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PATHWAYS TO ADVANCE AGROECOLOGY FOR A SUCCESSFUL TRANSFORMATION TO SUSTAINABLE FOOD SYSTEMS

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ABSTRACT

Agroecology is a powerful strategy that reduces the trade-offs between productivity and sustainability. It promotes the diversity of crops and livestock, fields, farms and landscapes that together are key to improve sustainability of food and farming systems in terms of long-term productivity, food actors' empowerment and inclusion and environmental health. Agroecology is a bundle of measures taken by farmers, which individually or combined, mobilize biodiversity and ecosystem services for productivity. Ideally, it leads to economically and ecologically resilient production systems that are high-yielding. It is not necessarily a predefined farming system and the shift from simplified by industrial standards to agroecological farms is gradual. The transformation and upscaling of agroecological practices requires changes that affect not only the management of farms, or production and consumption patterns at the food system level, but also the institutional framework conditions and the way we measure the performance of agricultural and food systems. In our paper, we describe four domains of transformation - knowledge systems, markets, collaborations and policy coherence - each with enabling and constraining factors.

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 and social justice of production and consumption. It combines the global challenge of ending hunger with locally adapted solutions and strengthens 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 which supports the shift from a capital to a more labor dominated approach which 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 paper is based on a well-documented multi-stakeholder process of the Swiss National FAO Committee (CNS-FAO) during several years to provide scientific support to the Swiss government and the public on agroecology (CNS-FAO, 2016; CNS-FAO, 2019; CNS-FAO, 2021). The aim of the paper is to highlight the potentials of agroecology for the strengthened effort of the UNFSS 2021 to achieve the SDGs, and to 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 (Willet 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 (Leclere et al., 2020; IPBES, 2019). Third, greenhouse gas emissions rise 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 more people living in extreme poverty (HLPE, 2020). Providing food for an estimated 10 billion people in 2050 is challenging. It will take a 56 per cent increase in crop calories compared to the base year 2010 (FAO, 2017), in case other issues such as unsustainable consumption patterns, food loss and waste and the use of food crops for animal feedstuff and biofuels are not addressed. The resulting substantial expansion of agricultural land, amounting to 593 million hectares (crop and grassland), must be contained wherever possible if we are not to release large amounts of CO_2 equivalents and put biodiversity reserves at risk. Current agriculture should mitigate 11 gigatons of greenhouse gases in order to meet the Paris climate target of less than 2 degrees Celsius warming (World Resources Institute, 2018). Future solutions must also

take into account that by 2050, it is forecasted that 68 per cent 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 livelihoods of farmers, farm workers and their families is necessary and does not 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, 2012) 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 10 elements (FAO, 2018b). The 10 Elements of Agroecology are interlinked and interdependent. They encompass ecological characteristics of agroecological systems (diversity, synergies, efficiency, resilience and recycling), social characteristics (co-creation and sharing of knowledge, human and social values, culture and food traditions), and enabling 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 to 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 integrated nutrient and pest management, introducing semi-natural habitats on the farm, applying no-till arable cropping, or sustainable river basin and groundwater management. Some farmers use bio-fertilizers and bio-protectants instead of agrochemicals, apply intercropping and cover crops in order to increase the Land Equivalent Ratio (LER), and involve in precision agriculture and climate-smart agriculture. Yet, 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 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 of 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, 2016; 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 only. Food system transformation requires (i) inclusive and participatory forms of innovation governance; (ii) information and knowledge co-production and sharing amongst 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 in order 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 fertilisers, pesticides or fuel. Level 2 involves replacing agrochemical inputs with more natural ones such as biofertilizers and bio-protectants. The way we understand agroecology, it also includes technologies that are safe for the environment and human health and strengthen the systemic processes. Level 3 is about redesigning farming systems with diversified crop rotations, mixed crops, 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 toward a higher degree of sustainability.

In our paper, 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 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 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, shown to improve farmers' income by 30% (FAO, 2018a). Integrated Pest Management for example 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 both productivity and profitability in 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; Pretty et al., 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 & LaValle, 2011). With a smaller farm size organic farms can achieve the same profitability as larger conventional farms (Smolik et al., 1995; Rosset, 1999) and that compared to monocultures, agroforestry systems can have a higher return on labor (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 & 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 for instance increases the access to food by increasing the quantity of foods produced per household and by producing food surpluses that can be sold at local markets (UNCTAD/UNEP 2011). 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 gives equal or slightly higher yields than conventional farming. However, on high-yield sites, organic farming is significantly lower yielding.

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 micronutrient density of the 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 food security and nutrition 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 to air, water and soil (Pretty et al., 2017; 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 by 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 on labor of agroecological - especially of organic - systems (Meemken and Qaim, 2018; Clark und Tillmann, 2017). Regarding climate change adaptation, agroecology may improve the resilience of smallholders through the diversification of production and increasing 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 (Khoury et al., 2014). This homogenization and high dependency on a few crops at global scale increases the 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; Sibathu 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, 2017; Muthini et al., 2020; Sibathu and Qaim, 2018). In a comparative analysis including 23 studies, Jones (2017) 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 combining 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, is better 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 (level 1,2 and 3 of Gliessman, 2015) and the wider food system changes (level 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 & 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 (GloPan, 2016; HLPE, 2019). The Consortium of International Agricultural Research Centres (CGIAR) Research Programmes still focus largely on breeding and efficiency in production systems, rather than expanding its scope to a food system perspective (Biovision & IPES-Food, 2020). A study analysing 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 programmes, while only a handful of projects take a participatory approach to research (Biovision & 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 & 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 systems thinking in research and training. Interdisciplinary courses at the graduate and undergraduate level should include non-academic actors. Educational structures and programmes are already showing signs of evolving towards systems analysis with several universities recently opening food system centres or units that break down the traditional structures of research. Knowledge for agroecological innovations requires front-end research, but needs also to be combined with “know-how” and “do-how” (Saliou 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 building a culture of accountability where 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 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 & IPES-Food, 2020; HLPE, 2019). New methodologies developed at universities and research centers such as 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 - 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, use of apps, videos, and social media is an effective means to reach large numbers of people, including youth. ICT has the added advantage of being highly customisable 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, Kremer & Schilbach, 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 10-12% 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., 2015). 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 in Herren et al., 2020). Strengthening local food systems depends on enhancing local authorities' (e.g. municipalities) capacity to design favourable 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 into FinTech research which accelerate and facilitate the access to transformational capital (e.g., mobile microfinance, peer-to-peer lending platform 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 as well as 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 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 na-

tional levels is key to support 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 literature highlighting the need for collective action and coordination at the local level to create favorable socio-technical conditions for agroecological transition (Lucas et al., 2019). Agroecological innovations to be successful and implemented at larger scale, require mobilizing a growing range of stakeholders with multiple perspectives (Triboulet et al., 2019). However, agroecological farmers often value community cooperation higher and 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 strengthen sustainability and resilience (Leippert et al., 2020). Through interactions with other stakeholders and networks, farmers and other agents of change are supported 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 & IPES-Food, 2020).

Social movements associated with agroecology have often arisen in response to agrarian crises and have joined forces to initiate 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 between 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 are 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 in order to address 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 including new indicators covering nutritional aspects, environmental impact and long-term stability of the system. Such a holistic accounting of the performance of food production would allow for an evaluation of all 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.

Agriculture benefits - at varying degrees - from government 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 great 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 has to do with 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) that needs to be compensated by 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 less emissions and 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 a 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 socio-economic 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 programmes, or that target groups vulnerable to food insecurity, to realize food sovereignty at local and state level, can be effective in addressing food security and nutrition 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 TAPE (Tool for Agroecology Performance Evaluation), SAFA-Guidelines of FAO (2013) or UN System of Environmental Economic Accounting (SEAA). Research projects in general and technology development in particular should be subjected to a holistic, multicriteria assessment measuring against the elements of agroecology: FAO's Tool for Agroecology Performance Evaluation (TAPE) (FAO, 2019), the Agroecology Criteria Tool (ACT), the growing body of work on 'true cost accounting' and specific metrics like the land equivalent ratio are at hand (Biovision & IPES-Food, 2020). Multi-criteria sustainability assessment tools for farms and food business 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 sustainable development goals (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), 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 achieve 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 contributes

to sustainable and resilient food production systems that help maintain ecosystems and that progressively improve land and soil quality. It further helps 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 of consumers.

All these potential benefits of agroecology mentioned above combined with long term productivity, social wellbeing and improved agency, reduction of food waste and loss and a sufficiency-oriented agricultural production, require both a rethinking of the indicators and the way we measure performance of agricultural and food systems (Mottet et al, 2020). Additionally, a coherent policy framework is necessary which is able to break policy silos and improve governance structures in many countries, to allow for a higher self-control of resource base, decrease dependency of traditional market mechanisms controlled by capital through the construction of new, nested, markets, a strong backing reliance of high quality of labor, exchange of experiences and the availability of skill-oriented technologies, and a high degree of self-regulation at the territorial level (Van der Ploeg, 2021). All these elements are strengthening farming as an interesting, fulfilling profession, attractive for 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 aiming to reduce the amount of trade-offs.

Promising examples of agroecological practices have developed and spread globally (CNS-FAO, 2021), and the increasing awareness of society for the urgency of food systems transformation increase the pressure on decision-makers to substantially support the development towards sustainable food systems. Strengthening knowledge systems, working with markets, enhancing collaboration between food system actors and creating an enabling policy environment will be crucial for this development.

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