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REVIEW ARTICLE

Converging and diverging principles and practices of organic agriculture regulations and agroecology. A review

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Abstract There is ongoing debate among stakeholders about the future development of agricultural and food systems to meet the global challenges of food supply, biological and cultural diversity, climate change, and social justice. Among other options, agroecology and organic agriculture are discussed. Both have similar goals and use a systems approach; however, they are recognised and received differently by stakeholders. Here we review and compare principles and practices defined and described in EU organic agriculture regulations, International Federation of Organic Agricultural Movement (IFOAM) norms, and agroecology scientific literature. The main finding are as follows: (1) Regarding principles, EU organic regulations mainly focus on appropriate design and management of biological processes based on ecological systems, restriction of external inputs, and strict limitation of chemical inputs. IFOAM principles are very broad and more complete, and include a holistic and systemic vision of sustainability. Agroecology has a defined set of principles for the ecological management of agri-food systems, which also includes some socio-economic principles. (2) Many proposed cropping practices are similar for EU organic, IFOAM, and agroecology, e.g. soil tillage, soil fertility and fertilisation, crop and cultivar choice, crop rotation, as well as pest, disease and weed management. In contrast, the origin and quantity of products potentially used for soil fertilisation and pest, disease, and weed management are different. Additionally, some practices are only mentioned for one of the three sources. (3) In animal production, only a few proposed practices are similar for EU organic, IFOAM, and agroecology. These include integration of cropping and animal systems and breed choice. In contrast, practices for animal management, prevention methods in animal health, animal housing, animal welfare, animal nutrition, and veterinary management are defined or described differently. (4) Related to food systems, organic agriculture focusses on technical aspects, such as food processing, while in agroecology there is a prominent debate between a transformative and conformative agenda. Both agroecology and organic agriculture offer promising contributions for the future development of sustainable agricultural production and food systems, especially if their principles and practices converge to a transformative approach and that impedes the conventionalisation of agro-food systems.

Keywords Agroecological practices · Animal production practices · Food system · Sustainable cropping practices · Organic farming

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Content

1 Introduction

There is ongoing debate among scientists, policy makers, and other stakeholders about the future scenario and development of local, national, and global food systems. The main challenges are to provide enough food for the growing world population, reduce food waste, increase healthy diets and food consumption, conserve natural resources, mitigate and adapt to climate change, and eliminate social injustice and cultural erosion, i.e. the loss of traditional knowledge (Kodirekkala 2017). Although we urgently need to change most farming systems, different approaches are proposed by the different stakeholder groups (Fig. 1).

On one side, there is the approach that increasingly relies on technology, such as precision farming, automatisation/mechanisation, and the use of genetically modified (GM) crops. On the other side are the more ecologically based or traditional farming systems. Since the first year of commercial planting of biotech crops in 1996, more than 60 countries from all over the world have either planted or imported biotech crops (Clive 2016). In 2015, 18 million farmers planted biotech crops in 28 countries on 179 million hectares. Precision farming has also strongly expanded in the last decade by using GPS and big-data technology. However, the more ecologically based systems have also expanded in the last decades: organic agriculture has been gaining popularity all over the world and traditional family farming, mainly in the tropics and subtropics, is still the backbone of world food production. Moreover, within classical conventional agriculture, ecological elements and the better use of ecological processes are proposed more and more often under the paradigm of sustainable or ecological intensification (Wezel et al. 2015).

The UN Special Rapporteur on the Right to Food (De Schutter 2011) asserts that agroecology can play an important role in finding solutions for the above challenges. Also, another international authority (IAASTD 2009) states that agroecological methods are already available and used, and that smallholder farmers in the world, which make up 80% of the total farm numbers and produce over 50% of the world's food on 20% of agricultural land, could double food production within 10 years in food-insecure areas of the planet.

Currently, agroecological farming is not market-driven: no certification systems nor labels exist so far for the produce, it

Fig. 1 Connecting livestock production, cropping and forestry with an agroecological approach, western France (Photo A. Wezel)

is not yet uniquely defined, and clear entry thresholds are absent, e.g. origin and amount of inputs (organic or chemical).

In contrast, organic farming has clear and rigorous regulations and restrictions (e.g. no synthetic pesticides and fertilisers, processing aids and additives, no genetically modified organisms or products), and farms lose certification and access to markets when they violate the regulations (Niggli 2015). Today, the demand for organic products is constantly increasing and is no longer a niche segment, although it still represents a low percentage share of the global market. Organic farming is a response to the global need for more sustainable farming practices, and is one of the so-called alternative forms of agriculture, e.g. natural agriculture (Fukuoka and Fukuoka 1978), permaculture (Ferguson and Lovell 2014; Mollison 1988), and biodynamic agriculture (Steiner et al. 2005). The organic agriculture label is the only one, together with the Demeter label, that identifies biodynamic products, that implies a system of control and certification, and that it is recognised worldwide.

The history of organic agriculture reaches back to the early twentieth century. It was one of the first social movements in agriculture, food, and nutrition and has strong roots in the paradigm shift in agriculture in Europe and USA (Beus and Dunlap 1991). In the pioneer phase of organic agriculture, the connection between farmer and consumer was very close. There were few regulations and little to no codification of practices except for the concepts and guidance provided by the movement's leaders, such as Rudolf Steiner in Austria and Germany, Sir Albert Howard and Lady Eve Balfour in UK, Hans and Maria Muller and Peter Rush in Switzerland, Jerome Irving Rodale in USA, and Alfonso Draghetti and Francesco Garofalo in Italy (Vazzana and Migliorini 2009). In the early 1970s, there was the establishment of International Federation of Organic Movement (IFOAM) and farmer-based organisations in Europe (Soil Association in UK, Suolo e Salute in Italy, l'Association Française d'Agriculture Biologique in France). Since the 1990s, the organic sector has followed the ISO model (International Organization for Standardization) for third-party certification and accreditation to assert its credibility in the market. The global market for organic food in 2014 has reached more than 60 billion euros, with the leading countries being the USA (27.1 million ha), Germany (7.9), France (4.8), and China (3.7). Worldwide there are 2.3 million organic producers using a total of 43.7 million hectares (Willer and Lernoud 2016). However, organic agriculture has been facing substantial challenges and criticism over recent years. Despite its acknowledged successes, it remains a small sector compared to global agricultural production (only 1%). However, as with conventional farming, organic farming is not a monolithic category and huge differences exist among organic production systems that still fall within the organic agriculture regulation: from multifunctional, small-scale farms rich in all kind of diversity to globally standardised and business-oriented industries for supermarkets and the export with mainly input substitution-based methods.

When speaking about ecologically based agriculture, agroecology is increasingly mentioned and recognised, and there are currently big discussions on similarities and on diverging principles and practices. Agroecology was firstly mentioned in the 1930s, but before the 1980s it did not have a specific definition (Wezel and Soldat 2009). While research began to study several traditional agroecosystems, in particular in the tropics and subtropics, agroecology started to grow and include a broad variety of topics, though up until the 2000s it still did not include the study of food systems (Wezel et al. 2009; Wezel and Soldat 2009). But finally, since 2000s onwards, the food systems dimension has been included (FAO 2016; Francis et al. 2003; Gliessman 2014; Wezel and David 2012). Agroecology is also more and more recognised as a social or political movement, represented by organisations and individuals that expose existing conflicts in society by proposing political and social change.

For several authors, agroecology cannot be restricted to a number of practices that can be standardised. Rather, agroecology is a fully systemic approach to sustainability, addressing a transformative process of the entire food system, including its perspectives on equity, justice, and access. The transformative process implies the redesign of the food system and the integration of both horizontal and vertical diversification of production systems within sustainable food systems (Gliessman 2014).

2 Materials and methods

In the present paper, we focus on organic agriculture and agroecology. We first provide an overview about the main characteristics of regulations, norms, and definitions of organic farming and agroecology. We then analyse the official regulations on organic agriculture in Europe (EC 2007; EC 2008) and vision, principles, and norms of the IFOAM (2014) and compare them with those of agroecology in scientific literature (Altieri 1995; Altieri and Nicolls 2005; Dumont et al. 2013; Gliessman 1997, 2014; Nicolls and Altieri 2016). A second comparison is carried out between organic practices and proposed agroecological practices for cropping and grass-based livestock systems in scientific literature (Peeters and Wezel 2017; Wezel et al. 2014; Wezel and Peeters 2014). Finally, we work out differences and similarities between the principles and practices, and also discuss food-related issues and current developments in organic agriculture and agroecology with regard to regulations and policies.

3 Regulations, norms, and definitions

3.1 European organic regulation

In Europe, the term "organic" on labels for food, feed, and seeds is legally governed by strict regulations and defines precise farming and processing techniques. The EU Council Regulation (EC 2007) No 834/2007 on organic production and labelling of organic products and the repealing Regulation (EEC) No 2092/91 define Organic Agriculture (art 1) as following: "*Organic production is an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes. The organic production method thus plays a dual societal role, where it on the one hand provides for a specific market responding to a consumer demand for organic products, and on the other hand delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development*." Specific codes of production are described in the EC Regulation 889/2008 of the European Commission (EC 2008), which lay down detailed rules for the implementation of Council Regulation N 834/2007 on organic production and labelling of organic products with regard to organic production, labelling, and control.

3.2 IFOAM

Another definition of organic agriculture is declared by IFOAM (2005): "*Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved*."

The IFOAM norms (IFOAM 2014) are composed of three documents: (i) Common Objectives and Requirements of Organic Standards (COROS)—IFOAM Standards Requirements, (ii) IFOAM Standard for Organic Production and Processing, and (iii) IFOAM Accreditation Requirements for Bodies Certifying Organic Production and Processing. The norms are based on a number of principles as given in the introduction of the standards (IFOAM 2007). The standard sections are formulated for organic ecosystems, crop production and animal husbandry, aquaculture, processing and handling, labelling, and social justice, and they include the definitions, the specific principles, the recommendations, and the standards, considered as minimum requirements.

3.3 Agroecology

Currently, agroecology can be interpreted as a movement, as a scientific discipline, and also as a set of practices (Wezel et al. 2009). Different institutions and countries provide now definitions for agroecology (FAO 2017a). As a science, common definitions that are used are: (i) *the integrative study of the ecology of the entire food systems, encompassing ecological, economic, and social dimensions* (Francis et al. 2003), and (ii) *the application of ecological concepts and principles to the design and management of sustainable food systems* (Gliessman 1997). As a set of agricultural practices, agroecology seeks to improve agricultural systems by imitating natural processes, creating beneficial biological interactions and synergies among the components of the agroecosystems (Gliessman 1990), and valorising ecological processes and ecosystem services for the development and implementation of agroecological practices (Wezel et al. 2014). Moreover, agroecology is also seen as a transdisciplinary, participatory, and action-oriented approach (Méndez et al. 2013). As a movement, agroecology is seen as the answer to how to transform and repair the material reality in a food system and rural world that has been devastated by industrial food production and its so-called Green and Blue Revolutions. The diverse forms of smallholder food production based on agroecology generate local knowledge, promote social justice, nurture identity and culture, and strengthen the economic viability of rural areas. Agroecology is seen as a real solution to modern crises (climate, malnutrition, etc.), not conforming to the industrial model but rather transforming it by building local food systems that create new rural-urban links, based on truly agroecological food production (Via Campesina 2015).

The Association of Agroecology Europe outlines agroecology as the following (www.agroecology-europe.org): "*Agroecology is considered jointly as a science, a practice and a social movement. It encompasses the whole food system from the soil to the organisation of human societies. It is value-laden and based on core principles. As a science, it gives priority to action research, holistic and participatory approaches, and transdisciplinarity including different knowledge systems. As a practice, it is based on sustainable use of local renewable resources, local farmers' knowledge and priorities, wise use of biodiversity to provide ecosystem services and resilience, and solutions that provide multiple benefits (environmental, economic, social) from local to global. As a movement, it defends smallholders and family farming, farmers and rural communities, food sovereignty, local and short marketing chains, diversity of indigenous seeds and breeds, healthy and quality food*."

4 Principles in organic agriculture and agroecology

The first aspects to be confronted are the principles of organic farming (EU and IFOAM) and agroecology (Table 1).

Table 1 Principles of organic farming and agroecology

Organic agriculture EU regulation (EC 2007, Article 4—Overall principles)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Nicolls and Altieri 2016, Gliessman 1997, 2014; adapted and further developed from Reijntjes et al. 1992, Altieri 1995 and Altieri and Nicolls 2005; Stassart et al. 2012, Dumont et al. 2013, Dumont et al. 2016)
Organic production shall be based on the following principles: (a) the appropriate design and management of biological processes based on ecological systems using natural resources which are internal to the system (…..); (b) the restriction of the use of external inputs. (….); (c) the strict limitation of the use of chemically synthesised inputs to exceptional cases (….); (d) the adaptation, where necessary, and within the framework of this Regulation, of the rules of organic production taking account of sanitary status, regional differences in climate and local conditions, stages of development and specific husbandry practices.	General principles of organic agriculture: these principles are the roots from which Organic Agriculture grows and develops. They express the contribution that Organic Agriculture can make to the world. Composed as inter-connected ethical principles to inspire the organic movement—in its full diversity, they guide our development of positions, programs and standards. • Health: Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. • Ecology: Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. • Fairness: Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. • Care: Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.	General principles of agroecology: • Enhance the recycling of biomass, with a view to optimising organic matter decomposition and nutrient cycling over time • Strengthen the "immune system" of agricultural systems through enhancement of functional biodiversity—natural enemies, antagonists, etc., by creating appropriate habitats • Provide the most favourable soil conditions for plant growth, particularly by managing organic matter and by enhancing soil biological activity • Minimise losses of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity • Diversify species and genetic resources in the agroecosystem over time and space at the field and landscape level • Enhance beneficial biological interactions and synergies among the components of agrobiodiversity, thereby promoting key ecological processes and services Principles for animal production systems: • adopting management practices aiming to improve animal health • decreasing the inputs needed for production, • decreasing pollution by optimising the metabolic functioning of farming systems • enhancing diversity within animal production systems to strengthen their resilience • preserving biological diversity in agroecosystems by adapting management practices Socio-economic principles for agroecology: • create collective knowledge and coping ability • foster farmers' independence from the market • recognise the value of a diversity of knowledge and know-how

Principles should guide the movement and also help in the application of the practices. The EU regulations on organic farming (EC 2007) have a specific article on Overall Principles (Article 4) that include four sub-paragraphs. Those four principles refer mainly to ecological aspects of sustainability focusing on ecological systems, restriction of external inputs, limitation of chemical inputs, and adaptation to local conditions.

In a process of several decades, the international organic community, organised by IFOAM, agreed on a common understanding on what the principles of organic agriculture are. Since 2007 those principles are included in the IFOAM Norms (IFOAM 2014) with the four major principles on health, ecology, fairness, and care (Table 1). Health refers to healthy soil, plants, animals, humans for a healthy planet; Ecology is emulating and sustaining natural systems; Fairness refers to the equity, respect and justice for all living things; and Care for the generations to come.

Regarding agroecology, different principles can be mentioned (Table 1). Modern agroecosystems require systemic change, but newly redesigned farming systems will not emerge from simply implementing a set of practices, but rather from the application of agroecological principles (Nicolls and Altieri 2016), referring to the promotion of ecological processes and services, including soil, water, air, and biodiversity aspects. The different principles include (i) recycling of biomass, (ii) enhancement of functional biodiversity, (iii) provision of favourable soil conditions for plant growth, (iv)

minimisation of losses, (v) diversification of species and genetic resources in the agroecosystem, and (iv) enhancement of beneficial biological interactions and synergies.

For agroecological animal systems, Dumont et al. (2013) add to the above-mentioned principles two more specific animal production principles: (i) adopting management practices aiming to improve animal health, and (ii) enhancing diversity within animal production systems to strengthen their resilience.

To the more production- and ecology-related principles, Stassart et al. (2012) and Dumont et al. (2016) further add three socio-economic principles for agroecology: creation of collective knowledge, independence from the market, and diversity of knowledge and know-how.

5 Practices in organic agriculture and agroecology

5.1 Crop production

To make a comparison between the description of crop production practices in EU regulations, IFOAM norms, and agroecology, we define nine categories, because no common categories exist for the three sources (Table 2): 1. Soil tillage; 2. Soil fertility and Fertilisation; 3. Crop and cultivar choice; 4. Crop rotation; 5. Intercropping; 6. Management of landscape elements and habitats; 7. Pest, disease and weed management; 8. Water quantity and quality; and 9. Agroforestry.

1. Soil is considered a living organism in all three sources, thus farmers should take this into account in managing it, e.g. soil tillage. Both the organic and agroecology practices strongly emphasise the importance to use appropriate soil tillage and cultivation practices to conserve or to increase soil organic matter, soil stability, and soil biodiversity, and to protect against soil erosion and compaction. Agroecology specifies the use of no tillage with direct seeding and superficial tillage.
2. Soil fertility and fertilisation practices are quite similar as described by organic EU and IFOAM: both consider as fundamental crop rotation with leguminous crops and the return of organic materials, preferably composted, to the soil. In addition, IFOAM specifies that the organic material should come from the farm or from local origin. The same can be found in organic EU, inside the animal section that refer to exchanging organic material in cooperation with other organic farms in the region. In both organic regulations, organic external materials can be added, but only if needed and if included in the list in the annex. Only organic EU specifies a maximum amount of nitrogen derived from livestock manure (170 kg per year per hectare). IFOAM does not allow the burning of vegetation and instead stresses the importance of soil cover. Agroecological fertilisation practices can include both organic and chemical inputs, but no indication of maximum amounts, type, and source are provided. More explicitly, split fertilisation and use of biofertiliser are mentioned.
3. Regarding crop and cultivar choice, both organic and agroecological practices call for the use of species and varieties that are locally adapted and resistant to pest and disease. In addition, organic agriculture requires organic seed origin (in the EU it is a strict obligation while in IFOAM it is a preference) and prohibits the use of GMO seeds.
4. The crop rotation practices are quite similar and include the cultivation of leguminous cover crops and green manure crops for diversified rotations.
5. Intercropping, the coexistence of two or more crops on the same field at the same time, is not mentioned in the organic EU regulation. In IFOAM, intercropping is mentioned in some IFOAM norms, but no specific definition is given, while two types of intercropping exist under agroecology (Fig. 2).
6. The management of landscape elements and habitats is not mentioned explicitly in the organic EU regulation, but it is indirectly linked to habitat development as the precautionary measures to be taken in order to reduce the risk of contamination. In IFOAM norms and in agroecology, it is specifically described as maintaining or establishing landscape elements or ecological infrastructure.
7. Pest, disease, and weed control practices are quite similar in organic and agroecology management systems, including several prevention practices and indirect methods (species and varieties choice; crop rotation, intercropping, and companion plant; cultivation technique, provision of favourable habitat for natural enemies) as well as direct controlling practices (release of predators and parasites, mulching, traps; trap crops or push-pull strategies). In contrast, the use of products for crop protection is described differently. In organic EU, only products from the annex list can be used. IFOAM distinguishes between on-farm preparations (plant, mineral, micro-organism) that are allowed, and external inputs that can be chosen only from the annex list. Agroecology also proposes the use of pesticides derived from plants or plant extracts.
8. Regarding management practices for water quantity and quality, EU regulation enounces the principle of the responsible use of this resource, imposing the practice of limiting the amount of livestock units and nitrogen inputs per hectares. The IFOAM norms indicate that farmers should preserve water quality and to monitor water extraction, thus encouraging the practice of recycling rainwater. Agroecology mentions the use of drip irrigation, as well as cover crops and intercropping, to reduce nutrient leaching.
9. Agroforestry is not mentioned in the organic regulations and norms, while it is described in agroecology as intercropping with crops and rows of woody vegetation, or establishing fruit tree meadows or pastures.

Table 2 Description in EU regulations and IFOAM norms concerning crop production practices in organic agriculture compared to agroecological practices

Category of practices	Organic agriculture EU regulation (EC 2007; EC 2008)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Wezel et al. 2014)
1. Soil tillage	Use tillage and cultivation practices that maintain or increase soil organic matter, enhance soil stability and soil biodiversity, and prevent soil compaction and soil erosion.	Take measures to prevent erosion and minimise loss of topsoil such as minimal tillage, contour ploughing, maintenance of soil plant cover.	No tillage with direct seeding: planting of crops directly in preceding cover crop (living or destroyed) or crop residues. Use of superficial tillage without soil inversion.
2. Soil fertility and fertilisation	Use of multiannual crop rotation including legumes and other green manure crops, and by the application of livestock manure or organic material, both preferably composted. Only fertilisers and soil conditioners referred to in Annex I may be used and only to the extent necessary. Mineral nitrogen fertilisers shall not be used. The total amount of livestock manure may not exceed 170 kg N per year/hectare.	Return microbial, plant or animal material to the soil to increase or at least maintain its fertility and biological activity with green manure, compost or mulch (organically produced on the farm, obtained from the surrounding farms or natural environment or from other inputs allowed under In appendix: Other techniques can be crop rotation, use of nitrogen fixation plants. Restrict land preparation by burning vegetation. No use of sodium (chilean) nitrate, of synthetic fertilisers or fertilisers made soluble by chemical methods, e.g. superphosphates.	Split fertilisation: fertiliser application (chemical and organic) with several operations Biofertiliser: application of living microorganisms to seed, plant surfaces, or soil Organic fertilisation: Application of exclusively organic or mixed with inorganic fertilisation.
3. Crop and cultivar choice	Choice of appropriate species and varieties resistant to pests and disease. Only organically produced seed and propagating material. Use of non-organic may authorise if not available from organic production. Prohibition of genetic engineering and its products.	Selection of species and varieties adapted to the local soil and climatic conditions and tolerance to pests and diseases. Give preference to organically bred varieties, when available. Prohibition of genetic engineering and its products.	Use of resistant crops to biotic and abiotic stresses (and mixing them) or crops with selected traits that enhance rhizosphere activities.
4. Crop rotation (including cover crops and green manure)	Multiannual crop rotation including legumes and other green manure crops.	Alternating the species or families of annual and/or biennial crops grown on a specific field in a planned pattern or sequence. Crop rotations shall be diverse and include soil improving plants such as green manure, legumes or deep rooting plants.	Integration of different crops in rotations (including cover crops).
5. Intercropping	Not mentioned	No specific description. The term intercropping is mentioned in the following sections of the Norms: organic crop production management; pest and disease and weed management.	Intercropping: coexistence of two or more crops on the same field at the same time. Relay intercropping: undersowing of relay crops in already existing crop.
6. Management of landscape elements and habitats	Not mentioned but indirect link to habitat development (natural barrier) as precautionary measures to be taken in order to reduce the risk of contamination by unauthorised products or substances by conventional neighbour	Maintain and improve landscape and enhance biodiversity quality, by maintaining on-farm wildlife, refuge habitats or establishing them where none existing (e.g. extensive grassland, hedgerows, field margins; pools and ditches).	Planting and management of vegetation strips and hedges in fields and at field borders. Management of hedges, vegetation strips and other landscape elements at territory scale.
7. Pest disease and weed management	Prevention and indirect: pests, diseases and weeds shall rely primarily on the protection by natural enemies, the choice of species and varieties, crop rotation, cultivation techniques and thermal processes.	Prevention and indirect: species and varieties choice; crop rotation, intercropping and companion plant; provision of favourable habitat for natural enemies.	Prevention and indirect: cultivar choice; crop otation, intercropping and cover crops; reduced tillage; direct seeding.

Table 2 (continued)

Category of practices	Organic agriculture EU regulation (EC 2007; EC 2008)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Wezel et al. 2014)
	Direct: certain plant protection products can be used as referred to Annex II of Regulation.	Direct: release of predators and parasites, mulching, traps; on-farm preparations (plant, mineral, micro-organism). When these measures are not sufficient, pest, disease and weed management substances permitted may be used from Appendix 3.	Direct: control of weeds, pests and diseases based on introduction of natural enemies, pheromones, pesticides derived from plants or plant extracts, integration of allelopathic plants in crop rotation; trap crops or push-pull strategies.
8. Water quantity and quality management practices	Use responsibly water. In order to avoid environmental pollution of natural resources such as soil and water by nutrients, an upper limit for the use of manure per hectare and for keeping livestock per hectare should be set. This limit should be related to the nitrogen content of the manure.	Prevent or remedy soil and water salinisation, nor excessively exploit water resources and preserve water quality and possible recycle rainwater and monitor water extraction.	Use of drip irrigation (without or in combination with cover crops or mulch). Use of cover crops or intercropping to reduce nutrient leaching.
9. Agroforestry	Not mentioned	Not mentioned	Alley intercropping with crops and rows of woody vegetation. Scattered fruit trees in meadows or pastures.

5.2 Animal production

For animal-related practices, we distinguish seven categories (Table 3): 1. Integration of cropping and animal systems; 2. Animal management; 3. Breed choice; 4. Animal housing; 5. Animal welfare; 6. Animal nutrition; and 7. Veterinary management.

1. Integration of cropping and animal systems is included in both organic and agroecology practices as a way to have a holistic approach and close the cycle of organic matter and nutrients. Only organic EU regulations impose a maximum number of animals per hectare in an annex.
2. In the organic EU and IFOAM regulations, animal management is based on access to open air or grazing areas, whereas it is not specifically mentioned under agroecology. For all three approaches, different animal health prevention methods are recommended or required.
3. The indications for breed choice are quite similar in the two organic regulations and agroecology, giving preference to indigenous breeds adapted to local condition avoiding hyper-specialisation.
4. The animal housing aspect is defined and described in detail in the EU regulation, taking into account the behavioural needs of the animals and also imposing the minimum surface for indoor and outdoor areas, and other characteristics of housing for different species and categories of animals as mammals, poultry, and beekeeping. The IFOAM norms similarly take into consideration animal welfare, but no minimum requirements are proposed. In agroecology, there are not specifications for animal housing.
5. Animal welfare is considered a priority for organic agriculture, and in EU regulation it goes beyond community welfare standards, which apply to farming in general. IFOAM norms requested specific animal welfare conditions. In agroecology, the maintenance or establishment of semi-natural landscape elements on the farm or in the landscape are mentioned to guarantee animal welfare. Also, these landscape elements allow each livestock species to express its natural behaviour in feeding, reproduction, social needs and preferences, and to fulfil its ecological requirements.
6. Animal nutrition. In organic agriculture, livestock should be fed on grass, fodder, and feeding stuffs produced in accordance with the rules of organic farming that assure a balanced diet. Both EU and IFOAM specify that more than 50% of the feed shall either come from the farm unit itself, from surrounding natural grazing areas, or be produced in cooperation with other organic farms in the region. Both organic EU and IFOAM regulations request maternal milk for young mammals. Specific rules for herbivores impose that they should have maximum use of grazing pasturage. Only the EU regulations impose that at least 60% of the dry matter in daily rations of herbivores shall consist of

Fig. 2 Intercropping of organic wheat and white clover in southeastern France (Photo A. Wezel)

roughage, fresh or dried fodder, or silage. Agroecology gives priority to feed (e.g. fresh grass, hay, silage) compared to food (e.g. cereal, pulses).

7. Veterinary management. Both organic EU and IFOAM give high importance to respecting high animal welfare standards and to meeting animals' species-specific behavioural needs. Animal-health management should be based on disease prevention, though the preventive use of chemically synthesised allopathic medicinal products is not permitted, and when needed it should be limited to a strict minimum. In organic agriculture and in agroecology, natural medicines and treatments (phytotherapeutic, homoepathic products, trace elements) shall be used in preference to chemically synthesised allopathic veterinary treatment or antibiotics. IFOAM includes also Ayurvedic medicine and acupuncture. In EU those products must be listed in Annex V. In organic EU and IFOAM, the use of hormones is prohibited. Agroecology mentions also a broad range of disease prevention methods.

6 Discussion

6.1 Conformity and differences of principles and practices in crop and animal production of organic farming and agroecology

The principles of organic farming (EU and IFOAM) and agroecology (Table 1) have several conformities but also some specific differences. Their common vision is one that favours ecologically based practices and agricultural management that preserve biodiversity and sustainably use natural resources, and that encourage the transformation towards sustainable agri-food systems.

EU organic regulations mainly focus on the restriction of external inputs and the limitation of chemical inputs. This aspect may also have the socio-economic impact of promoting independency from the market, although it is more a consequence than a clear goal. IFOAM principles are very broad and more complete, and include a holistic vision of sustainability. These principles show that organic agriculture is much more than the renunciation of agro-chemicals or pharmaceuticals. This seems to be also due to a long participatory and transdisciplinary task force approach within IFOAM, thus principles such as fairness and care are also defined. The EU regulations are more a technocratic development of regulations in which holistic principles are only of secondary importance. Finally, agroecology has a defined set of principles for ecological management of agri-food systems and also includes some socio-economic principles.

Many practices proposed in crop production are similar for EU organic, IFOAM, and agroecology (Fig. 3). This includes soil tillage, soil fertility and fertilisation, crop and cultivar choice, crop rotation, and pest, disease, and weed management. In contrast, the origin, sources, and quantity of products potentially used for soil fertilisation and pest, disease, and weed management are different. The obligation of organic certified seeds is, for example, only mentioned under EU organics, but do not appear for the others. Similarly, for example IFOAM only lists practices to preserve water quality, monitor water extraction, and recycle rainwater, and agroecology only lists intercropping and agroforestry.

Also TP Organics (2017) strengthen research and innovation for organics and other agroecological approaches that

Table 3 Description in EU regulations and IFOAM norms concerning animal practices in organic agriculture compared to agroecological practices

Category of practices	Organic agriculture EU regulation (EC 2007; EC 2008)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Wezel and Peeters 2014; Peeters and Wezel 2017)
Integration of cropping and animal systems	Livestock production related to the land, where the produced manure is used to nourish the crop production.	Landless animal husbandry systems are prohibited.	Optimum management of organic matters and transfer between livestock and arable land (manure) and between arable land and livestock (litter, forage, by-products) to close the matter and nutrient cycling.
Animal management	Animals should have, whenever possible, access to open air or grazing areas, weather conditions permitting, and such open air areas should in principle be organised under an appropriate system of rotation. Particular attention should be paid to housing conditions, husbandry practices and stocking densities. Annex IV Maximum number of animals per hectare. Animal-health management should mainly be based on prevention of disease.	Ensure that the environment, the facilities, stocking density and flock/herd size provides for the behavioural needs of the animals. All animals shall have unrestricted and daily access to pasture or a soil based on open air exercise area or run, with vegetation, whenever the physiological condition of the animal, the weather and the state of the ground permit.	Systematic use of prevention methods to apply integrated disease and parasite control (e.g. rotational grazing, balanced feeding, adapted housing, hygiene, rustic breeds, mixed grazing of different livestock species).
Breed choice	Animals shall be selected to avoid specific diseases or health problems associated with some breeds or strains used in intensive production. Preference is to be given to indigenous breeds and strains.	Breeding systems shall be based on breeds that can reproduce successfully under natural conditions without human involvement.	Use of locally adapted breeds for maximum use of grasslands to reduce concentrate feed including commercial feed. Use of modern types of double-goal breeds to have both meat and milk production to limit hyper-specialisation of high yielding animals while conserving good income.
Animal housing	Insulation, heating and ventilation of the building shall ensure that air circulation, dust level, temperature, relative air humidity and gas concentration, are kept within limits which are not harmful to the animals. The building shall permit plentiful natural ventilation and light to enter. Stocking density: provide for the comfort, the well-being and the species-specific needs of the animals (species, breed, age). Take into account the behavioural needs of the animals (in particular the size of the group and animals' sex). Provide sufficient space to stand naturally, lie down easily, turn round, groom themselves, assume all natural postures and make all natural movements such as stretching and wing flapping. Annex III: The minimum surface for indoor and outdoor areas, and other characteristics of housing for different species and categories of animals. Specific housing conditions and husbandry practices for mammals, poultry and beekeeping are provided.	Where animals require bedding, provide adequate natural materials. Bedding materials that are normally consumed by the animals shall be organic. Building construction provides for insulation, heating, cooling and ventilation of the building, ensuring that air circulation, dust levels, temperature, relative air humidity, and gas concentrations are within levels that are not harmful to the livestock. No animals shall be kept in closed cages. Animals are protected from predation by wild and feral animals. Animals are regularly visited and monitored. When welfare and health problems occur, appropriate management adjustments are implemented (e.g. reducing stocking density).	No specifications to housing, just: systematic use of prevention methods (e.g. rotational grazing, balanced feeding, adapted housing, hygiene, rustic breeds, mixed grazing of different livestock species).
Animal welfare			

Table 3 (continued)

Category of practices	Organic agriculture EU regulation (EC 2007; EC 2008)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Wezel and Peeters 2014; Peeters and Wezel 2017)
	Animal welfare is a priority and therefore may go beyond community welfare standards which apply to farming in general. Mutilations which lead to stress, harm, disease or the suffering of animals should be banned. Operations such as attaching elastic bands to the tails of sheep, tail-docking, cutting of teeth, trimming of beaks and dehorning shall not be carried out routinely. Any suffering to the animals shall be reduced to a minimum by applying adequate anaesthesia and/or analgesia and by carrying out the operation only at the most appropriate age by qualified personnel.	Sufficient free movement and opportunity to express normal patterns of behaviour, such as space to stand naturally, lie down easily, move around freely, groom themselves, sleep and nest comfortably, as well as assume all natural postures and movements such as stretching etc. Sufficient fresh air, water, feed, thermal comfort and natural daylight, to satisfy the needs of the animals. Access to resting areas, shelter and protection from sunlight, temperature, rain, mud and wind adequate to reduce animal stress. Provision of suitable materials and areas for exploratory and foraging behaviours. e. in addition to these general welfare conditions for all animal categories, Provisions for specific animal groups have to be taken into account, e.g. for cattle: social grooming and grazing; for pigs: rooting, separate lying, activity/dunging and feeding areas, free farrowing, group housing; for poultry: nesting, wing stretching/flapping, foraging, dust bathing, perching and preening. Mutilations are prohibited. Animals are subjected to minimum stress during transport and slaughter.	Maintenance or establishment of semi-natural landscape elements on the farm or in the landscape to guarantee animal welfare. Give the opportunity to each livestock species to express its natural behaviour in feeding, reproduction, social needs and preferences, and to fulfil its ecological requirements.
Animal nutrition	Feed on grass, fodder and feeding stuffs produced in accordance with the rules of organic farming, by taking into account the physiological needs of livestock. For the basic nutritional requirements of livestock, certain minerals, trace elements and vitamins may need to be used under well-defined conditions. At least 50% of the feed shall come from the farm unit itself or in case this is not feasible, be produced in cooperation with other organic farms primarily in the same region. All young mammals shall be fed on maternal milk in preference to natural milk, for a minimum period of 3 months for bovines including bubalus and bison species and equidae, 45 days for sheep and goats and 40 days for pigs.	Animals shall be fed organic feed. Offered a balanced diet that provides all of the nutritional needs of the animals in a form allowing them to exhibit their natural feeding and digestive behaviour. More than 50% of the feed shall come from the farm unit itself, surrounding natural grazing areas, or be produced in cooperation with other organic farms in the region. List of prohibited substances. All ruminants shall have daily access to roughage. Ruminants must be grazed throughout the entire grazing season(s). Young stock from mammals shall be provided maternal milk or organic milk from their own species	Giving priority to feed (e.g. fresh grass, hay, silage) compared to food (e.g. cereal, pulses).

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Table 3 (continued)

Category of practices	Organic agriculture EU regulation (EC 2007; EC 2008)	Organic agriculture IFOAM Norms (IFOAM 2014)	Agroecology (Wezel and Peeters 2014; Peeters and Wezel 2017)
	Rearing systems for herbivores: maximum use of grazing pasturage. At least 60% of the dry matter in daily rations of herbivores shall consist of roughage, fresh or dried fodder, or silage.		
Veterinary management	Animal-health management should be based on disease prevention. The preventive use of chemically synthesised allopathic medicinal products is not permitted. In the event of a sickness or injury of an animal requiring an immediate treatment, the use of chemically synthesised allopathic medicinal products should be limited to a strict minimum. The use of chemically synthesised allopathic veterinary medicinal products or antibiotics for preventive treatment is prohibited. The use of substances to promote growth or production (including antibiotics, coccidiostatics and other artificial aids for growth promotion purposes) and the use of hormones or similar substances to control reproduction or for other purposes (e.g. induction or synchronisation of oestrus), is prohibited. Where despite preventive measures to ensure animal health as laid down in Article 14(1)(e)(i) of Regulation (EC) No 834/ 2007 animals become sick or injured they shall be treated immediately, if necessary in isolation and in suitable housing. Phytotherapeutic, homoepathic products, trace elements and products listed in Annex V, part 3 and in Annex VI, part 1.1. shall be used in preference to chemically synthesised allopathic veterinary treatment or antibiotics, provided that their therapeutic effect is effective for the species of animal, and the condition for which the treatment is intended.	The operator shall take all practical measures to ensure the health and well-being of the animals. If an animal becomes sick or injured despite preventative measures, that animal shall be treated promptly and adequately, if necessary in isolation and in suitable housing. Operators shall give preference to natural medicines and treatments, including homeopathy, Ayurvedic medicine and acupuncture. Use of synthetic allopathic veterinary drugs or antibiotics will cause the animal to lose its organic status. Producers shall not withhold such medication where doing so will result in unnecessary suffering of the livestock. Prophylactic use of any synthetic allopathic veterinary drug is prohibited. Hormones are prohibited to induce ovulation and birth unless applied to individual animals for medical reasons and under veterinary supervision. Substances of synthetic origin used to stimulate production or suppress natural growth are prohibited. Vaccinations are allowed only a. when an endemic disease is known or expected to be a problem in the region of the farm and where this disease cannot be controlled by other management techniques, or b. when a vaccination is legally required.	General use of prevention methods: e.g. rotational stocking including optimum stocking rate and long rest periods of grasslands, mixed stocking of different livestock species, balanced feeding, adequate mineral supplementation, continuous provision of straw or late cut hay at grazing especially on high quality swards and during rainy periods, use of tannin-rich forage species for parasite control, well-designed housing, hygiene, use of rustic breeds, isolation of sick animals in case of infectious disease; When necessary disease treatment with plant extracts, essential oils (phytotherapy) or other natural means such as clay, vinegar, $MgCl_2$ to replace synthesis chemical treatments when possible.

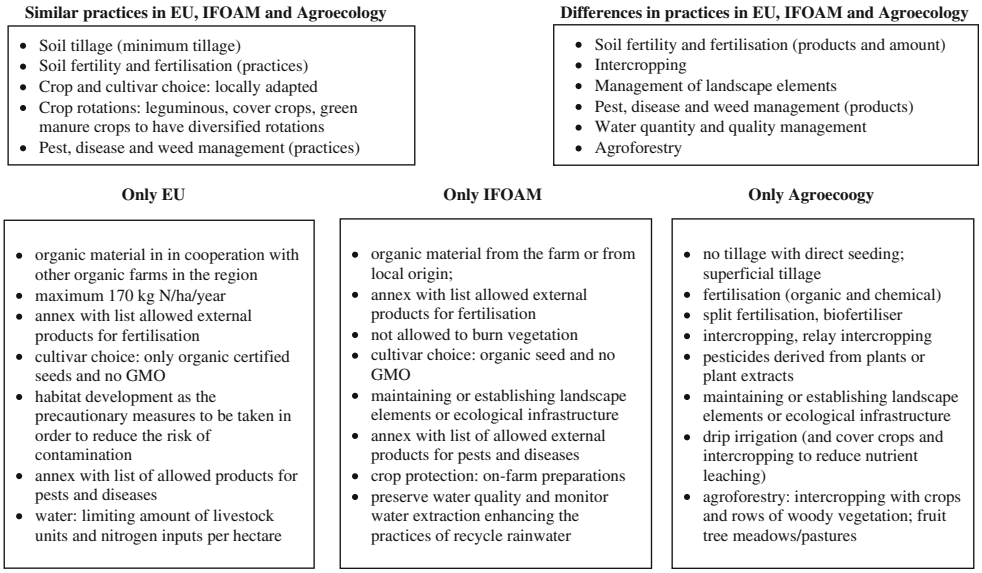

Fig. 3 Conformity and differences in EU organic, IFOAM, and agroecology crop production practices

contribute to sustainable food and farming systems and defined a series of agroecological principles and practices that are highly recommended for planning organic farming systems that respond to an ecological mission as part of their social undertaking.

Soil management practices are quite similar among organic EU, IFOAM, and agroecology, emphasising the maintenance of soil fertility, the protection from soil erosion, and compaction and the use of minimal tillage. In organic EU, a strong focus is posed on quantity of nitrogen from animal origin. This is strongly related to the EU Nitrate Directive (CD 1991) that imposes a maximum amount of nitrogen in vulnerable areas, and so organic agriculture practices were assimilated to the best environmental practices in the European context.

IFOAM norms consider it important that the organic material of any source should come from the farm or the local area, as this not only factors in the ecological aspects (organic matter balance and nutrient cycling) but also the socio-economic consideration (e.g. independency from the markets, foster social relationships in local community). Finally, is important to stress that in organic (both EU and IFOAM) external organic materials can be used, but only if needed and if included in the annex lists. In contrast, no precision is provided in agroecology on source (both organic and chemical inputs can be used) nor on quantity or type, but rather on techniques of application.

For cultivar or breeds, in agroecology and organic agriculture locally adapted seeds are preferred, in order to foster pest and disease tolerance and resistance. Because producing and selling seeds is an activity specifically controlled by seed companies, organic farmers have more obstacles to access organic species and locally adapted varieties due to official seed regulations, organic certification, and markets limitations than do agroecological farmers. A strategy gaining popularity is to develop local varieties and population with participatory and evolutionary plant breeding and small seed exchange networks among farmers (Migliorini et al. 2016).

In animal production, only a few practices proposed are similar for EU organic, IFOAM, and agroecology (Fig. 4). This includes the integration of cropping and animal systems and breed choice. In contrast, practices for animal management, prevention methods for animal health, animal housing, animal welfare, animal nutrition, and veterinary management are differently defined or described among organic and agroecological practices.

In EU regulation, there are many specific rules and limits, in IFOAM it is similar but less specific, and in agroecology this is not yet defined.

6.2 Food system practices

The EU organic regulations, IFOAM norms, and agroecology incorporate practices that are beyond plant and animal production practices, but instead relate to the larger food system.

6.2.1 Food processing

Clear indications about food processing are provided by organic EU regulations and IFOAM norms, whereas in agroecology there exist, to our knowledge, so far, no specific indications. In EU regulations, additives, processing aids and other substances and ingredients used for processing food or feed, and any processing practice applied, such as smoking, shall respect the principles of good manufacturing practice. Operators that produce processed feed or food shall establish and update appropriate procedures based on a systematic identification of critical processing steps. Only the substances

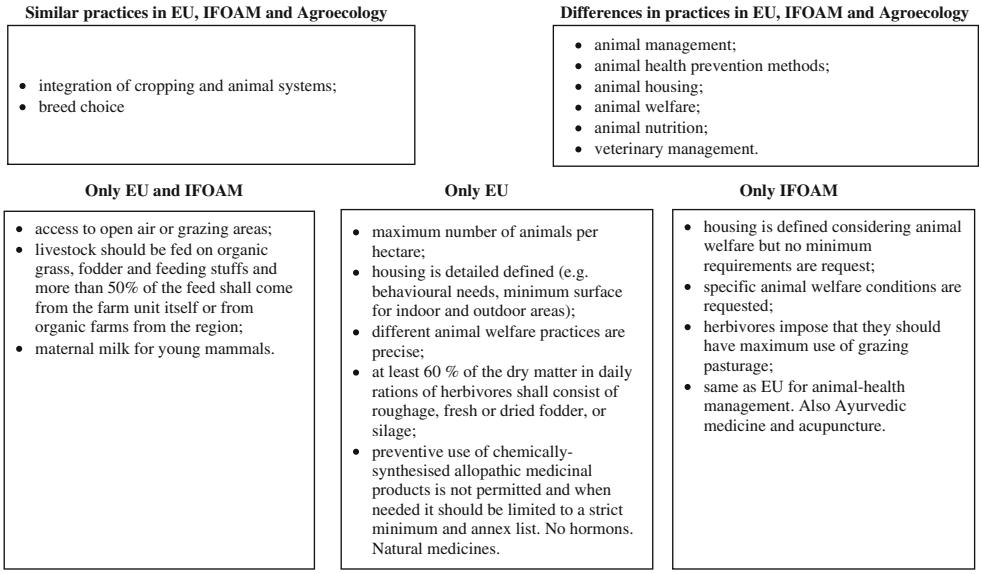

Fig. 4 Conformity and differences in EU organic, IFOAM, and agroecology animal production practices. Note: No practices are exclusively mentioned with agroecology

listed in Annex VIII can be used in the processing and at least 95% of the product's dry matter needs to be organic.

In IFOAM norms, the use of synthetic or harmful methods, processing aids, and ingredients in food processing are prohibited. Handlers and processors shall not co-mingle organic products with non-organic products. Traceability, clear identification of products and stages and of critical processing steps has to be guaranteed. All ingredients used in an organic processed product shall be organically produced, except for those additives and processing aids that appear in Appendix 4.

Moreover, regarding waste and packaging, EU organic regulations demand that companies primarily rely on renewable resources within locally organised agricultural systems. In order to minimise the use of non-renewable resources, wastes and by-products of plant and animal origin should be recycled in order to return nutrients to the land. IFOAM even clearly specifies that companies avoid using polyvinyl chloride (PVC) and aluminium. Operators shall minimise packaging and/or choose packaging materials with minimum environmental impact.

6.2.2 Certification and labelling

Because of the "Organic Agriculture" label, there exist clear indications for organic EU and IFOAM. In agroecology, no specific indications exist so far for any "agroecological" labels. However, the first initiatives are on the way in France to discuss and define which agroecological practices and principles are already found or should be included in the production rules of quality labels such as Protected Denomination of Origin (PDO) or Protected Geographical Indication (PGI) (INAO 2016; MAAF 2016).

In organic EU regulations, the operator needs to provide (a) full description of the unit and/or premises and/or activity; (b) maintain or implement practical measures to ensure compliance with the organic production rules; and (c) take precautionary measures to reduce the risk of contamination by unauthorised products or substances and the cleaning measures to be taken in storage places and throughout the operator's production chain. Normally controls are carried out at least once a year. The IFOAM norms deal with the accreditation requirements for bodies that certify organic production and processing and the Organic Guarantee System that supports the worldwide adoption of environmentally, socially, and economically sound systems based on the principles of organic agriculture. The IFOAM accreditation requirements are very similar to the EU, with the obligation of documentation and records, inspections and visits, sampling and testing, reports and certification process and decisions. Specific to IFOAM is the Group Certification (internal control systems) and the support to the development of participatory guarantee systems. Examples from different parts of the world can be found in IFOAM (2008).

Participatory guarantee systems have been developed in recent years, particularly in South America (e.g. AgriCultures Network 2016; IFOAM 2013). Often, these types of systems are mentioned at the same time as organic and agroecological guarantee systems (Abreu 2012; Boeckmann and Caporal 2011).

6.2.3 Social issues

For the sustainability of agricultural production and food systems, social issues are fundamental.

The organic EU regulation does not mention social issues. This might be due to other EU regulations in place that target this issue. Social Accountability is an auditable certification standard developed in 1997 by Social Accountability International that encourages organisations to develop,

maintain, and apply socially acceptable practices in the workplace. The SA8000 standard (SAI 2014) is one of the world's first auditable social certification standards, across all industrial sectors, for decent workplaces. It is based on the UN Declaration of Human Rights, conventions of the ILO (ILO 2008), UN and national law, and spans industry and corporate codes to create a common language to measure social performance.

In contrast, IFOAM norms indicate different measures. For example, permanent employees and their families should have access to education, transportation, and health services. Also, operators should respect the rights of indigenous peoples, and should not use or exploit land whose inhabitants or farmers have been or are being impoverished, dispossessed, colonised, expelled, exiled, or killed, or which is currently in dispute regarding legal or customary local rights to its use or ownership. Moreover, organic operations should make a positive social and cultural contribution over and above legal obligations in the areas of education and training, support the local and wider community, and enhance rural development (SOAAN 2013).

Social issues play a central role in the movements of agroecology (Altieri and Toledo 2011; Cohn et al. 2006; Rosset et al. 2011) in order to address a transformative food system framework that includes its perspectives on equity, justice, and access of food and integrates practices, sciences, and social changes (Méndez et al. 2013). There is an open debate between a conformist and a transformative agenda (Levidow et al. 2014).

Other issues are knowledge production and knowledge sharing, the recognition of the central role of women, and solidary economies (Friends of the Earth 2016; Via Campesina 2015), and the development of skills and work conditions (Timmermann and Félix 2015).

Finally, a search for diversified, local markets that are based on closer relationships between farmers and consumers is part of many organic agriculture and agroecological approaches to increase sustainability in the paradigm shift from competition on prices to community development.

6.3 Beyond regulations in organic agriculture

Although globally organic agriculture is continuously increasing in terms of surface area and number of farmers, it still remains niche compared to conventional agriculture, covering only 1% of global agricultural area (but with good exception of some regions in Austria, Italy, or Swiss where it reaches up 60%), and even to GMO agriculture that reached 12% of total cultivated land in just a few years. Therefore, the question was raised of how to reinforce the global impact and to produce "organic for all" without losing the organic principles. As a result, in last years, IFOAM has started to work on a new concept: Organic 3.0 (Arbenz 2015).

The organic timeline can be measured in approximately 100 years. Organic 1.0 by was started from the early days of imagining organic agriculture by numerous pioneers, who observed the problems with the direction that agriculture was taking at the end of the nineteenth century and the beginning of the twentieth century. These pioneers saw the connections between how we live, eat, and farm, and between our health and the health of the planet, and recognised the need for radical change. A second phase, Organic 2.0, started in the 1970s with the formation of the organic agriculture movement. At this time, the writing and agricultural systems developed by the pioneers were codified first into standards and then later into regulatory systems that have established organic agriculture in 82 countries with a market value of over $72 billion per year (IFOAM 2014).

Organic 3.0 is now the third phase of organic agriculture (IFOAM 2016). It is about bringing organic out of a niche and into the mainstream, and positioning organic systems as part of the multiple solutions needed to solve the tremendous challenges faced to feed the world and conserve biodiversity. It is about developing the new collective vision for the organic sector and about actively engaging with major global issues. Organic 3.0 is a call to action and a call for a paradigm shift to what the next phase of organic can and should be.

The Best Practice Guideline for Agriculture and Value Chains of the Sustainable Organic Agriculture Action Network (SOAAN 2013) of IFOAM aims to increase the sustainability of organic agriculture and help to identify unsuitable developments of organic practices. In this prospective, organic agriculture becomes very similar to current agroecology in that it does not limit the operators to regulations and thresholds, but rather develops a movement approach for the ecology of sustainable food systems (Gliessman 1997). It is recognised that organic farming is largely rooted in agroecological approaches, both in principles and actual practices, and agroecology and organic farming should be considered in their synergy and co-evolution (FAO 2017b).

6.4 Towards agroecology regulations and policies?

No regulations, labels, or certifications officially exist for agroecology, but debates and initiates are starting, e.g. the aforementioned examples of integration of agroecological practices and principles in production rules of quality labels in France, or the participatory guarantee systems for agroecological production systems and produce in South America.

For polices, there exist only few examples which support or promote agroecological practices and systems, e.g. for the EU and the USA (Wezel and Francis 2017). Thus far, there has been no clear EU strategy for agroecological practices and sustainable agriculture, and national action plans and political will on this topic still remain both marginal and varied. France is the sole country among the 28 member states to have set up

an explicit "Agroecological Project for France" strategy in December 2012 (Ministre de l'Agriculture, de l'Agroalimentaire et de la Forêt 2016). However, the newly defined Common Agricultural Policy (CAP) for 2014–2020 includes valuable elements, in addition to already existing agri-environment measures, which are oriented towards some agroecological practices.

The major novelty of the new CAP is a new financial subheading named "Green Payment", which represents 30% of direct farm supports. A green component based on compulsory practices to be followed by farmers addressing both climate and environment policy goals is set up in Pillar 1 (direct payments), while previously the trend was only to reinforce environmental measures within Pillar 2 (rural development). Greening practices take the form of simple, generalised, non-contractual, and annual actions that go beyond the common requirements and the regulatory cross-compliance, which is the EU directive for good agricultural and environmental practices. The three proposed compulsory practices of greening include (i) crop diversification, (ii) maintenance of permanent grasslands, and (iii) establishment or maintenance of ecological focus areas (European Commission 2016a).

Under the second pillar of the CAP, different agri-environment measures are also proposed by the different member countries (European Commission 2016b). Examples which are covered by national/regional schemes are (i) environmentally favourable extensification of farming, (ii) management of low-intensity pasture systems, (iii) integrated farm management and organic agriculture, (iv) preservation of landscape and historical features such as hedgerows, ditches, and woods, and (v) conservation of high-value habitats and their associated biodiversity. An example of an agri-environment measure recently developed for cereal-dominated systems in France includes different elements concerning crop diversification, reduced use of inputs, and maintenance of woody infrastructure (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt 2016).

7 Conclusions

Organic agriculture and agroecology are in many parts quite similar in principles and practices, with the main differences currently being in production with certification and use of chemical pesticides and fertilisers. Regarding principles, EU organic regulations mainly focus on the restriction of external inputs and the limitation of chemical inputs. IFOAM principles are very broad and more complete, and include a holistic vision of sustainability. Agroecology has a defined set of principles for ecological management of agri-food systems and also includes some socio-economic principles. Many cropping practices proposed are similar for organic EU, IFOAM, and agroecology, e.g. soil tillage, soil fertility and fertilisation, crop and cultivar choice, crop rotation, and pest, disease, and weed management. In contrast, the origin and quantity of products potentially used for soil fertilisation and pest, disease, and weed management are different. Also some practices are only mentioned for one of the three sources. In animal production, only a few practices proposed are similar for EU organic, IFOAM, and agroecology. This includes the integration of cropping and animal systems and breed choice. In contrast, practices for animal management, prevention methods for animal health, animal housing, animal welfare, animal nutrition, and veterinary management are differently defined or described.

Beyond regulations in organic agriculture, new developments are underway that would allow the integration of more diversified practices and would support social goals. As of now, no clear norms, regulations, or certifications officially exist for agroecology, but debates and initiatives are starting, and policies for agroecology are developing. Both organic agriculture and agroecology approaches offer promising contributions for the future development of sustainable agricultural production and food systems because they are based on holistic approaches, put forward sustainable use of natural resources and inputs, and take into account biodiversity conservation. These considerations foster the transformative food system approach including social issues and impede the risk of conventionalisation.

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