit and pork are produced using agroecological methods; the Campesino-a-Campesino method is a key strategy; - land reform, which provided 75000 new farmers with access to land, helped address SFSs; - urban agriculture contributes ~70% of vegetables in major cities; - agroecological research centres develop locally adapted solutions across the country; - agroecology is taught in rural vocational high schools, which includes daily field work; - government, university researchers and NGOs have provided technical support to farmers; - food security improved; nutritional issues remain a problem for marginalized groups. Four key steps have been identified in driving this transition: (i) the farmer-to-farmer horizontal training and systematic knowledge exchange; (ii) farmers treated as the experts in research and exchanges; (iii) development of crop varieties and biological products that are adapted to local conditions; and (iv) building institutional cooperation between stakeholders, including research centres and advisory services

[24] http://www.fao.org/countryprofiles/index/en/?iso3=CUB
[25] https://www.cbd.int/countries/profile/?country=cu
[26] Funes Monzote F.R. 2017. Reseña sobre el estado actual de la agroecología en Cuba. Agroecología 12 (1): 7-18 https://revistas.um.es/agroecologia/article/view/330301/229261
[27] http://www.fao.org/cuba/noticias/detail-events/en/c/1251083/
[28] https://www.cbd.int/doc/nr/nr-06/cu-nr-06-p1-es.pdf

for agroecology. The research centres are spread across the country and provide locally-adapted biological pest and disease management solutions, including organic fertilizers, locally-made biopesticides and raising beneficial organisms. (HLPE 2019, Mier y Terán et al. 2018, IPES-Food 2018, Rosett et al. 2011, Gliessman 2007).

3.17.3 Sustainability assessment addressing the environmental, social and economic dimensions

Scientific and grey literature on agroecology in Cuba clearly highlights the different aspects of sustainability of the current process. Although figures may vary and many practices are still in transition, a considerable effort is underway to identify, monitor and evaluate main criteria (environmental and more strictly ecological, economic, social, cultural and political) and indicators of the state and progress of agroecology. This effort is even more significant if we consider that agroecology is still lacking in the majority of countries of official (and national) statistical data while comparisons with intensive agriculture are limited.

Figure 11 shows data on chemical use and food production in Cuba before the Special Period - the years after the fall of the Soviet Union from the early 90s on - and more recently (2008). It reveals a drop in production in 1994, a critical year during the Special Period, as a result of decrease in availability of imported inputs required for conventional agriculture. Since that time, the campesino sector has greatly recovered productive levels, due to the consolidation of agroecology, as can be seen for the largely campesino-produced food items in the graph. This has been possible despite a massive reduction in agrochemical use from 1988 levels, when the Green Revolution was at its peak. The data show an opposite trend for sugar cane, a crop that is still largely cultivated in Cuba according to the precepts of the Green Revolution, and which is not known as a campesino crop, for which yields have been continually decreasing; moreover, evidences show that the damage from the hurricane on most agroecological farms ranged from 30% to 60%, which is 15 to 45% less than in non-agroecological farms[29].

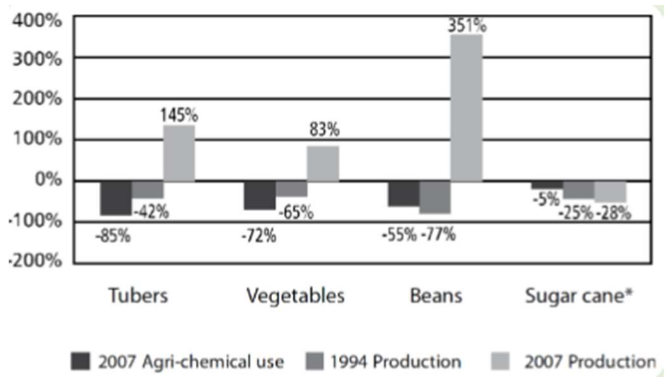

Figure 11. Four examples of agro-chemical use vs. production (*Source:* http://www.fao.org/3/a-bl991e.pdf).

Although field data (and statistics) are still lacking, Cuba provides examples of agroecosystem sustainability through sets of indexes or indicators, such as the agrobiodiversity index to identify the role of food varieties in human health, economy, social cohesion, among others (Leyva and Lores, 2018). Agroecological practices show high ratios of labour intensity/productivity, diversified economic outcomes, clear environmental advantages (organic matter, good soil conditions or recovery, prevention of soil erosion, resilience from pests or climatic events). The social benefits (at household, village, watershed, national levels) are found in a large framework of social cohesion, beside the improvements in some specific aspects such as employment (higher number of jobs). In fact, agroecology in Cuba demonstrates the capacity of balancing the components of sustainability through a social movement of communities, groups and individuals. Most, if not all, of the scientific papers and grey literature in this country recall the key role of farmers and their groups in making agroecology viable and acceptable.

[29] http://www.fao.org/3/a-bl991e.pdf

3.17.4 Promotion of agroecology in the Country: evidences from literature

Scientific papers and grey literature refer to different sources of promotion of agroecology. Projects and programmes, such as the Farmer-to-Farmer, a social process method of "learning by doing" (e.g. Rosset, 2011), farmers cooperatives, local institutions and the government have been paying attention and providing support to the development of agroecology and a praxis, while scientific research and evidences have been strengthening the narrative through various disciplines. Cuba's transition to agroecology is perhaps as widely known as it is misunderstood. In response to the economic crisis of the early 1990s, the Cuban agricultural sector largely departed from the industrial model of food production that it had previously pursued. The subsequent transition towards an agroecological model has been a dynamic and uneven process, elevating Cuba on the world stage as a global leader in sustainable agriculture while at the same time producing unique challenges for Cuban farmers, policy makers, researchers and academics. By analysing both the historical and contemporary processes through which agroecology has taken root in Cuba, it has been demonstrated that, despite its uneven and incomplete implementation, such a sustainable agroecological transition holds great, untapped potential. Agroecology in Cuba currently faces pressure from normalizing Cuba-US relations, with potentially profound implications for agriculture in both countries. But increasing opportunities are also emerging for investment, collaboration, knowledge exchange, and solidarity. Contributions from science provide overviews of the evolution of the Cuban agroecology movement, analysing the state of food security and challenges to food sovereignty on the island today and recommending support to agroecology for food security, food sovereignty, and sustainability[30].

3.17.5 Conclusions

The agricultural sector in Cuba is made up of five types of productive entities: 1) Basic Units of Cooperative Production (UBPC); 2) Agricultural Production Cooperatives (CPA); 3) Credit and Services Cooperatives (CCS); 4) private owners and 5) state areas, which correspond to different forms of property. Following the scientific evidences, the most efficient are the CCS and private farms, which in recent years have produced 57% of the country's total agricultural food, with only 24.4% of the arable land, while registering only 3.7 and 1, 7% respectively of idle land (Nova 2016). The core components of agroecological development that are able to overcome limitations and obstacles coming from both domestic and international factors are: re-organisation of the property forms, learning agrobiodiversity, agroecological technologies (ex. organic fertilizers, irrigation, microbial and stimulant inoculants, biodigesters and native microorganisms, biological control, participatory plant breeding and Local agricultural innovation program, agricultural mechanization, polyculture and rotation , among others). Agroecology in Cuba, as in many other countries of Latin America and the Caribbean, is basically a movement coming and carried by farmers securing a high level of sustainability, including food sovereignty and security.

3.17.6 Number of analysed documents

Cuba has an extensive scientific and grey literature on agroecology from different perspectives. Most of it stresses the social and socio-economic aspects also in relation to the national and international historical developments of the latest four decades. Little is still available in pure agronomic terms, given the fact that agroecology is a complex combination of traditional knowledge, innovation, skills that embrace a large agrobiodiversity, a diversity of soil conditions, and the changing patterns of climate. The application of the protocol for the literature review has led to the identification of 44 scientific papers and 15 documents within grey literature. Of these, 13 and 6 respectively have been declared apt for the present study.

3.17.7 References

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4 General synthesis: what science is telling us on agroecology, and benefits deriving from agroecological practices on food security – a study on 17 food insecure countries

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 for 17 countries (Benin, Burkina Faso, Mali, Senegal, Ghana, Niger, Togo, Kenya, Ethiopia, Zimbabwe, Malawi, Madagascar, Tanzania, Lao PDR, Cuba, Guatemala, Nicaragua). Overall, 172 papers have been synthesized and on the basis of the selected body of literature, including scientific and grey literature, some conclusions can be drawn on characteristics of existing research and available scientific results addressing the agroecological transitions and implementation of agroecological practices.

It should be noted that the search method adopted aimed at identifying agroecological approaches in the strict sense, and this may have restricted the identification of relevant papers, since literature on agroecology has been increasing in recent years and some practices or approaches may have not be labelled as agroecology as such in older papers (the selection procedure focused on documents published in the 2000-2019 period). Morevoer, by focusing on agroecology as farming approach, result hits were not exhaustive for individual agroecological practices, e.g. "organic production" is not identified through a search string including "organic farming". On the other hand, searching for each individual agroecological practice was not the scope of the study, which aimed at identifying the evidence of the contribution of the agroecological approach in relation to the improvement of food security.

The majority of the reviewed cases are small scale, extensive farming systems that produce food at subsistence levels and for sale on local markets. Most of the analyzed production systems were focusing on smallholder farming producing staple crops (millet, sorghum, yam, etc.) or vegetable gardening for local markets. Cash crops (e.g. rice, cotton, oil palm, rubber, cocoa) are overall much less targeted by research focusing on agroecological practices. This may reflect the fact that cultivation of cash crops is mostly driven by conventional intensive models to export to the world market, and is less interested by the agroecological perspective.

The recurrent agroecological practices studied are agroforestry, intercropping (or mixed cropping), introduction of legumes in rotations, soil and water conservation practices (mulching, return of crop residues, zaï holes etc.), use of animal manure and biocontrol methods to mitigate chemical pesticide use. However, some documents dealt with fertilization practices mixing manure/compost/crop residues with synthetic fertilizer. It is questionable whether these practices are fully agroecological, as they do not necessarily mean significant savings in chemical inputs. It is often the case that constraints to production deriving from soil erosion, soil infertility and lack of water for irrigation were the reasons why agroecological practices were implemented.

Some aspects of production resulted insufficiently addressed, such as post-harvest practices and crop-livestock integration.

Overall, though the assessments of fully agroecological systems not using chemical inputs found within the selected literature were few, studies on specific agroecological practices were much more common. In this regard some significant contributions of such practices to household food security were identified (it has to be noted, importantly, that the link to food security may not be a specific research target, and therefore is not always reported).

At least 50% of the analysed papers report a positive contribution of agroecological practices to food security, notably due to improved yields and/or a better economic situation of producers. For example, an improved use of organic fertilisers (with manure or compost), results in a significant improvement in yields. However, access to manure can often be a problem in the absence of significant crop-livestock integration. Diversified crop systems, including the introduction of agroforestry, improved household nutritional status and had positive links to better health conditions. Higher on-farm crop species diversity often results in more diversified diets. In many cases, the improvement of soil quality is key to improve yields and consequently income and food security; this can be achieved using various practices including the use of residue mulch from tree leaves in agroforestry, as well as crop mixtures or intercropping and longer more diversified crop rotations. In fact, throughout different articles, the lack of access to inputs is a recurring issue, particularly for what concerns the improvement of soil fertility (manure, mineral fertilizer, leaf litter, etc.), remaining a major hindrance for food security.

In a few cases increased resilience to extreme weather events and climate change deriving from the implementation of an agroecological approach to farming was mentioned.

Concerning environmental benefits, practices such as water management, use of manure and residue management were found to reduce the negative effects of agriculture on the environment and contributed to improved soil characteristics, biodiversity and environmental health.

Lack of financial support from the government, lack of scientific knowledge regarding practices alternative to what currently in applied, higher labour requirements, and lack of higher market value for the products have been identified as main constraints to the development of agroecology at the farm level.

Within the selected literature, very few social aspects of agroecology have been reported in West African countries. This is not the case for the Latin American countries analysed, where social aspects very often underpin the transition to agroecology. Agroecological research and development in Africa is more technical-based than socio-economic in nature.

The results of the analysis highlight the need to intensify research projects to get more evidence on the potential of agroecology in terms of efficiency in general terms and in particular for improving yields and nutritional quality of products and consequently food security in the countries studied. Economic, social and environmental benefits should be equally studied. Investments should be made in research for understanding and modelling the functioning of the soil-crop system in interaction with various types of agroecological practices and techniques, with the aim to develop a solid scientific basis for agroecology.

In general terms the great majority of the papers focuses on only one specific key aspect of sustainability (whether environmental, social, agronomic, economic), and shows a lack of balance between quantitative and qualitative data. Quantitative data are often missing, especially in describing the direct association of the agroecological practices analysed to food security. For some countries, the absence of such information has represented a strong limitation to carry out a complete analysis of the link with food security. Overall, there is currently scattered knowledge on the functioning of agroecological systems, and a systemic approach to research should be adopted, to cover a greater diversity of practices and cropping systems, in a wide variety of biophysical-climatic zones.

Moreover, traditional knowledge, when still available and suitable to changing conditions (e.g. climate, soil, ecosystem degradation), has in general not been taken into sufficient account by scientific and analytical observations, although it is an essential aspect of the agroecological approach.

At the systemic level, an important aspect shown by the study is the absence of a sector-wide approach in most agroecological research and development activities, with literature focusing on production only, and not addressing local supply chains and networks for agroecological products. Literature also often neglects the linkage with land tenure regimes and possible implications on sustainability.

It is also important to characterize the effectiveness of disseminating practices to farmers, for example fertilization with organic manure is not always accessible because of limited resources or structures. Some countries, such as Senegal and Lao PDR, have intense NGO activity with substantial publication of agroecological practice guides for farmers.

A last recommendation which can be drawn from the analysis is that in order to better assess the performance of the agroecological systems, a set of common criteria (fixed) and indicators (variable) valid for all countries should be considered for monitoring, communicating and evaluating current processes and results. This could lead to establish a permanent system of observation on the long term to inform and assist policies.

Annexes

Annex 1. Items in the table template utilised for document synthesis

The 172 documents selected following the procedure described in chapter 2 were summarised in a table according to the following items (one document per line), if the information was not available in the original paper, "NA" was reported:

1. Bibliographic reference
2. Type of document (unregistered report, student study (BSc, MSc), PhD thesis, referenced article, book chapter)
3. Web link
4. Category of document: (1) NGO report; project report (2) conference proceedings, master thesis; (3) institutional report and synthesis; (4) PhD thesis; (5) peer reviewed literature
5. Country
6. Period (years of the work)
7. Farming system (according to a typology: entrepreneurial, business or family farming) and cropping systems (according to a typology: agroforestry, home gardening, extensive, intensive, high-tech)
8. Area (in ha) or territory (field, village or watershed)
9. Land ownership (structure, holding)
10. Number of farms / % of farmers (according to the considered territory)
11. Study scale / Type of organization (farmers group, purchasing or marketing organization, production means sharing, waste management zone etc.)
12. Crops grown and type of production (grain for food or feed, biomass for forage, etc.)
13. Cropping practices, description and further specification if: traditional practices (adapted); practices adapted/proposed by science and technology; practices co-designed with local actors
14. Postharvest agroecological practices for avoiding or reducing product's damages and wastes
15. Unit of measure of each practice (where possible)
16. Current status (including not yet started in the "true life", just as an experimental plot, under transition in farmer's fields, certified as organic, fair trade or other, other)
17. Reason for the farmer to have changed to agroecological practices
18. Connection to the food system (local markets, regional markets, niche markets, exports)
19. Certification process to increase the price value (yes / no; very important to success / not necessary)
20. Are there specific policies in the country fostering or supporting agroecology
21. Average yield or income (and % in comparison to conventional production)
22. Description of the level of input (seeds, fertilizer/manure, pesticides, water, energy power, mechanisation)
23. Unit of measure of each input
24. Labour input (quantity, gender and qualification)
25. Costs of transition (e.g. investment, new material needed)
26. Economic benefits (at household, village, watershed, national levels) in income, property (land, buildings, tools), influence (political, business)

27. Environmental benefits: improvements in biodiversity (e.g. number of trees per ha, presence of bees, Shannon index), decrease in pollution of water/soil/air, improvements in proximity of markets, soil fertility, decrease of soil erosion (number of flood per year), improved water management (water harvesting facilities, irrigation area and type of irrigation, water quality), waste management (composting platforms, recycling process, storage facilities), and energy management (wood and charcoal, solar panels, transport means)
28. Social benefits (at household, village, watershed, national levels): improvements in employment (e.g. higher number of jobs), schooling, gender equity, access to public health, access to information (Internet and mobile phone, infrastructures), number (% and size) of farmers groups, of cooperatives, of SMEs
29. Contribution to food and nutrition security: direct (surveys, census, health indicators) or indirect (food availability, food price evolution, income evolution, food diet and consumption behaviour changes) evaluation
30. How contribution to food and nutrition was measured and assessed
31. Number and accuracy of observations
32. Nature of causal effect on food and nutrition security/ Summary of findings
33. Perceived impact on food and nutrition security (positive, negative, null)
34. Conditionality: Under what conditions is this valid?/ Limitations of the study
35. Upscalable experience (yes/no/under certain conditions)
36. Explain why you suggest this recommendation or the conditions needed to expand the experience
37. How AE is perceived/promoted at national level by the local/public authorities? What is the enabling environment for AE practices at individual/collective level?
38. Other useful information: Context/Objective of the study
39. Other useful information

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