Pathways to Advance Agroecology for a Successful Transformation to Sustainable Food Systems

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1 Introduction

Transforming agriculture and food systems in line with Sustainable Development Goals (SDGs) is an imperative that can no longer be ignored or deferred (CNS-FAO 2019; Eyhorn et al. 2019). In facing up to this challenge, agroecological approaches stand to play an indispensable role by connecting environmental sustainability with social justice in production and consumption. It combines the global challenge of ending hunger with locally adapted solutions and strengthens both participation and the mobilization of local actors and their knowledge (HLPE 2019). Agroecology optimizes the system approach and integrates scientific progress responsibly. To allow for agroecology to exploit its potential, there is a need for transformation that supports the shift from a capital- to a more labor-dominated approach that strengthens the social relations of production and moves farming beyond the logic of scale-enlargement, technology-driven intensification and specialization (Van der Ploeg 2021).

This chapter is based on a well-documented multi-stakeholder process of the Swiss National FAO Committee (CNS-FAO) developed over several years to provide scientific support to the Swiss government and the public on agroecology (CNS-FAO 2016, 2019, 2021). The aim of the chapter is to highlight the potentials of agroecology in regard to the strengthened effort of the UNFSS 2021 to achieve the

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SDGs, and highlight the necessary actions for mainstreaming agroecological management practices.

2 Global Challenges

We identify three major key challenges of global agriculture and food systems: the first challenge is that much of the world's population remains inadequately nourished, with more than 820 million people suffering from hunger. Many more consume low-quality diets, contributing to a substantial rise in the incidence of diet-related illness and obesity (Willett et al. 2019; IPCC 2019). A second challenge with global impact is the unsustainable way in which food production and consumption patterns substantially exploit the natural resources of soil, water and air (IPBES 2019). This has caused an immense biodiversity loss (Leclère et al. 2020; IPBES 2019). Third, greenhouse gas emissions are rising dramatically all around the world, with global agriculture causing 23% of anthropogenic greenhouse gas emissions, and therefore contributing substantially to global warming (IPCC 2019).

Not least due to the current Covid-19 pandemic, the fragility and vulnerability of food systems are clearer than ever. Food insecurity and acute hunger have increased, along with the number of people living in extreme poverty (HLPE 2020). Providing food for an estimated 10 billion people in 2050 is challenging. It will take a 56% increase in crop calories compared to the base year 2010 (FAO 2017), and that without even addressing such other issues as unsustainable consumption patterns, food loss and waste and the use of food crops for animal feedstuff and biofuels. The resulting substantial expansion of agricultural land, amounting to 593 million hectares (crop and grassland), must be contained wherever possible if we are to avoid releasing large amounts of CO_2 equivalents and putting biodiversity reserves at risk. Current agriculture should mitigate 11 gigatons of greenhouse gases to meet the Paris climate target of less than 2 °C of warming (World Resources Institute 2018). Future solutions must also take into account that, by 2050, it is forecasted that 68% of the world's population will live in cities (United Nations 2019), increasing the importance of urban food production.

3 Need for Transformation

A radical transformation of global food systems that addresses both the way we produce, process, trade and consume food and, with the same priority, the improvement of the livelihoods of farmers, farm workers and their families is necessary and cannot tolerate any delay. To provide enough food for the global population, several overriding strategies are being pursued, namely, a substantial increase in productivity, a sustainable intensification (Godfray and Garnett 2014) and an ecological intensification (Tittonell 2014). Agroecology implements the ecological intensification strategy in agricultural practice.

Agroecology offers a powerful means of accelerating the needed transformations. Agroecology, as we understand it, has a common framework grounded in the FAO's ten elements (FAO 2018b). The ten elements of agroecology are interlinked and interdependent. They encompass ecological characteristics of agroecological systems (diversity, synergies, efficiency, resilience and recycling), social characteristics (the co-creation and sharing of knowledge, human and social values, culture and food traditions), and the enabling of political and economic environments (responsible governance, circular and solidarity economy) (FAO 2018b). These elements come together in a model that relies centrally on the non-exhaustive and non-destructive use of biodiversity and ecosystem services, with off-farm inputs playing a diminished role in production (CNS-FAO 2019).

Hundreds of thousands of farmers manage their farms with agroecological practices in one way or another, either to improve their own productivity and livelihoods or gain privileged access to markets with certificates. These practices include regenerative conservation agriculture, organic agriculture, agroforestry, permaculture, agro-silvo-pastoral systems, and sustainable pastoralism in rangelands, among others. An even higher number of farmers adopt only one or more selected techniques of agroecology, such as using integrated nutrient and pest management, introducing semi-natural habitats on the farm, applying no-till arable cropping, or adopting sustainable river basin and groundwater management. Some farmers use bio-fertilizers and bio-protectants instead of agrochemicals, apply intercropping and cover crops to increase the land equivalent ratio (LER) and involving precision agriculture and climate-smart agriculture. Nonetheless, fully agroecological farms have remained a niche. The classic role of niches is that of a "protective space" or a shelter where future solutions and novel ideas can be tried out (Smith and Raven 2012). These novel ideas could change or even replace the current regime (Geels 2011) or paradigm (Beus and Dunlap 1991).

Although agroecological practices have been successfully implemented on many farms globally and practices such as resource-conserving agriculture continue to spread to more farms and more hectares (Pretty et al. 2006), they have not become mainstream until now. The most salient obstacles to mainstreaming agroecology include the fact that it is currently unknown to the public; the time lag between implementing agroecological practices and observing positive results; weak knowledge and advisory systems; transaction costs; policy incoherence; crucial deficits in landscape-level coordination, incentive systems in research, and compensation for yield reductions; and the need to strengthen the aspect of sufficiency in a sustainability context (IIED 2015; CNS-FAO 2021).

The HLPE report (2019) found that, to effectively and sustainably address food and nutrition security, it is not sufficient to focus on technological solutions and innovations or incremental interventions alone. Food system transformation requires (i) inclusive and participatory forms of innovation governance; (ii) information and knowledge co-production and sharing among communities and networks; and (iii) responsible innovation that steers innovation towards social issues (HLPE 2019).

Given its holistic approach, transformation to agroecological practices and systems happens at various scales and dimensions, from management decisions on farms to complex and erratic transformations resulting from the sum of decisions of various actors within a wider landscape (Anderson et al. 2021). Therefore, a multi-level perspective has to be taken so as to understand enabling and disabling factors and processes relevant for mainstreaming (Geels 2011). Anderson et al. (2021) introduced the term "domains of transformation," within which they described factors, dynamics, structures and processes that constrain or enable transformation in sustainability transitions.

Agroecological transformation can be understood as having five levels (Gliessman 2015): at level 1, farming systems become more efficient by reducing the use of fertilizers, pesticides or fuel. Level 2 involves replacing agrochemical inputs with more natural ones such as bio-fertilizers and bio-protectants. The way we understand agroecology, it also includes technologies that are safe for the environment and human health and that strengthen the systemic processes. Level 3 is about redesigning farming systems with diversified crop rotations, mixed crops, and intercropping, leading to better closed cycles of nutrients and organic material. Successful food system transformation also includes increased farmer-consumer collaborations (level 4), either with short distribution channels or internet-based remote applications, and, finally, a comprehensive transformation of policies, rules, institutions, markets and culture (level 5). The various stages proceed dynamically and in parallel, so that when framework conditions are conducive, a variety of production systems coexist and rural regions continuously change towards a higher degree of sustainability.

In our chapter, we address all five levels and propose actions that enable transformation and remove lock-ins. There is no contradiction between mainstreaming agroecology and strongly improving sustainability. Therefore, agroecology plays a crucial role for achieving the SDGs and works remarkably well in both theory and practice (COAG 2018; HLPE 2019).

4 Impact of an Agroecological Transformation

Agroecology has the potential to contribute to economic growth and decent work (Van der Ploeg et al. 2019), particularly for the rural poor. It contributes to local economic and resource circulation, considerably increases and stabilizes the yields of subsistence farmers (Pretty et al. 2006), and reduces costs and external dependencies. Strategies such as diversification, external input reduction and alternative marketing channels have, in some cases, been shown to improve farmers' income by 30% (FAO 2018a). For example, integrated pest management can generate remarkable improvements: in a study in low-income countries, pesticide use declined by 71% and yields grew by 42% (Pretty et al. 2006). A study on 946 farms in France concluded that total pesticide use could be reduced by 42% without negative effects on either productivity or profitability on 59% of the investigated farms (Lechenet et al. 2017). Conservation tillage can improve soil carbon while raising yields, and integrated plant nutrient systems can achieve the same benefits with reduced fertilizer application (Bruinsma 2003; Pretty et al. 2003, 2006; Uphoff 2007).

Furthermore, there are indications that the economic performance of alternative and agroecological farming systems can be comparable to, and is sometimes better than, conventional farming systems (D'Annolfo et al. 2017), and provide greater predictability for farmers (Chappell and LaValle 2011). Organic farms can achieve the same (Smolik et al. 1995; Rosset et al. 2011) or even higher (Nemes 2009) profitability as conventional farms. Also, agroforestry systems can have a higher return on labor compared to monocultures, (Armengot et al. 2016). Extensive evidence indicates that agroecology can, on a global scale, provide a level of food security comparable to that of conventional agriculture (Chappell and LaValle 2011). Under conditions of subsistence agriculture in Sub-Saharan Africa, agroecological methods significantly improved food security and nutritional diversity (Bezner Kerr et al. 2019). Organic agriculture increases access to food by increasing the quantity of foods produced per household and producing food surpluses that can be sold at local markets, for instance (UNCTAD/UNEP 2008). The yields of organic agriculture outperform traditional subsistence systems. In their study, Pretty et al. (2006) analyzed the impacts of 286 resource-conserving practices in 57 low-income countries and found that these projects led to an average yield increase of 79%. Differences in terms of yield productivity are highly site-specific, as Tittonell (2013) showed for organic agriculture: on marginal sites, organic farming produces equal or slightly higher yields than conventional farming. However, on high-yield sites, organic farming produces significantly lower yields.

Furthermore, agro-biodiversity (a key element of agroecology) is an important driver for making a diverse range of food products available. Although the pathway is complex and not always positively correlated, agricultural diversity plays an important role in improving dietary diversity, which has a strong association with improved nutrition status, particularly the micronutrient density of diets (Fanzo et al. 2013). A recent publication by Bezner Kerr et al. (2021) found evidence for positive outcomes linked to the use of agroecological practices on food security and nutrition (FSN) in households in low- and middle-income countries. While 78% of the studies reported positive outcomes, some studies found mixed outcomes, and a few studies reported negative impact on FSN, using indicators such as dietary diversity. The most common agroecological practices included crop diversification, agroforestry, mixed crop and livestock systems, and practices improving soil quality, with positive outcomes on FSN indicators such as dietary diversity and household food security.

Yield increases alone will not address our concomitant challenges of hunger, micronutrient deficiencies and obesity. This requires broad-ranging system changes that tackle poverty, inequality and barriers to access. The systemic approach based on ethical values, often considered a part of agroecological methods, offers an opportunity to address these issues in an integrated manner. For example, in Madhya Pradesh, India, a development institute provided integrated training in agroecological techniques, health and nutrition to more than 8500 women from 850 villages over 30 years. This improved livelihoods for the majority of the women and broke the cycle of poverty (FAO 2018a).

Agroecological systems use natural resources more sustainably and efficiently, and reduce the release of agrochemicals into air, water and soil (Pretty et al. 2003; Lechenet et al. 2017). Through the enhanced proximity between producers and consumers, agroecology helps raise awareness and reduce food waste, e.g., by redistribution to food bank charities or by repurposing urban organic waste as animal feed or fertilizer (Beausang et al. 2017). Agroecology puts an emphasis on maintaining soil fertility and ecosystem services, which can improve the long-term productivity of the land. As species richness is, on average, 34% higher in organic farming (Tuck et al. 2014), and organic farming systems have higher floral and faunal diversity than conventional farming systems (Mäder et al. 2002), biodiversity can be conserved and potentially restored within agroecosystems. As organic farming is one of the best-documented agroecological farming systems in scientific terms, these results are fundamentally important for a better understanding of all agroecological practices. Studies have shown that, through diverse and heterogeneous agroecological approaches, it is possible to preserve and increase wild and domesticated biodiversity by up to 30% (FAO 2018a). The connection between climate action and agroecology is two-way – agroecological systems have the potential to contribute to reducing greenhouse gas emissions and offer management practices to adapt to climate change (FAO 2018a). Agroecological farming may lead to reduced greenhouse gas emissions by reducing emissions from the production of synthetic fertilizer and carbon capture in the soil (Müller et al. 2017; Smith et al. 2008; Wood and Cowie 2004). However, these benefits have to be weighed against the lower land use efficiency or the increased requirements for labor of agroecological – especially organic – systems (Meemken and Qaim 2018; Clark and Tilman 2017). Regarding climate change adaptation, agroecology may improve the resilience of smallholders through the diversification of production and the increase in resource use efficiency by integrating social aspects (Altieri et al. 2015; Liebman and Schulte-Moore 2015). Furthermore, soil fertility, which is higher in agroecological systems, is a key prerequisite for protection against erosion and flood (Seufert and Ramankutty 2017).

5 The Role of Diversity for Food Productivity

One central characteristic of agroecology is diversity (FAO 2018b). In contrast, most public policies and incentives designed to increase agricultural production carry the risk of reducing the diversity of diets, food systems and landscape. A defining feature of the agroecological approach is diversity of landscape and habitats, of farm activities, of crops grown, of livestock kept and of above- and below-ground flora and fauna. Agrobiodiversity represents the creativity of life; its irreversible erosion means less capacity to innovate and adapt in the future, especially to climate change (Dury et al. 2019). Substantial improvements in the environmental sustainability of agriculture are achievable now, without sacrificing food production or farmer livelihoods (Davis et al. 2012). While short-term productivity is increasing, there is a clear loss of diversity when traditional varieties or races are replaced by improved varieties (Khourya et al. 2014). This homogenization and high dependency on a few crops at the global scale increases vulnerability to pests, as historically illustrated by many examples in maize, banana and wheat (Dury et al. 2019). Additionally, risks of resistance increase through the wide use of pesticides and antibiotics (Dury et al. 2019). The development of ecosystem services over time in more diverse cropping systems and rotations increasingly displaces the need for external synthetic inputs while still maintaining crop productivity or even increasing yields (Ferrero et al. 2017; Davis et al. 2012).

While socioeconomic factors such as farm commercialization, off-farm income, education or seasonality significantly affect diets of rural households, the linkages between a household's own agricultural production and dietary diversity are not always clear (Muthini et al. 2020; Sibhatu and Qaim 2018; Bellon et al. 2016). A positive relation between agricultural diversification and diversified diets is shown in different contexts for both subsistence and income-generating household strategies (Jones et al. 2014; Muthini et al. 2020; Sibhatu and Qaim 2018). In a comparative analysis including 23 studies, (Jones et al. 2014) demonstrated that agricultural biodiversity has a small but clear and consistent association with more diverse household- and individual-level diets. These various relations between diversity and food and nutrition security calls for a production strategy that combines local productivity and yield stability to make best use of between- and within-crop diversification to increase long-term food and nutritional security.

Agroecological approaches elevate the role of farmers and other food producers in associated knowledge and value chains. This is especially the case for the knowledge and experience of women, as women play a key role in all stages of food production in almost all regions around the world, encompassing their practical knowledge on biodiversity, including seeds, on food preservation and recipes. Women's control of farm level decision-making is an important determinant in understanding household-level diet diversity, expressed by a positive relation between agricultural biodiversity and household diet diversity for households headed by women (Jones et al. 2014). Agroecology can create better opportunities for women by integrating diverse work tasks and specific forms of knowledge, providing a more significant role for women in the household and farm economy. As agroecology, through low initial investment costs and knowledge-intensive technologies, becomes more accessible to women, it also fosters their economic opportunities and autonomy. In its political dimension, agroecology seeks to achieve and implement a just system (Seibert et al. 2019).

6 Domains of Transformation with Enabling and Restraining Factors

The domains of transformation that we want to address are (i) strengthening knowledge on agroecology, (ii) working with markets, (iii) enhancing cooperation, and (iv) ensuring policy coherence to create a conducive policy context for agroecology. These four domains address both agroecological practices (levels 1, 2 and 3 of Gliessman 2015) and the wider food system changes (levels 4 and 5).

6.1 Strengthening Knowledge (Research, Education and Innovation) on Agroecology

The knowledge and advisory systems required to support agroecology and build the capacity of actors are insufficient (Wezel et al. 2018). A systems-oriented, transdisciplinary, and long-term field research approach is lacking. Instead, current global knowledge and research systems promote fragmented short-term output (Aboukhalil 2014; Edwards and Roy 2017).

In 2011, total global public and private investment in AgR4D exceeded 70 billion US dollars (in purchasing power parity dollars) (Pardey et al. 2016). Current global R&D investments focus mainly on major staple crops. More nutrient-dense crops such as pulses, fruits and vegetables, as well as orphan crops, are often neglected (Pan 2016; HLPE 2019). The Consortium of International Agricultural Research Centres (CGIAR) Research Programs still focus largely on breeding and efficiency in production systems, rather than expanding its scope to a food system perspective (Biovision and IPES-Food 2020). A study analyzing 728 AgR4D projects with a total budget of 2.56 billion US dollars showed that local and regional value chains, traditional knowledge and cultural aspects of food systems are underrepresented in research programs, while only a handful of projects take a participatory approach to research (Biovision and IPES-Food 2020). The public investment in agroecological approaches is estimated to range between 1% and 1.5% of total agricultural and aid budgets (HLPE 2019). In order to transform the current food system, it is crucial for research projects to address and include key aspects of socioeconomic and political change, such as decent working conditions, gender equality (Biovision and IPES-Food 2020) and the important role of young and highly qualified people.

To tackle these challenges, the research focus should be shifted to agroecological principles, research activities should be better contextualized and funding mechanisms should be adequately altered, providing more funding for systemic, interdisciplinary and transdisciplinary research. This also usually requires longer funding periods.

Besides providing adequate funding for agroecological research, it is also crucial to break down institutional silos and enhance system thinking in research and training. Interdisciplinary courses at the graduate and undergraduate levels should include non-academic actors. Educational structures and programs are already showing signs of evolving towards systems analysis, with several universities recently opening food system centers or units that break down the traditional structures of research. Knowledge on agroecological innovations requires front-end research, but also needs to be combined with "know-how" and "do-how" (Salliou et al. 2019). Therefore, tools and platforms allowing for the transdisciplinary exchange and development of knowledge are key, particularly with young people and women.

It is hence key to provide training that includes practitioner-led learning and to build a culture of accountability in which research is undertaken with and for farmers as the ultimate beneficiaries. Currently, these agents of change for agroecology are rarely among the recipients of research funding. Farmers' intuition and tacit knowledge, practical know-how and scientific R&D can be harnessed together to yield solutions that are better suited to their particular context and are more quickly implemented.

Public support should be provided to further develop agroecological curricula at colleges and universities and facilitate exchange between experienced and interested stakeholders (from research, civil society, donor organizations and the private sector). Establishing a network of decentralized centers of excellence in agroecology would further reinforce system thinking and enhance exchanges between different knowledge holders (Biovision and IPES-Food 2020; HLPE 2019). New methodologies developed at universities and research centers, such as the co-creation of knowledge and citizen science using digital tools, enhance participation and transdisciplinarity.

Implementing agroecological practices successfully is knowledge-intensive and requires more experimentation and site-specific adaptation than standardized, industrial farming practices (HLPE 2019). This potentially makes agroecological practices attractive to young people, and requires the skills and expertise of a diversity of practitioners and specialists, including farmers, researchers and extensionists. In many parts of the world, private extension services financed by the sales of goods and services are predominant. When it comes to developing extension systems that align with agroecological approaches, publicly funded extension services are crucial. Tackling them requires re-configuring knowledge and extension systems in ways that place a much greater emphasis on participation and social learning, e.g., farmer-to-farmer learning and on-farm demonstrations. Expanding the use of low-cost information and communication technology (ICT), such as interactive radio and the use of apps, videos, and social media, is an effective means to reach large numbers of people, including youths. ICT has the added advantage of being highly customizable to suit specific contexts, while digital tools are also highly versatile. Widening access will also require innovative approaches in the delivery of information, so that the private sector, farmer groups, volunteers, social workers and youth entrepreneurs can become partners in extension and advisory systems (Fabregas et al. 2019).

6.2 Working with Markets

Agroecological systems are more diversified in terms of farm activities and tend to yield a greater number of crop or livestock products, but with a smaller volume of each product. This can limit market and processing opportunities and requires higher levels of knowledge and risk-taking. Furthermore, local marketing structures have, in many regions, been replaced by food retail chains, with food producers finding themselves in the weakest position along the value chain.

Only 23% of all agricultural products are traded on international markets, and most food in the world is produced, processed, distributed and consumed within local, national and/or regional food systems (CSM 2016). The Covid-19 pandemic has shown that sustainable local food systems are crucial for maintaining stable access to food when the global system fails. Supporting short supply chains and alternative retail infrastructures with stronger participation and control of more and various food system actors, such as farmers' markets, fairs, food policy councils, and local exchange and trading systems, may enhance farmers' livelihoods and increase access to local, sustainably-produced and diverse food (Hebinck et al. 2014). More support should be given to develop local and regional markets, processing hubs and transportation infrastructures that provide greater processing and handling capacities for fresh products from small and medium-sized farmers who adopt agroecological and other innovative approaches, and to improve their access to local food markets (Wezel 2020). Strengthening local food systems depends on enhancing local authorities' (e.g., municipalities) capacity to design favorable local policies. These, in turn, could work to enhance direct connection between producers and consumers, provide public facilities, support farmers´ associations in building strong local marketing networks, and entrench participatory guarantee systems (PGS) to certify organic and agroecological producers (HLPE 2019).

Farmers (particularly smallholders, women and young people), producer organizations, input providers and businesses transforming their operations based on agroecological principles need access to credit and alternative investment platforms with low capital costs. Not only farmers, but food systems actors in general, require access to secure and low-cost capital to absorb risks (e.g., momentary lower profitability) in the course of converting towards more sustainable business models. Investments in FinTech research that accelerate and facilitate access to transformational capital (e.g., mobile microfinance, peer-to-peer lending platforms and crowdfunding) must be given due priority.

Food prices and the price for food waste should be "right," internalizing external costs and enhancing positive externalities. This means that both the nutritional value of a food item and its production- and consumption-associated costs along the entire food value chain should be taken into account (FAO 2018c). However, an increase in food prices has a negative impact on the ability of those on low incomes to buy food of appropriate quality. Similarly, the Eat-Lancet Commission states that "food prices should fully reflect the true costs of food." However, options that support vulnerable population groups and protect them from the negative consequences of the potential increase of food prices need to be considered (Willett et al. 2019). Besides food prices, financial and fiscal incentives of unsustainable production systems also have a significant influence on current food systems. To allow for food system transformation, the creation of a shared understanding of all of the positive and negative externalities of the food system, as well as of the best approaches to defining reduction targets, is crucial (Perotti 2020).

6.3 Enhancing Collaboration

Agroecological practices often depend on collective action across a landscape scale, involving multiple farms and a range of actors. Furthermore, agricultural innovations respond better to local challenges when they are co-created through participatory processes and endorsed by local-specific knowledge. Collaboration and coordination across local, regional and national levels is key to supporting the active involvement and self-organization of food system actors such as producers, private sector investors, academia, civil society and governments. There is growing evidence from the literature highlighting the need for collective action and coordination at the local level to create favorable sociotechnical conditions for agroecological transition (Lucas et al. 2019). Agroecological innovations, to be successful and implemented at a larger scale, require mobilizing a growing range of stakeholders with multiple perspectives (Triboulet et al. 2019). However, agroecological farmers often value community cooperation more highly and see it as more important compared to colleagues working in non-agroecological farming systems. This is in line with agroecology principles, in which the links to members of the community for knowledge-sharing and problem-solving are key to strengthening sustainability and resilience (Leippert et al. 2020). Through interactions with other stakeholders and networks, farmers and other agents of change are supported in their efforts to strengthen existing initiatives and further develop collective awareness, identity, and agency around agroecological management issues (Chable et al. 2020). This requires higher levels of coordination and increases transaction costs.

Multi-stakeholder dialogues built on evidence-based arguments can help to bring together different perspectives, as long as they are developed in an inclusive manner (HLPE 2019). Agricultural research projects and partnerships too often remain focused on one-way knowledge transfer via institutes based in the Global North. It is therefore crucial not only to promote a shift towards agroecological research, but also to rebalance North-South power relations through equal research partnerships and direct access to research funding. Additionally, increased funding to build lasting bridges for South-South collaboration is needed. Supporting the emergence of long-term partnerships and coalitions with a focus on agroecology, local ownership, and the meaningful involvement of social movements and farmers' organizations is equally important. In parallel, the Public-Private Partnership model that is so central to current AgR4D needs to be continually scrutinized with regard to the delivery of benefits vis-à-vis the SDGs (Biovision and IPES-Food 2020).

Social movements associated with agroecology have often arisen in response to agrarian crises and have joined forces to initiate the transformation of agriculture and food systems. Agroecology has become the overarching political framework under which many social movements and peasant organizations around the world assert their collective rights and advocate for a diversity of locally adapted agriculture and food systems mainly practiced by small-scale food producers. These social movements highlight the need for a strong connection among agroecology, the right to food and food sovereignty. They position agroecology as a political struggle, requiring people to challenge and transform existing power structures (HLPE 2019).

6.4 Ensuring Policy Coherence to Create a Conducive Policy Context for Agroecology

To take agroecology to the next level, a solid governance structure, combined with a set of coherent policy measures, is essential (Eyhorn et al. 2019). Laws, regulations, publicity awareness campaigns and fiscal incentives are all part of a framework that should serve society. Many policy measures have negative impacts on the goals of different national strategies and policy objectives such as climate, biodiversity, soil protection, animal welfare, environmental protection, nutrition and health. Current agricultural and trade policies, including subsidy schemes, still favor intensive, export-oriented production of a few crops, as well as the intensive use of fossil fuel and agrochemical inputs, and must be revised to address the multi-functionality of agriculture (Eyhorn et al. 2019; HLPE 2019). The holistic nature of agroecology requires a well-coordinated coherent policy framework and a shift from a production-focused perspective to one that includes new indicators covering nutritional aspects, environmental impact and the long-term stability of the system. Such a holistic accounting of the performance of food production would allow for an evaluation of all of the positive and negative externalities (Perotti 2020).

International trade relations should include or allow for specific tools or mechanisms to foster the marketing of products derived from agroecological systems. Bi- and multilateral trade agreements should not include policies or ask for laws that might hinder agroecological production and even put its central elements, as defined by FAO, at risk.

Government-provided agriculture benefits – at varying degrees – support measures all over the world. In Europe, these are mainly direct payments, which are paid out to farms to support their income. "Public money for public goods" is a claim that environmental politicians and NGOs have been making for 30 years. Fortunately, there is a growing consensus that this would be an effective greening strategy and would bring major benefits to agroecology. Piñeiro et al. (2020) investigated which measures were most effective in promoting sustainability in agriculture. By far, the most effective measures are government-supported eco-schemes in all political, economic and social contexts, worldwide. Education, extension or market incentives (demand) come second. This relates to the fact that the market only settles private goods and services, but not public goods. The important function of state intervention (direct payments, investment subsidies, contributions to research, education and advisory services) is therefore to minimize the conflict of goals between private and public goods and functions. If the funds available for the various policy areas were channeled into agroecology, a huge transformative force would develop very quickly.

One major challenge is that, on average, conversion to agroecological systems typically results in a short-term reduction of yields (Tittonell 2014; WWF 2021) that needs to be compensated for through cost savings, higher product prices or policy support measures to ensure the economic viability of the farms. Additionally, the definition of sustainability in agriculture and food systems must be broadened beyond the efficiency narrative. Sufficiency means reducing resource consumption by adopting sustainable diets, reducing the demand for certain goods (e.g., feedstuff and biofuels produced on arable land), or increasing the demand of goods with relative advantages that cause fewer emissions and less resource depletion under certain situations and in certain locations, and by reducing food waste. Although the efficient use of natural and human-made resources remains important, efficiency alone is often offset by rebound effects (Polimeni et al. 2008) such as higher consumption or wastage. Global mass-flow models show that narratives based on sufficiency can successfully reduce the trade-offs between productivity and eco-stability (Schader et al. 2015; Müller et al. 2017).

Making use of existing public purchasing obligations can provide economic and political opportunities to implement policy and build new and innovative socioeconomic relationships that create sustainable food systems. Public procurement of sustainably-produced food, for example, can support low-income and other groups within schools, hospitals and other public institutions, setting off mutually reinforcing circuits. Interventions that focus on local procurement of sustainably-produced food for school feeding programs, or that target groups vulnerable to food insecurity, so as to realize food sovereignty at the local and state levels, can be effective in addressing FSN while supporting sustainable food systems (Barrios et al. 2020). These initiatives can also support safe, decent, meaningful employment for marginalized groups, including young people and low-income workers within the food system.

International guidance to comprehensively measure outcomes of agroecological farming systems are the Tool for Agroecology Performance Evaluation (TAPE), SAFA Guidelines of FAO (2017) or UN System of Environmental Economic Accounting (SEAA). Research projects in general, and technology development in particular, should be subjected to a holistic, multi-criteria assessment measured against the elements of agroecology: FAO's TAPE (FAO 2019), the Agroecology Criteria Tool (ACT), the growing body of work on 'true cost accounting' and specific metrics like the LER are at hand (Biovision and IPES-Food 2020). Multicriteria sustainability assessment tools for farms and food businesses are very helpful in assessing complexity and holistic sustainability and can accelerate transformation processes in agriculture and nutrition (Mottet et al. 2020).

7 Conclusions: Contribution of Agroecology to the SDGs

The SDGs recognize the strong interconnectivity among development goals and stress the need for holistic approaches and profound transformation of human activity across multiple dimensions and at multiple scales (Barrios et al. 2020).

Due to the fundamental importance of agriculture, the state of agriculture and food systems directly or indirectly affects all 17 of these goals. Agroecology provides one tool to help build sustainable food systems, and thus contribute to the ambitious targets laid out under the SDGs (Farrelly 2016). In particular, agroecology can contribute to no poverty (SDG 1), zero hunger (SDG 2), good health and wellbeing (SDG 3), gender equality (SDG 5), decent work and economic growth (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13) and life on land (SDG 15).

Agroecological approaches are increasingly called upon to play a greater role in contributing to the achievement of sustainable global food systems. Numerous promising examples demonstrating the potential of agroecology to stimulate and drive sustainable transition of food systems around the world were presented in a stakeholder paper (CNS-FAO 2021). If we implement the concept and, at the same time, apply a coherent policy set, agroecology will contribute to sustainable and resilient food production systems that help maintain ecosystems and progressively improve land and soil quality. It will further help in maintaining the genetic diversity of seeds, cultivated plants and domesticated animals. Through the promotion of reduced, alternative (non-chemical) and safe application of crop protection products, agroecology can reduce risks associated with agrochemical exposure, thus positively influencing the health of rural workers and consumers.

All of these potential benefits of agroecology mentioned above, combined with long-term productivity, social wellbeing and improved agency, reduced food waste and loss and a sufficiency-oriented agricultural production, require a rethinking of both the indicators and the way in which we measure performance of agricultural and food systems (Mottet et al. 2020). Additionally, a coherent policy framework is necessary that is able to break policy silos and improve governance structures in many countries to allow for increased self-control of the resource base, reduce the dependency of traditional market mechanisms controlled by capital through the construction of new, nested, markets, facilitate a strong backing reliance of high quality of labor, exchange of experiences and the availability of skill-oriented technologies, and establish a high degree of self-regulation at the territorial level (Van der Ploeg 2021). All of these elements are strengthening farming as an interesting, fulfilling profession that is attractive to young people. To allow agroecology to play a role in food system transformation, different governance levels and different departments, teams and stakeholder groups need to closely work together to define the key performance indicators for sustainable food systems and a policy frame aimed at reducing the amount of trade-offs. Promising examples of agroecological practices have developed and spread globally (CNS-FAO 2021), and the increasing awareness of society about the urgency of food system transformation increases the pressure on decision-makers to substantially support the development towards sustainable food systems. Strengthening knowledge systems, working with markets, enhancing collaboration among food system actors and creating an enabling policy environment will be crucial for this development.

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