中国生态农业学报(中英文)
Chinese Journal of Eco-Agriculture
中文核心期刊
中国科技核心期刊
中国精品科技期刊
百种中国杰出学术期刊
中国科学引文数据库源刊

生态农业和有机农业的创新

Urs Niggli, Qiyan Wang-Müller, Helga Willer, Jacques Fuchs

引用本文:
Urs Niggli, Qiyan Wang-M ü ller, Helga Willer, 等. 生态农业和有机农业的创新[J]. 中国生态农业学报(中英文), 2021, 29(3): 423-430.

在线阅读 View online: https://doi.org/10.13930/j.cnki.cjea.200469

(向下翻页，阅读全文)

DOI: 10.13930/j.cnki.cjea.200469

NIGGLI U, WANG-MÜLLER Q, WILLER H, FUCHS J. Innovation in agroecological and organic farming systems[J]. Chinese Journal of Eco-Agriculture, 2021, 29(3): 423−430

Innovation in agroecological and organic farming systems

Urs Niggli[1], Qiyan Wang-Müller[2,3*], Helga Willer[2], Jacques Fuchs[2]

(1. Research Institute of Organic Agriculture (FiBL), Vienna A-1010, Austria; 2. Research Institute of Organic Agriculture (FiBL), Frick CH-5070, Switzerland; 3. Swiss Chinese Herbal Medicine and Functional Food Innovation Center (SwissHerbs), Zürich CH-8008, Switzerland)

Abstract: In light of major ongoing environmental damage and the destruction of natural resources, developing a truly sustainable mode of agricultural production is of great importance. Among different ways to reduce trade-offs between ecological sustainability and productivity, we present the approaches taken by agro-ecological and organic farmers. Both fall within the narrative of ecological intensification. According to finding of many previous scientific meta-analyses, both have a great potential to reduce environmental pollution. However, these very positive effects unfortunately result in lower yields. These could be compensated for by changing people’s eating habits (e.g. less food waste, less meat consumption from concentrate-fed livestock). However, since global developments and trends are moving in exactly the opposite direction, this paper examines the possibilities of improving the yields of low-input farming systems through scientific research and the outlook for finding new productive solutions. Here we outline the significant potential in the redesign and differentiation of farms and fields including landscapes, in digitalization, the promotion of low-input breeding programs, high quality recycling of organic matter, and non-chemical crop protection.

Keywords: Agroecology; Productivity; Organic farming; System-oriented research
Chinese Library Classification: S345; [X171.3]

生态农业和有机农业的创新

Urs Niggli[1], Qiyan Wang-Müller[2,3*], Helga Willer[2], Jacques Fuchs[2]

(1. Research Institute of Organic Agriculture (FiBL), Vienna A-1010, Austria; 2. Research Institute of Organic Agriculture (FiBL), Frick CH-5070, Switzerland; 3. Swiss Chinese Herbal Medicine and Functional Food Innovation Center (SwissHerbs), Zürich CH-8008, Switzerland)

摘　要: 现代农业系统在明显提高产量、保证粮食安全的同时, 也对人类健康和地球的可持续性产生了影响。在持续不断的严重环境破坏和自然资源毁坏的背景下, 建立可持续的农业生产方式至关重要。生态农业和有机农业是减少生态可持续性和生产力及社会可持续之间权衡关系的重要方法。这两种农业方法都属生态集约化范畴, 均具有减少环境污染的巨大潜力; 然而, 生态农业和有机农业常导致产量降低。虽然产量降低带来的损失可以通过改变人们的饮食习惯来弥补(如减少食物浪费、减少食用精饲料喂养的肉类), 但是, 由于全球的发展趋势与之相反, 因此本文探讨了通过科学研究寻求新的解决方案前景来提高低投入农业系统作物产量的可能性。为权衡生产力与可持续发展的关系, 使生态农业和有机农业有助于粮食安全, 我们对未来研究提出5点建议: 1)农场和田地的景观设计与复合种植模式、2)数字化技术的应用、3)以农田低投入为目标的作物育种、4)农业废弃物的高质量循环利用和 5)非化学作物保护。

关键词: 生态农业; 生产力; 有机农业; 系统导向性研究

Organic farming is now a global trend and the growth in consumption is steep. Together with agroecological farm practices that are often not certified, it will contribute to the transformation of current practices and the development of a more sustainable agriculture.

* Corresponding author, E-mail: qiyan.wang-mueller@swissherbs.org
Urs Niggli, E-mail: urs.niggli@fibl.org
Received Jun. 19, 2020; accepted Jul. 20, 2020

1 Challenges of sustainable food security

Current high yield food systems have massively increased food, feed, fiber and fuel production, and so reduced the number of food-insecure people. At the same time, however, they affect the health of people and the planet in ways that are fundamentally unsustainable. Agricultural production systems contribute to climate change and are at the same time affected by it. Additionally, they promote soil degradation, inefficient nutrient use, eutrophication of water and biodiversity loss. Pesticide use harms land and water ecosystems. Moreover, agriculture produces externalities in other parts of the world (telecoupling), such as creating inequalities and negatively affecting small-scale agriculture in the global south. The problems are generally compounded by high rates of food losses and waste. A strong trend towards both animal-derived and highly processed foods negatively affects people through, for example, increased rates of obesity and heart disease. Meat consumption will further grow with the increasing wealth of low and mid-income countries. The global production of food comes at the expense of non-commodity ecosystem services, eco-stability and human wellbeing, and consequently it threatens the stability of the planet (Steffen et al., 2015). In conclusion, current agriculture is very much characterized by numerous trade-offs; the most obvious of these is between productivity and environmental and social sustainability.

All these facts are well-known. The need for action is obvious. However, there exist different narratives as to where solutions should be sought (see figure 1). The prevailing narrative is sustainable intensification as promoted by FAO (Garnett et al., 2013): It is characterized by a drive towards greater output of food and feed per agricultural input and per land unit. 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, on the one hand, and areas serving the common good, on the other, are segregated.

The contrasting narrative is ecological intensification (Tittonell, 2014). Ecological intensification relies on natural functions of the ecosystem, such as soil fertility and biodiversity, while off-farm inputs like chemical pesticides and mineral fertilizers are minimized. Biodiversity becomes an integrated part of the farms and fields, rather than being segregated from them. By design, maximum yields are unlikely to be reached. Consequently, it is important to reduce food wastage and meat consumption accordingly (Schader et al., 2015; Müller et al., 2017). Otherwise, more land would need to be ploughed and more forests cleared.

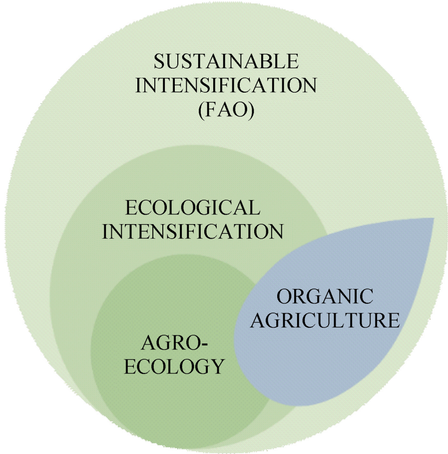

Fig. 1 Different concepts of sustainable food production. The concepts differ regarding the relationship between productivity and ecological footprint. The size of the circle symbolizes the productivity and the intensity of the green color the excellence in ecology and environment (schematically). Organic agriculture spreads over all three concepts, depending on the intensity and the production sector.

The narrative sustainable intensification covers farming systems like technologically improved conventional or integrated agriculture. With the help of digitalization up to 50 to 80 percent of pesticide and mineral fertilizer can be reduced. This might become possible soon thanks to precise control of the interventions, image analysis and real time analyses of several years of soil, crop and farmer intervention data for every 10 square inch of farmed land. The ecological intensification narrative, on the other hand, includes farming systems like agroecology and organic farming. Our paper will focus on these two farming concepts as they represent promising responses to the current problems, critically analyzing their potential to feed the world in a sustainable way.

2 Ways forward

2.1 Agroecology — from science to practice

FAO described agroecology with ten principles (FAO, 2018): Diversity, synergies, efficiency, resilience, recycling, as well as co-creation and sharing of knowledge. Moreover, these principles highlight human and social values, culture and food traditions. Agroecology also needs an enabling environment, especially responsible or good governance, and a circular and solidarity-oriented economy (HLPE, 2019).

In the last 80 years, the evolution of the term agroecology encompasses drastic shifts, from 1) its use in scientific research, 2) to ecological farm practice, and on 3) to describe a farmer-led social movement. Firstly, agroecology emerged in the early 20th century, when researchers studying the interaction between crops and the environment applied a scientific understanding of ecology to agriculture (Tischler, 1965). It encompassed research on the better understanding of environmental impacts of agriculture (OECD, 2003). Then, in a second step, scientists used the findings of agroecological research to design sustainable cropping systems (Altieri, 1996). In contrast to industrialized agriculture, these farming practices were contextualized to regions, ecological zones, landscapes, and socio-economic spheres, and adapted agricultural practices by listening to and involving farmers (HLPE, 2019). Hence, 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).

The diversity of agroecological farm practices and techniques include best sustainable practice, such as wide 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 programs 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. These are seen to pursue well-shaped goals within their own spheres of responsibility, without an overly heavy focus on inspection and certification. 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). In some cases, pastoral livestock farming on natural pastures is also part of this, if no overgrazing takes place. Many subsistence farms, especially in Africa, are also included, provided they work sustainably and regeneratively and do not leach the soil, allow no erosion or neglect the diversity of crops and natural habitats.

Agroecological farming is less restrictive than organic agriculture about applied techniques. Farmers can use combined fertilization with organic manure and synthetic fertilizers, or they might even spray synthetic herbicides and pesticides in very exceptional cases, such as a clear and serious threat to the harvest (Parmentier, 2014).

Thirdly, peasant farmer groups, like La Via Campesina, have pressed further changes to the concept of agroecology. Their emphasis on social, cultural and political principles transformed the idea of agroecology into a strong global movement against globalization 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 into 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 the successful scaling of agro-ecological farm management practices (Pretty et al., 2018). Many such farmer organisations and social movements currently use the concept of agroecology as an overarching political framework to ascertain their rights and safeguard locally adapted small-scale farms (HLPE, 2019).

Recently, scientists assessed sustainable and ecological intensification initiatives worldwide and estimated that 29% of all farms are practicing some form of redesigned more sustainable systems on 9% of global agricultural land (Pretty et al., 2018). They concluded that adoption of sustainable systems may be on the brink of effecting a global transformation.

2.2 Organic agriculture

Organic belongs to both narratives, sustainable and ecological intensification. For annual and perennial horticultural crops, e.g. but also for maize (*Zea mays*) and rice (*Oryza sativa*) production, organic tends to be intensively managed and high yielding. It uses different input materials, such as organic fertilizers instead of chemical ones. Or, for plant protection biocontrol organisms, plant extracts (botanicals), mineral substances like lime or clay powders or simple chemical compounds like sulphur and copper instead of complex chemical-synthetic pesticides. For arable cropping systems, especially when they practice polyculture and mixed farming with animals, organic is an excellent example of ecological intensification. This also applies to organic agroforestry systems, as practised in tropical zones for cocoa (*Theobroma cacao*) and coffee (*Coffea arabica*) mixed with annual crops and with other perennial tree or bush crops. The good ecological and social performance of organic and agroecological farm practice is documented by a number of global meta-analyses (Pretty et al., 2018; Seufert and Ramankutty, 2017).

What is typical for organic agriculture, whether it is shaped by low or high external input, is a high degree of codification. The different organic standards regulate in all details what farmers can and cannot do. Important organic regulations are the European Union's organic regulation, the National Organic Programme (NOP) of the United States, the Chinese Organic Standard, the Japanese Organic Regulation (JAS Organic) and many others. Meanwhile, 84 state regulations exist around the globe, along with several hundred private standards linked with labels. For organic producers who want to enter remote and anonymous market places, third-party inspection and certification is crucial. As the market for organic food has become global, harmonization between the different private and state standards has become a great challenge, and the mutual acceptance of control and certification bodies remains a major obstacle.

In many European countries, organic farming has already reached a tipping point. It is becoming mainstream in the Alpine regions of Austria, Germany and Switzerland, where, in some areas, more than half of all farmers produce organically certified, and organic milk has become the standard. Producers have thus responded to the strong demand for such products. Worldwide, however, the organic share of total farmland is still small; currently, 1.5 percent farmland is organic. However, many countries have far higher organic shares area. The countries with the highest organic share of their total farmland are Liechtenstein (38.5%), Samoa (34.5%), and Austria (24.7%). In sixteen countries, 10% or more of all agricultural land is organic (Willer et al. 2020). A total of 71.5 million hectares were reported to be managed organically, which is a bit less than the total country area for Chile. In the decade 2009−2018, organic farmland has more than doubled. By country, Australia has the largest organic agricultural area (35.7 million hectares), followed by Argentina (3.6 million hectares), and China (3.1 million hectares).

Organic is a fast-growing market, and global retail sales reached almost 97 billion Euros in 2018. The United States was the leading market with 40.6 billion Euros, followed by Germany (10.9 billion Euros) and France (9.1 billion Euros). The European Union's market amounted to 37.4 billion Euros. In 2018, some major markets continued to show double-digit growth rates, and the French organic market grew by more than 15%. In the European Union overall, the market grew by 7.8% and in the United States by 5.5%. Danish and Swiss consumers spent the most on organic food (312 Euros per capita in 2018). Denmark had the highest organic market share worldwide, with 11.5% of its total food market being organic (Willer et al. 2020).

During the last months and fuelled by the CoVid 19 fears, the sales of organic food have grown by 30 percent in most European countries as the preference of consumers have changed towards locally grown and subjectively perceived safer foods. Complementarily, the political will to support with policy measure, the buying patterns of people has positively changed as well. A sign of this shift in social and political priorities is that the European Commission has set a new benchmark with 25 percent of the total agricultural land area earmarked for organic agriculture by 2030 (EU Commission, 2019).

3 Open research questions

The biggest challenge is certainly the inherent trade-off between productivity and 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, has pointed out that productivity could be doubled in regions where the hungry live 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 practices – represent an important first step towards intensification.

The question of the productivity of cultivation systems is highly complex. 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, frame their arguments within different time horizons, and ignore facts and figures that do not support their respective positions. The predominant opinion is that agricultural productivity has to automatically follow the growth of demand (Meemken and Qaim, 2018). In fact, this represents only outdated thinking in agricultural research and innovation: nitrogen fertilizers, 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. Therefore, the direct relation between productivity increase and consumption increase might lead to a dead end. It also ignores other factors of food insecurity, such as the poor management of world harvests, poverty, conflicts and natural disasters.

Nevertheless, it is important to mention that the FAO expects a food gap of 7400 trillion calories by 2050, which would call for an increase of production by 56 percent (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 percent conversion to organic farming, the global agricultural land may expand by 33 percent in addition to the scenario set out by the FAO (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). Therefore, eating less meat and reducing food waste effectively mitigate this productivity gap, and this is likely to represent the only realistic exit strategy in the long run. If this insight is finally integrated into policy development, then ecological intensification with agro-ecological and organic farming systems emerges as an excellent solution.

But here we should be cautious as well. A fairly likely scenario is that this kind of change in consumer behavior (the sufficiency narrative) will take several generations, and that prosperity in emerging countries will have exactly the opposite effect. While promising and innovative solutions can be found here and there, food losses and waste continue to grow. Ultimately, this is due to the tremendous scale of the challenge and the disruptive development of global society especially climate change, rural exodus, migration and pandemics. At the level of consumer choice, falling food prices encourage wastefulness due to a corresponding reduction in the perceived value of food. And the trend towards high meat diets and precooked and highly processed foods, although harmful to people's health through increased rates of obesity and heart diseases, will further grow.

Hence, society will continue to be caught in the productivity trap. On the one hand, more ecologically sound farm practices are crucial. On the other hand, productivity has to be kept stable or even growing. How do we meet this pressing challenge? What can research contribute? Indeed, does this call for a new research paradigm? Five examples will frame the ways forward.

3.1 Farm and field redesign

Farm redesign is key to tackling lower productivity without using more external input. There are various system-related solutions for this. For example, the typical agroecological techniques described above are already doubling yields in subsistence farming. This is because subsistence farmers often fail to use very simple techniques such as planting annual and perennial leguminous crops able to fix nitrogen from the air. The basics of crop rotation, pasture rotation, raising fewer but better fed grazing animals, and polyculture are not applied. Furthermore, in as many contexts as possible, a higher land equivalent ratio (LER) could be attained. Intercropping or polyculture is in any case the future solution here. 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 and coffee etc. In the scientific literature, polyculture has been reported to give yields 40 to 145 percent higher than sole cropping. Here, the highest increase has been achieved with ginger (*Zingiber officinale*), maize and soybean (*Glycine max*) polyculture in Nepal (Chapagain et al., 2018). In temperate climate zones, prevalent in Europe, 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 in temperate zones of Europe are barley and pea or oats (*Avena sativa*) and faba bean (*Vicia faba*). In addition to having a slightly higher LER, they improve nitrogen supply, soil fertility and soil physical stability, and they have an excellent weed suppression effect, reducing the need for mechanical weeding. Currently, mixed farming systems, mixed cropping cultivation and multilayer use of sunlight, water and temperature are the focus of a series of European Union funded research programs that bring together teams from different countries, integrating scientists, farmers and farm advisors. A number of these polyculture techniques are still traditional in some parts of the world. An example is provided by highly productive small-holder peasant farms in the Himalayan region which grow large cardamom (*Hornstedtia hainanensis*) in agroforestry settings, shaded by different tree species such as *Alnus nepalensis*, *Tremalia myrocarpa* or *Viburnus eruberens*. These additionally supply wood, fruits or spices.

Research can do a lot for the introduction of modern polyculture systems. On one hand, completely new combinations of different crops are to be sought. These can be modelled in knowledge of the population dynamics of pests and diseases as a function of host plant density and differently resistant or tolerant accompanying plants. Breeding for mixed crops should also be promoted, since crops for mixed cultivation must have completely different properties than for pure stands. Moreover, mixed crop cultivation can be optimized from the point of view of labour, thanks to precision farming. Farm economy and marketing channels are of great importance in the choice of mixed cropping systems.

3.2 Digitalization

Digitalization is a key technology for enabling highly diversified farms and fields. Improved precision farming systems can lead to a very efficient use of external inputs, such as pesticides and fertilizers. With further advances in robotics, GPS technology, remote sensing and hyperspectral image analysis, the speed of wireless data transmission, real-time data processing, and the precision of control intervention, highly diversified farms and fields become possible without bringing back farm laborers to rural areas. Digitalization increasingly offers opportunities to achieve the goals of agroecological and organic farming systems, representing a turning point in modern agriculture. For the first time, mechanization 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, to grow and level out fields, and to remove "disturbing" habitats is reversed, since the new mechanization can be adapted to a diverse, small-scale landscape and various local conditions. The next step in this technology will be physical interventions instead of chemical one. Weed or pest pickers are under development, and work on micro or even nano robots carrying out cleaning and repair on and in plants is underway. All kind of automatic separation processes on the field, during and after harvest and before processing will completely change the ways, farmers grow crops.

3.3 Breeding for low-input farm systems

A great potential for yield increase in organic and agroecological production also lies in breeding programs well-adapted to the conditions of low external input cultivation systems and farms. Highly important traits of the two systems under debate are increased resilience or tolerance to plant pests and disease. Equally important is the ability of plants to compensate for growth when the mineralization of organic fertilizers starts late and to 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 molecular markers very extensively to speed up breeding, and there is now also an intensive discussion about whether targeted mutagenesis with genome editing could here be an option, especially for sustainable farming systems where off-farm input is considerably reduced.

3.4 Circular economy with the example of recycled fertilizers

A circular economy is one of the foundations of sustainability. Circular economies integrate all aspects of our society: products, infrastructure, services, energy etc. They involve both technical resources and biological resources from all economic sectors. The basic principle of the circular economy is the 3Rs: reduce, reuse and recycle.

The concept of the circular economy is of course also essential in agriculture, especially in organic farming (Toop et al., 2017). Considering that agriculture in Europe produces 700 million tons of waste (Pawelczyk, 2005), the potential for optimization in this area is huge. Also in China, the development of a circular economy is a fundamental point for achieving sustainable agriculture (Jun and Xiang, 2011). Recycling organic waste through composting or anaerobic fermentation must therefore play a central role (Antoniou et al., 2019; Bekchanov and Mirzabaev, 2018). This is all the more important because it is not only a question of saving natural resources, but also because it prevents environmental pollution. Meanwhile, of course, the products resulting from composting can significantly improve soil fertility (Bekchanov and Mirzabaev, 2018).

One of the most important impacts of compost on soil fertility is the improvement of the soil organic matter (Tits et al., 2014). This plays an important role in the fertility of the soil, especially in the farm system without livestock. For this, it is also important to recycle by composting the crop residues and to reintroduce them into the system instead of burning them, as is still done in some regions. A second crucial effect is the potential of quality composts to protect plants from disease (Bonanomi et al., 2018; Noble and Coventry, 2005). This is what differentiates compost from other fertilizers. Another important aspect of sustainable organic waste management is that it reconnects urban and rural communities (Masullo, 2017). However, this also represents one of the important challenges of the system: how to motivate consumers to sort and collect their organic waste, and to do this properly so that the products collected are of a quality that allows them to be processed and returned to agriculture (Borrello et al., 2017).

To be successful, the recycling of organic waste cannot be improvised, but must be perfectly organized and carried out. Quality assurance systems adapted to each specific situation must be put in place, systems that include the entire chain from the collection of waste to the use of the resulting products (Fuchs et al., 2014). The concept of sorting and collecting organic waste is the first necessary condition for obtaining quality products, especially to avoid its contamination with undesirable materials such as plastic, which can cause significant problems in the environment (Weithmann et al., 2018). Additionally, the management of the composting process itself is obviously essential to obtain a quality product that improves soil fertility and promotes plant growth (Azim et al., 2018; Fuchs, 2010). Finally, the choice of compost and its application is also important, as different crops and soil types have different needs.

If carried out according to best practice, the recycling of organic waste by composting has many advantages for agriculture (Pergola et al., 2018; Masullo, 2017): carbon sequestration, reduction of chemicals inputs, reduction of water irrigation need, decrease of production costs and of negative environmental impact. For all these reasons, the recycling of organic remains, whether they come from crop residues or from the sorting of consumer waste, must be one of the foundations of sustainable agriculture. The benefits are economic, environmental and agronomic, manifesting the value of the circular economy.

3.5 Improved inputs especially for plant health

The standard of plant protection renders a huge difference in crop yields. This is the case in conventional agriculture where this is mainly achieved with chemical pesticides. But insufficient disease and pest control is also a major reason for lower yields on organic and agroecological farms. According to global meta-analyses, yield loss due to harmful organisms is estimated to be between 17% and 40% (Savary et al., 2019).

The great challenge for research will be to find promising alternatives to chemical pesticides. In organic and agroecological production systems, alternatives that have been explored include wide crop rotations in order to slow down the population growth and spread of pest and diseases. The same effect can be achieved with polyculture cropping. Resistance breeding is another approach. And finally, non-chemical direct control measures with biocontrol organisms, compounds, and plant extracts (botanicals). Many of these techniques are successfully used in greenhouse cultivation but also become applied in outdoor farming systems. An example is the control of the European corn borer by the Trichogramma wasp. Thanks to new application techniques using drones, this method can also be used on very large farms (Filho et al. 2020).

Meanwhile, half of all new registration of pesticides in the European Union are products for biocontrol, plant extracts, or other techniques that are accepted in organic farming (Koch et al., 2019). The development of non-chemical pesticides is a log and expensive process, from basic research to testing under practical conditions, to formulation for spraying, and finally for registration with the necessary human and ecotoxicological data. As such, this research cannot be completely delegated to industry as their economic interest has not yet been sufficiently triggered.

4 Conclusions for China

Organic farming has a potential for Chinese agriculture. It reduces significantly the amount of off-farm input such as nitrogen fertilizers, herbicides and pesticides which is good for the environment. To the same extend, residues of chemical pesticides in foods do not occur. It adds value to agriculture and food production, whether in domestic markets or exports. Yet, the practice of organic agriculture needs to become adapted the many different site conditions and therefore needs to be supported by innovative research. The goal of research is to increase the productivity of organic agriculture while not loosing its environmental benefits. Agroecology which is a farming concept with less detailed regulations and bans on technology might be a second option for China to render food production more sustainable and to reduce the negative externalities and the pollution.

References

ALEXANDRATOS N, BRUINSMA J. 2012. World agriculture towards 2030/2050: the 2012 revision[R]. FAO, Rome

ALTIERI M A, FARRELL J G, HECHT S B, et al. 1996. Agroecology: the Science of Sustainable Agriculture[M]. 2nd ed. Westview Press. Boulder, USA

ANTONIOU N, MONLAU F, SAMBUSITI C, et al. 2019. Contribution to Circular Economy options of mixed agricultural wastes management: Coupling anaerobic digestion with gasification for enhanced energy and material recovery[J]. Journal of Cleaner Production, 209: 505–514

ARMENGOT L, BARBIERI P, ANDRES C, et al. 2016. Cacao agroforestry systems have higher return on labor compared to full-sun monocultures[J]. Agronomy for Sustainable Development, 36(4): 70

AZIM K, SOUDI B, BOUKHARI S, et al. 2018. Composting parameters and compost quality: a literature review[J]. Organic agriculture, 8(2): 141–158

BEKCHANOV M, MIRZABAEV A. 2018. Circular economy of composting in Sri Lanka: Opportunities and challenges for reducing waste related pollution and improving soil health[J]. Journal of Cleaner Production, 202: 1107–1119

BONANOMI G, LORITO M, VINALE F, et al. 2018. Organic amendments, beneficial microbes, and soil microbiota: toward a unified framework for disease suppression[J]. Annual Review of Phytopathology, 56: 1–20

BORRELLO M, CARACCIOLO F, LOMBARDI A, et al. 2017. Consumers' perspective on circular economy strategy for reducing food waste[J]. Sustainability, 9(1): 141

BURNEY J A, DAVIS S J, LOBELL D B. 2010. Greenhouse gas mitigation by agricultural intensification[J]. Proceedings of the National Academy of Sciences of the United States of America, 107(26): 12052–12057

CHAPAGAIN T, PUDASAINI R, GHIMIRE B, et al. 2018. Intercropping of maize, millet, mustard, wheat and ginger increased land productivity and potential economic returns for smallholder terrace farmers in Nepal[J]. Field Crops Research, 227: 91–101

DE SCHUTTER O. 2010. Report submitted by the Special Rapporteur on the right of food, Oliver de Schutter[R/OL]. (2020-12-17). https://www2.ohchr.org/english/issues/food/docs/a-hrc-16–49.pdf

European Commission. 2019. A European Green Deal[EB/OL]. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

FAO. 2018. FAO's Work on Agroecology – A Pathway to Achieving the SDGs[R/OL]. http://www.fao.org/3/i9021en/I9021EN.pdf

FILHO F H I, HELDENS W B, KONG Z D, et al. 2020. Drones: Innovative technology for use in precision pest management[J]. Journal of Economic Entomology, 113(1): 1–25

FUCHS J F, BERNER A, MAYER J, et al. 2014. Concept for quality management to secure the benefits of compost use for soil and plants[J]. Acta Horticulture, 1018: 603–609

FUCHS J. 2010. Interactions between beneficial and harmful microorganisms: from the composting process to compost application[M]//INSAM H, FRANKE-WHITTLE I, GOBERNA M, eds. Microbes at Work: From Wastes to Resources. Berlin Heidelberg: Springer-Verlag, 213–229

GARNETT T, APPLEBY M C, BALMFORD A, et al. 2013. Sustainable intensification in agriculture: Premises and policies[J]. Science, 341(6141): 33–34

GLIESSMAN S R. 2006. Agroecology: the Ecology of Sustainable Food Systems[M]. 3rd ed. CRC Press, Taylor & Francis Group. London & New York

HLPE, 2019. Agroecological and Other Innovative Approaches for Sustainable Agriculture and Food Systems that Enhance Food Security and Nutrition[R]. Rome

JUN H, XIANG H. 2011. Development of circular economy is a fundamental way to achieve agriculture sustainable development in China[J]. Energy Procedia, 5: 1530–1534

KOCH E, HERZ A, KLEESPIES R G, et al. 2019. Statusbericht Biologsicher Pflanzenschutz 2018[R]. Julius Kühn-Institut (JKI), Bundesforschungsinstitut für Kulturpflanzen, Institut für Biologischen Pflanzenschutz, Quedlinburg

LA VIA CAMPESINA. 2018. Report of the 7th Conference[R/OL]. https://viacampesina.org/en

MASULLO A. 2017. Organic wastes management in a circular economy approach: Rebuilding the link between urban and rural areas[J]. Ecological Engineering, 101: 84–90

MEEMKEN E-M, QAIM M. 2018. Organic agriculture, food security, and the environment[J]. Annual Review of Resource Economics, 10: 39–63

MÜLLER A, SCHADER C, SCIALABBA N E H, et al. 2017. Strategies for feeding the world more sustainably with organic agriculture[J]. Nature Communications, 8: 1290

NIGGLI U. 2015. Incorporating agroecology into organic research-an ongoing challenge[J]. Sustainable Agriculture Research, 4(3): 149–157

NOBLE R, COVENTRY E. 2005. Suppression of soil-borne plant diseases with composts: A review[J]. Biocontrol Science and Technology, 15: 3–20

OECD. 2003. Glossary of Statistical Terms[R/OL]. https://stats.oecd.org/glossary/detail.asp?ID=81

PARMENTIER S. 2014. Scaling-up Agroecological Approaches: What, Why and How?[R]. Oxfam-Solidarity, Belgium

PAWELCZYK A. 2005. EU policy and legislation on recycling of organic waste to agriculture[J]. International Society for Animal Hygiene, 1: 64–71

PERGOLA M, PERSIANI A, PALESE A M, et al. 2018. Composting: The way for a sustainable agriculture[J]. Applied Soil Ecology, 123: 744–750

PRETTY J, BENTON T G, BHARUCHA Z P, et al. 2018. Global assessment for agricultural system redesign for sustainable intensification[J]. Nature Sustainability, 1(8): 441–446
ROSSET P M, SOSA B M, ROQUE JAIME A M, et al. 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty[J]. The Journal of PEASANT STUDIES, 38(1): 161–191
SAVARY S, WILLOCQUET L, PETHYBRIDGE S J, et al. 2019. The global burden of pathogens and pests on major food crops[J]. Nature Ecology & Evolution: 3(3): 430–439
SCHADER C, MULLER A, SCIALABBA N E, et al. 2015. Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability[J]. Journal of the Royal Society Interface, 12(113): 1–12
SEUFERT V, RAMANKUTTY N. 2017. Many shades of gray — The context-dependent performance of organic agriculture[J]. Science Advances, 3(3): e1602638
STEFFEN W, RICHARDSON K, ROCKSTRÖM J, et al. 2015. Planetary boundaries: Guiding human development on a changing planet[J]. Science, 347(6223):1259855
TISCHLER W. 1965. Agrarökologie[M]. Jena, Germany: Gustav Fischer Verlag, 499
TITS M, ELSEN A, BRIES J, et al. 2014. Short-term and long-term effects of vegetable, fruit and garden waste compost applications in an arable crop rotation in Flanders[J]. Plant and Soil, 376: 43–59
TITTONELL P. 2014. Ecological intensification of agriculture — sustainable by nature[J]. Current Opinion in Environmental Sustainability, 8: 53–61
TOOP T A, WARD S, OLDFIELD T, et al. 2017. AgroCycle — developing a circular economy in agriculture[J]. Energy Procedia, 123: 76–80
TWN, SOCLA. 2015. Agroecology: Key Concepts, Principles and Practices[R/OL]. SOCLA, Berkeley, USA. https://foodfirst.org/agroecology-key-concepts-principles-and-practices/
WEITHMANN N, MÖLLER J N, LÖDER M G J, et al. 2018. Organic fertilizer as a vehicle for the entry of microplastic into the environment[J]. Science Advances, 4(4): eaap8060
WEZEL A, BELLON S, DORÉ T, et al. 2009. Agroecology as a science, a movement and a practice. A review[J]. Agronomy for Sustainable Development, 29(4): 503–515
WILLER H, SCHLATTER B, TRÁVNÍČEK J, et al. 2020. The World of Organic Agriculture Statistics and Emerging Trends 2020[M/OL]. https://www.fibl.org/fileadmin/documents/shop/5011-organic-world-2020.pdf