POSITION PAPER

Agroecology empowers a new, solution-oriented dialogue

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1 Introduction

The global production of food comes at the expense of non-commodity ecosystem services, eco-stability, and human wellbeing; consequently, it threatens the stability of the planet (Steffen et al., 2015). An ongoing growth of the world population combined with the increasing wealth of low and mid-income countries, which is accompanied by higher protein consumption (especially of meat), threatens to escalate the overexploitation of natural resources, leading to higher greenhouse gas emissions, deforestation, and land degradation (FAO, 2017).

While scientists and politicians broadly share this analysis and acknowledge the urgent need for action, there are several different narratives as to where solutions should be sought (see *Figure 1*). Of these, the prevailing one, is sustainable intensification. While the term dates back to 1997 (Pretty, 1997), today this narrative finds broad support, is promoted by FAO, and is widely employed by the international research and development community as well as businesses driving industrial agriculture (Tittonell, 2014; Garnett et al., 2013). Sustainable intensification is characterised by a drive towards a greater output of food and feed per agricultural input, including land. It also causes less pollution and other negative externalities per output and is therefore said to be more (eco)efficient. It leaves some room for nature conservation and high-natural-value areas because most of the agricultural surface is highly productive. Productive land and areas serving the common good are segregated. The contrasting narrative is ecological intensification. “While sustainable intensification is generally loosely defined, so that almost any model or technology can be labeled under it, ecological intensification proposes landscape approaches that make smart use of the natural functionalities that ecosystems offer. The aim is to design multifunctional agroecosystems that are both sustained by nature and sustainable in their nature.” (Tittonell, 2014). Ecological intensification relies on ecosystem functions like soil fertility and biodiversity, whereas off-farm inputs become less important. By design, maximum yields are unlikely to be reached. Consequently, it is important to reduce food waste and meat consumption accordingly (Schader et al., 2015; Müller et al., 2017). The contrast between these two narratives can be summarised as efficiently managed productivity versus moderation or sufficiency in nutrition to reduce the need for further increases in agriculture productivity. In practical implementation, these two strategies mean a technologically improved conventional or integrated agriculture on the one hand and organic farming on the other (Reganold and Wachter, 2016). But this either-or is more clearly separated in theory than in practice. Often, diversified or extensive conventional farms are as sustainable as very intensive organic

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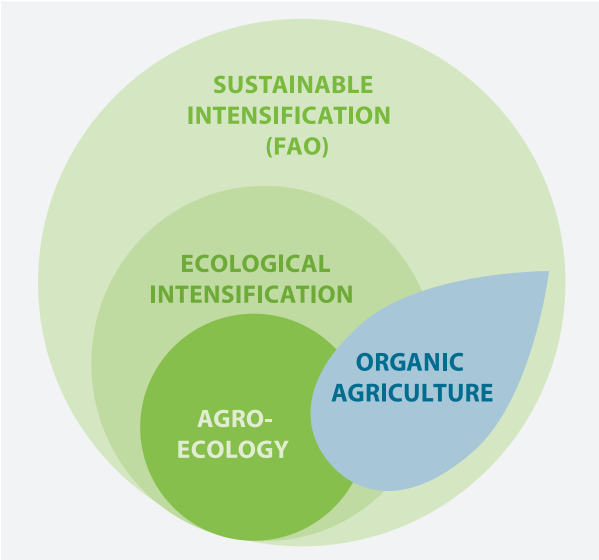

FIGURE 1
Different concepts of sustainable food production. The concepts differ in terms of the relationship between productivity and ecological footprint. The size of the circle symbolises the productivity and the intensity of the green colour the excellence in ecology and environment. Organic agriculture extends across all three concepts, depending on the production sector and the intensity of production.

sectors of production or whole farms and sometimes even more so (Sanders and Heß, 2019; Haupt et al., 2018). Could the concept of agroecology help to build bridges between these perspectives and facilitate solution-oriented dialogues?

2 Agroecology: from science to practice

Regional and international conferences on agroecology held by FAO from 2014 to 2017 led to the identification of ten principles characterising agricultural and food systems as agroecological (FAO, 2018). These principles describe the common mechanisms of such systems as diversity, synergies, efficiency, resilience, recycling, as well as co-creation and sharing of knowledge. Furthermore, the principles highlight human and social values, culture, and food traditions. Responsible governance, as well as circular and solidarity-oriented economy, are crucial as they produce the enabling environment, necessary for agroecology to thrive. In its latest and 14th report, the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE) complemented the definition of agroecology with its 13 principles (HLPE, 2019), of which some were more technical and production-oriented, although they all point into the same direction.

The evolution of the term 'agroecology' encompasses a drastic shift from its use in scientific research to ecological farm practice and on to describe a farmer-led social movement. Agroecology emerged in the early 20th century when researchers studying the interaction between crops and the environment started applying a scientific understanding of ecology to agriculture (Tischler, 1965). Altieri went a step further when he used scientific findings to design sustainable cropping systems (1995). He contextualised productivity related to regions, ecological zones, landscapes, and the socio-economic sphere and adapted agricultural practices by listening to and involving farmers (HLPE, 2019). Hence, the key aspects of agroecological research include participatory knowledge development, on-farm studies, and holistic research approaches that consider wide-ranging social and economic factors (TWN and SOCLA, 2015).

This new integrative scientific approach has led to a multitude of developments in farm practices and techniques. Agroecological farms apply the best sustainable practice, such as diverse crop rotations, mixed crop-livestock systems, polycultures, inter-, cover-, and mixed cropping, natural or semi-natural habitats and corridors, and local marketing and value creation. Further important aspects are local breeding programmes and re-using resources from local agroecosystems (Gliessmann, 2006). However, agroecological farming is best understood as a guiding principle and a practical approach that develops over time rather than as prescribing a static set of practices. Unlike the related concept of organic agriculture, it is explicitly uncodified and unrestrictive. Crucially, agroecological farming emerged from a participatory process and often through the active cooperation of enthusiastic producers, processors, and consumers, who pursue well-formed goals within their own spheres of responsibility, without an overly heavy focus on inspection and certification. At the same time, agroecology does not lose sight of the importance of this for organic producers who want to enter remote and anonymous market places. An instructive example is provided by the state of Sikkim, India, which has successfully transitioned towards the application of 100 % organic farming while becoming a major exporter of fruits, flowers, spices, and vegetables (Kumar et al., 2018). Successes like this bear the agroecological principles devised by FAO and HLPE, which depend on an enabling socio-economic environment, a fair and participatory political process (including financial support from the state government), a focus on crops with market potential for export, and the recognition of group certification (Bharucha et al., 2020; Meek and Anderson, 2020).

At its best, agroecology can take advantage of a multiplicity of solutions, combining technology and traditional knowledge to improve inputs and outputs of the agricultural process. Agroecological systems include organic farming (Niggli, 2015), permaculture, low external input sustainable agriculture (LEISA), and agroforestry (Armengot et al., 2016). All those systems fall under the ten elements of the FAO framework as well as the thirteen principles consolidated by the HLPE, albeit with different weighting and target achievement. Some of their techniques are not compatible with organic standards, like combined fertilisation with organic manure and synthetic fertilisers or the spraying of synthetic herbicides and pesticides in exceptional cases, which is decided on by the farmer (such as a risk of a severe harvest loss that threatens the economic sustainability of the farm).

Peasant farmer groups, like La Via Campesina, have pressed for further changes to the concept of agroecology.

Their emphasis on social, cultural, and political principles has transformed the idea of agroecology into a strong global movement against globalisation and free trade and for food sovereignty (La Via Campesina, 2018; Wezel et al., 2009). Strong political commitments and the horizontal integration of civil society organisations provide an excellent incentive for farmers not to fall back to old, unsustainable practices (Tittonell, 2014; Rosset et al., 2011). Indeed, building social capital and new modes for the co-creation of knowledge are vital prerequisites for a successful scaling-up of agro-ecological farm management practices (Pretty et al., 2018). Many such farmer organisations and social movements now use the concept of agroecology as an overarching political framework to secure their rights and safeguard locally adapted small-scale farms (HLPE, 2019).

Meanwhile, selected agroecological practices are being applied to industrial agriculture in farming systems, such as low input agriculture, precision farming, integrated pest management[3] and integrated production, farms optimised by life cycle assessment, and conservation tillage. These all fall under the concept of sustainable intensification. Many of these management practices have been fostered by agri-environmental measures taken by governments. For example, in 2013, the European Commission established a policy of 'greening' and since then has required a few agroecological practices for all direct payments to farmers (EC, 2013). However, these requirements are low, and the measures have proven ineffective in achieving sustainability targets.

3 The greatest obstacles to the upscaling of agroecology

Recently, scientists assessed sustainable intensification initiatives worldwide and estimated that 29 % of all farms are practicing some form of redesigned systems for sustainable intensification (including agro-ecological systems) on 9 % of global agricultural land (Pretty et al., 2018). They concluded that the adoption of sustainable systems might be on the brink of effecting a global transformation (Parmentier, 2014). Organic farming, on the other hand, has already reached this point in many European countries and regions and has become mainstream in the Alpine regions of Austria, Germany, and Switzerland, where 60 % of all farms are certified organic and organic milk has become the standard. Producers have thus responded to the strong demand for such products. Worldwide, however, the share is still marginal at 2.2 % of the agricultural area (Willer et al., 2020).

The biggest challenge is certainly the inherent contradiction between productivity and excellence in environmental standards, as well as the associated trade-off between the economic and the ecological dimensions of sustainability. This creates great uncertainty as to whether both agroecological and organic farming systems can contribute to food security (Seufert and Ramankutty, 2017). However, the former UN Special Rapporteur on the Right to Food stated that productivity could be doubled in twenty African countries if agroecological methods were adopted (De Schutter, 2010). But this conclusion mainly applies to subsistence farming, where agroecological practices – actually, as mentioned above, the best agronomic practice – represent an important first step towards intensification. In any case, this contradiction will have to be resolved since intensive agricultural production depends on high utilisation of resources, which will become scarce in the future (FAO, 2017). In contrast, agroecology strives to minimise reliance on external inputs as far as possible. Many of the techniques of organic agriculture and low-input practices have shown that this is feasible. Mäder et al. (2002) and Oel et al. (2003) demonstrated that close correlation between organic, low-input farming systems and higher soil biomass, higher AMF mycorrhiza diversity, and higher root colonialisation lead to higher phosphorous use efficiency. Moreover, they pointed out that organic fertilisers, reduced soil tillage, reduced pesticide use, diverse crop rotations, mixed cropping, as well as green manure – all characteristic of agroecological practice – were the most effective available techniques.

Yet, it remains uncertain whether resolving the trade-off is possible without fundamentally changing the existing capitalist socio-economic system (Jackson and Victor, 2019; Seidl and Zahrnt, 2019). The economic paradigm that underlies most economical and financial systems originate from the Chicago School. These neoclassical economic models are not socially embedded in the sense that they neglect societal and environmental factors such as institutions, natural resources, and energy. They promote a form of globalisation that amplifies transportation activities, increases global competition, and reduces prices of food commodities. And finally, these economic models are infused with an optimistic belief that technological progress coupled with market mechanisms has the capacity to overcome all limitations of natural systems. A fundamental change would be a herculean (if not demiurgical) task if it were even possible or desirable. In any case, the resulting reduction of economic growth would, in turn, entail a trade-off against the social dimension of sustainability (as it reduces prosperity) and therefore would be a source of conflicts.

The question of the productivity of cultivation systems is a very complex one. For many years, it has been discussed in a markedly inconsistent manner. Those involved in the debate often only draw attention to partial aspects of the problem, argue within different time horizons, and ignore facts and figures that do not support their own position. The predominant opinion is that it is primarily the strongly growing demand for food that drives agricultural productivity (Meemken and Qaim, 2018) and that this productivity has to be upheld. In fact, nitrogen fertilisers, crop protection, and irrigation together with high yielding varieties have massively increased yields over the last 60 years. But, critical voices have asked, at what cost does this come? It is also certainly true that the long-term productivity of agriculture is threatened by the depletion of natural resources such as fertile soils, water reserves, biodiversity, and landscape habitats.

[3] The term 'integrated pest management' for us refers to a strict and binding implementation of a combination of biological, biotechnical, plant breeding, and cultivation measures in order to reduce the application of chemical plant protection products to a bare minimum (Niggli et al., 2020.

The main arguments against the over-emphasis on the future yield deficit that could be caused by agro-ecological cultivation methods are right to highlight other factors, such as the poor management of world harvests, poverty, and conflicts. Nevertheless, the FAO expects a gap of 7,400 trillion calories by 2050, which would call for an increase of production by 56 % (Alexandratos and Bruinsma, 2012). According to current patterns of land use, such an increase would then require 593 million hectares of additional agricultural land, an expansion of both cropland and permanent grassland. For a scenario of 100 % conversion to organic farming, the global agricultural land may further expand by 33 % (Müller et al., 2017). Additional productive land would have to be gained through deforestation, drainage of high moors, and conversion of grassland to arable land. The negative impact on biodiversity and climate change in this scenario would be dramatic (Burney et al., 2010). On top of the FAO basic scenario for 2050, Müller et al. (2017) and Schader et al. (2015) modelled scenarios with a rising percentage of organic land (0 to 100 %), with changing meat consumption, with more or less successful food wastage reductions, and with three global warming impacts (no impact on yield, medium, and strong impact). Their simple conclusion was that eating less grain-fed meat and reducing food waste would most effectively mitigate this productivity gap and is likely to represent the only realistic exit strategy in the long run.

But here we should be cautious. A fairly likely scenario is that this kind of change in consumer behaviour (the sufficiency narrative) will take several generations and that prosperity in emerging countries will have exactly the opposite effect. For the time being, meat consumption and food wastage will continue to grow, the latter triggered by a trend towards convenience food in the growing middle class and the dramatic increase in disruptive societal crises such as rural exodus, conflicts, or pandemics. Hence, it seems likely that society will continue to be caught in the productivity trap. How do we meet this pressing challenge?

4 The way forward

Against this backdrop, it is evident that agroecology in science and education has a pivotal role to play. However, we are still far from achieving this state of affairs. Science might find better and more sustainable solutions, but this relies on them being conducted in the context of a strongly diversified production system based on low external input, high internal activation of resources, and high transformative efficiency. This type of research also requires meaningful cooperation between disciplines. This means more than multi- or interdisciplinarity; in the best-case scenario, boundaries between the disciplines dissolve and disciplines merge into a common working framework also known as design thinking or even postdisciplinarity (Brown, 2009). This will lead to a better understanding of agricultural practice and local production conditions but requires different working procedures. The problem here is that in mixed research consortia, individual competences often drift apart and results in more competition instead of cooperation. Yet, new digital communication possibilities may offer better opportunities to create data jointly and to work with several teams on method development. One could label this new approach to collaboration ‘swarm intelligence’ as it directs distributed creativity towards the same goal, instead of fostering unproductive competition. Decision-makers have too often complacently relied on competition and contradictions among scientists since the unclear recommendations that result from those contradictions make it easy to avoid costly or unpopular actions, even where this is necessary.

Farm redesign is the key to tackling lower productivity without more external input (Bharucha et al., 2020). Various system-related solutions for this are possible. On the one hand, the typical agroecological techniques described above are already doubling yields in subsistence farming. This is because subsistence farmers often neglect simple techniques such as planting annual and perennial legumes, crop rotation, pasture rotation, raising fewer but better fed grazing animals (through improved grassland management), and polyculture. Furthermore, a higher land equivalent ratio (LER) must be attained in as many contexts as possible. Intercropping or polyculture is in any case the future solution. In agroforestry systems, this is mainly a combination of annual crops (cereals, sorghum, many grain legumes, vegetables, flowers, etc.) with fruit trees, wood trees for energy production, cocoa, etc. In scientific literature, polyculture has been reported to give yields 40 to 145 % higher than sole cropping. In this case, the highest increase has been achieved with ginger, maize, and soybean polyculture in Nepal (Chapagain et al., 2018). In temperate climate zones, mixed cultures with only annual plants are more common. Agroforestry systems are still rare as both temperatures and light intensities are too low for two- or three-layer plantings. Popular on organic farms are barley and pea or oats and faba bean. In addition to having a slightly higher LER, they improve the nitrogen supply, soil fertility, and soil physical stability, and they have an excellent weed suppression effect that also reduces the need for mechanical weeding.

Digitalisation is a key technology for enabling highly diversified farms and fields. The digitalisation started with precision farming and was originally implemented in order to use external inputs such as pesticides and fertilisers in a more targeted, economical, and demand-oriented manner. Organic and agroecolocical farmers saw no advantages in precision farming: the former because they generally ban most inputs, while for the latter the technology was expensive and led to dependence on substantial investment. In the meantime, however, this has changed, mainly due to advances in robotics, GPS technology, the tremendous development of remote sensing and hyperspectral image analysis, the speed of wireless data transmission, real-time data processing, and advances in precision of control. Digitalisation increasingly offers opportunities to achieve the goals of agroecological farming systems, representing a turning point in modern agriculture. For the first time, mechanisation is moving away from ever-heavier tractors and back to self-propelled equipment, which is becoming ever smaller and lighter. This is not only good for energy consumption but is even better for physical and biological soil quality. Moreover, the compulsion to simplify landscape structures, grow and level out fields, and remove 'disturbing' habitats is reversed, and the new methods of mechanisation can be adapted to a diverse, small-scale landscape and various local conditions.

Great potential for yield increase also lies in breeding programmes well-adapted to the conditions of low external input cultivation systems and farms. Highly important traits of these are increased resilience or tolerance to plant pests and disease. Equally important is the ability of plants to compensate for growth when the mineralisation of organic fertilisers starts late and take advantage of the microbial activity of the soil. The latter depends, among other things, on root architecture, symbiotic fungi and bacteria in the rhizosphere, and on plant hormones that act as growth and development regulators and activate the induction of disease resistance mechanisms. The fact that plant breeding is important and must adapt to the context of agroecosystems is undisputed. However, there are major differences in the choice of breeding techniques. Organic farmers focus above all on the potential of classical cross-breeding, while others use markers extensively to speed up breeding, and there is now also an intensive discussion about whether targeted mutagenesis with genome editing would be an option, especially for sustainable farming systems where off-farm input is considerably reduced.

5 Conclusion

The discussion on agroecology in its current state is pleasantly unagitated and not yet caught up in political quibbles and market interests. This allows a freer and more creative debate. Agroecology is a promising concept of how agricultural practice and research can be geared to the needs of people and the planet. Effects are in the foreground, and synergies are always sought: between nature and technology, productivity and natural resources, scientific knowledge and traditional experience. All actors have a great deal of freedom, provided that the goal is not lost sight of. This orientation towards goals requires a stringent and holistic understanding of sustainability. A productivist farmer optimises yields and efficiency. An organic farmer strives for best compliance with the standards. Future agroecological farmers must strike a more delicate balance. They must mobilise all their skills in order to make responsible use of the freedom offered by a methodology that as yet remains uncodified. They must manage their business in an economically, socially, and ecologically sustainable manner with the help of appropriate evaluation methods. And for now, they experience the same fate of all pioneers: a lack of support from the agricultural research community and established knowledge systems.

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