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Review

A Promising Niche: Current State of Knowledge on the Agroecological Contribution of Alternative Livestock Farming Practices

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Abstract: Agroecology is increasingly used to study the evolution of farms and food systems, in which livestock plays a significant part. While large-scale specialized livestock farms are sometimes criticized for their contribution to climate change and nutrient cycle disruption, interest in alternative practices such as raising multiple species, integrating crop and livestock, relying on pasture, and marketing through short supply chains is growing. Through a narrative review, we aimed to determine if the scientific literature allowed for an evaluation of the agroecological contribution of alternative livestock farming practices. Taking advantage of ruminants' capacity to digest human-inedible plant material such as hay and pasture on marginal land reduces the competition between livestock feed and human food for arable land. Taking advantage of monogastric animals' capacity to digest food waste or byproducts limits the need for grain feed. Pasturing spreads manure directly on the field and allows for the expression of natural animal behavior. Animals raised on alternative livestock farms, however, grow slower and live longer than those raised on large specialized farms. This causes them to consume more feed and to emit more greenhouse gases per unit of meat produced. Direct or short supply chain marketing fosters geographical and relational proximity, but alternative livestock farms' contribution to the social equity and responsibility principles of agroecology are not well documented. Policy aimed at promoting practices currently in place on alternative livestock farms is compatible with agroecology but has to be envisioned in parallel with a reduction in animal consumption in order to balance nutrient and carbon cycles.

Keywords: multispecies; agroecology; animal; sustainability; alternative food networks; pasture; direct marketing

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1. Introduction

Livestock was found to contribute to climate change, resource use, and health and pollution issues [1–4]. One of the ways currently put forward to resolve some of these issues is to enact a transition from industrial agriculture towards agroecology [5–7]. Agroecology is a concept linking science and praxis that embodies a social and ecological justice movement [8], and even moral and spiritual aspects for some [9–11]. The difference between agroecology and other terms such as sustainable, conservation, organic, or regenerative

agriculture is that agroecology is the only one explicitly involving political and social justice issues within its scope [12–15]. An agroecological transition therefore involves changes in food systems and not only at the farm scale.

Large-scale livestock farms are often highly specialized—sometimes in only one part of the life cycle of a given species—have minimal considerations for natural animal behavior and aim for national and international markets through long supply chains [16,17]. On the opposite side of the spectrum, we witness a growing interest in farms taking part in alternative food networks. These farms differ from their industrial counterparts not only on the basis of their agricultural practices, but mostly in that they are rooted in values such as autonomy, cooperation, ecosystem health, localization of food systems, and a smaller and sometimes artisanal production scale [18–22]. It remains unclear, however, if alternative livestock farming practices can be considered compatible with a desired agroecological transition. The objective of this narrative review was to determine whether or not literature could determine if livestock farms using alternative practices followed agroecological principles.

In the recent literature, agroecology was described using different principles and elements [23–25]. Physical and biological principles tend to apply at the field and farm scales, whereas economic and social principles tend to apply at the farm and food system scales [5,7,26,27]. For the purpose of this review, we chose to rely on the 13 principles of agroecology described by the High Level Panel of Experts on Food Security and Nutrition [7]. These principles are internationally recognized, applicable, detailed, and overcome some of the limitations of previously elaborated ones [28].

Assessment of the agroecological performance of farms or farming sectors has only recently started to appear in the scientific literature, especially since the release of the Tools for Agroecological Performance Evaluation (TAPE) method [29]. That assessment method, much like methods used for sustainability assessment, relies on compiling a series of indicators aiming to encompass most or all principles or elements of agroecology [30–32]. Since the TAPE method is relatively new, peer-reviewed literature using it is scarce, albeit growing [33–37]. Recent reviews on the topic of environmental, economic, or social assessment of farming systems used sustainability or ecosystem service (ES) frameworks, either for agroecology in general [38], or more relevantly for this review, livestock production [39–41] or alternative livestock farms specifically [42].

2. Search Strategy and Analysis

We chose to use a narrative review, a flexible and practical method used to set the stage for future research by offering an interpretation and pointing at knowledge gaps on broad topics [43]. Although narrative reviews are not reproductible, like systematic reviews are, they can be appropriate for reviewing current state of knowledge in broad emerging fields or on topics with few published articles, or to explore a heterogeneous topic area by highlighting the different ways in which researchers have studied it [44], which is the case for agroecological performance evaluation. For the purpose of this narrative review, any study assessing livestock systems adopting one or many of the following practices was considered to be addressing alternative livestock systems: raising multiple species, relying on silvopasture, pasture on semi-natural grassland or marginal land, integrating crop and livestock production, using food waste or byproducts as feed for monogastric animals, raising traditional or heritage breeds, limiting the use of synthetic pesticides and fertilizers, limiting the reliance on technology, infrastructure, and capital, operating at a small scale, as well as marketing through short supply chains [42,45–47]. Since agroecological principles are not indicators, we categorized the practices of alternative livestock farms found in the literature based on their correspondence with those principles, thereby painting a partial

picture of the agroecological contribution of alternative livestock farms. That proxy method is used in the TAPE method, and therefore, we deemed it sufficiently accurate [28,29].

A literature search focusing on alternative livestock farming practices, without any geographical or time boundary, was conducted using CAB abstracts, Web of Science, and Scopus databases between the months of January 2023 and July 2024. Search terms included "livestock", "beef", "pig", "poultry", "efficiency", "sustainability", "agroecology", "regenerative", "ecological intensification", "integrated crop-livestock", "pasture", "multispecies", "direct marketing", "short supply chains", and "alternative food systems", or a combination of these terms. To determine if articles were pertinent to the review's objectives, an initial article selection from over 2000 articles based on titles and abstracts yielded a total of over 650 potentially pertinent articles. From an initial reading, we narrowed the sample to 150 publications by eliminating articles which did not specifically discuss alternative livestock practices. Since the literature on alternative livestock farms is scarce and did not allow for the assessment of the social equity and responsibility principles of agroecology, we had to further broaden the scope of the review to include articles studying any kind of farm taking part in alternative food networks and short supply chains in general. We subsequently included articles cited in the references of the most relevant papers and influential authors in the field. We kept 241 publications for the present review. A large majority of those were found to focus on livestock farms in Global North countries. The contribution of alternative livestock farms relative to the 13 principles of agroecology is described in the form of specific characteristics and practices listed in Table 1.

Table 1. Performance of alternative livestock farms with respect to the 13 principles of agroecology as defined by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2019).

Agroecology Principles as Defined by HLPE (2019)		Scale of Application	Performance of Alternative Livestock Farms	References
		Improve resource efficiency		
1	**Recycling.** Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.	field, farm	Use of byproducts and food waste as feed for monogastric animals and pasture of ruminants on marginal land reduces feed vs. food competition, crop–livestock integration promotes closing of nutrient and biomass cycles.	Ryschawy et al. (2012; 2019); van Zanten et al. (2016; 2018); Röös et al. (2016; 2017)
2	**Input reduction**. Reduce or eliminate dependency on purchased inputs and increase self-sufficiency.	farm, food system		
		Strengthen resilience		
3	**Soil health**. Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.	field	Reliance on pasture and manure instead of mineral fertilizer can promote soil health, but is highly dependent on pasture and manure management.	Xu et al. (2018); O'Brien and Hatfield (2019); Bai and Cotrufo (2022)
4	**Animal health**. Ensure animal health and welfare.	farm	Pasture, traditional breeds, low animal density and limited use of antibiotics promote animal welfare.	Modernel et al. (2019); Delsart et al. (2020)
5	**Biodiversity**. Maintain and enhance diversity of species, functional diversity and genetic resources and thereby maintain overall agroecosystem biodiversity in time and space at field, farm and landscape scales.	field, farm	Pasture, and traditional breeds maintain plant and farm animal diversity; smaller farm sizes promote varied landscapes and habitats.	Karlsson et al. (2022); Dominati et al. (2021); FAO (2015)
6	**Synergy**. Enhance positive ecological interaction, synergy, integration and complementarity among the elements of agroecosystems (animals, crops, trees, soil, and water).	field, farm	Crop–livestock integration or multi-species farms generate synergies such as recycling manure as fertilizer on pasture and forage crop fields (see principles 1 and 2).	Ryschawy et al. (2019); Dumont et al. (2023)
7	**Economic diversification**. Diversify on-farm incomes by ensuring that small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.	farm, food system	Production and marketing diversification through economies of scope, diversification of economic activities such as combining production with processing and marketing.	Mundler and Jean-Gagnon (2020); Rowntree et al. (2020); Martin et al. (2020)

Table 1. *Cont.*

	Agroecology Principles as Defined by HLPE (2019)	Scale of Application	Performance of Alternative Livestock Farms	References
	Secure social equity/responsibility			
8	**Co-creation of knowledge**. Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.	farm, food system	Literature on alternative food networks does not show explicit links between taking part in such networks and co-creation and horizontal sharing of knowledge.	Dolinska and d'Aquino (2016); Utter et al. (2021)
9	**Social values and diets**. Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.	farm, food system	Cultural heritage and traditions around livestock are important for farmers and the rural populations where livestock has traditionally been part of the landscape.	Ryschawy et al. (2017); Beudou et al. (2017)
10	**Fairness**. Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment, and fair treatment of intellectual property rights.	farm, food system	Farmers display high work satisfaction but there is a reliance on low paid labor and risk of overwork due to lack of specialization.	Mundler and Jean-Gagnon (2020); Ulukan et al. (2022); Steinmetz et al. (2021)
11	**Connectivity**. Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.	farm, food system	Direct or short supply chain marketing fosters consumer education through the farmer-to-consumer link and integration of alternative livestock farms in local food systems.	Alonso (2010); Forssell and Lankoski (2015)
12	**Land and natural resource governance**. Strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers as sustainable managers of natural and genetic resources.	farm, food system	Livestock systems relying on pasture and traditional breeds are considered good land stewards in some jurisdictions.	Wells and Gradwell (2001); Mann and Lanz (2013); von Greyerz et al. (2023)
13	**Participation**. Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.	food system	Alternative food networks actors participate in food system governance, albeit with less power than actors along the industrial food chain.	Van Der Ploeg (2014); Zhang and Barr (2019)

3. Improve Resource Efficiency

"Recycling" and "input reduction" are the two principles of agroecology grouped under the resource efficiency heading in the High Level Panel of Experts' report [7]. We chose to divide this section into the three subsections of "Nutrient cycling", "Land use", and "Greenhouse gas emissions", as these were the dominant topics related to resource efficiency when it came specifically to livestock systems (Table 1).

3.1. Nutrient Cycling (Principles 1 and 2)

Livestock is responsible for water pollution and nutrient cycle disruption due to the use of grain as feed, manure leakage to waterways, and the concentration of its production in densely stocked regions [48]. Although not present in all alternative livestock farms, crop–livestock integration means that a farm will produce some of the feed for their livestock, that will in turn fertilize fields with their manure, closing the nutrient cycle [49,50]. In a review of crop–livestock integration on French farms, higher integration led to more efficient N cycling, lower pesticide use and fossil fuel consumption while having no effect on work productivity but better work efficiency due to lower expenses and smaller farm size [51]. Other authors found that integrated crop–livestock farms in France greatly differ from one to the other and that no clear conclusion can be drawn with respect to their environmental benefits when compared to specialized livestock operations. In a study using indicators such as land use diversity, N flows, and crop management practices, crop–livestock farms however presented a lower potential for N pollution, which was similar to that of pastured beef operations [52].

European multi-species farms with best overall performance with respect to land productivity, N input dependence, and farmer income satisfaction had relatively high autonomy for feed and limited diversification in terms of animal species, crops, and non-livestock activities such as agritourism, direct marketing, and on-farm processing in order to limit work overload [53]. These high performing farms limited management activities integrating multiple animal species such as co-grazing of different species and crop residue grazing. Only matter flows such as grains, hay, straw, and manure were optimized for economies of scope. These results suggest the presence of a trade-off between the advantages (resilience and increased income from reduced inputs) and disadvantages (increased workload) of diversification and integration. Alternative practices displaying higher N integration potential were found to be using crop residues and food waste to feed pigs and using animal manure as fertilizer [54]. On the other hand, a high proportion of monogastric animals tends to favor the import of grain feed on the farm, creating potential N surpluses as manure is not necessarily exported outside the farm [55,56].

Nutrient cycling is in direct line with the "Recycling" and "Input reduction" principles of agroecology. The use of feed harvested from the farm fields and their fertilizing with the animal manure produced on the farm both recycles nutrients and reduces the need for feed and fertilizer inputs. This practice however adds to the workload of farmers.

3.2. Land Use (Principles 1 and 2)

A reduction in land use for animal feed production can be considered to be an objective compatible with principles of agroecology involving resource use, as land is a finite resource. Much like growing corn to produce ethanol to fuel cars, using land to feed livestock is often cited as an example of a diversion of resources that could be used to directly feed humans [57,58]. Worldwide, about half of the land used for agriculture is devoted to raising animals for human consumption [3]. Different interpretations of how to address this issue include increasing the efficiency of grain-based farms, moving towards pastured ruminant

farms, feeding animals non-human-edible feedstuffs, and reducing meat consumption and production altogether [59,60].

Pasture or forage for ruminants is often the only possible agricultural product to be obtained from marginal lands, since these present severe constraints to agriculture, being outside "the margin of cultivation" because of topology or soil limitations [61]. Similarly, food waste or byproducts can replace grain feed for monogastric animals. Both are known as "low-opportunity cost feedstuff" or "ecological leftovers" [57,58,62,63]. Since these feed sources do not compete with human food for land, they are considered promising alternative livestock feeding strategies [59,64–66]. The competition for land between livestock feed and human food is most often quantified using an energy [67], human-edible energy [68], protein [69], or human-edible protein [70] baseline. Since animal products in the human diet are firstly a source of protein, protein can be considered the limiting nutrient when considering livestock feed vs. human food competition for arable land. The edible protein conversion ratio (EPCR) compares the amount of human digestible protein present in livestock feed with the amount of human digestible protein produced by that livestock. An EPCR below 1 means the farm generates more human digestible protein than it consumes. At the global level, ruminants are more efficient human-edible protein converters than monogastric animals, with EPCRs of 0.6 and 2.0, respectively [3]. Grazing cattle were found to be much more efficient than feedlot cattle in OECD countries, with EPCR of 0.5 and 4.1, respectively, highlighting a major difference between the two production systems. The difference between industrial and alternative feeding strategies is even starker for monogastric animals, with EPCR for domestic farms ("backyard" livestock feeding mostly on food waste) ranging from 0.5 to 0.6 and industrial farms from 2.9 (layers) to 5.1 (broilers), with pigs in between at 4.4. This indicator is useful to illustrate the digestive capacities of ruminants. It does not, however, discriminate between hay or pasture grown on marginal land from that grown on arable land, a distinction necessary to evaluate if farm animals are actually competing with humans for arable land use. To this end, the land use ratio (LUR) compares the human digestible protein that could be produced from the specific land used to produce livestock feed with the human digestible protein produced by that livestock. Calculating the LUR of different livestock species in the Netherlands, laying hens had an LUR over 2, meaning that the crops grown to feed a hen could have produced twice as much human digestible protein than the eggs and the meat that the hen gave [57]. Comparing EPCR with LUR of dairy (0.22 vs. 0.58), beef (0.29 vs. 1.34), and pig (1.51 vs. 1.74) farms in Ireland demonstrated the importance of considering the arable nature of the land used to produce livestock feed when assessing feed vs. food competition [71].

To optimize the use of N for human nutrition, sizing the monogastric fraction of multi-species farms according to its capacity to produce or obtain feed by-products or food waste is ideal [72]. In a model scenario sizing livestock production to the available land base and human population, a significant fraction (12 to 30%) of the protein in human diets would come from animal sources using low-opportunity cost feedstuff [58,73]. In those scenarios, the production of crops for feeding animals would be null and the proportion of animal protein in the human diet would entirely depend on the local availability of leftovers and of forage from land not suitable for crops destined to direct human consumption [74]. Excluding these systemic interconnections of feed vs. food competition and waste or by-product recycling from the equation otherwise favors a strictly vegetarian diet, as growing crops for animal consumption is much less efficient than for human consumption with respect to resource availability and environmental impacts per nutritional unit value [75,76]. This shift in the human diet in the direction of a higher proportion of plant-based protein

raises the issue of the needed changes in consumer preferences with respect to legume-based foods in industrialized countries [77].

Food waste has great potential, as animal feed, to reduce pressure on farmland [73,78,79]. Feeding food waste to monogastric animals offers multiple advantages, including waste reduction (e.g., reducing methane emissions from food waste decomposition), resource use efficiency, and economic benefits [80]. Such a practice is, however, banned in most industrialized countries because of concerns for bovine spongiform encephalopathy [57,58]. Heat treatment of food waste has been found safe and is widely used in Asia, and such practices could reduce land use for pork by 20% in Europe [81]. Wet-based treatment of food waste for animal feeding even has the best economic cost vs. benefit ratio (2.6) of different waste management options, including composting (4.9), incineration (5.1), anaerobic digestion (10.2), and landfill (40.4) [82].

In sum, limiting arable land use for feed production and pasture and maximizing the resort to food waste and byproducts to feed monogastric animals are desirable practices. This being said, its large-scale adoption would involve an important overhaul of the current livestock production paradigm in the Global North, in which land use optimization for human edible protein production is not economically incentivized.

3.3. Greenhouse Gas Emissions (Principles 1 and 2)

Like land use, greenhouse gas (GHG) emissions and their corresponding climate change impacts are not explicitly cited in agroecological principles. However, scientific literature addressing sustainability issues around livestock farms gives much attention to GHG emissions, making this topic an unavoidable one in a review concerning alternative livestock farming practices [69,83,84]. Livestock production is currently responsible for over 15% of GHG emissions worldwide [4,83]. The main sources of emissions are enteric fermentation in ruminants through methane emissions and grain feed production for both ruminants and monogastric animals, mostly through nitrous oxide emissions from grain crop fields [85]. Manure management, especially when stored in a liquid form, is also a large contributor to GHG emissions from livestock production [83].

A widely used method for environmental impact assessment, and GHG emission calculation in particular, is life cycle assessment (LCA). In LCA, the system's output is called a "functional unit", and its choice comes with related consequences on the environmental impacts calculated from the model. For example, a less input-intensive production system will generally have higher emissions per unit produced, favoring industrial production when a provisional (e.g., 1 kg of meat) functional unit is used [86]. When a land-based functional unit is used (e.g., 1 ha of land), a less intensive production system will have lower environmental impacts, as it produces less per land area and therefore consumes and emits less per unit of land [87,88]. In general, however, a kilogram of carcass meat produced is the most often used functional unit. In North America, average carbon dioxide (CO_2) equivalent emission values per kg carcass meat (or eggs) were approximately 30.0 for beef cattle, 4.6 for swine, 4.4 for chicken, and 2.9 for eggs [83]. Such reviews of LCA-generated GHG emissions of industrial livestock production are common [69]. In a review of the carbon footprint of beef cattle worldwide, values were found to range between 4.6 [89] and 34.9 [90] kg CO_2 equivalent per kg of meat produced [91]. Similarly, in a systematic review of 56 LCA articles of intensive production studies worldwide, the range was found to be between 1.4 and 5.8 kg CO_2 equivalent and 1.1 to 9.4 kg CO_2 equivalent per kg of meat produced for pork and chicken, respectively [92]. This demonstrates to what extent, even within the LCA framework, estimates of kg CO_2 equivalent per kg of meat produced can vary depending on the production system modeled, the assumptions made, and the impact assessment method used within the different available LCA software.

There also appears to be a divergence in the interpretation of the carbon sequestration potential of the soil in pasture-based farms, with this sequestration assumed to represent 0 to 80% of these farms' carbon footprint depending on methodologies and assumptions [4,91,93]. Practices promoting soil organic carbon storage include plant biodiversity restoration, reduced grazing stocking rates, as well as sowing legumes and planting trees in pastures [4,94]. High carbon sequestration values were obtained assuming a degraded initial soil state, raising the sequestration potential before attaining a steady state at which sequestration effectively stops [95,96]. The potential of grazing systems to sequester carbon appears to sit between 20 and 60% of their GHG emissions, or 4 to 11% of total livestock emissions [97–99]. According to these assessments, reducing ruminant-based protein consumption by over 11% has therefore a larger potential of reducing GHG emissions than the potential of pastures to sequester carbon.

Shorter animal lifespan (excluding the reproductive herd) lowers the emissions per unit mass of meat produced [100,101]. Since enteric emissions are the major contributor to GHG emissions by cattle, reduced emissions caused by shorter animal lifespan are in direct favor of a grain-based, energy-rich diet supplementation for cattle. Extensive cattle operations have a much higher carbon footprint on a unit protein basis [102]. The quicker the animals are brought to a profitable slaughter weight, the lower the amount of methane emitted in their lifespan.

In an original methodology aimed at evaluating functions of livestock farms other than producing food, Swedish payments for ES were used as a proxy for an economic allocation of the environmental impacts between different livestock farm functions, including the provision of meat as well as non-provisioning ES [103]. Their models showed that up to 48% of climate change impacts caused by the farm could be attributed to ES other than food production. Put another way, this means that a potentially significant amount of the meat production carbon footprint is due to positive externalities. Examples of paid ES include the maintenance of semi-natural pastures, raising endangered domestic animal breeds, farming on areas of natural constraints, and organic farming.

Alternative systems' high GHG emissions per unit of animal produced, either due to a more extensive system, heritage breeds, or pasture, sometimes obscures trade-offs in favor of less quantifiable indicators such as intraspecific diversity, resilience, and adaptation to local social and environmental conditions, among others. According importance to reducing the amount of GHG emissions would certainly result in advising against raising the same amount of meat with alternative methods. Reducing livestock production and consumption remains the best avenue to curb emissions.

4. Strengthen Resilience

Resilience has its own body of literature, and multiple definitions are used in different scientific domains [104], with common traits revolving around the flexibility of social-ecological systems [105]. For the purposes of this review, resilience is understood as the capacity of alternative livestock farms to operate in the face of short- or long-term stresses and disturbances [106,107]. The principles of agroecology grouped under the "Strengthen resilience" category are "soil health", "animal health", "biodiversity", "synergy", and "economic diversification" (Table 1).

4.1. Soil Health (Principle 3)

Soil health is generally defined in terms of a function or capacity to sustain life through agriculture but also to play a role in water quality, climate regulation, and human health [108,109]. It is measured with a diversity of indicators such as organic matter content, pH, available P, and water storage [110–113]. Pasturing livestock can have beneficial effects

on soil health, such as higher microbial activity and soil carbon content [94], but can also be detrimental if the animal stocking rate is excessive, causing soil compaction, excessive carbon removal from the soil, as well as sediment and P loss to the environment [114]. As for mineral fertilizer applications, it can be detrimental to soil health when applied at high rates, much like animal manure, which is richer in P and organic matter content and can lead to eutrophication and the accumulation of toxic metalloids in the soil [115,116].

Deep tillage and excessive fertilization rates are detrimental for all crop production, whether it be for animal or human consumption. Excessive stocking rates and animal density on pastured fields are to be avoided.

4.2. Animal Health and Welfare (Principle 4)

Asides from its environmental impacts and the pressure it exerts on land and water resources, animal welfare is possibly the biggest issue brought up against industrial or conventional livestock farms in western societies [117–119]. Humans are responsible for the welfare of the farm animals they raise. Some authors advocate for animals' rights to live a life worth living [120], and even for animals to be considered as stakeholders in the transition towards a circular economy [121]. In typical industrial livestock production operations, there are multiple welfare issues related to health problems such as mastitis in dairy cows [122], pneumonia in pigs [123], and leg disorders in poultry [124], as well as affective states such as anxiety, frustration, and boredom [120]. Large-scale specialized farms often overcrowd and confine animals, use growth promoting substances such as hormones or preventive antibiotics, and perform practices such as dehorning, tail docking, and castration [118,125–127]. Large-scale use of antibiotics in livestock already has serious implications for antimicrobial resistance in animals, and even in humans [128,129].

Animal welfare is one of the main differences with industrial livestock farms highlighted by proponents of alternative farming. This being said, neither industrial nor alternative farms have fixed practices with respect to animal welfare, except for limits imposed by local legislation [130]. Some of the practices that are criticized in industrial farms can also be found in alternative farms, such as castration, absence of outdoor access and loss of intraspecific diversity. However, pigs were found to fare better in terms of animal-friendly housing, possibility to express natural behavior, freedom from fear, pain, and injuries, good animal health, and animal-friendly management in organic farms than in conventional farms [131].

A practice commonly used in organic or alternative farms is pasturing, which allows for a better expression of natural behaviors such as rooting for swine, grazing for ruminants, and pecking for poultry, on top of allowing free movement and roaming [93,132,133]. Ruminants on pasture, and especially small ruminants, have a relatively high resistance to climate variations, albeit with effects on fertility and growth, especially during droughts [134]. While monogastric animals are not digesting grasses like ruminants do, pig production farms with higher land use (including pasture) have lower antimicrobial use and better animal welfare [135]. This outdoor access is also one of the reasons why pigs in alternative farms are less affected by respiratory diseases than in indoor slatted floor systems [136].

Other alternative livestock management practices, depending on the species raised, include lower animal density, enriched housing, later weaning, breeding genetics better adapted to the local environment, and a less intensive feeding schedule with more fiber in the diet for monogastric animals [136]. These practices present downsides, however, including the enhanced complexity of all the basic chores (watering, feeding, temperature and predator control, biosecurity) as well as the prevalence of parasites due to grazing, piglet crushing in farrowing units, and climate-related stresses in extensive grazing of ruminants [136–138].

4.3. Biodiversity (Principle 5)

In alternative livestock farms, semi-natural pastures benefit biodiversity mainly because of the structural heterogeneity of the grasses and other plants caused by selective grazing behaviors [139,140], which in turn depend on breed, season, and soil moisture [141]. While diversification of grassland types and livestock species increases the resilience of livestock farms, it has to be tailored to the specific biophysical and human conditions within which the farm evolves [142]. Moreover, grazing intensity has to be limited in order to maintain biodiversity in grasslands, which greatly diminishes the potential of grasslands to support current meat and milk consumption rates [143]. However, implementing biodiversity-enhancing actions such as fencing and restoration plantings has multiple positive side effects, namely increasing indigenous vegetation, protecting riparian margins, reducing erosion and enhancing water filtering and nutrient retention in the soil, increasing carbon sequestration, sense of place, esthetics, recreational and spiritual values, and the provision of other food products [144]. Other indicators used for biodiversity assessment include monitoring of species richness, evenness, and relative dominance of birds, butterflies and other pollinators, plants, species of conservation concern, and invasive species [145], as well as habitat-based indicators (e.g., habitat quality, landscape heterogeneity, canopy connectivity, crop diversity, and field size) [146,147]. Agroforestry and silvopasture can also be found on alternative livestock farms. These practices were shown to have positive effects on biodiversity and carbon sequestration, as well as water retention and soil health, making them preferable to pasture or forage crop fields under conventional management [148–150].

Most studies using the LCA framework do not include biodiversity loss as an impact category, giving a methodological advantage to practices that might have a lower carbon footprint but higher impacts on habitat loss and lower species richness at the field level [151]. Only a few studies incorporated biodiversity characterization factors into LCA models, i.e., factors with which to multiply the land use data to obtain the biodiversity impact results. These relied on categorizing the practices between organic and conventional farming [152]—a distinction that can sometimes be misleading as these two can both be at either side of the agroecology vs. industrial agriculture spectrum [153]—or land use in kind and intensity [154–156]. A grain crop monoculture, for example, will have more detrimental effects on biodiversity per surface area than semi-natural pasture. Consequently, low-intensity land use by grazing livestock farms will reduce its negative impacts on biodiversity, leaving more space for native grasses and more time for the flowering of plants. In a comprehensive assessment of three cattle farms in Southwestern Europe, it was found that a higher use of semi-natural pasture per kg of animal protein produced was preferable than reliance on grain feed supplements, both for biodiversity but also for reducing the amount of human-edible protein devoted to livestock [102].

Biodiversity is at the center of a heated debate in environmental scholarship related to land use, which is the land sharing (promoting biodiversity-friendly agriculture) vs. land sparing (separating high-yielding agriculture from natural ecosystems) debate [157–160]. Intrinsically, agroecology sits on the land sharing side, favoring a complementarity rather than an opposition between nature and agriculture. Sharing and sparing are not mutually exclusive, however, and large-scale conservation does not necessarily exclude wildlife-friendly agriculture in areas chosen for food production [161]. Indeed, sharing (for provisioning ES such as food production) and sparing (for biodiversity conservation) are necessary to balance the multifunctionality of agricultural landscapes [162,163]. They advocate for context-specific measures that promote ecological connectivity, which is necessary for spared land to be useful, since natural habitats that are isolated from each other do not allow wildlife migration to and from them. Live fences of planted trees in cattle rangelands of Central America were found to provide habitat and improve ecological connectivity [164].

Ecological connectivity is high in semi-natural pastures where scattered trees and small, linear vegetative patches promote free circulation of wildlife [165]. Landscapes with small fields bordered by hedges promote pollination and defoliator regulation while larger fields favor crop production and aphid regulation, as different ES respond differently to landscape heterogeneity variables [166]. In consequence, smaller farms and farms with ruminants are associated with better non-provisional ES than field crop or farms with monogastric animals [147].

An aspect of biodiversity that is sometimes overlooked is intraspecific diversity, i.e., genotype and phenotype variations within the same species. Along with interspecific diversity, intraspecific diversity contributes to ES provision [167]. Farm animal breeds are examples of intraspecific variations that are actively managed by humans to adapt to local conditions in response to changes in production technology and trade environments [168,169]. Alternative livestock systems use traditional breeds more often than their industrial counterparts, especially for their rusticity for pasture and outdoor environments as well as for differences in meat quality [170,171]. Traditional pig breeds, for example, are often better prepared to withstand variations in climate conditions [138] but grow slower and take longer to transform post-slaughter as they have more hair and the muscle and fat disposition is not the same as for hybrid breeds used in the industry. While breeding increasingly productive breeds for indoor production conditions enhances immediate economic profitability, it generates an ever-decreasing genetic diversity in farm animals worldwide. This genetic erosion is at the origin of preoccupations with respect to livestock operations' resilience to climate change and emerging diseases [172].

In sum, the plant and animal diversity present on alternative livestock farms are beneficial to biodiversity, but this advantage comes with the unavoidable trade-off of a lower immediate crop or pasture yield and slower animal growth.

4.4. Synergy (Principle 6)

The integration of multiple animal species on a single farm can create synergies, but they come with trade-offs. Indeed, co-grazing systems can optimize the resource acquisition strategies of different ruminant species, but can also be detrimental depending on the grazing management practices [42]. Combining species that can infect each other with diseases, for example, is to be avoided [72]. Combining monogastric with ruminant animals, however, allows for monogastric manure spreading on grasslands, thereby reducing the need for fertilizers [173]. Practices involving worktime and space integration require the greatest management attention [174]. This is pertinent for alternative livestock farms as they have different objectives and constraints with respect to integration, labor availability being a central one.

Other than closing resource and nutrient cycles, the integration of crops and livestock on a single farm is also a form of synergy. While synergies are compatible with agroecology, crop–livestock integration does not automatically come with better environmental or economic performances [53,55]. It can, however, generate economic efficiencies by reducing the effects of price fluctuations for fertilizer [175].

A recent study showed that, due to specialization, policies, and limited labor availability, crop–livestock integration in France was starting to occur less at the farm level but more and more at the regional level, where farms would rely on their neighbors for animal feed, for example [176]. Integrated crop–livestock systems are in the process of specializing into multi-species pastured farms (or sometimes even specialized livestock farms) on one hand, and feed production farms on the other. In a follow-up study, it was found that this multi-farm crop–livestock integration can be a good example of a possible future for the cohesion of an agroecological system seen from a landscape perspective [177]. A network

of seven French farms was selected to collectively design a system of feed production and manure spreading based on the supply and demand of each farm. Individual gross margins increased and environmental impacts decreased, but workload as well as logistical and social issues emerged as communications and interdependence within farms increased. This shift in crop–livestock integration from the farm scale to the regional scale seems under way in many industrialized countries [72,178,179].

Synergies linked to raising multiples species and integrating crop and livestock production are beneficial, but these two practices come with trade-offs, namely increased work complexity, possible animal health issues, and inter-farm communication and logistical issues when crop and livestock production are integrated at a multi-farm scale. Such integration, as well as any diversification of the animal species raised, has to be planned with the corresponding labor demands in mind.

4.5. Economic Diversification (Principle 7)

In agroecology, diversification is valued for its systemic character. It is seen as compatible with biodiversity, but also with flexibility and economic resilience. As one of the most common characteristics of alternative livestock farms, diversification often comes in the form of raising multiple animal species. In a review of the sustainability of multi-species livestock farms [42], found that there were many environmental, technical, economic, as well as animal and farmer welfare advantages to this diversification, such as making more efficient use of farm resources, higher grassland biodiversity, and economies of scope. However, they also found that diversification does not automatically come with sustainable farming practices, and that overgrazing and farmer work overload are common issues found in diversified livestock farms during peak season. In a multi-species pastured farm case study [93], found that animal diversification combined with pasture did not clearly improve the environmental sustainability of livestock farms, especially since carbon sequestration potential was uncertain and that the trade-off between a greater land use for pasture and greater on-farm biodiversity was hard to quantify. This being said, integration of livestock species and marketing strategies certainly influence and complexify diversified livestock farms [173].

Along a different diversification axis, alternative livestock farms often combine economic activities such as production, processing, and marketing within a single farm business. This diversification is relatively common for enterprises engaged in alternative food networks (AFN), and more specifically for farms engaged in short supply chains. In a study involving a sample of 32 farms (19 of which raised livestock) in Québec, Canada, it was found that labor productivity was relatively low on farms that combine production, processing, and direct marketing activities, as this vertical integration does not allow for much specialization and has detrimental effects on net earnings and long-term viability of the farm due to work overload [180]. Marketing without intermediaries, however, can be the only option for farms that cannot be competitive in conventional supply chains, as the latter depend on economies of scale. Similarly, diversification of both production and marketing outlets are factors of risk mitigation [181–183] independently of the supplementary work and potential inefficiencies they incur for farmers. This coupling of the diversification of economic activities and the reliance on local supply chains fosters dynamic territorial development, especially in peri-urban areas [184,185].

Diversifying livestock species and adding processing and marketing activities on top of production certainly helps to strengthen resilience, but again at the expense of economies of scale and work productivity.

5. Secure Social Equity and Responsibility

Along with principles mainly applicable at the field and farm scales, agroecology puts forward social equity and responsibility principles, which are applicable at the farm and food system scales. The six principles of agroecology grouped under the "Secure social equity and responsibility" category are "Co-creation of knowledge", "Social values and diets", "Fairness", "Connectivity", "Land and natural resource governance", and "Participation" (Table 1).

5.1. Co-Creation of Knowledge (Principle 8)

Co-creation of knowledge has always taken place between farmers without in itself being an object of study [186]. Communities of practice take form amongst regional- or production-based groups of farmers who engage in a mixture of collaboration and competition [187,188]. These communities are not only spaces where farmers learn from each other, but also where innovation takes place [189]. Co-creation of knowledge is commonplace in rural farming communities and certainly does not take place exclusively in alternative food networks, and therefore cannot be considered to be a feature of alternative livestock farms. However, farmer-led research and co-creation of knowledge by farmers appears to have positive effects on the adoption of ecological management practices at the farm level, as this collaboration among peers fosters confidence and a stronger social network [190].

5.2. Social Values and Diets (Principle 9)

The legacy and traditions around the co-evolution of humans and animals is strong in most parts of the world. At first guided by the need for nutrient and waste management as well as draft power, and only secondarily that of providing food, the role of livestock shifted to providing meat, milk, and eggs in the last century [191,192]. Eating meat has been a practice of *Homo sapiens* for a long time, and it has allegedly shaped many of our long-standing traditions of social organization [193] and local food and agriculture traditions [194–196].

In the contemporary context of countries where agriculture is mostly industrialized, meat and animal product provision remain the most valued role of livestock. In France, environmental and cultural services were negatively correlated to food provisioning services, while rural vitality was strongly correlated with food provisioning services [197]. This suggests that the food production function of agriculture does not warrant the respect of cultural values even though it creates local employment. Along the same lines, cultural and territorial vitality services provided by livestock farms undergoing an agroecological transition were found to differ from one region to the other, highlighting the importance of adapting policy and communications to the local context [198]. Cultural landscapes linked to livestock tradition and the social bonds fostered by the presence of agroecological livestock farms were the most significant to farmers, processors, consumers and experts interviewed.

While alternative livestock farming practices do not warrant social values and diets, most of them (pasture, raising multiple species, direct marketing) have been in place since before industrialization. They often go hand in hand with a lower resource use and a lower reliance on technology, which in turn is associated with culturally acceptable diets and production methods.

5.3. Fairness (Principle 10)

Fairness, in the case of alternative livestock farms, can be assessed in terms of work conditions and economic reward of the farmers involved. No significant body of literature

on the welfare of the farmers involved in such farming exists [42]. Widening the scope to alternative farming systems in general, we could infer results on the economic performance of alternative livestock farms as well as on the working conditions of the farmers involved.

Multiple agroecological practices are already implemented on many European farms by farmers who chose those practices not only for environmental or social reasons, but also for economic ones by reducing costs, diversifying their offer through economies of scope, sharpening their skills, and shortening supply chains [183]. One major downside to the economic performance of agroecological practices was identified, namely the heavy reliance on human labor in a context of labor shortage in industrialized economies. Moreover, this labor is often not compensated at the height of its value, a reality that is not different from that of industrial food systems [199,200].

In Guadeloupe, small, labor-intensive alternative livestock farms had low levels of work productivity but very high land productivity [54]. Medium, capital-intensive farms had high labor and land productivity, while medium extensive farms had low labor and land productivity. These results highlight the need to characterize land properties and social contexts. Outside the specific case of livestock, multiple authors have highlighted the resort to low-paid labor in alternative food networks, in which farm owners and their staff operate on a fine line between acceptable working conditions and self-exploitation [199,201,202].

For farm-level economic assessment, life cycle costing (LCC) aims to evaluate the economic performance of an activity through an analysis of its costs [203]. For agricultural LCC, costs include labor, inputs, machinery, and sometimes other expenses, as well as, very seldom, externalities, i.e., costs that are not included in the price of a transaction [204]. In a systematic review of LCC studies of agricultural activities [205], nine LCC studies involved livestock farms, only two of which included alternative production systems elements [100,206]. Valorizing by-products was a winning strategy in all LCC and LCA studies that included that indicator, which is a strategy often implemented in alternative livestock farms.

Other studies assessing economic aspects of different management strategies use farm revenue, costs, depreciation, and debt as primary indicators to calculate the net profit margin, net present value, annuity, labor productivity, capital productivity, dependence on inputs, and sensitivity to financial aids [144,207]. Steinmetz et al. (2021) [55] found that a higher level of interactions between components of a livestock farm, such as N flows from the field to the animals in the form of feed and back to the field in the form of manure, did not enhance economic performances [55]. This suggests that a high nutrient independence within the farming system, namely through self-sufficiency in nutrients, is not necessarily the best economical option for farmers.

Working conditions assessments do not solely encompass economic performance indicators and use more human-centered indicators than traditional economic assessments. In a review of publications on farmers' working conditions in agroecological livestock farms, difficult working conditions were found to be one of the main reasons why agroecological livestock farmers have a challenging time transferring their farm upon retirement [208]. In a study involving 22 French cattle farmers adopting some agroecological practices, improving working conditions was not the main motivation to adopt such practices [209]. Other interesting findings on the effects of adopting agroecological practices are a loss of work flexibility [210], a need for a broader skillset [211], a work that is more aligned with personal convictions and motivations [212], and contradictory results relating to the impact on workload [210,211]. Working conditions are hard to compare among studies as they rely on qualitative data pertaining to sensitive and taboo topics [213] and depend on the farmer's cultural values and mindset at the moment of the interview [214].

High levels of income satisfaction on multi-species livestock farms were found to be correlated with high land productivity and low N input dependence [53]. Cournut et al. (2018) [212] identified four work organization models based on the size and species in the herd, management practices, infrastructure, and workforce composition. One of these models, which can sometimes correspond to alternative livestock farms but never to industrial ones, was named "difficult" and combines low work efficiency, small herd size, low capital and few equipment, few resources, and a heavy reliance on family members who have close to no free time. This model is at a disadvantage when it comes to most workforce configuration indicators, namely work autonomy, efficiency and flexibility, infrastructure, and farm dimensioning. Managing a complex multi-species farm, however, does not decrease work satisfaction due to excessive mental workload [55]. This was corroborated in other studies, where it was found that autonomy in the work schedule, as well as the perceived (by themselves and consumers) contribution to sustainable food production, were related to higher levels of work satisfaction [208,215].

In sum, alternative livestock farms suffer from the same fairness issue as other alternative farms, namely that of being economically disadvantaged by their production models. These models often harbor many qualitative benefits but are not the most economically efficient and involve managing complex tasks. This complexity, however, appeared to be correlated with higher levels of work satisfaction. In that sense, the social equity balance of alternative livestock farmers with others is not reached on an economic scale, but rather that of work satisfaction and alignment with one's values.

5.4. Connectivity (Principle 11)

Reliance on short supply chains for input acquisition and product marketing is a common trait of alternative livestock farms and is compatible with the connectivity principle of agroecology. At the food system level, the development of new markets linking farmers and consumers is a way for farmers to obtain better prices [183]. Short food supply chains can have positive effects on territorial development, namely for indicators of employment, work satisfaction, and adoption of environmentally sound practices [216]. Multiple other studies were conducted on short supply chains in agriculture with respect to different aspects of sustainability [217–219]. These point to areas of consensus, such as the importance of the perceived human relationship between the farmer and the end consumer [220], and the fact that farms marketing through short supply chains use less pesticides than farms operating along longer supply chains [221,222]. They also point to areas of uncertainty, such as the poor environmental footprint performance of short supply chains compared to that of industrial ones from a transportation perspective [223] and the impact of short supply chains on the adoption of sustainable farming practices in general [224].

As for the connectivity between farmers and consumers, research on short supply chains and alternative food networks have shown that direct marketing plays a role in the education of consumers [225]. While alternative food networks are not clearly defined, one of their aims is to embed food systems into local economies, and the indirect impacts of connectivity between actors play an essential role in creating a social environment ripe for an agroecological transition [20,226].

Connectivity and fairness are linked in that the economic shortcomings of small-scale diversified production are compensated by the economic and satisfaction-related benefits of direct marketing.

5.5. Land and Natural Resource Governance (Principle 12)

Participating in alternative food networks and short food supply chains fosters sustainable land and resource governance by farmers. Local marketing is a driving force for

sustainable farming practices, as farmers become accountable to their consumers who want to know the story behind the food they eat [227,228]. There are positive links between alternative food networks and care for local community, nature, land, water, soil and other resources [229]. Some jurisdictions even recognize an association between livestock and sustainable land and natural resource governance, namely by allocating payments for the ES rendered by certain livestock management practices. In Sweden, for example, the government pays farmers who raise traditional breeds, maintain semi-natural pasture, or pasture in marginal lands [103]. In Switzerland, farmers receive payments for maintaining landscape quality, especially by maintaining grasslands and pastures in mountainous terrain [230,231]. These examples point to the importance, for various reasons in different parts of the world, of certain practices implemented by livestock farmers, especially pasture. This emphasis on pasture is not trivial, since conventional livestock farms are highly sanctioned by environmental regulations in industrialized countries, especially due to nutrient cycle disruption and pollution due to excessive manure loads in regions with high concentrations of industrial livestock operations, which do not send animals on pasture.

This agroecological principle has an emphasis on family farming, which can refer to the scale of operation often adopted by alternative livestock farmers. In this sense, policy aimed at promoting the persistence of family farming in a context of rapid industrialization of agriculture can be considered to be in line with this principle. This being said, and while alternative livestock farming practices are sometimes rewarded, this does not necessarily warrant a participation of farmers into land and natural resource governance mechanisms.

5.6. Participation (Principle 13)

Short supply chains give rise to new governance mechanisms such as community-supported agriculture associations, which are pertinent for the political involvement and representation of farmers operating alternative farms [232–234]. Food justice, food democracy, and local food governance revolve around the participation of food system actors in food-related issues and embody the agroecological ideal at the food system scale [235]. Power relationships are at the heart of agricultural and food-related inequities, and this translates into power asymmetries between and among farmers, between input suppliers, farmers, and wholesalers, but also between farmers and consumers, and between consumers themselves [236–239]. As an example of large-scale power asymmetry, only four firms dominate the US meat sector, and these are often integrated with grain feed trade businesses [240], making negotiation difficult for smaller actors, be they farms or even legislators. Solutions to these power inequities come in the form of a series of approaches all along the individual versus political solutions spectrum, but most rely on power collectivization of alternative food networks actors, such as cooperative farms and agricultural cooperatives aimed at mutualizing marketing efforts [241–245]. As soon as alternative livestock farms integrate localized economies, they take part in a movement aiming to bridge the gap between farmers and consumers, and more generally the citizen with its food [220,246].

This being said, we found no study on the participation of alternative livestock farmers in initiatives aimed at decentralizing governance and promoting local adaptive management food systems. This would be particularly pertinent in nomad pastoralism contexts as well as in far North environments, where crop production is marginal. As alternative livestock farming remains alternative by definition, it does not constitute the voice of the majority and is seldom brought forward in policymaking contexts.

6. Agroecological Contribution of Alternative Livestock Farms

Literature shows that alternative livestock farms perform well with respect to nutrient and resource use efficiency, mainly due to the fact that these farms are diversified, rely on pasture and food residues to feed animals. This is coherent with the views of authors emphasizing the potential of certain livestock raising practices to address land use issues [247]. Farms also displayed strong resilience attributes, mainly assessed through their level of diversification. Social equity and responsibility principles were not found to be directly evaluated in the literature, except for some aspects of fairness, evaluated in qualitative studies focusing on farmer well-being and work satisfaction, both relatively high for alternative livestock farms.

In previous studies on livestock farms involving alternative practices, farms performing well with respect to GHG emissions and nutrient cycling tended to minimize diversification so as not to lose efficiency [53,55]. This is not in line with the synergy and diversification principles of agroecology, but it highlights the fact that agroecology is not a purely environmental concept and that farms have to adjust to economic efficiency imperatives to be viable and to exist in the first place. These imperatives are compatible with the indicators most often found in the literature on environmental impact assessment, especially those using the LCA methodology, and are a reminder that the current economic system continues to externalize most environmental costs.

In alternative livestock farms, the use of pasture and traditional breeds causes animals to live longer before reaching slaughter weight. This makes alternative farms less efficient in terms of GHG emissions than their industrial counterparts, which rely on confined animals that are fed grain-based feed. High GHG emissions and climate change impacts are a major downside of less intensive and less specialized livestock farms. Moreover, their low economic reward is in contradiction with the agroecological principle of providing fair working conditions and maintaining control over the labor process [248]. This being said, alternative livestock farmers were found to be satisfied by their work conditions.

Our findings highlight the importance of indicator selection when assessing agricultural systems, especially when taking into account their multifunctionality. Alternative livestock farms balance environmental, economic, and social objectives while producing food. All three objectives present their own trade-offs, which can be summarized by a tension between efficiency on one side and resilience, synergy, and connectivity on the other. A better reward for this agricultural multifunctionality—and even for correspondence with agroecological principles—would help bring forward the positive aspects of this kind of farming and divert the current emphasis on economic performance and GHG emissions.

7. Challenges in Assessing Contribution to Agroecology

Assessing unavoidably comes with a framework with which to assess. Environmental and economic assessment frameworks, for example, generate different results as indicators are not the same. Favoring economic efficiency can come with an environmental impact trade-off that is invisible to economic indicators. In a review of sustainability assessments of livestock farms, it was found that literature segregated between impacts of and services rendered by livestock farms emphasized environmental impacts over social ones, and preferred assessment at the farm level over the landscape or food system levels [40]. Our assessment of alternative livestock farms based on an agroecological framework yielded similar findings, albeit expressed in different terms, but also highlighted the fact that agroecological principles are relatively far from a strong trend in the agricultural and livestock scientific literature mainly revolving around carbon footprints obtained through LCA and other model-based methodologies [249].

As mentioned in the introduction, recent farm assessment methodologies involving multiple indicators [31,32] and even mixed methods aimed at assessing agroecological performance or contribution [29] have not been used in a large number of studies. Moreover, such methods unavoidably run into issues of indicator weighing and discussion of trade-offs between positive and negative externalities that are hard to put on a common denominator, especially when these concern environmental, economic, and social indicators all at once. Systematic assessment of cultural and policy dimensions, which largely shape local farming, should be included when assessing farming practices and farmers' choices.

One main finding of the application of an agroecological framework to a body of literature on alternative livestock farms is that farm-level assessments can only paint a partial portrait of agroecological contribution, as the latter highly depends on food system-level parameters such as culture and politics. We found that alternative livestock farm-level assessment indicators can be categorized into the different agroecological principles, but that farms' contribution to some principles depends on the social and political context in which they operate. Since agroecological principles were not designed to serve as indicators but rather as analytical tools and that about half of them are not applicable at the field or farm scale, it is logical to find that the context-oriented principles are not addressed in farm-level studies, especially without a geographical boundary that could serve to limit the context to a specific situation. Even agroecology-specific assessment frameworks such as TAPE run into this issue, highlighting the need to step outside strictly quantitative methods when assessing any aspect of farm performance.

8. Knowledge Gaps

A strong trend in the livestock scientific literature appears to revolve around quantifying GHG emissions, and secondarily around the recoupling of nutrient cycles. The "less but better meat" prescription made in publications such as [84,250] is in need of clarification and is context-specific [251–253]. In any case, this concept has the merit of considering production and consumption at both sides of the same coin. "Better" meat can mean different things in different places, but "less" meat is most likely necessary in all Global North countries with high meat consumption rates [254–256]. For those countries, certain knowledge gaps with respect to the role and place of livestock in agroecological food systems remain. These gaps can be grouped into two broad categories, namely biophysical and socioeconomic.

We suggest prospective studies based on diets or resource availability involve practical assessments of the farm-scale implications of such scenarios [38]. Which practices already put in place by farmers appear promising in light of reduced meat production and consumption scenarios? Moreover, we observed the absence of ecological connectivity assessment at the regional scale. Smaller field sizes present in alternative livestock farms create better connectivity due to the presence of field hedges, but studies aimed at assessing ecological connectivity were mostly aimed at the farm scale. Mapping tools could be relevant for these sorts of assessments, as well as for dimensioning land suitable for pasture but not suitable for crops. The latter would be crucial in addressing the land use impacts of livestock production. It would also help determining the suitable proportion of monogastric versus ruminant livestock in a given area by identifying where and which animals constitute the best land use option for protein production while minimizing feed vs. food competition, resource use, and impacts on biodiversity [257].

Documenting the food system-level availability of food waste and by-products for monogastric animals would inform policymakers with respect to the localized suitability of monogastric operations. Research and extension pertaining to pulse crop management will be needed in areas that are currently dedicated to producing crops for animal

consumption in a context of fertilization issues caused by a drastic reduction in manure availability [258–260].

In line with recent reviews, we found that socioeconomic aspects of livestock farms were poorly documented compared to biophysical ones [40,41]. Social equity and responsibility principles of agroecology do not play out at the field scale, but rather at the farm and food system scales, which corresponds to the last two levels of food system transformation towards agroecology [5]. It is therefore difficult to paint a complete picture of the role of alternative livestock farms in the agroecological transition without looking at their role in embedded food systems evolving in varying cultural and political contexts. Farms are highly dependent on—and sometimes encouraged or constrained by—the systems in which they operate with respect to these socioeconomic principles. An agroecological farm in a non-agroecological food system inevitably has to strike compromises.

These involve balancing nutrient and economic flows at different scales based on policies and practices operating within different biophysical and political boundaries [257,261,262]. Social issues involving local employment, technology, physical and economic access to local markets, minimizing distances between production, processing, and marketing activities of livestock must also be addressed. Along those lines, research on the authenticity of the alternative character of alternative livestock farms would be interesting to conduct, as many processes involved in those farms depend on the presence of industrial supply chain systems, namely piglet, chick, and grain feed production, as well as slaughtering services, especially in the Global North. Production and consumption of livestock products can be disconnected in the minds of consumers, the latter often bearing responsibility for current high consumption rates, thus occulting the responsibility of other value-chain actors between production and consumption [252].

The present and future role and place of livestock in Global North and Global South contexts are definitely not the same, and any solution will have to be adapted to the local context. For example, while less meat is an obvious imperative in industrialized countries, more meat is a pressing need in famine-struck areas. At the international level, it remains unclear which power dynamics are the most significant in determining the role and shape of alternative and industrial livestock farms in our globalized food systems [263].

9. Conclusions

In this narrative review, we aimed to determine how scientific literature could be used to assess the agroecological contribution of alternative livestock farming practices. We have found that most of these practices are compatible with resource efficiency and resilience principles of agroecology. While a promising niche in Global North food systems, alternative livestock farming practices alone cannot solve the problems raised by industrial-scale livestock farming. A transition towards practices currently in place in alternative systems and towards agroecology in general has to be envisioned in parallel with a major reduction in animal products consumption to balance nutrient and carbon cycles at the local level, as current alternative livestock farms are not as efficient as industrial systems in terms of resource use and GHG emissions. Research is needed to add precision to the required scale of this reduction as well as the political and practical means towards it, especially since alternative farms experience economic viability issues. Policies aimed at reducing meat production and consumption have to be developed in parallel with plant-based protein replacements and soil fertility management solutions to the corresponding reduction in animal manure availability.

Agroecology is a relatively new framework whose particularity is to explicitly consider social and political dimensions beyond farming practice and science. These dimensions, especially at the food system level, are currently not assessed in the literature on alternative

livestock systems. To fill this gap, we suggest probing deeper into the power relationships involved in policymaking at the food system level. Why does the livestock industry and related feed production still take up so much of our farmland and farming economy? Who benefits and who suffers from this state of affairs? Answering these questions from a scientific standpoint would allow for a better understanding of the levers held by different actors to implement a fair agroecological transition.

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