Policy dossier
2024 | No 2000

Cultivating change with agroecology and organic agriculture in the tropics

Bridging science and policy for sustainable production systems

FiBL

Referencing this report
FiBL, 2024. Cultivating change with agroecology and organic agriculture in the tropics: Bridging science and policy for sustainable production systems. Research Institute of Organic Agriculture FiBL, Frick

Acknowledgements

The editors would like to thank the team of FiBL experts and the advisory committee for their commitment to improving the report. This publication would not have been possible without the research done by our partners working around the world. We gratefully acknowledge those who contributed to the research included in this dossier.

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We would also like to thank Sophie Thanner for her support in editing and layout.

Finally, we gratefully acknowledge the financial contribution of the Knowledge Centre for Organic Agriculture and Agroecology in Africa (KCOA) project, implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and the Farming Systems Comparison in the Tropics (SysCom) project.

Projects involved

KCOA
Knowledge Centre for Organic Agriculture and Agroecology in Africa

SysCom

Project funders

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

LED LIECHTENSTEIN DEVELOPMENT SERVICE

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

This project is supported by the Coop Sustainability Fund. coop

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Executive summary

Despite the technological advances in food systems since the green revolution, current global agricultural and food systems are not meeting the world's needs. Although food availability has increased substantially, the number of people suffering from hunger and malnutrition has remained steady in the last 40 years, coupled with a surge in obesity and diet-related diseases. Additionally, current food systems have contributed to extensive deterioration of land, water, and ecosystems; depletion of biodiversity; and enduring livelihood pressures for farmers. Nowhere are such challenges more evident than in the tropics, where disproportionate food insecurity, malnutrition and impacts of climate change pose significant threats.

This myriad of challenges in current food production systems is projected to worsen if we continue with "business as usual" due to the increasing impacts of climate change, demographic shifts, political instability, conflicts, and heightened demands on natural resources. Indeed, the current food system paradigm has proven unable to support the people and natural resources it depends on, making it a threat to its own existence. To address these pressing issues, it is imperative to explore alternative approaches which show promise in transforming food systems and achieving the Sustainable Development Goals.

In this context, agroecology and organic (AE/O) agriculture present promising alternatives supported by a growing body of evidence. AE/O systems that implement holistic farm management, going beyond simply substituting synthetic agrochemicals with AE/O alternatives, show promise in achieving yields and incomes that are on par with conventional. In fact, AE/O systems have been shown to improve household income and livelihood resilience compared to conventional in the tropics.

The hidden costs of the current global food system amount to around 10 percent of global GDP. The transition to AE/O systems offers a pathway to lower costs to the public by increasing climate adaptation and mitigation, increasing resilience to external shocks, improving food security and nutrition and lowering exposure to harmful pesticides. Thus, investments towards AE/O are not only a moral imperative but an economic win. Beyond these benefits, AE/O can have additional environmental benefits that clearly outweigh conventional systems, including preserving biodiversity and improving soil health and water quality.

Despite notable progress, a transition towards sustainable food systems requires increased attention, understanding, and action. Transition to AE/O systems requires long-term funding models that prioritise a holistic approach, and value chain development that supports fair pricing and strengthens the connection between consumers and farmers. Equitable access to essential resources, i.e. AE/O inputs, mechanisation, credit and land, is imperative. To empower farmers to transition to AE/O farming, they need improved access to farmers' organisations, capacity development and market access. Transdisciplinary and participatory education and research must also be advanced to facilitate knowledge co-creation and the adoption of optimal local solutions.

Furthermore, engagement programmes should aim to improve food literacy of citizens. Initiatives to accelerate the transition must carefully consider social and cultural values, empowering women, marginalised groups and youth. Finally, decisions and policies must be coordinated and informed by close participation with relevant stakeholders, including those that incentivise AE/O agriculture.

1. Introduction

1.1 Rethinking food systems beyond "business as usual"

Food serves as a "prime connection between people and the planet" and is intricately intertwined with the success of the Sustainable Development Goal (SDG) [1]. In today's global economy, the prosperity, resilience, and safety of all depend on meaningful progress toward reaching these goals [1,2].

The current "business as usual" food system[1] is failing to meet the needs of both society and the environment. This model for food production contributes to climate change, degrades and pollutes soil, land, air, and water, and plays a part in biodiversity loss [3–6]. Approximately 33 percent of soils worldwide are degraded, with over 90 percent projected to become degraded by 2050 if we continue business as usual [4,7]. Agriculture has significantly contributed to the destruction of natural habitats and, therefore, the loss of biodiversity worldwide [4,7]. Moreover, existing food systems perpetuate social inequities, with small-scale farmers and marginalised communities struggling to produce above the subsistence level, facing land tenure issues and limited access to resources and markets.

These interlinked crises are notably pronounced in the Tropics, where a growing population exacerbates pressures on natural and social resources [2,3]. Furthermore, populations living in the tropics are disproportionately affected by climate change, e.g. suffer from more frequent extreme weather events [4,8], which, in turn, contributes to conflicts, human migration and the rapid loss of livelihoods.

Even with these negative impacts, the current food system has failed to deliver on its promise to end hunger, with food insecurity and malnutrition persisting [6]. Given the scale of global food system challenges, continuing with "business as usual" is no longer a viable option [5,6,9,10]. It is imperative that we take immediate and concerted action to address these challenges and forge a path towards positive change in the food system.

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[1] *Often referred to as the "industrial agricultural model". This type of food production model reduces agriculture to a singular function: producing raw materials. This model is delineated by uniform, specialised production systems that focus on the efficiency of a few commodity crops, often planted in monoculture, or industrial-scale livestock operations. It relies on intensive external inputs, i.e., synthetic agrochemicals and fossil fuels. [4,5].*

A growing body of evidence suggests that agroecology and organic agriculture[2] (AE/O) have the potential to facilitate the transition towards more sustainable food systems, and an increasing number of high-level experts consider this evidence to be compelling [2,4,9,11]. Indeed, it is estimated that 30 percent of farms worldwide have redesigned their production systems around agroecological principles [9], and certified organic agricultural land has increased five-fold since 2001 [12], suggesting a positive trend towards the acceptance and adoption of more sustainable food systems.[3]

1.2 Purpose of this report

Despite the potential of AE/O, their full benefits cannot be realised in most countries due to political and institutional barriers and lock-ins, including incentives and funding that favour "business as usual" food systems [5,9,10]. Overcoming present and future challenges will require educated and empowered stakeholders to support AE/O agriculture in their fields [2].

This dossier aims to present decision and policymakers and experts in the context of international cooperation with scientific evidence on how AE/O approaches can contribute to a beneficial transformation of production systems in the Tropics.

The Research Institute of Organic Agriculture FiBL's research findings in the tropics act as the core of the document.[4] These scientific findings are supported by external publications relevant to the role of AE/O in the future of global food systems. FiBL's research in the tropics has focused on organic agriculture's agronomic and socio-economic performance to enhance the know-how on the potential and limitations of different production systems. Accordingly, this publication focuses primarily on the production level and touches on social, health, value chain and market level where possible. We acknowledge the need to go beyond the production level to transform food systems, e.g. cultural and economic aspects, like equity, participation, democracy, and justice.

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[2] For more information about the terms agroecology and organic agriculture, see annex 1.

[3] Several countries in Africa are currently developing national strategies around agroecology as part of mainstreaming into national programmes.

[4] Refer to reference list for more information. All FiBL references are shown in blue.

2. Productivity

Key message: AE/O systems that implement a holistic farm management approach show promise in achieving yields that are on par with conventional. Production challenges in AE/O must be addressed with targeted research, capacity development and social networking activities. The discussion must also go beyond the "yield gap" to consider major challenges along the value chain and landscape level.

Agroecology and organic agriculture (AE/O) face scrutiny, in large part because of the perceived yield gap[5] compared to conventional agriculture and doubts about their ability to meet rising food needs without requiring more land [2]. While some studies have shown a yield gap, well-managed and diverse AE/O farms have potential to match conventional yields [10,13–16]. However, results are highly context-specific and depend on the type of system, crops, and soil quality, amongst other factors [17,18].

2.1 Positive effects of diversification on yield

AE/O can positively impact yields in the tropics, especially when good agricultural practices are used (e.g., see Box 4). A meta-analysis found that practices to diversify farms (e.g., crop rotations and multi-cropping) can reduce the yield gap significantly [10]. Similarly, a literature review in low and middle-income countries found that diversified systems produce almost twice as much yield per hectare as monocultures [17].

Yields in AE/O systems can also be higher if the total farm yields are considered rather than just "cash crop" yields. For example, while cacao monocultures tend to achieve better cocoa yields, diverse agroforestry systems[6] that integrate different types of trees and plants can generate significantly higher total yields (Figure 1) [13,14,19]. In fact, Armengot et al. (2021) found that the total calories from cacao agroforestry systems were significantly higher than monocultures. This also results in a higher diversity of nutrients.

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[5] For the purposes of this dossier, the yield gap refers to the gap between AE/O and conventional yields. The extent of the "yield gap" is brought into question in section 2.3.1.

[6] Agroforestry systems combine agricultural crops and/or livestock with trees or shrubs in a way that mimics the structure and function of natural forests.

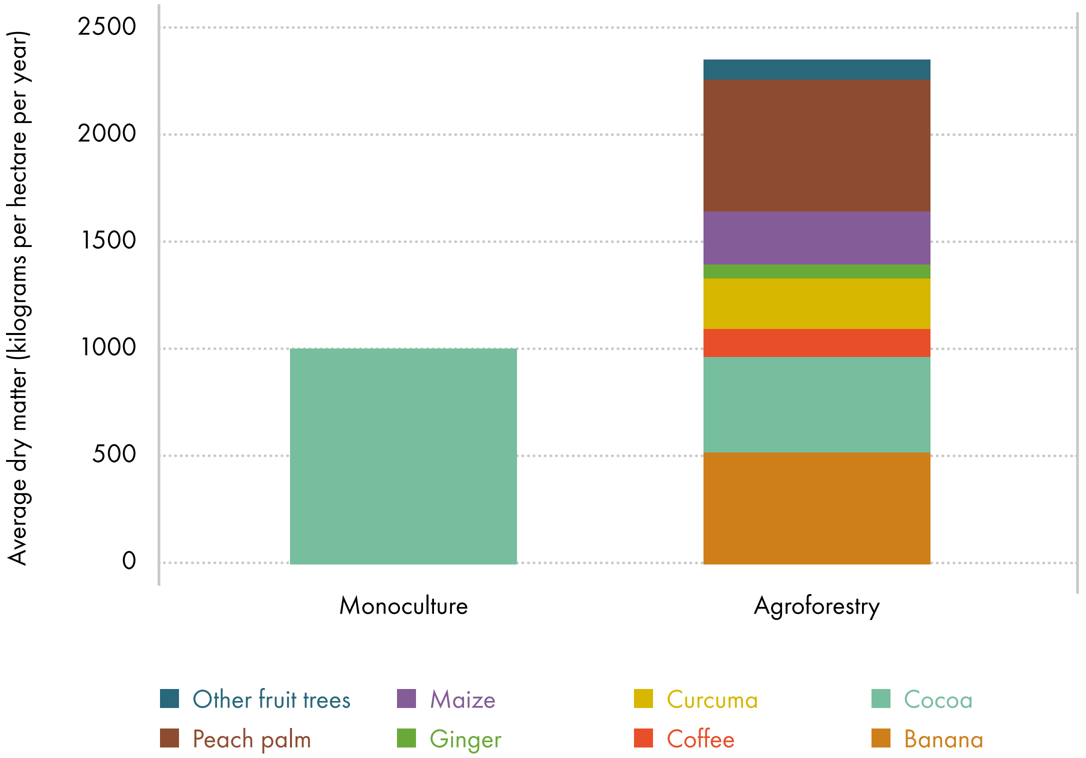

Figure 1: Yields of all crops harvested in cocoa monoculture vs. diverse agroforestry system (average yields from 2013–2022). Source: SysCom project data [22]

Similarly, integrating livestock into crop production systems can improve overall system yields [20] and the efficiency of production [21]. Diversity can also support pest reduction (see Chapter 5.4) and help maintain yields if one crop is adversely affected by extreme weather, pests or other factors.

> » Diversified farm systems can generate higher total yields than monocultures.

2.2 Opportunities to shrink the yield gap

Despite the potential of AE/O, a yield gap between organic agriculture and conventional is often reported, while the results for agroecology are more mixed [4,10,15,17,18,23]. Some key factors that need to be tackled to improve the productivity of AE/O systems are pest pressure, nutrient availability, a lack of AE/O crop varieties and capacity development.

Pest pressure has a strong impact on AE/O yields [15], especially when synthetic pesticides are substituted with often less effective organic pesticides rather than redesigning the agroecosystem to use AE/O best practices (see Box 1 and Box 2) [13]. In many cases, however, practitioners face challenges accessing local organic alternatives to synthetic pesticides due to a scarcity of local solutions and a lack of access to the necessary alternatives and raw materials for their production. Finding solutions will be increasingly important as pesticide resistance increases and more highly toxic pesticides are banned [24–26].

Similarly, challenges with **nutrient availability** often affect AE/O crop yields. Many soils in the tropics lack nutrients or cannot make nutrients available to crops [27–30]. It is, therefore, important to build up soil fertility and identify locally adapted and context-specific best practices.[7]

Pest and nutrient availability problems are compounded by the fact that most **crop varieties** on the market have been selected or bred to be productive in high-input, conventional farming systems. As a result, they often lack the traits necessary to be high-yielding under AE/O conditions [10,31]. On the other hand,

[7] *For example, dissolving phosphate rock in buttermilk or lemon and applying it with compost during planting can help crops take up phosphorus from the soil. These materials are often locally available and affordable for producers [146,147].*

varieties bred in their native environments thrive without relying on synthetic agrochemicals as they have the potential to promote pest resistance and nutrient-use efficiency through natural mechanisms [31]. These varieties are often unavailable, hindering their potential to help close the yield gap.

Box 1: AE/O best practices case study: French bean yields in Kenya

In Kenya, French beans are a major export crop and are also consumed locally. As with many vegetables, pests are a key challenge and often affect yields, especially in organic. However, long-term experiments in Kenya comparing organic and conventional approaches showed that organic production systems can have similar or even higher French bean yields if the systems are holistically managed, integrating AE/O best practices.

In the early years of the trial, organic systems replaced synthetic pesticides with inefficient organic pesticides, resulting in 30–60 percent lower yields compared to conventional. By adapting the trials to include intercropping and improved, locally sourced organic pesticides, it was possible to achieve similar or even higher yields. This holistic approach requires building up knowledge about suitable intercrops and locally available materials for making organic pesticides [22]. While other locations might require different solutions, it demonstrated the potential of a holistic management approach.

Implementing good agricultural practices shows potential to address some of these production challenges. FiBL's research in the tropics[8] has consistently shown that an approach grounded in ecological thinking and encompassing the farm system as a unified whole is key to increasing productivity in AE/O systems, rather than simply substituting synthetic agrochemicals for organic alternatives (see Box 2) [15].

> A holistic approach to AE/O helps address the major production challenges in AE/O production.

Knowledge plays a strong role in achieving holistic farm management and reducing reliance on inputs, highlighting the need for **capacity development**. Studies show that organic farms with higher yields compared to conventional are often connected to cooperatives, farmers organisations and/or local non-governmental organisations [15,16,32,33]. Such organisations provide capacity development programmes and platforms for knowledge co-creation, and these types of programmes better connect farmers in social networks, resulting in stronger self-organisation and improved access and exchange of critical knowledge and inputs [16,32,33]. In other words, when farmers are well trained and connected, they have the tools, strategies and networks to realise best practices, which increase productivity.

Despite capacity development's clear positive contribution to productivity, many countries in the tropics lack robust and accessible capacity development programmes. Those that exist lack resources, have a strong focus on conventional agriculture and/or are not equipped to address the unique aspects of the AE/O approach [15,34–37].

> Capacity development and building social networks are success factors that improve productivity on AE/O farms.

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[8] E.g. *"Farming Systems Comparison in the Tropics" (SysCom), ProEcoAfrica and Organic Food Systems Africa (OFSA). For more information, see [121].*

2.3 Beyond the “yield gap”

2.3.1 A closer look at the yield gap

If the yield gap is to be used as the primary measure for the prospects of AE/O, the research and structures that support it must be looked at critically. For example, studies frequently compare yields in conventional systems with low-input or poorly managed organic systems rather than those implementing a holistic approach. Additionally, the sample sizes of the studies are often limited, are short in duration and/or tend to concentrate solely on primary “cash crops” rather than total farm yields [4,9,17].

A meta-analysis revealed a publication bias favouring studies in which conventional yields surpass organic, suggesting an overestimation of reported yield gaps [10]. The authors attributed this partly to the research discrepancies discussed above and the consistent underfunding of AE/O relative to conventional [10]. Indeed, there is limited investment in research and development for AE/O systems, especially in tropical regions [9,10,38]. The yield gap could, therefore, be minimised with sufficient support for AE/O research, development and capacity development.

> The yield gap has likely been overestimated. Increased support in AE/O research, development and capacity development is needed.

2.3.2 A food system perspective for “feeding the world”

There is a widely held assumption that agricultural production needs to increase significantly to feed the growing global population [2,10,39]. However, this yield-focused narrative does not contribute to the solutions needed to achieve sustained food security [5,10].

In fact, many estimates show that a growing future population can already be fed with the food that we produce today [2,4,40]. Nevertheless, social, political and economic factors inhibit food security and equality in some regions and populations, while in others, food waste and obesity increase [5,10,40,41]. That is why increased agricultural yields alone do not address SDG2 to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture.”

It is essential to expand the discussion beyond the “yield gap,” considering the food system from field to fork [42–44]. For example, environmental degradation, like soil depletion, seriously threatens future food production worldwide, especially in tropical regions [4,7]. It is, therefore, essential to consider AE/O’s role in regenerating such degradation, particularly in the context of worsening climate change impacts into the future. Another example is food waste and losses in the tropics,[9] negatively affecting productivity and profitability. Furthermore, the role of livestock in future sustainable food systems must be carefully considered. As the demand for livestock products surges in “developing” and “transition” countries, a comprehensive and holistic perspective is essential [7,42].

Strategies that aim to “feed the world” must consider how food is produced, stored, traded, and distributed, and how much is wasted after harvest and along the value chain to ensure lasting change [5,42].

> The discussion around productivity must go beyond the “yield gap” and consider social, political and economic factors from field to fork.

2.3.3 Land-use in AE/O

There is a long-standing debate about land-use change required for AE/O yields to reach conventional, and whether high-yielding intensive agriculture can contribute more to biodiversity and conservation by “sparing” land from conversion to agricultural use [2,4,7]. Several aspects are frequently overlooked in this ongoing discussion: 1) As discussed above, AE/O yields have strong potential to match conventional yields [10,17], especially if proportionate resources are invested in addressing challenges; 2) the environmental and social impacts of intensive agriculture practices and synthetic agrochemical use must be accounted for [2,7]; 3) studies suggest that reducing the consumption of animal products combined with waste reduction could reduce land-use change and deforestation while also maintaining environmental benefits of AE/O [44]; and 4) the potential gains from “land sparing” may be limited by the land degradation caused by intensive agriculture [4].

> The argument in favour of “land sparing” overlooks AE/O yield potential and the broader negative impacts of intensive agriculture, which will likely negatively impact long-term conventional yields.

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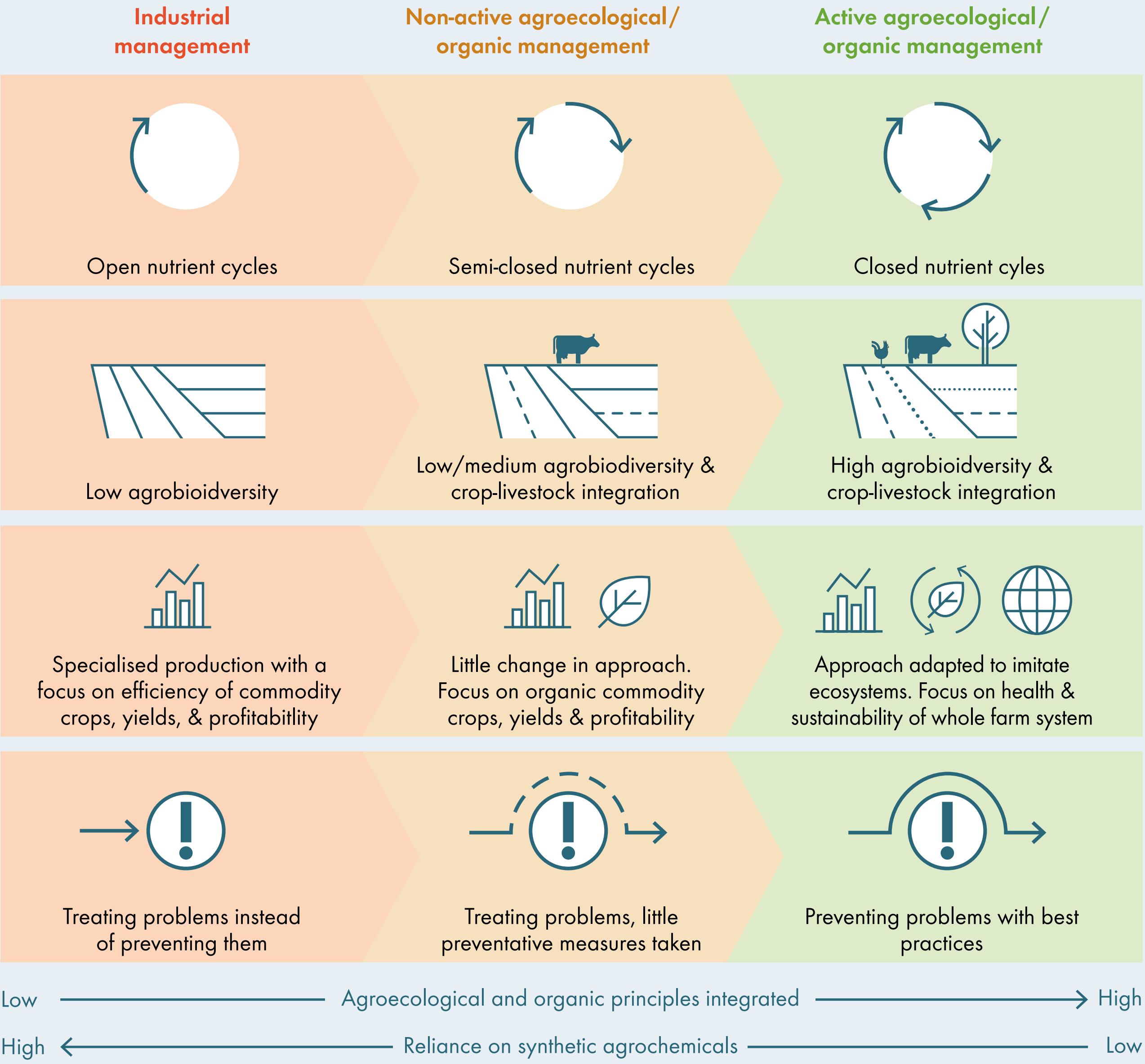
[9] *Food waste along the food chain is estimated to account for up to 40 % of total food produced globally [148]. In Sub-Saharan Africa and South/Southeast Asia, food losses and waste reach approximately 120 kg per capita per year, with most of these losses concentrated at harvest and post-harvest [40].*

Box 2: Holistic farm management: the key to exploit the benefits of agroecology and organic systems

A shift away from conventional agriculture often takes an inputs replacement approach: synthetic agrochemicals are avoided or merely substituted by less harmful inputs (i.e. biofertilizers or organic pesticides), with little change in the overall farm system design. This approach can result in many of the same problems that occur in the "business as usual" systems, e.g. pest and disease infestation, soil degradation, etc. [15,36,45]. Even though this approach tends to be much less effective than a holistic, best-practice approach, it is adopted for various reasons, including limited knowledge, resources and/or market access [15].

Other farms take things a step further, implementing a more holistic approach grounded in ecological thinking and encompassing the farm system as a unified whole, incorporating diversification and engaging in best practices tailored to the local culture and climate. This approach requires a shift to prioritise agroecosystem management (e.g., recycling on-farm nutrients, diversifying crop rotations, agroforestry systems, push-pull intercropping, etc.), better suited to the context of smallholder farming in tropical regions [15] (Figure 2).



Industrial management	Non-active agroecological/ organic management	Active agroecological/ organic management
Open nutrient cycles	Semi-closed nutrient cycles	Closed nutrient cyles
Low agrobioidversity	Low/medium agrobiodiversity & crop-livestock integration	High agrobioidversity & crop-livestock integration
Specialised production with a focus on efficiency of commodity crops, yields, & profitabitlity	Little change in approach. Focus on organic commodity crops, yields & profitability	Approach adapted to imitate ecosystems. Focus on health & sustainability of whole farm system
Treating problems instead of preventing them	Treating problems, little preventative measures taken	Preventing problems with best practices

Low → Agroecological and organic principles integrated → High

High ← Reliance on synthetic agrochemicals ← Low

Figure 2. Farm management approaches on a spectrum. "Business as usual," input replacement and holistic AE/O management approaches exist on a spectrum according to the degree to which a) agroecological and organic principles are integrated and b) the approach relies on synthetic agrochemicals. The figure focuses on the production level. Inspired by figures from [15,38].

3. Profitability and livelihood

> **Key message: AE/O agriculture can improve household income and livelihood resilience compared to conventional, especially in diverse systems and with price premiums. It also helps lower negative externalities and costs to the public, which will be increasingly important as climate change impacts worsen.**

Over a billion people worldwide rely on agriculture for their livelihood, contributing up to two-thirds of the gross domestic product in some low-income countries [46,47]. Organic production has steadily increased over the past decade [12], which can be attributed, at least in part, to the system's potential for improving farmers' profits and livelihoods. Many analyses have confirmed that agroecology and organic agriculture (AE/O) have the potential to generate higher gross margins than conventional production [13,15,29,48–51] and that future costs associated with conventional agriculture are likely to increase [24,25].

3.1 Boosting livelihoods through diversified systems

Diversification is an important AE/O strategy as it can not only support higher system yields (as discussed in 2.1) but also better economic performance compared to conventional monoculture systems [50,52]. A study across eight tropical countries revealed that household income rose with the number of crops grown [53].

These advances in yield and income associated with AE/O approaches can contribute to more resilient livelihoods (e.g., Box 3) [4,32,51,54]. This is due to various factors, including risk reduction, improved income stability, resource efficiency, and market opportunities. More diverse farming systems include crops and/or livestock with different growth cycles and market opportunities. This helps spread risk across space and time and acts as a "safety net." For instance, if one crop is adversely affected by pests, diseases, or extreme weather, others may still thrive; this can lead to a more stable income throughout the year and less dependence on one crop for revenue [4,52]. This is particularly important during seasonal food shortages, which remain common in some tropical countries [4,52].

> Diversified AE/O systems support higher yields and perform better economically than conventional monoculture systems, contributing to more resilient livelihoods.

3.2 Balancing labour, inputs and societal costs

In an effort to increase productivity, the current agricultural production model has largely replaced labour and locally produced inputs with external synthetic agrochemicals, machinery, and infrastructure based on non-renewable energy [4,59]. As a result, AE/O farms tend to have higher labour costs and lower input costs than conventional (e.g., Figure 3) [13,23,50,60].

While labour requirements are challenging for many farmers in the tropics, the investment can generate a higher return on labour (i.e. income per day of labour) than conventional, especially when associated with good agricultural practices [13,15,61]. Furthermore, there is potential to reduce labour requirements in AE/O through technical innovation and medium-scale mechanisation,[10] which could contribute to higher gross margins [13]. This is important as rural labour becomes increasingly scarce [62].

Box 3: Enhancing socio-economic functions with livestock

Livestock production models promoted in AE/O, e.g. integrated crop-livestock systems, agro-silvopastoral systems, grassland-based ruminant production, etc., can improve farm economic performance and stability [21,42,55,56]. Indeed, livestock has important socio-economic functions for smallholder farmers in the Tropics, i.e. providing income, assets (as living "savings"), security (and informal "insurance") and contribute to social links and economic status [21,42,57,58]. These functions are particularly important in many countries in the tropics, where financial markets and access to them are often underdeveloped, and opportunities for risk management via insurance are generally lacking [57,58].

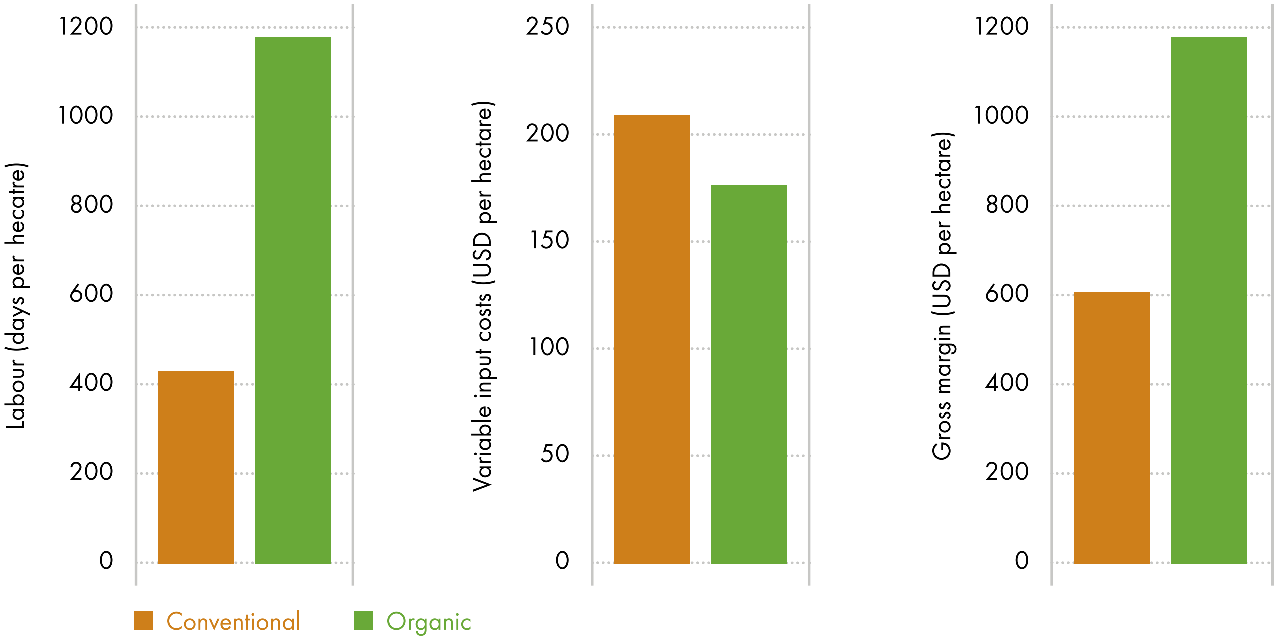


Figure 3: Labour, input costs and gross margins in participatory guarantee vs conventional systems. A recent study in northern Vietnam found that farmers in participatory guarantee systems (PGS) had higher labour costs, lower input costs and higher gross margins with premium prices than those who were not participating in the scheme. The study examined three groups of 180 white cabbage farmers [23].

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10 E.g., for preparing organic manure and fertilizers where market-ready products are not available.

High labour requirements in AE/O tend to be offset by low input costs compared to conventional (e.g., Figure 3) [15,23,51]. This reduced dependency on purchased inputs also increases farm autonomy, thus fostering resilience and adaptive capacity [63,64].

» AE/O farms can reduce reliance on purchased inputs and enhance farm autonomy.

However, policies such as input subsidies can artificially reduce the cost of harmful synthetic agrochemicals, e.g. pesticides, fertilizers, etc. [4,65], while good quality organic inputs can be comparably costly. This further skews economic comparisons between conventional and AE/O, which already fail to consider the positive externalities associated with AE/O (see the following chapters) [2,66].

When viewed in this light, the current farming paradigm costs society far more than is reflected in currently accepted profitability figures. This is compounded by the fact that costs associated with the "business as usual" agricultural model are likely to increase with increased pesticide resistance, increased impacts of climate change and other environmental and health implications [24,25].

» Policies incentivising synthetic agrochemicals distort economic comparisons, which already fail to consider many current and future benefits of AE/O.

3.3 Markets and premium prices

Profitability, particularly in AE/O agriculture, is also closely tied to functioning markets and fair prices. In export markets that offer premium prices, demand is usually focused on "cash crops," while other crops are sold at local markets, often with no price premium. In many cases, even cash crops are sold at conventional prices because market access is lacking [15]. This highlights the importance of building up market access and demand for AE/O products, as organic gross margins tend to significantly exceed conventional when farmers receive fair premiums [13,15,23,50,67]. Market premiums can improve organic farmers' profits by 22–35 percent compared to conventional [4,50] while also contributing to resilience to market shocks, increased liquidity and greater investment in farms over the long term [36,49,50].

The certification process, however, can be a barrier for smallholder farmers in the tropics, especially during the period of conversion when no price premiums are applied [50,68]. Participatory guarantee systems (PGS)[11] and group certification are emerging solutions that help lessen this burden [23] and, at the same time, strengthen capacity development. These systems are largely facilitated through farmer organisations.

Non-certified organic and agroecological farmers can build consumer trust through regional markets and online platforms. Engaging directly with consumers can help farmers convey their stories and share their practices, emphasising product quality while educating consumers and fostering loyalty. Such interactions between consumers and farmers hold great social significance [69] and support a strong customer base despite the lack of formal certification.

» Access to stable markets, certification, and fair prices are driving factors of profitability in AE/O.

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[11] "Participatory Guarantee Systems (PGS) are locally focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange" (Official IFOAM Organics – International definition [149]).

3.4 Impact of farmer organisation and capacity development on profits

Group membership and effective capacity development programmes have been found to positively affect smallholder farmers' profitability [15,70]. This positive relationship has long been understood [71]. Farmer organisations play a particularly important role in AE/O farming for several reasons: members often have better access to resources, and as a group, they can participate in economies of scale not available to them as individuals [16,72]. They can also assist in commercialisation, market linkages and organic certification, positively affecting profitability and sustainability [35,70]. Similarly, farmer organisations can provide better access to capacity development [72], which has been associated with higher profits (see Box 4).

> » Farmer organisations can improve access to resources, training and economies of scale while making certification more accessible, thus improving livelihoods.

Box 4: Effective farmer organisation and capacity development: A success story from Kenya

A study looked at five groups of farmers in Kenya and Ghana, covering 1,645 existing farms. The case studies included certified and uncertified organic farms, and conventional farms. Most organic farms practised "input replacement" organic management (see Box 2). On those farms, yields and gross margins were similar to conventional values. One group, which produced coffee, maize and macadamia nut, even stood out: yields increased by 127–308 percent, and farm-level gross margins increased by 292 percent overall. These increases were found to be attributable in large part to effective capacity development programmes and internal control systems [15].

4. Climate change adaptation and mitigation

> **Key message: AE/O agriculture positively contribute to both climate adaptation and mitigation via smaller carbon footprints and increased carbon storage, helping farms better adapt to climate change.**

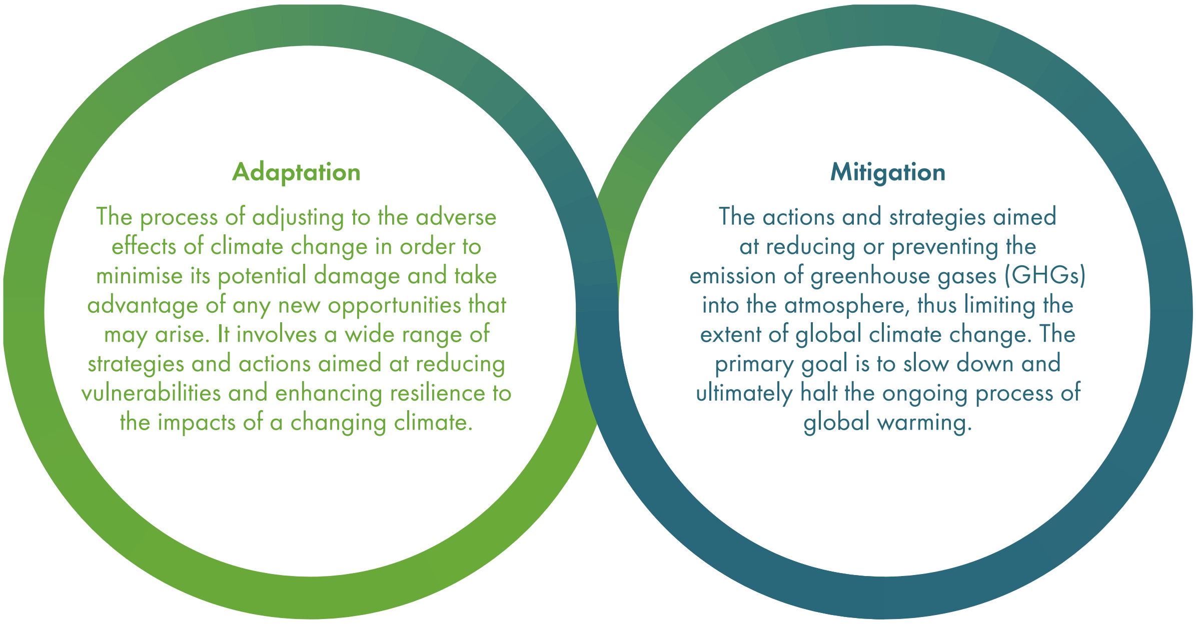
The agriculture sector is one of the most vulnerable sectors to climate change [3] and a key contributor to it, accounting for approximately 20 percent of human-caused greenhouse gas (GHG) emissions [73]. The "business as usual" agricultural model contributes significantly to these emissions [4,74]. Climate change is already negatively impacting agriculture and food security [4,8], and tropical countries are disproportionately more vulnerable to climate change than countries with temperate climates [75].

Agroecology and organic agriculture (AE/O) have been shown to positively contribute to climate adaptation and mitigation (see Figure 4 for definitions) via smaller carbon footprints and increased carbon storage. They also help farms become better adapted to climate change, providing alternate pathways to transition to more climate-friendly food production systems [4].

4.1 Better adapted to climate change

Adaptation to current and future challenges is critical in shaping the extent of climate change's future impact on food production [76]. AE/O practices and interventions promote climate change adaptation with no or minimal trade-offs for productivity and profitability [4,17,76–79]. This is because, in contrast to the "business as usual" agricultural model, AE/O systems are designed to enhance soil fertility and health, on-farm diversity and long-term yields and profitability of the whole farming system, capitalising on natural synergies that allow for adaptation to challenges presented by climate change. AE/O, by their principles, also encourage the use of adapted plant materials and animal species or breeds, which are less demanding in terms of management.

For example, agrobiodiversity is crucial for improving the ability of farmers to adapt to climate change [80]. Diverse landscapes, such as those promoted in AE/O agriculture, that are rich in natural elements and habitats can mitigate risks associated with



Adaptation

The process of adjusting to the adverse effects of climate change in order to minimise its potential damage and take advantage of any new opportunities that may arise. It involves a wide range of strategies and actions aimed at reducing vulnerabilities and enhancing resilience to the impacts of a changing climate.

Mitigation

The actions and strategies aimed at reducing or preventing the emission of greenhouse gases (GHGs) into the atmosphere, thus limiting the extent of global climate change. The primary goal is to slow down and ultimately halt the ongoing process of global warming.

Figure 4: Defining climate change adaptation and mitigation.

climate change, such as crop failures due to adverse weather conditions [4,36,43,51,79]. In fact, integrated crop-livestock systems[12] have been shown to increase total system yields compared to specialised systems and provide a productivity buffer against chronic climate stress, remaining stable under current and simulated future climate conditions [20,21,78].

AE/O approaches also promote knowledge exchange and co-creation, embrace traditional, local knowledge and scientific innovations, and support community-based and farmer-led initiatives [15,48,51,72,81]. These approaches can improve social connectivity and mutual support, ultimately enhancing local adaptive capacity, i.e. allowing farmers to adapt better and refine their practices to suit changing climate conditions [4,32].

> » AE/O supports better climate change adaptation because of the focus on diversity, the use of locally adapted varieties and breeds and long-term sustainable productivity.

4.2 Higher potential for climate change mitigation

4.2.1 Smaller carbon footprints

In addition to climate change mitigation, AE/O systems can have a smaller carbon footprint through increased energy efficiency and reduced GHG emissions compared to conventional systems, especially monocultures [4,13,14,44,49,59,82–84]. This is partly due to the reduction or elimination of synthetic agrochemicals, high reliance on manual labour, and integrated crop-livestock systems [59,85].

Chappell & LaValle's [82] literature review found that farms using AE/O techniques[13] can be two to four times more energy efficient than large conventional farms. Similarly, long-term experiments in cocoa systems in Bolivia showed that organic systems used fewer non-renewable resources than conventional (10 vs 75 percent) (Figure 5) [59]. In integrated crop-livestock systems and grassland-based ruminant production promoted in AE/O systems, climate impacts can also be notably lower than in intensive, conventional livestock systems [17,86].

> » AE/O farms can have lower greenhouse gas emissions, be more energy efficient and use fewer non-renewable resources than conventional.

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[12] *See chapter 5.3 Sustainable livestock production systems for more information.*

[13] *The study uses "alternative agriculture," which aligns with the principles and definition of AE/O agriculture in annex 1.*

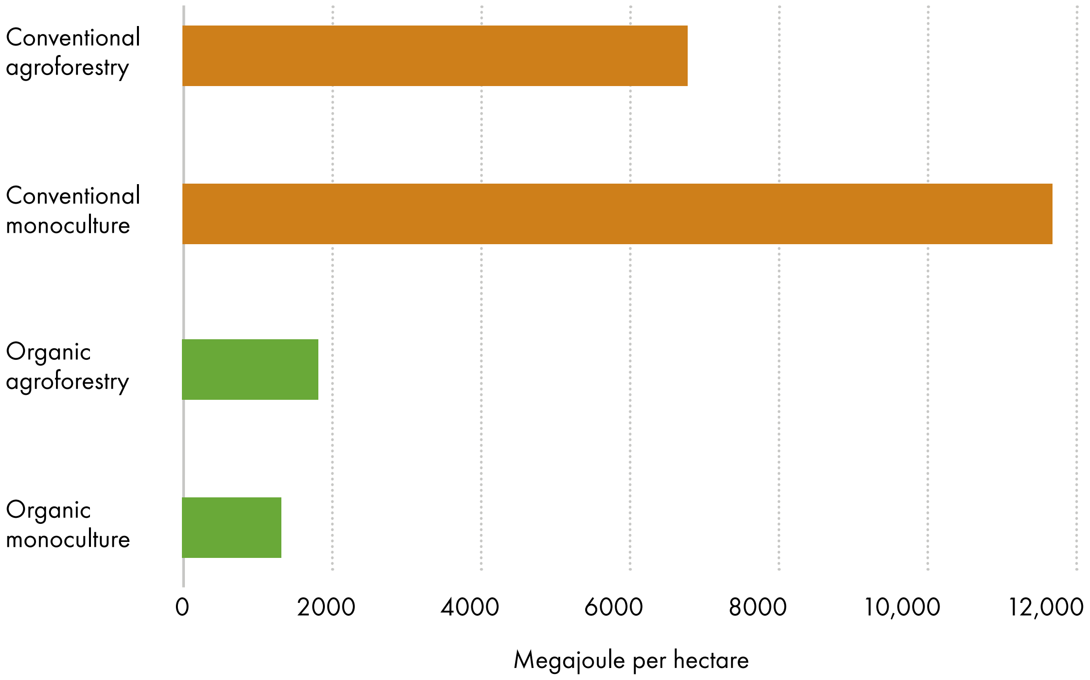

Figure 5: Cumulative demand for non-renewable energy. The demand for non-renewable energy was slightly higher in organic agroforestry systems than in organic monocultures because some small-scale machinery was used, e.g. motorised saws for tree pruning. Pruning is an example of a good agricultural practice with various environmental and economic benefits. Source: Syscom project data [22].

"Business as usual" agriculture contributes significantly to agricultural GHG emissions from producing and applying mineral fertilizers, livestock, feed production, poor manure management, land use changes, transportation and energy use [4]. While some scientific studies, and the claims made from them in the media, have argued that organic systems can have higher emissions because of land use requirements due to the yield gap [87] and livestock emissions, they often lack a systemic view and focus on production efficiency.[14] In fact, they often exclude other sustainability indicators and trade-offs, e.g. the role of food waste, demand, animal welfare, livestock feed and biodiversity (See chapter 2.3 Beyond the "yield gap" for more).

4.2.2 More carbon stored in soil, plants and trees

Capturing and storing carbon from the atmosphere in the soil, plants, and trees, i.e. carbon sequestration, can contribute to the overall effort to combat climate change [8,73,74]. Carbon sequestration is highly dependent on climatic conditions and soil type. It is also reversible if, for example, trees are cut down. Still, AE/O systems have shown potential to contribute to carbon sequestration [4,21,27,28,43,74,78] due mainly to practices that focus on building and maintaining healthy soils with integrated nutrient management, integrated crop-livestock systems and promotion of diverse systems.

Long-term system comparisons in Kenya and a meta-analysis in India have shown that AE/O practices, particularly integrated nutrient management, improve soil organic carbon (SOC) over time compared to conventional systems (Figure 6) [13,22,74].

» AE/O practices improve soil organic carbon (SOC) over time.

Diversified, integrated systems, e.g. agroforestry, legume-based cropping systems, etc., have shown high climate mitigation potential due to their ability to sequester atmospheric carbon in soils and plant matter [13,17,74,78,88,89]. In fact, one long-term study found carbon stocks in agroforestry systems to be almost three times higher than those in monoculture systems, especially in the early years of the system (Figure 7) [22]. In cropping systems, retaining residues in the field after harvest and integrating livestock with crops have also improved SOC [21,74,78].

» AE/O practices have the potential to sequester more carbon in soil, plants and trees.

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[14] For example, GHG emissions per kg of food product or land area required per kilogram of food. Indeed, GHG emissions are almost always lower in AE/O systems when total energy input/output of products is considered.

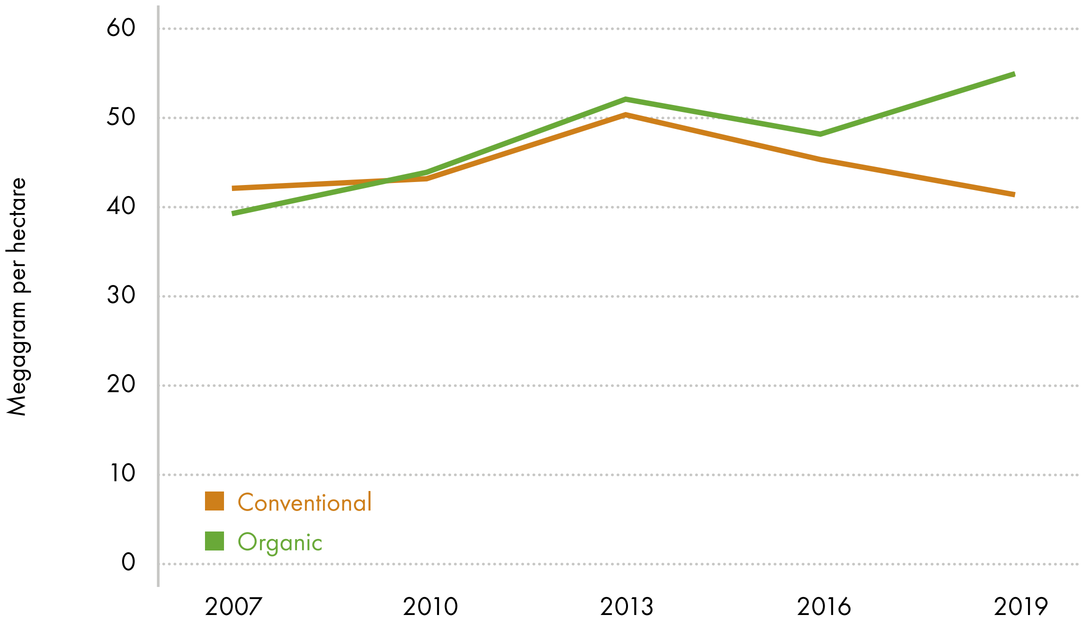

Figure 6: Soil organic carbon in organic and conventional farming systems over time in Kenya. Source: SysCom project data [22].

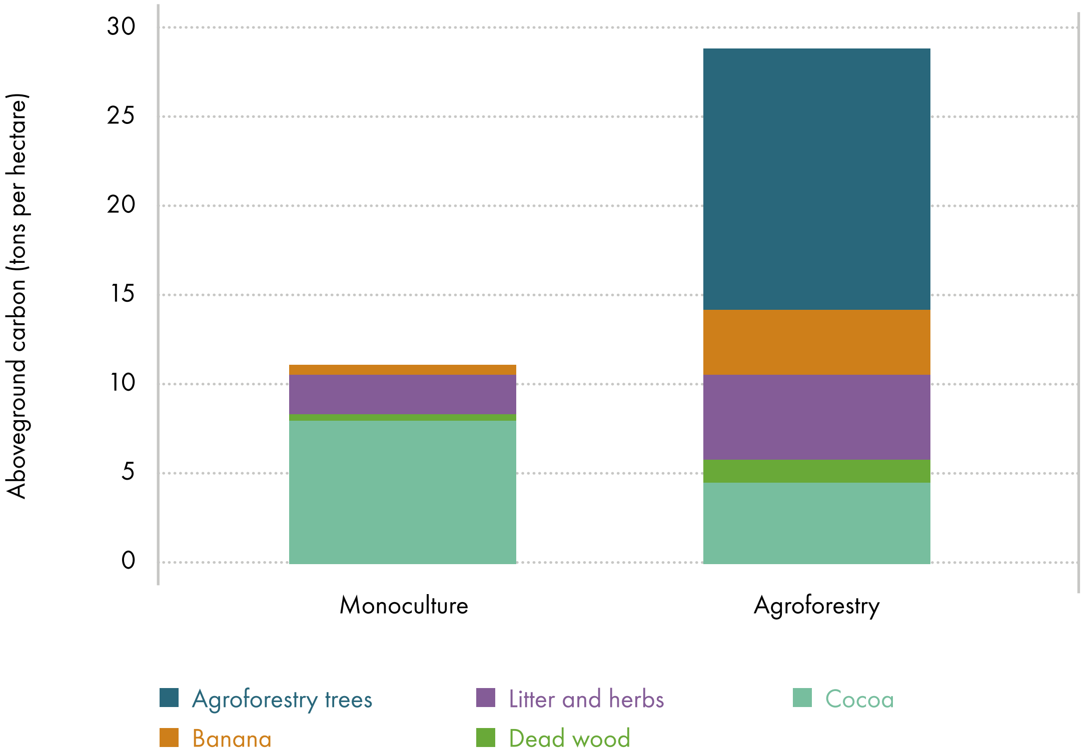

Figure 7: Average aboveground carbon stocks from trees, bananas, litter and herbs, and deadwood in an agroforestry vs monoculture system (2011–2022). Source: SysCom project data [22].

5. Environmental integrity and agrobiodiversity

Key message: AE/O agricultural practices help to combat the biodiversity crisis, improve soil health and water quality and encourage the adoption of crop-livestock systems.

As agriculture expanded and industrialised during the 20th century, it also became a driver of environmental degradation and global biodiversity loss, including land degradation and pollution of land, air, and water [3,4,21,90,91]. Analyses suggest that food systems have already exceeded certain "planetary boundaries" crucial for long-term sustainability [3,92].

Indeed, 33 percent of soils worldwide are already degraded, and over 90 percent could become degraded by 2050, posing a serious threat to future food production [4,7]. Water resources are being depleted and increasingly contaminated, exacerbated by the current agricultural model that introduces harmful synthetic agrochemicals into the environment [8,91]. Over the last 50 years, the livestock industry and consumption of animal products have intensified and industrialised, with subsequent environmental impacts growing accordingly [4,7,21,42,58]. Simultaneously, there has been an average decline of 69 percent in species populations since 1970 [93], and 75 percent of the world's crop diversity has been lost since 1900 [94].

Environmental degradation of essential natural resources, like soil, water and biodiversity, has local effects on productivity and profitability while also impairing essential ecosystem services like water purification, carbon sequestration, and pollination [3,4]. The outcome poses significant threats to human health and food production, resulting in adverse effects on communities far downstream [4,7,91,95].

AE/O farming offers an alternative by taking a holistic, ecological approach to food production, which can reduce agriculture's environmental impact while promoting biodiversity on and off-farm [14,49,96,97].

5.1 Better soil health and fertility

Healthy soils[15] balance physical, chemical, and biological properties to support agricultural production, biodiversity, and environmental sustainability. Sustainable soil management practices, as advocated for in AE/O systems, hold great potential to support the reversal of soil degradation and help improve soil health in the tropics in the long-term [4,21,36,43,98].

Healthy soils are home to a diverse and active microbial community, contributing to better nutrient cycling, organic matter decomposition, pathogen regulation, nutrient availability for plants and an array of ecosystem services [28,99,100]. Soils in AE/O systems have been found to be more biologically diverse, which contributes to an increased capacity of soil processes critical for nutrient supply [28,100].

Soil Organic Carbon (SOC), discussed in the scope of climate mitigation in the previous chapter 4.2.2., is a key indicator of soil fertility. Farmers, society and the environment benefit by increasing carbon in the soil, as seen in AE/O systems [13,22,27,28,74]. Increasing SOC in soils conserves or enhances soil fertility and nutrient availability for plants and reduces the system's vulnerability to water stress by improving soil capacity for water absorption and retention, reducing runoff, and evaporation [101].

» Soils in AE/O systems have been found to be healthier and more biologically active, which helps crops access nutrients.

5.2 Improved water management and quality

Water is a vital resource for human well-being, the environment and, notably, food production. AE/O approaches play a crucial role in advancing more sustainable water management practices and improving water quality. Compared to intensive and conventional farming, AE/O practices enable farmers to enhance water resource management, including more efficient water use [4], wastewater treatment (disposal and reuse), water filtration and retention, and higher sustainability scores for water withdrawals and rainwater utilisation [3,49]. Additionally, agroforestry systems have demonstrated the ability to yield more using less water than conventional monocultures [14]. Improved water management helps AE/O farmers cope with changing precipitation patterns and water scarcity, an ever-present issue in the face of climate change.

The AE/O approach has also been shown to minimise water pollution and improve water quality significantly compared to conventional farms [4,98,102] by reducing agrochemical contamination and other processes. This has repercussions locally and far downstream by protecting aquatic ecosystems and human health [4].

» Water management and quality can be improved with AE/O practices.

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[15] Soil health is a holistic concept that encompasses various physical, chemical, and biological attributes of soil. While there isn't a single, universally agreed-upon definition, a healthy soil is characterized by key attributes, e.g. nutrient content, organic matter, structure, water retention, biodiversity, etc.

5.3 Sustainable livestock production

To address the environmental challenges of the industrial livestock production model[16] and provide more sustainable options for animal-based food products, it is imperative to re-integrate livestock and cropping systems and utilise grassland-based ruminant production in suitable locations. Integrated crop-livestock systems are key aspects of the AE/O approach [42]. Such systems better serve the needs of a growing consumer base while mitigating the negative impacts associated with the industrialisation of the livestock industry [21].

In the context of many tropical countries, low-yielding extensive grassland and pasture-based ruminant production systems are the norm. Such systems can cause environmental degradation and could benefit from sustainable intensification, i.e. adopting practices like rotational grazing, incorporation of legumes and integrated crop-livestock-forestry systems [42,56].

Integrated crop-livestock systems and well-managed grazing systems reduce or even restore land degradation. They allow for better management of nutrient flows and landscape structures, with beneficial effects, e.g. improved biodiversity, reduced input use, higher productivity and economic performance [21,42,55,56]. Implementing such practices and systems, which integrate different elements, can be complex, especially in areas lacking traditional practices and knowledge [42].

» Integrated crop-livestock systems promoted in AE/O agriculture improve farm nutrient flows, productivity, profitability and resilience.

5.4 Higher agrobiodiversity

Biodiversity, and more specifically agrobiodiversity (see Box 5), is the foundation for productive and resilient farming systems and is one of the main currencies of AE/O agriculture [4]. Maintaining and supporting agrobiodiversity improves soils, supports productivity and helps protect wild native species to repair or maintain a functioning food web.

Box 5:. Defining agrobiodiversity

Agrobiodiversity, short for agricultural biodiversity, refers to the variety of living organisms that are utilised or contribute to food and agriculture. It plays a crucial role in food security, nutrition, and the sustainability of agricultural systems by providing various ecosystem services (e.g. food, clean water, medicine and shelter) that can enhance farm resilience.

The AE/O approach works with nature and supports biodiversity. AE/O systems have been shown to enhance agrobiodiversity, i.e. plant and animal diversity and abundance, compared to conventional [3,13,17,36,49,103]. Outside the farm borders, diverse agroecosystems have also been shown to sustain wild biodiversity in surrounding natural and semi-natural ecosystems [3,10].

On-farm biodiversity in terms of crop and livestock varieties has also decreased under the current agricultural model, leading to negative human health impacts (discussed further in Chapter 6) and making farms less resilient to stressors, e.g. climate change, pests and disease outbreaks [3]. AE/O practices support agrobiodiversity and can, therefore, contribute to reversing this trend.

» AE/O farms enhance agrobiodiversity, a key to productive and resilient farming systems.

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[16] *The industrial livestock production model moves animals away from their natural habitats and local feed sources [4]. The high animal density contributes to land degradation, high greenhouse gas emissions, increased waste and nutrient runoff and leaching into surface and groundwater [4,7,21,42,91,95]. Moreover, this production model requires more veterinary medicines, which carry risks of pollution to soil, water and the livestock products themselves, with risks to biological and human health as well as food security [7,21].*

Pest and disease management is one of the main challenges to AE/O agriculture. It can severely reduce crop yields and pose major challenges for AE/O farmers [15]. AE/O approaches aim to prevent pests and diseases using a variety of methods and, when necessary, use botanical pesticides that are much less harmful [102]. Preventative approaches emphasised in the AE/O approach encourage on-farm diversity and encourage beneficial insects to flourish.

An increased beneficial insect population can result in natural pest control and, therefore, reduced pest pressure (e.g. a higher ratio of beneficial organisms to pests) [103]. In a comparison of organic and conventional citrus orchards in Mexico, a key pest population (the Asian citrus psyllid) was 700 percent lower in the organic orchards due to a greater biodiversity of weeds, flowers, and wild plants that attracted beneficial insects, which kept pest numbers low (Figure 8). This kind of AE/O strategy reduces the need for pesticides, reducing both input and labour costs for farmers and environmental impacts from agrochemical use, e.g., impacts on soil health and pollinators [13].

> Agrobiodiversity and preventive pest management practices in AE/O agriculture protect and improve yields while reducing the need for synthetic pesticides.

Conventional citrus orchards have seven times more pests.

Organic citrus ochards have 70 % more plant diversity, attracting beneficial insects that feed on the citrus pests.

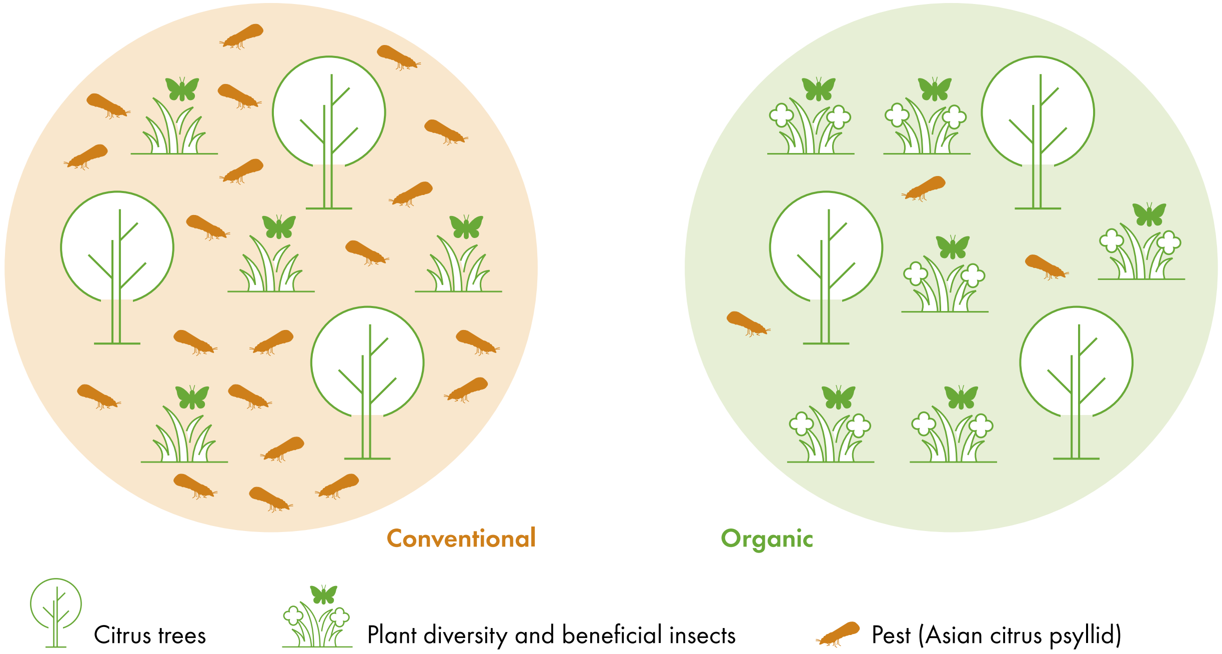

Figure 8: Benefits of biodiversity in organic agriculture: pest reduction and increase in plant diversity and beneficial insects
Source: Citrus Greening project data [103].

6. Food security and human health

> **Key message: Diverse agroecology and organic systems can help to improve food security and nutritional outcomes and reduce exposure to harmful pesticides.**

Despite increases in food production, the number of people currently suffering from food insecurity and malnutrition has remained steady over the last 40 years [2,3]. One in every three individuals worldwide faces hunger or malnutrition [3]. If current trends continue, one in two persons is projected to be malnourished by 2030 [2]. Different forms of malnutrition, including obesity and hidden hunger, are also growing at alarming rates [46].

Pesticide exposure and accumulation in water and the food chain also pose serious short and long-term human health risks for farmers[17] and consumers, especially if ingested regularly over time or at high levels [4,26,91,102,104,105]. This is of particular concern in the tropics, where pesticide use is higher than commonly assumed [106], including more hazardous, broad-spectrum pesticides banned in Europe [26,91,102]. These concerns are further exacerbated by the fact that pesticides are often overused [107], underregulated [26,91], improperly stored [108], and applied with limited knowledge of the use of hazardous chemicals, leading to misuse [26,91,109].

These problems with pesticide use incur externalised costs and have broad societal health implications; combined with the other vexing, multifaceted challenges discussed in previous chapters, a need for major changes in global food systems is urgent [3,26]. AE/O approaches can help address these challenges by promoting sustainable and resilient food systems that better prioritise food security[18] and diverse, healthy diets free of harmful synthetic agrochemicals.

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[17] Smallholder farmers in the tropics, especially those with low levels of education and socioeconomic status, who often use highly hazardous pesticide formulations, are particularly vulnerable to the health risks imposed by synthetic agrochemicals [26,91,109].

[18] The editors concur with HLPE's [3] six dimensions of food security: Availability, Access, Utilization, Stability, Agency, and Sustainability.

6.1 Food security

More diverse systems promoted in the AE/O approach, e.g. agroforestry, integrated crop-livestock systems, etc., can play an important role in alleviating food insecurity and hidden hunger. Diversified systems can increase food availability and income to better meet household needs, facilitate food exchange within communities, and foster stronger social bonds, leading to more resilient communities [21,110]. Ultimately, such approaches can help improve household food security in low-income countries [3,21,48,96] and mitigate hidden hunger and food availability during lean/dry periods [21,42,57,58].

> Diversified AE/O farms improve household food security.

For example, yields from a diverse agroforestry system include the cash crop, cocoa, but also other fruits, grains, spices, and coffee, while a traditional cocoa monoculture only produces cocoa. These systems can produce higher and more diverse overall yields and have the potential to promote more diverse diets than specialised monoculture systems (Figure 9).

6.2 Human health: Nutritional diversity and reduced pesticide exposure

6.2.1 Promote nutritional diversity

Food security isn't just related to caloric intake; nutritional diversity is vital to combat malnutrition and its associated health issues. Diverse farming systems, like those advocated by the AE/O approach, can lead to a wider array of available foods, consumption of a larger variety of food groups, and positive nutritional outcomes [21,48,53,110–112]. Indeed, more diverse agricultural landscapes produce the majority of global micronutrients and proteins globally [111]. Diverse secondary crops promoted in AE/O landscapes, e.g. underutilised, culturally-appropriate indigenous, traditional, and/or wild crops, can play an important role in food security, dietary variety and nutritional stability in the tropics [3,113].

> Diversified AE/O systems offer a broader range of food options, leading to favourable nutritional outcomes.

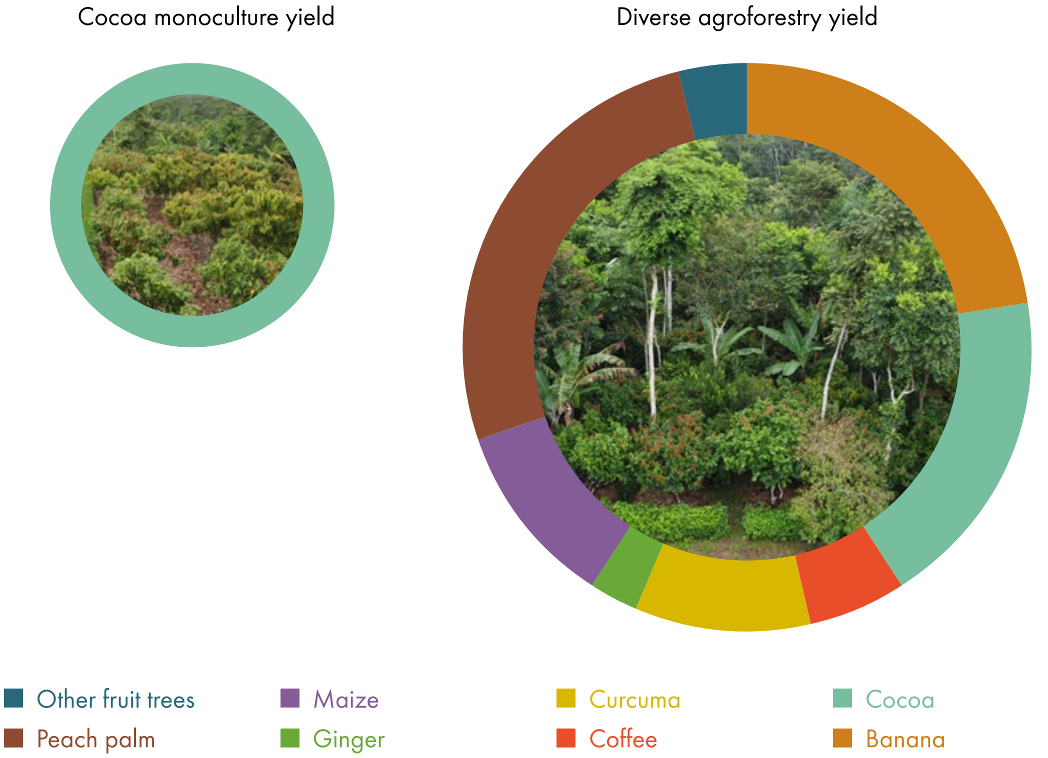

Figure 9: Total system yields of a dynamic agroforestry system. Average yields from 2013–2022. Total yields in the agroforestry systems were more than double the cocoa monoculture yields. Source: SysCom Bolivia project data [22]

Modern crop varieties have seen a general decrease in nutritional density, yielding food that is rich in energy but lacking in macro- and micro-nutrients [4,114]. Organic agriculture may also provide some benefits in terms of nutrients: two systemic review papers found that organic food has consistently higher levels of antioxidants [105,115], organic dairy products contain more omega-3 fatty acids, and organic meat products show improved fatty acid profiles [105].

6.2.2 Reduced pesticide exposure and residues in AE/O agriculture

Not surprisingly, synthetic pesticide residues tend to be found in higher levels in conventional foods and soils than in organic, often exceeding the maximum residue levels allowed by the EU [13,26,102,115]. Indeed, one long-term study in Kenya, which compared conventional and organic systems, revealed the absence of residues from botanical pesticides in both the soil and on produce [102].

In addition, AE/O farming reduces farmers' reliance and exposure to synthetic agrochemicals, e.g. synthetic pesticides, thus minimising environmental pollution and resulting in better health outcomes than their conventional counterparts [48,102,109,116]. In fact, some findings show that farmers who converted their farms from conventional to organic were largely motivated by human and environmental health concerns and food safety [117].

> » AE/O farming practices reduce reliance on synthetic agrochemicals, promoting better human health outcomes, as evidenced by lower pesticide residues on organic foods.

Towards more sustainable food systems: bringing science to practice

This dossier has demonstrated the potential of AE/O to boost productivity [10,13–18] and profitability [15,23,36,49,50,118] while generating a range of other co-benefits: enhanced climate resilience [4,13,14,44,49,59,82–84] and biodiversity, better soil and water quality [3,14,49,96,97], as well as food security and human health outcomes [48,96,109–112,116]. Policymakers are encouraged to develop strategies for transitioning to AE/O to capitalise on these benefits.

This section offers 11 opportunities for change. These suggestions are intentionally broad, intending to be accessible to decision and policymakers as well as other stakeholders with diverse environmental and societal priorities and challenges. The opportunities are organised according to five key factors, which were identified by the High Level Panel of Experts (HLPE) to **hamper** or **slow down** innovations that support transitions to sustainable food systems and food security and nutrition: knowledge, economic, resource, social and cultural, and governance factors [2] (Table 1).

Table 1: Summary of opportunities to facilitate sustainable food systems

Factors	Opportunities
Economic factors	1. Accelerate the transition towards sustainable food systems by creating long-term funding models that prioritise the AE/O approach.
	2. Prioritise value chain development to support fair pricing for AE/O products and enhance consumer connection to food and farmers.
Resource factors	3. Ensure fair access to AE/O inputs and input subsidies.
	4. Invest in appropriate scale mechanisation and digitalisation to reduce the dependency on manual labour and make rural areas more attractive for the youth.
	5. Reform policies to improve land tenure security for AE/O farmers in the tropics.
Knowledge factors	6. Enhance agronomic and economic performance, social capital and resilience through capacity development. This can be done by strengthening farmer organisations and improving extension services.
	7. Provide farmers and advisors with access to tailored and locally-specific knowledge, including through digital tools.
	8. Advance transdisciplinary and participatory education and research to facilitate knowledge co-creation and exchange, and identify optimal local solutions, fostering their widespread adoption and expansion.
Social and cultural factors	9. Engage consumers in programmes aimed to improve food literacy and implement supportive policies.
Governance factors	10. Empower decision and policymakers to advocate for informed, coordinated, participatory governance.
	11. Support AE/O agriculture through the use of smart incentives and supportive policies.

Economic factors

Funding

Development aid and public support to the agricultural sector have stagnated [3,9]. Despite AE/O's potential to support policy objectives related to biodiversity, climate change, etc., funding structures remain focused predominantly on the "business as usual" agricultural paradigm, with support for AE/O remaining on the margins within many governments, international organisations and non-governmental organisations [9,10]. This disparity of support for research and development likely contributed to a widening of the yield gap over time [10].

Policy measures should enhance long-term funding mechanisms to strengthen capacity development, extension services, education, and research, improve access to inputs and other resources and further develop market and retail opportunities for AE/O; this is essential to foster food system transformation [9,10,21,119,120].

1. **Opportunity:** Accelerate the transition towards sustainable food systems by creating long-term funding models that prioritise the AE/O approach.

Markets and value chains

A lack of sales channels and market access can deter farmers from transitioning to AE/O. For example, many organic farmers in the tropics only receive premium prices for cash crops destined for export (e.g., cocoa, cotton). In contrast, other "secondary crops" are often sold in conventional channels due to insufficient stable and differentiated markets, value chains and infrastructure that allow for organic price premiums [13,15,119].

Market chain development, including strategic partnerships with regional retailers, impactful marketing, strategic placement of AE/O products, and certification programmes like participatory guarantee systems (PGS), help shape consumer preferences and demand for such products. This, in turn, promotes AE/O farming practices as producers respond to market signals and consumer demand for sustainable, healthier choices. See Case study 1 for a successful example.

In addition, short value chains and direct sale channels hold promise, as they can help reduce farmers' dependency on a few export-oriented cash crops and further promote economic equity and diversified farming systems and incomes [4,13]. Similarly, regionalised food systems where consumers and farmers can interact, e.g. through local markets, have more social meaning [69] and can be effective at sustaining organic farmers' motivation and dedication [119] and reducing supply vulnerabilities.

2. **Opportunity**: Prioritise value chain development to support fair pricing for AE/O products and enhance consumer connection to food and farmers.

Resource factors

Productivity and inputs

Farmers interested in AE/O agriculture face challenges accessing suitable inputs (e.g., fertilizers and pest control measures), which is exacerbated by the unsuitability of many crop varieties that are bred for high-input conventional farming (see Case study 2). Even when available, they can be more expensive than synthetic versions [26]. Efforts in research and policy should prioritise and fund the availability of high-quality inputs essential for successful AE/O production [15,26,119]. Minimising governmental subsidies for synthetic agrochemicals to avoid adverse policy effects is key to providing a level playing field in the market and giving farmers a fair choice between conventional and AE/O agriculture.

3. **Opportunity**: Ensure fair access to AE/O inputs and input subsidies.

Labour and mechanisation

AE/O systems often require more labour input than conventional farming methods [13,59], and AE/O farmers often lack access and resources to invest in labour-saving, scale-appropriate agricultural equipment and mechanisation that is adapted to local conditions [13]. This dilemma is exacerbated by urbanisation trends and the unattractiveness of agriculture for the youth, which often reduce available labour for agricultural activities. These challenges can force smallholder farmers to either scale down or simplify their activities, threatening food security and livelihoods [13].

To address this complex challenge, governments, organisations, and communities should improve access to innovations and appropriate-scale mechanisation that reduce dependency on manual labour at all levels, i.e. production to processing. Such mechanisation can also enhance the quality of rural work, making it more engaging and less physically demanding. Improving transportation and storage infrastructure, access to electricity, internet connectivity and digitalisation are strategies that improve the attractiveness of rural spaces, also for youth. The private sector should be incentivised to invest in rural areas and aim to provide attractive jobs. These initiatives should target young people [4].

4. **Opportunity**: Invest in appropriate scale mechanisation and digitalisation to reduce the dependency on manual labour and make rural areas more attractive for the youth.

Land tenure

Land tenure systems influence land use patterns, agricultural practices, and overall development. In the tropics, many small-scale farmers encounter challenges with the stability and security of land tenure. This contributes to food insecurity and poverty, limiting long-term investments in land conservation [2,36]. Secured land management rights with a long-term perspective are of specific importance for AE/O to strengthen long-term sustainable farm management practices, e.g. soil building practices. To take full advantage of the benefits of AE/O farming, reforms are necessary that improve land tenure security [2].

5. **Opportunity**: Reform policies to improve land tenure security for AE/O farmers in the tropics.

Case study 1: Using the Participatory Market Chain Approach to develop organic markets in Murang'a, Kenya

In the ProEcoAfrica/OFSA [121] research projects, a participatory approach was used to link organic farmers in Kenya to markets using the Participatory Market Chain Approach (PMCA). The approach brings all relevant value chain actors together to get to know each other, jointly discuss the situation and prevailing bottlenecks, explore potential business opportunities, identify concrete business ideas and implement them while building trust.

This pilot resulted in two local organic markets being established in Murang'a County, Kenya. The local government allocated space for the markets to be established, allowing farmers to sell their produce directly to the consumers. The process enabled links with markets in Nairobi and export markets, as well as opportunities for branding and group certification through Participatory Guarantee Systems. Building capacity and trust among the value chain actors was emphasised throughout and contributed to success.

Case study 2: Organic cotton seed breeding

In recent decades, it has become increasingly difficult for farmers to obtain good quality organic cotton seed. Genetically modified (GM) seeds from large companies with significant resources dominate the market. Given the maller organic market and relative lack of investment, traditional, non-GM seeds have not been sufficiently developed, leading to a decline in productivity.

After a decade of collaborative breeding efforts under the "Seeding the Green Future" project, organic cotton varieties were approved by the State Seed Sub Committee of Madhya Pradesh, India, in 2022. These were the first Indian cotton varieties to be produced under organic conditions. Developed through a participatory organic breeding program, the new varieties reflect farmers' knowledge and needs while also ensuring non-GM cotton seed availability, supporting smallholder farmers, preserving agrobiodiversity and maintaining the integrity of the organic cotton value chain [122].

Knowledge factors

Capacity development

Strategies for capacity development with a "bottom-up" collective approach that involves all relevant stakeholders have ripple effects throughout the food system, e.g., improving yield stability, profitability and market opportunities [15,16,72] while increasing resilience through adapted and contextualised knowledge. Cooperative learning, e.g. in farmer organisations, supports capacity development through peer-to-peer knowledge sharing and the co-creation of innovative solutions [13,15,70]. It also helps foster resilience [32] and improves farmers' awareness and adoption [33]. Building up competences and harnessing the social capital of farmer groups is, therefore, a key factor in scaling up AE/O agriculture [123] and improving performance [4,15]. Some useful ways to build competencies include sharing innovations and showcasing best practices on flagship farms or demonstration sites.

Extension services also play a vital role, especially in AE/O systems, where knowledge enables farmers to take a holistic approach. Regular, targeted training with a special focus on AE/O farming is vital to support both farmers and advisors [119,124] while also encouraging them to experiment and put knowledge into practice [15,119,124]. Advisors' expertise must go beyond the status quo to cover diverse topics like the farm as an interconnected ecosystem, farmer motivations, finances, organic certification, culturally sensitive nutrition, as well as climate change adaptation measures [4,34,36,91,101,112]. To achieve such expertise, advisors require affordable and high-quality education. Educational programmes and support for advisors are strategic investments rather than mere expenses.

6. **Opportunity**: Enhance agronomic and economic performance, social capital and resilience through capacity development.

Access to knowledge

Farmers that transition to a holistic AE/O approach must learn a variety of best practices that address production challenges in order to be productive and profitable [15,101,125]. While field trials have demonstrated the potential to boost yields in AE/O systems, on-farm yields often fall short [13,126]. This is often due to insufficient implementation of best practices and limited access to knowledge [15,126]. Only a small proportion of smallholder farmers have direct access to information on AE/O farming.

Combining digital tools with personal extension services or tailored training is, therefore, a promising approach to facilitating knowledge exchange and co-creation for a large number of farmers in the tropics. This is especially promising for AE/O, where tailored and locally-specific knowledge is needed. Digital technologies offer cost-effective ways to reach many farmers and other supply chain actors with this information. Its promise is still largely unfulfilled, as most investment in digital extension services is focused on marketplaces and improving access to synthetic agrochemicals. Digital solutions not only increase direct access to knowledge but also create a link to extension services. See Case study 3 for successful examples.

7. **Opportunity**: Provide farmers and advisors with access to tailored and locally-specific knowledge, including through digital tools.

Participatory, transdisciplinary and system-oriented education and research

Education and research raise interest and acceptance of AE/O agriculture and produce innovative solutions. To foster a shift towards sustainable systems, AE/O topics should be integrated into the general curriculum for students at all levels, encouraging the next generation to become interested in these approaches and practices [4,9].

Important knowledge gaps also persist in AE/O agriculture, encompassing productivity challenges, adoption barriers, and more. These gaps are often context-specific, necessitating participatory research to uncover and co-create on-farm best practices and innovations that address them (see Case Study 4) [3,9,33,119,131].

Participatory learning and research, e.g. living labs, not only align with citizen expectations but have also been shown to enhance farmers' learning and adaptive capacity [101], as well as improve the efficiency of research outcomes [132]. These approaches can harness rich local and indigenous knowledge, re-establish forgotten and neglected food crops [133], encourage knowledge co-creation and bridge the gap between researchers, farmers, local communities, advisory services, and the private and policy sectors [9,101].

Education, research and extension services must embed systemic approaches that adopt holistic, farm-level, long-term perspectives to address environmental, health, culture and social aspects [4,9,13,33]. These research and education strategies enable long-term educational environments, accounting for the complexity of AE/O production patterns [4,9,124]

8. **Opportunity**: Advance transdisciplinary and participatory education and research to facilitate knowledge co-creation and exchange, and identify optimal local solutions, fostering their widespread adoption and expansion.

Case study 3: Digital learning for farmers

Digital approaches with mobile phone applications offer unique potential in regions with limited infrastructure, as they can efficiently reach most households with minimal investment. In several FiBL pilot projects, SMS-based training and Interactive Voice Response (IVR)-based training have been identified as promising solutions to enable self-directed learning for farmers with limited internet access or literacy (e.g. [127])

Digital learning platforms can also increase the quality of physical training by enabling self-directed learning for farmers, advisors and trainers. There are increasing offers that put AE/O best practices and tailored know-how directly in the hands of farmers across the Global South. Some examples include: 1) the Knowledge Centre for Organic Agriculture and Agroecology in Africa (KCOA) platform [128], 2) the Access Agriculture platform [129], and 3) farmbetter [130].

Case Study 4: The potential of participatory on-farm research

The project „Farming Systems Comparison in the Tropics" (SysCom) combines long-term experiments with participatory on-farm research (POR) to promote sustainable agricultural production. POR has facilitated innovative solutions and promoted partner institutions' capacities. For example, in one site in Kenya, pest pressure in vegetable crops negatively affected yield and income. In partnership with the International Centre of Insect Physiology and Ecology (icipe), SysCom improved existing plant extracts for pest control. The extracts were tested by farmers, who provided essential feedback on handling and effectiveness. The results garnered international interest, expanding icipe's network and resources. The POR approach therefore facilitated new technology, enhanced capabilities among local networks and secured funding for this work to continue.

Social and cultural factors

Food literacy

By improving food literacy, citizens can be empowered to make more informed and sustainable food choices, reduce food waste and support AE/O agriculture. The patterns in which food is produced, cooked, purchased and consumed are strongly governed by social and cultural values [134]. These choices are, therefore, difficult to change [134]. Food literacy can be supported by investing in educational initiatives and public awareness campaigns to allow stakeholders to learn and exchange about the benefits of AE/O production methods and products [134].

Programmes should focus on building community around sustainably grown, seasonal, diverse, as well as culturally appropriate food to drive local demand for AE/O products. Social and cultural dynamics must be carefully considered to empower communities for transformative change and foster collective action [4,9]. Digital technologies like social media can be particularly useful in reaching youth and other target groups (e.g. through influencer campaigns – see Case Study 5), especially when combined with practical applications (e.g. school gardens).

To further empower citizens, supportive policies can include product labelling, public procurement programmes (e.g. including AE/O products in meals at public institutions), and differential taxes and subsidies that incentivise healthy diets and disincentivise food waste [4,66].

9. **Opportunity:** Engage consumers in programmes to improve food literacy and implement supportive policies.

Governance factors

Coordination and participation

Decision and policymakers should be well-informed and empowered to advocate for evidence-based policies that support long-term food security, wellbeing and health of the environment and society [33]. Encouraging coordination and inclusivity in food systems governance is vital to achieving a more sustainable and equitable food system. Coordination between relevant state agencies, such as agriculture, land, health, commerce and trade, energy and finance departments, should be strengthened to ensure harmonised policies. Beyond internal coordination, the diverse stakeholders, from private, community and government, must better cooperate and align various projects and programmes to capitalise on synergies and increase the sector's resilience. This approach involves engaging diverse civil society groups in formulating food policies and regulations [4]. One example is the Committee on World Food Security (CFS) Framework, a multi-stakeholder, evidence-based approach to policy making [136]. Such participatory policymaking processes create adaptable, proactive frameworks and locally adapted solutions. See Case Study 6 for a good example.

Additionally, power and financial dependencies must be minimised. Empower and establish audit mechanisms to ensure policies are independent of business interests. For example, extension services should operate independently of agri-business, affording farmers the autonomy to decide which practices align most with their unique situation.

10. **Opportunity:** Empower decision and policymakers to advocate for informed, coordinated, participatory governance.

Incentives and regulations

Policies should strive to align environmental and food safety regulations, limit synthetic agrochemicals, support equitable certification schemes and mechanisms for compliance, and internalise hidden costs. The institutions and agencies overseeing these mechanisms need to be established and/or fortified to ensure effective governance [15].

Financial incentives, subsidies, and tax breaks can support the economic viability of sustainable practices [139,140]. Equitable public support for AE/O agriculture is the goal [4,91]. Initiatives like agri-environmental payments contribute to sustainability and should be supported by suitable capacity development programmes [15,91]. One example is supporting farmers transitioning to AE/O production through financial incentives, such as grants and subsidies.

11. **Opportunity:** Support AE/O agriculture and farmers with smart incentives and supportive policies.

Case Study 5: Organic Lifestyle Influencer Approach

The Organic Lifestyle Influencer Approach (OLIA) aims to promote a more sustainable lifestyle among consumers in emerging economies through social media influencer campaigns that promote and encourage organic, pesticide-free diets. By using a wide array of storytelling techniques, digital creators inform their followers of the benefits of organic food production and consumption. In the long run, this leads consumers to shift towards sustainable diets and producers to adopt production practices that are good for people and the planet. OLIA was developed as part of the Social Media Influencer Project (2021 – 2023) [135] in Kenya to create awareness about organic, especially among young, tech-savvy, urban consumers. Different awareness campaigns were designed and tested to reach millions of Kenyans.

Case Study 6: Key agreements supporting the advancement of organic agriculture in Africa

In 2011, the African Union Heads of States and Governments committed to incorporating organic agriculture into national plans, programmes, and policies by 2020 (now 2025). This resolution paved the way for a continental initiative on Ecological Organic Agriculture to be implemented. This initiative highlighted the importance of organic and sustainable agriculture, extending beyond certified organic practices [60].

Support for organic has also been shown at the national level, e.g., by Uganda and Tunisia in their dedicated national organic policies. Tunisia established a comprehensive national action plan in 1999 [137]. This plan encompasses various measures, including financial incentives such as tax breaks and subsidies for producers transitioning to organic agriculture, as well as substantial investments in research and extension services [137]. Consequently, Tunisia currently boasts the largest organic area among African countries [138].

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To facilitate transparency, FiBL citations are shown in blue and non-peer-reviewed publications are indicated with an asterisk (*) before the reference.

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Annex 1: What are agroecology and organic agriculture?

The terms agroecology and organic can be complicated to delineate, differentiate, and discuss. Agroecology is a multidimensional concept rooted in the fusion of agronomy and ecology, encompassing scientific principles, agricultural practices, and a socio-political movement [38,141,142]. It promotes a transformative approach to agriculture and is increasingly recognised in political initiatives at global, national and regional levels as a pathway to achieving the SDGs [142].

While global official and private regulations govern organic farming as an agricultural production system, the four organic principles transcend the current regulations, advocating for continuous improvement and a shift toward agroecological systems [141].

Both agroecology and organic farming stem from a rejection of "business as usual" systems and offer promising solutions to contemporary environmental and social challenges. They are grounded in ecological thinking, aim to work with nature to sustain and capitalise on living systems and cycles, and emphasise farmer involvement and social justice [141]. Agroecology and organic agriculture have differing histories, and their connection is variable in the scientific literature, but the overlap in principles, as seen in Box 6 and Figure 10, is evident. The implemented on-farm practices and approaches can look quite similar [2,141].

Despite the significant overlap, there are differences between agroecology and organic agriculture. Perhaps the main difference is that agroecology does not currently have a standardised and regulated control and certification process[19] and does not exclude any particular type of production system, inputs or techniques. Instead, agroecological farming systems are guided by its principles which allow for locally adapted and relevant solutions varying according to the individual socio-cultural, environmental and climatic context [2]. From a market and consumer perspective, the organic certification process increases trust and reliability in local and international marketing channels. Moreover, the organic production system is described in detail; "Organic" is a protected term [141]. However, "IFOAM – Organics International deems that organic is a well-defined subset of agroecology and that certification is a tool, not a prerequisite" [141(p. 7)].

The discourse on agroecology enhances the organic movement by fostering genuine interest in creating locally adapted, sustainable farming practices that extend beyond certification. Together, these two approaches have the potential to fundamentally transform the current food system [141].

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[19] *"Organic is the only agroecological farming approach today with a legally ensured guarantee system" [141(p. 5)]. The third-party certification in organic agriculture ensures adherence to standards, yet the relatively high cost poses challenges, particularly for smallholders in the tropics, something discussed in the coming chapters.*

Box 6: Defining agroecology and organic agriculture
Agroecology is "a holistic and integrated approach that applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. It seeks to optimise the interactions between plants, animals, humans and the environment while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced. Agroecology is concurrently a science, a set of practices and a social movement..." [143]. Agroecology is based on 13 principles (see Figure 10).

Organic agriculture is "a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than using inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved" [144]. Organic agriculture is based on four principles (see Figure 10)

Agroecology principles	**Organic principles**			
	Ecology	Health	Fairness	Care
Recycling	×			
Input reduction	×	×		
Soil health	×	×		×
Animal health	×	×	×	×
Biodiversity	×	×		
Synergy	×	×	×	×
Economic diversity			×	
Co-creation of knowledge		×	×	×
Social values and diets		×	×	×
Fairness			×	×
Connectivity			×	×
Land & natural resource governance	×		×	×
Participation			×	×

Figure 10: Overlap between the principles of agroecology and organic agriculture. The figure shows how the agroecology and organic principles overlap. Due to the nature of these principles, the interpretation of where they overlap may vary. However, it is evident that there are substantial similarities. The agroecology and organic principles are described in detail in [2] and [145], respectively.

Publication details

Publisher:
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Graphics: Kurt Riedi (FiBL)

Photos: Joost Bastmeijer (Biovision): cover, p. 11, 22, 23, 29; Pallav Pandey (bioRe): p. 7; Alexander Valeton (Yielder): p. 8, 16; Judith Riedel (FiBL): 9; Forster Bionys (FiBL): p. 14; Eva Goldmann (FiBL): p. 17; Johanna Rueegg (FiBL): p. 18, 27 (2); Laura Armengot (FiBL): p. 26; Ivan Chita (FiBL): 27 (1); Thomas Alföldi (FiBL): 28; Amritbir Riar (FiBL): 33

FiBL article no.: 2000
DOI: 10.5281/zenodo.10521540

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This document has been produced with the support of the Knowledge Centre for Organic Agriculture and Agroecology in Africa (KCOA) project and the Farming Systems Comparison in the Tropics project (SysCom). The KCOA project is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The editor(s) gratefully acknowledge the financial support provided by GIZ.
Further acknowledgements are on page 2.