Agronomy for Sustainable Development (2022) 42: 24
https://doi.org/10.1007/s13593-021-00737-5

RESEARCH ARTICLE

Delivering “less but better” meat in practice—a case study of a farm in agroecological transition

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Accepted: 3 November 2021 / Published online: 23 March 2022

Abstract

Eating “less but better” meat can be a strategy to guide meat consumption in Western or high-income countries towards sustainability, but what “better” means depends on the perspective. Multiple studies and reports suggest that agroecological farming systems could contribute to a broad range of sustainability benefits, but few studies have examined the implications for people and nature following trade-offs between sustainability priorities at the farm level. Therefore, this study explored the effects on a broad range of sustainability themes following agroecological transition on a case farm in east-central Sweden. We applied a novel mixed-methods approach, combining the indicator-based SMART-Farm tool with additional quantitative and qualitative analysis of the farm’s climate impact, contribution to global food security, economic performance, and working conditions. The results showed improvements for aspects within environmental, social, economic, and governance-related sustainability dimensions, with corroborating results across methods. The case farm thus served as an example of transition to a more sustainable production system, but as expected, there were both trade-offs and synergies between sustainability aspects. Negative effects were found for economic aspects at the farm and societal level. For this case, one may conclude that “better” meat production both supports and depends on, a more sustainable farm; but that “better” meat and a more sustainable farm cannot be viewed in isolation from the wider food system. Also, “better” can be described by several states along a transition pathway. Key contributions of the study are threefold, a) articulation of the links between agroecology and the concept “less but better,” b) empirically demonstrating synergies and trade-offs in striving for more sustainable meat production, and c) a novel methodological approach for sustainability assessment.

Keywords “Less but better” Meat · Agroecological transition · Sustainability assessment · SMART-Farm Tool RRID:SCR_018197

1 Introduction

There is growing scientific consensus that Western or high-income consumers must reduce meat intake to lower the environmental impact of diets (Resare Sahlin et al. 2020). Intensively and extensively managed pastures and cropland for the production of food, feed, and fiber occupy 33% of the global ice-free land surface and livestock production, mainly cattle, accounts for 10–15% of anthropogenic greenhouse gas (GHG) emissions (IPCC 2019a). However, livestock, especially ruminant livestock, are integral to some farming systems, e.g., agroecological systems (Altieri and Rosset 1996). Hence, while there is a need for drastic reductions in meat production and consumption (in high-income countries), there is also a need to integrate some animals into farming systems in smart ways so that they contribute positively. The concept of “less but better” meat, used by several organizations and institutions as a strategy to guide meat consumption towards sustainability, is an attempt to capture this dual need (see, e.g., A Greener World 2017; Slow Food 2018; Tirado et al. 2018; WWF-Germany 2018; Eating Better 2017). It prescribes eating smaller quantities of meat (“less…”) with increased attention to quality aspects (“…but

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better"). What "better" meat actually refers to is, however, a matter of perspective (Resare Sahlin et al. 2020), but a common interpretation is that it entails a more environmentally sustainable meat choice (see e.g., Eating Better 2021). One such choice is extensively reared livestock, where agricultural production is aligned with local ecosystems according to agroecological principles, building on the integration of livestock into mixed farming systems, and as utilizers of pasture biomass (de Boer et al. 2014; Dumont et al. 2018) (Fig. 1). In such systems, livestock can act as engineers to forge beneficial links between agricultural systems and ecosystems and create synergies between environment and production in agroecosystems (Tittonell 2014; Dumont et al. 2018). Therefore, transitioning to agroecology as a pathway to sustainability in farming is gaining increasing attention (see, e.g., Poux and Aubert 2018; FAO 2019; HLPE 2019) For example, the recent farm-to-fork strategy of the European Union aims for 25% of agricultural land to be farmed organically by 2030, a tripling of the current level (European Commission 2020).

Agroecological transitions occur along a continuum, where the initial stages are characterized by "weak" agroecological practices, focusing on efficiency in the use of inputs and replacing conventional inputs and practices with biological options. In later stages, production systems are "re-designed" to build on "strong" agroecological practices that are integrative, locally determined, and biodiversity-based (Prazan and Aalders 2019). A key aspect of agroecology is using animals as convertors of biomass that is inedible to humans instead of feeding animals cereals and pulses (Altieri and Rosset 1996). Limiting livestock production to leftover biomass places a cap on the amount of meat that can be produced without causing feed-food competition (van Zanten et al. 2018). To avoid expansion of arable land following increased use of agroecological methods, the overall number of livestock and associated consumption of animal-source foods would need to decrease, both at the global (Muller et al. 2018) and regional level (Karlsson and Röös 2019). Reducing the number of ruminants is also essential for meeting global climate goals (Clark et al. 2020).

Meat produced in agroecological farming systems could be an example of producing both "less" and "better" meat, but there are known trade-offs between sustainability aspects in extensive and improved meat production (Resare Sahlin et al. 2020). Most previous studies on sustainable meat have examined a limited range of aspects (e.g., Clark and Tilman 2017; Poore and Nemecek 2018) and few studies have assessed the implications for people and nature of trade-offs between sustainability priorities at the farm level. Here, we extended existing research by investigating the effects on a broad range of sustainability aspects following the agroecological transition of a farm in line with the "less but better" concept. As a case, we used a Swedish beef and arable farm that is undergoing an agroecological transition from intensive bull beef production to a more extensive organic system. The study contributes to previous research by articulating the links between agroecology and the concept "less but better" and to previous work on assessing the sustainability of meat by combining a holistic assessment encompassing ecological, social, economic, and governance dimensions with additional quantitative and qualitative analysis of climate impact, contribution to global food security, economic performance and effects on working conditions.

Fig. 1 Cattle on semi-natural pastures in an organically certified farm in east-central Sweden. Photograph by Kajsa Resare Sahlin.

2 Material and methods

2.1 Case study methodology

It is challenging to make an all-encompassing sustainability assessment of a farming system because of its complexity, as many independent components interact dynamically. By empirically combining qualitative and quantitative approaches in a novel way, the case study methodology we applied facilitated a more holistic understanding of the complex outcomes for people, nature, animals, and society of this agroecological transition (see, e.g., Harrison et al. (2017) on case study methodology). By doing so, the study exemplifies and explores, but it is of course context specific, and the study does not aim to produce generalizable results. Instead, the particular case captured the real-world experiences and effects of a journey toward sustainability as one node in the greater food system. Many more will need to make this journey in the future, as meeting sustainability challenges become ever more urgent. In discussing the results, however, we refer to existing literature and highlight when outcomes are typical/non-typical for this type of agroecological transition.

2.2 A farm in agroecological transition

The case study farm (hereafter "the farm") is located in east-central Sweden and produces beef and crops for food, feed, and biofuels. As is common in the region, the farm is a cluster of several (previous) family farms and the farm owns some land and farm buildings but leases the majority of its land and pastures through long-term agreements with old aristocratic estates. In 2019, the farm applied for and was selected to participate in the UNISECO project on diversification of Swedish beef and dairy farms to improve sustainability (see www.uniseco-project.eu; Landert et al. 2020). In initial interviews for the project, the farm reported that it had begun transforming from conventional, intensive beef and crop production to an organic, more extensive system because it wanted to be part of the growing consumer movement to eat less meat and choose meat more selectively. The farm also wanted to be less dependent on purchased inputs and to have more equal buyer–seller relations.

Over the 3-year period 2017–2020, substantial changes occurred at all levels on the farm, from types and amounts of inputs used to on-farm processes and outputs (Table 1). In 2017 (pre-transition, year 1), the farm was an intensive, large-scale system finish-feeding 1200 intact bulls in closed indoor systems using mainly purchased concentrate feed. Livestock was kept at three different locations on the farm and transported between these locations as they transitioned through age groups. The cropping system for producing commercial crops and silage relied on the intensive use of fertilizers and chemical pesticides, and the farm employed approximately 14 full-time workers. Production was highly market oriented and had a relatively high flow of capital. In addition to the intact bulls, the farm also reared 50 suckler cows and 150 heifers extensively to maintain semi-natural pastures included in its leasing agreements.

In 2018, the farm began converting to organic and stopped purchasing bull calves, as part of a transition to keeping only heifers (Table 1). In the year 2020 (the second year of assessment, year 2), the farm reared 350 heifers extensively on semi-natural pastures and organic silage from the farm, thus totally abolishing the need for feed imports. Stocking density has been reduced substantially and the year-round bullpens have been replaced with loose-housing for 5–6 months in winter. The cropping system still produced commercial crops and silage, but using only organic fertilizers and no pesticides and with some increase in the complexity of the crop rotation, e.g., under-sown green manure and flowering plants. Downsizing production has more than halved the annual turnover and staff. The farm is still highly market-oriented, but the number of buyers of the farm's products has doubled.

This particular farm was selected for analysis because out of the 11 farms participating in the Swedish UNISECO case, its changes to its management regime were the most substantial and all-encompassing. Additionally, changes were relevant for both components of the "less but better" meat strategy (Resare Sahlin et al. 2020), and this case can thus make an important contribution to understanding the concept's usefulness for sustainable meat at the farm level.

In the extensive system created by the agroecological transition on the farm, the production relies increasingly on local resources and more integrated management (Prazan and Aalders 2019) (Fig. 2). However, the agroecological practices implemented in cropping are mostly "weak", while beef production is based on "strong" agroecological practices, most importantly adjusting stocking density to available semi-natural pastures and relying only on forage as feed, in an effort to use livestock as convertors of fiber-rich biomass instead of consumers of human-edible resources.

2.3 Sustainability assessment tools and indicators

To investigate whether the agroecological transition has contributed to more sustainable farming and meat options, we used several sustainability assessment tools and indicators in a mixed-methods approach. How best to assess sustainability at the farm level is a source of much debate (e.g., de Olde et al. (2017)), and there are a great number of tools available (e.g., Arulnathan et al. 2020; Chopin 2021). We used the SMART-Farm tool (Sustainability Monitoring and Assessment RouTine; RRID: SCR_018197, hereafter referred to as SMART) which is considered to be one of the most complete sustainability assessment tools (Arulnathan et al. 2020).

Table 1 Characterization of production systems on the case study farm for the first (year 1) and second year (year 2) of assessment.

		Year 1 (2017): The Intensive System		Year 2 (2020): The Extensive System	
Arable land (ha)		519 (5.2% owned)		485 (5.6% owned)	
Crops (ton/ha) and % total ha	Ley	8.0	37%	3.5	34%
	Oats	3.3	6.5%	5.5	11.5%
	Wheat	6.5	39%	5.2	20.5%
	Barley	4.3	4.5%	4.3	8%
	Rape seed	4.5	9.5%	*Not cultivated*	-
	Triticale	7.8	3.5%	5.5	12%
	Rye	*Not cultivated*	-	3.0	14%
Fertilization		413 kg total N/ha Biogas digestate (220 kg/ha), chemical fertilizers (138 kg/ha), N-fixation (50 kg/ha), and other organic fertilizers (Biofer) (3.6 kg/ha)		274 kg total N/ha Biogas digestate (250 kg/ha), N-fixation (21 kg/ha), and other organic fertilizers (Biofer) (5.3 kg/ha)	
Pesticides		Fungicides, herbicides, and insecticides 39 different active substances		*None applied*	
Number of animals		1200 intact bulls, 50 sucklers, and 150 heifers		350 heifers	
Feed		Silage ≈ 1500 tons Energy-based compound feed ≈ 2600 tons		*Grazing* Silage ≈ 570 tons	
Grazing		0 days for bulls ≥180 days for sucklers and heifers		≥180 days	
Meat production (tons bone-free meat)		200		40	
Certifications		Oats and barley organically certified The rest of the production is not certified		2nd year of embargo awaiting organic certification with Swedish KRAV for whole farm. Beef certified as semi-natural pasture-fed.	
Annual turnover (SEK)		≈22 million		≈9 million	
Total subsidies obtained (SEK)		≈2.5 million		≈3.3 million	
Annual work units (full-time work equivalent)		14.5		7.15	
Family working units (full-time work equivalent)		1.5		1	
5 largest input products (SEK)		1. Intact bull calves 2. Compound feed and milk replacement 3. Chemical fertilizer 4. Pesticides 5. Seeds		1. Heifer calves 2. Seeds 3. Organic fertilizers 4. Machinery spare parts 5. Round bale plastic and nets	
Market orientation		Highly market-oriented Number of buyers: 3 70% of revenue from largest customer 2% of household food produced on-farm		Highly market-oriented Number of buyers: 7 18% of revenue from largest customer 2% of household food produced on-farm	

However, it does not permit in-depth assessments of all sustainability dimensions, so we, therefore, complemented the analysis by investigating four further key areas: 1) climate impact, studied because SMART does not calculate GHG emissions, which are critical for the sustainability of meat, especially beef (Poore and Nemecek 2018), 2) the farm's contribution to global food security, as a common criticism of agroecology and organic farming is that yields are too low to feed the world (Barbieri et al. 2017; Dumont et al. 2018), 3) the economic performance in quantitative terms, to address the core challenge of economic viability for sustainable farming (de Roest et al. 2018; van der Ploeg et al. 2019), and 4) working conditions for staff, as the foreman and owner of the farm were the main informants for the SMART analysis. Further details on all parts of the sustainability assessment can be found in Supplementary Material (SM) to this paper.

2.3.1 SMART

SMART operationalizes the Sustainability Assessment of Food and Agriculture (SAFA) indicators, which are core themes and criteria for sustainable food and agriculture developed by the FAO (FAO 2013). SAFA encompasses the three principal pillars of sustainability—ecological, social, and

Agroecological practices	Year 1 (2017) The intensive system	Year 2 (2020) The extensive system
Fertilizer	Chemical fertilizer	Precision application, organic fertilizer, green manure
Weed and pest control	Chemical control	Biological pest control
Feed and grazing	Silage, concentrated feed	Grass-fed, extensive grazing on permanent pastures
Tillage	No tillage	Standard tillage
Crop selection	High-yielding crop varieties, pest- and disease-resistant	High-yielding crop varieties, pest- and disease-resistant, inclusion of legumes and cover crops
Crop spatial diversity	Mixed crop spatial diversity	Mixed crop spatial diversity
Crop rotation	Standard crop rotation	Crop rotation including legumes
Livestock density and diversity	High-stocking rates, specialized dairy breed	Low stocking rates, specialized beef breed
Biodiversity	Linear biodiversity features (buffer strips and flowering fields)	Linear biodiversity features (buffer strips and flowering fields)

Fig. 2 Agroecological practices, characterized by Prazan and Aalders (2019), which are applied at the farm in year 1 and year 2. In columns two and three, the black text indicates practices which are conventional or not agroecological, the red text indicates practices which constitute "weak" agroecology, and the green text indicates practices which constitute "strong" agroecology.

economic dimensions—and also incorporates criteria for sustainable governance. SMART can, thus, be used for holistic comparisons of farming systems and for identifying more sustainable practices or products. It uses over 350 quantitative and qualitative indicators, which are weighted and aggregated to assess 21 themes and 58 sub-themes of sustainability (see SM). It is operationalized in licensed software which requires training before application in the field. On-farm assessments are made through interviews with farm managers, using over 300 interview questions (Landert et al. 2019, 2020).

After completing the software training, we held structured on-farm interviews for SMART with the foreman and owner of the farm in July 2019 and April 2020 (see SM). Some background and complementary information were obtained using templates, where the interviewees were asked to provide management details. Verification of some information was made by phone and email. The SMART assessments were also quality checked by the tool owners before results were generated in the software.

2.3.2 Climate impact of beef

We calculated the carbon footprint of 1 kg of beef meat (slaughter weight, SW) before and after the agroecological transition on the farm, using a "cradle to farm-gate" life cycle approach. To clearly illustrate the effect of transition from intensive rearing to grass-based extensive production, we delimited the calculation to the bull herd in year 1, thus excluding suckler cows and heifers present on the farm in 2017. The following major emissions sources were accounted for: enteric fermentation, manure management, feed production, grazing, transports, energy use in animal houses, purchased calves, and production and use of fertilizers, pesticides, and bedding. Emissions from enteric fermentation, manure management, and soils used for feed production and grazing were calculated using IPCC tier 2 methodology, while nitrogen (N) in manure was calculated using tier 1 methodology (IPCC 2019b). Emissions from bought-in products were calculated using emission factors from the literature (see Sect. 1.8 in SM). For bought-in dairy calves, which are a "by-product" of milk production, emissions associated with the mother animal (the dairy cow) were allocated to both milk and meat, while suckler cows are reared solely to produce meat, and thus emissions from the mother cow were allocated only to the meat. The climate impact was calculated as kg CO_2 equivalents with global warming potential including feedbacks using a 100-year time horizon, with a factor of 1 for CO_2, 34 for CH_4, and 298 for N_2O (IPCC 2013). Changes in soil carbon were not accounted for but are discussed in the SM.

2.3.3 Global food security

Drawing on previous work by Cassidy et al. (2013) on assessing farm contributions to global food security, we calculated the number of people that could be fed per hectare in terms of energy (kcal), protein, complete protein (a complete amino acid profile), and fat. On-farm land use and land required for growing purchased feed were considered. Areas of semi-natural pasture were not included in total land use, as it is not suitable for cropping and is thus not relevant for this indicator of food-feed competition. For crops sold for feed, we calculated two versions of the food security indicator: one delimited to production on the farm (hence not considering the nutrients in feed crops) and one considering also meat (theoretically) produced from sold feed, assuming that the crops sold for feed were used to produce beef according to an average Swedish feed ration for beef production. We calculated the associated land use that this theoretical production would require in terms of additional feed and included these "virtual" hectares in the total land use (see SM).

2.3.4 Working conditions

To evaluate the effects of the agroecological transition on working conditions, which is a critical aspect for agricultural sustainability (Dumont and Baret 2017), we developed an interview guide to assess the impacts for employees, based on Dumont and Baret (2017) and conducted interviews with four members of farm staff in April 2020 (see SM). We transcribed and abductively coded the interview responses using the first set of codes based on the dimensions of working conditions discussed in Dumont and Baret (2017), while subsequent codes emerged during coding. Using the method developed by Ose (2016), we then thematically clustered the material, focusing on perceived changes and impacts of the on-farm transition.

2.3.5 Economic performance

To quantitatively evaluate the economic impact of the farm transition, we collected economic data to compute indicators (Table 2) from the Farm Accountancy Data Network of the EU (FADN 2018). These data reflect central aspects affecting farm income at the farm level (e.g., costs for labor, machinery and buildings, and subsidies) and specifically for crop and beef production (e.g., costs of fertilizer, seeds, veterinary services, and revenues) (see SM).

3 Results and discussion

3.1 SMART shows an overall improvement in sustainability

The SMART assessment revealed an overall improvement in the sustainability performance of the farm (Fig. 3a and 3b). Of the 21 SMART themes, extensification of farming and transition to agroecology led to improvements in 19 themes, with the largest changes in performance scores recorded for product quality and information (an increase from 34 to 83%), accountability (an increase from 25 to 55%), human safety and health (an increase from 59 to 89%), corporate ethics (an increase from 34 to 63%), biodiversity (an increase from 43 to 66%), and animal welfare (an increase from 59 to 84%). Participation was not affected by the transition, while the local economy was negatively affected (decrease from 64 to 45%).

Some management changes had particular impacts across indicators. For example, abolishing the use of pesticides, a common feature of many agroecological farming systems (including organic farming, which only permits the use of a

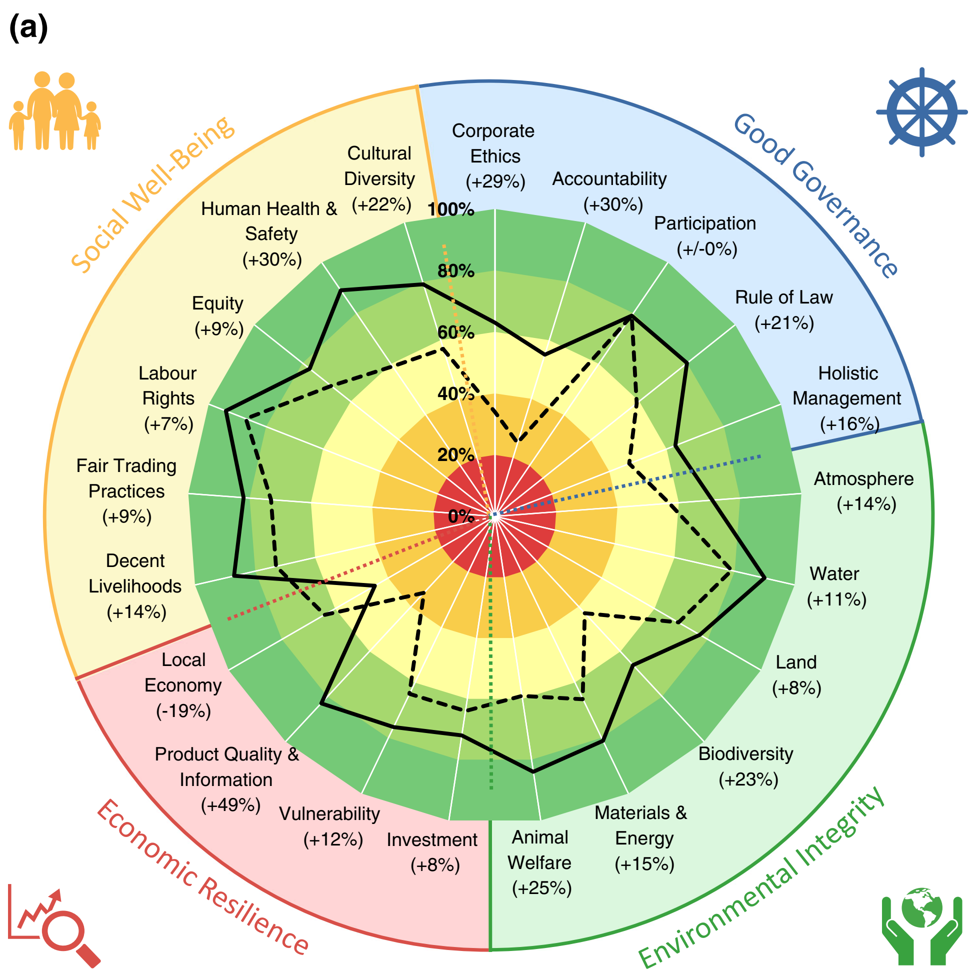
Table 2 Farm accountancy data network (FADN) indicators are used to assess economic performance before and after the agroecological transition.

Indicator	Explanation
Total input	All costs that are related to the agricultural activity of the farm and linked to the output of the accounting year, i.e., the specific costs, the overheads, the depreciation, and other external factors. The specific (also called variable) costs refer to crop- and livestock-specific inputs, such as feed, fertilizer, or seeds. In contrast, the overheads are fixed and linked to the production activity but not to specific enterprises and lines of production (material, office costs, etc.). The external factors comprise the price of inputs that are not the property of the farm holder (i.e., wages, rent, and interest payments).
Total intermediate consumption	All specific and overhead costs linked to the production in the accounting year, i.e., the total input excluding the depreciation and the external factors.
Total output	The total output of all products, including their sales, the changes in product stocks, and the change in livestock valuation. For the change in livestock valuation, the potential market price of the purchased but unsold livestock is considered, excluding the variable (breeding) costs that would be required until the point of selling.
Net value added	Remuneration to the fixed factors of production (work, land, and capital). Thus, the net value added is defined as the gross farm income minus the depreciation over the accounting year. The gross farm income, in turn, describes the total output excluding the total intermediate consumption, as well as the balance of the received subsidies and paid taxes.
Net farm income	Remuneration to the fixed factors of production (work, land, and capital) and the remuneration to the loss or profit in the accounting year (i.e., the net value added and the balance subsidies and/or taxes on investments, minus the total external factors.
Labor productivity	Labor productivity expresses the farm's net value added per agricultural work unit.
Gross margin per crop or finishing cattle	The average value of the output of some product (e.g., the revenues per hectare or livestock) is less than its variable costs
Output-to-input ratio	The total output is divided by the total input

limited amount of substances (EC 834/ 2007)), reduced health risks for workers, and improved food safety and quality, as it lowered the risk of residues in harvested crops. It also contributed positively to biodiversity, especially abolishing the use of substances listed as particularly persistent in soil and water by the Pesticide Action Network (PAN) database referenced by SMART. Abolishing the use of pesticides also implied that the farm is acting more responsibly towards its surrounding community, thus contributing positively to aspects of good governance. Another change that brought benefits in several areas was applying for organic certification, in which a thorough review of the entire farming business was performed, ensuring that management had knowledge of all aspects of the farm and its implications. This process also sparked more active sustainability work in general, including participation in the present sustainability assessment. Certification also provided more information and certainty for the consumer, e.g., regarding pesticides and associated risks, thus having positive impacts on product quality and transparency. Outcomes for biodiversity improved too, thanks to the reduced use of N fertilizer following agroecological transition (from > 400 kg of total N/ha to < 300 kg (Table 1)). Despite this, SMART still rated the total amount of N applied in year 2 to be too high (within the orange zone in Fig. 3). In general, N inputs to agroecological systems are substantially lower per hectare than those to conventional systems, due to the non-use of synthetic N fertilizers (Billen et al. 2021). Organic farms have also been shown to be associated with higher on-farm biodiversity, although the variation is large and outcomes are dependent on surrounding landscapes (Tuck et al. 2014).

Animal welfare improved thanks to better indoor conditions, less crowding, improved silage storage, and allowing all ruminants access to grazing, although the naturally short grazing season in Sweden reduced the score. By extension, improved animal welfare also positively affected the product quality score, partly explaining its large increase (from 34 to 83%). In general, animals in organic production, especially beef animals, have a greater possibility to express natural behaviors (Presto Åkerfeldt et al. 2021). Lameness is however commonly reported to be a problem in both organic and conventional production (Presto Åkerfeldt et al. 2021) but was not an issue on the

Fig. 3 (**a**) Overall performance score on the 21 sustainability themes included in SMART. The dotted line shows assessment results for year 1 (2017), and the black solid line shows results for year 2 (2020). Percentages in brackets refer to change between year 1 and year 2. (**b**) Results for the subthemes to the 21 themes in SMART, divided by (from top left) social well-being, governance, economic resilience, and environmental aspects. For all charts, the dotted line shows the results for year 1 (2017), and the black solid line shows results for year 2 (2020). Percentages in parentheses refer to change between years 1 and 2.



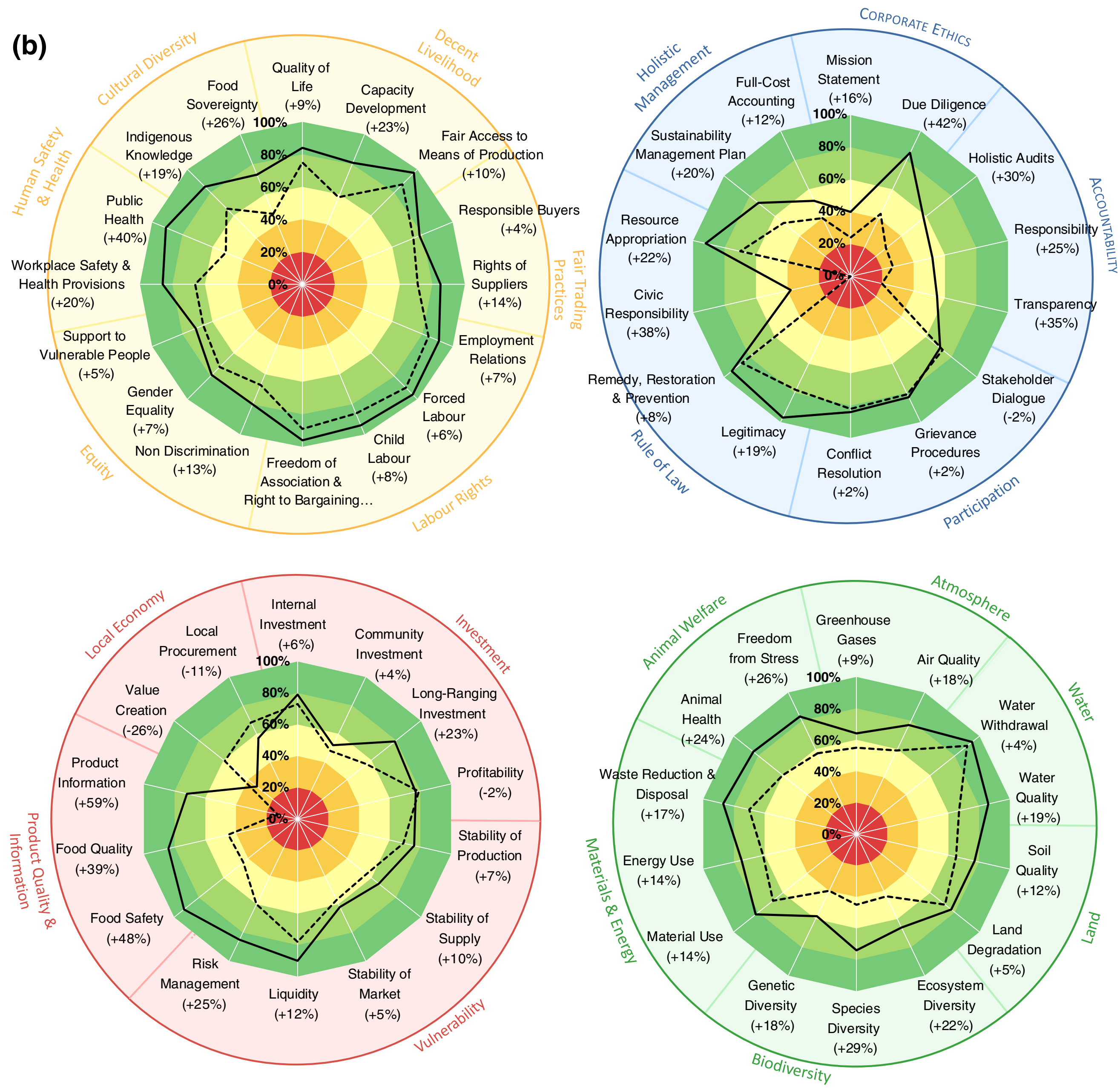


Fig. 3 continued.

case farm, where SMART deemed the prevalence of lame animals to be below threshold values.

The reduced performance for the local economy (decrease from 64 to 45%) was largely driven by a reduced number of local work opportunities and partly also by lack of internships on the farm and reduced purchases from local or national sellers, which in turn were explained by the overall reduced use of inputs in year 2.

In the similar SMART assessment of the 131 farms which participated in UNISECO, Landert et al. (2020) found large variations in sustainability performance, with SMART scores for practically all themes ranging from 0 to 40% for the worse performing farms to 80–100% for the best performing farms. The case farm's performance is roughly in line with the European median, but the agroecological transition has brought its performance more into line with that of the top-scoring European farms (some theme results in the 80–100% range in Fig. 3a), although the precise comparison is difficult. The great variation found between UNISECO farms (Landert et al. 2019) makes generalization challenging, but Landert et al. (2020) established that agroecological farms performed better than conventional farms for biodiversity (scoring 54%

on average for farms in different types of agroecological transition and 42% for conventional farms). Similar results were found in this study (biodiversity scores of 43 and 66% before and after agroecological transition, respectively). Interestingly, the pre-transition score for biodiversity (year 1) is partly attributable to the semi-natural pastures grazed by the 200 extensively managed suckler cows and heifers, arguably indicating that some agroecological practices were used on the farm already within the conventional system. If the farm in its conventional state (year 1) had reared only intact bulls and thus not managed the semi-natural pastures, the score for biodiversity would have been 34%, i.e., below the European average for conventional farms, instead of the actual 43%.

Despite the overall greater sustainability in year 2, SMART results and comparison to European top scores showed there is still room for improvement. The complementary methods used provided some nuance to the SMART results and indicated that, for some aspects, on-farm decisions may not be sufficient to change outcomes for sustainability. This is discussed in the following sections.

3.2 Less stress and a safer working environment, but changes can be challenging

SMART showed that contracts and salaries were unaffected by the agroecological transition and, in interviews, staff reported feeling that they have secure employment. The daily tasks changed for several interviewees and the change in management was primarily perceived as positive by all four employees, largely pertaining to reduced overtime, less stress, and a generally more controllable workload:

> *"Before…well, it was almost unbearable really. No matter how much you worked, it was always the same amount left. We could never keep up. Now we are perhaps catching up a little. It's like…well, it's not fun if you can never see the light at the end of the tunnel"* (Employee 4)

The working environment had also become safer thanks to the shift from keeping intact bulls indoors in pens to the loose-housing and grazing system with heifers. The employees reported several injuries caused by handling the bulls and mentioned that they always had to take precautions in an attempt to reduce risks. One member of staff even refused to handle the bulls because they felt it was too dangerous:

> *"Now we have the heifers, and of course, there are some of those that can be tricky as well, but it is, well…you can go in and pet them, it's like night and day. Now I dare to, but I wouldn't go in before."* (Employee 2)

However, the transition was perceived as a substantial change and all changes can be challenging and demand good leadership, especially in a situation where the case farm transitioned from conventional to organic production, which has different philosophical underpinnings. The staff reported that, despite feeling supported and able to manage their new tasks and responsibilities, they were not involved in the transition decision and had no common understanding of why the shift had occurred, other than that the old system was "too much to handle." The vision for the organic farming system was perceived as originating from the farm owner and manager, but there were indications of a common understanding developing between management and staff:

> *"Well, it's both fun and scary…I think it's easier with a small farm where it's just you. Now everyone has to be interested and pull in the same direction. [-] The pressure is quite big on [the farm manager]…I mean, he/she has to tell us about it [organic] so that we get into it and also get interested".* (Employee 4)

3.3 Smaller farming business with higher labor productivity and margins

The agroecological transition led to a significant downsizing of the farming business, both for costs and outputs (Table 3). In particular, the downscaled beef production was reflected in the net value-added, and thus net farm income, both of which declined substantially. Consequently, while beef production contributed nearly 85% of total revenues in 2017, its contribution was reduced to around 60% in 2020, making the farm less dependent on this source of income. In contrast, labor productivity was higher in 2020, largely explained by the reduced number of employees: net value added decreased by roughly 40% and, the labor input decreased from 14.5 to 7.15 annual work units, resulting in an increase in labor productivity of 18%.

Despite the reduced overall economic activity, the gross margin of the majority of agricultural commodities was higher in 2020, including the gross margin for finishing cattle. This was due to generally lower variable production costs, particularly for pesticides and fertilizers, and higher market prices for all products except barley, the market price of which dropped in 2020. Despite increasing gross margin and market prices, the quantity of meat sold, and thus overall revenue, decreased substantially. This led to an output-to-input ratio < 1, which is not economically sustainable in the long term.

The smaller farming business in 2020 had a negative impact on the SMART score for the local economy because of fewer job opportunities. This gives nuance to previous findings that agroecological farming acts as a driver for

Table 3 Farm accountancy data network (FADN) indicators of the changes in economic performance between years 1 and 2. All figures in 1000 SEK.

	Year 1 (2017) The Intensive system (kSEK)	Year 2 (2020) The Extensive system (kSEK)	Relative change (in %)
Total inputs	19,162	8881	−54
Total intermediate consumption	10,874	3546	−67
Total outputs	21,784	8502	−61
Crops and crop production	3144	3338	6
Livestock and livestock products	18,640	5165	−72
Net value added	12,188	7093	−42
Net farm income	5174	2959	−43
Labor productivity	841	992	18
Gross margin per crop			
Oats	4.6	20.3	341
Wheat	2.2	3.5	59
Barley	8.9	2.9	−67
Rape seed	5.5	*Not cultivated*	-
Triticale	−1.4	5.2	471
Rye	*Not cultivated*	−1.2	-
Gross margin per finishing cattle	11.0	14.9	35
Output-to-input ratio	1.14	0.96	−16

increased local employment by replacing input factors with labor. For example, van der Ploeg et al. (2019) claim that agroecological farming offers "huge potential and radical opportunities" for European farming because it can deliver a win–win-win; increased farmer income, lower use of agrochemicals, and societal benefits from increased employment. As pointed out by Rosset and Altieri already in 1997, however, agricultural science in developed countries has been geared towards maximizing production with minimal labor—"the most limiting factor." In all high-income countries, including Sweden, farming has therefore moved towards increased farm size, mechanization, specialization, and pursuit of economies of scale. This is also evident on the case farm, as several former small farms are now managed as one large farming company, mechanization is high, the farm produces only beef and cereals and, in 2017, still sought to increase profitability through higher outputs, and not higher product value or lower costs. Given this historical legacy and the investments made in mechanization and increasing efficiency, the reduced number of job opportunities in the initial stage of agroecological transition is perhaps not surprising. Many beef farmers in Sweden face financial struggles (Hessle et al. 2017) and, like many conventional farms, the case farm has experienced "the squeeze on agriculture," i.e., rapidly increasing costs relative to revenues (Rosset and Altieri 1997; van der Ploeg et al. 2019). However, the increased labor productivity found in year 2 showed that, per worker, more economic net value was created compared with the pre-transition assessment (2017). Combined with the larger margin for both crops and cattle in year 2, this could indicate that the farm is potentially moving from economies of scale to "economies of scope," where value is created from more diverse and efficient use of on-farm resources rather than increasing outputs (de Roest et al. 2018). Additionally, working conditions have evidently improved, which indicates that, despite fewer job opportunities, the jobs available seem to be more sustainable after the transition, both in terms of economic value and job satisfaction among workers. Overall, this nuances the negative SMART result for the local economy, but judging by the reduced output-to-input ratio and the reduction seen for the SMART sub-themes profitability and value creation, the farm has not yet fully realized the potential economic sustainability gains from agroecological transition. This potential is also uncertain, e.g., Landert et al. (2020) did not find a clear pattern of better (or worse) economic performance on agroecological farms, which instead seems to be more context specific. One aspect of this for the case study farm was that in year 2, some parts of the farming operation were still awaiting organic certification, which affected sales opportunities. Embargoed crops were reported by the farmers to generate higher revenues when sold as organic feed than as conventional crops for human consumption. Additionally, the gross margin for oats and triticale increased by several hundred percent between years 1 and 2 (Table 3), mainly because of higher market prices and, somewhat surprisingly, higher yields for oats and lower variable costs for triticale. This shows that factors beyond the control of the farm (e.g., certification processes and fluctuating market prices) heavily impact on-farm sustainability. Further, the agroecological transition is ongoing and not complete, and the close partnerships in short value chains that are central to agroecological system re-design (de Roest et al. 2018) take time to establish.

3.4 Higher emission intensity and shift in emission sources show that "less" and "better" must go hand in hand

The agroecological transition increased the emission intensity per kg meat from 24 to 32 kg CO_2e/kg SW (with a Swedish average of 23 kg CO_2e/kg SW (Moberg et al. 2020)). This shows a trade-off arising from agroecological transition, for example, in relation to the increased SMART scores for biodiversity and soil and water quality. The increase in emission intensity was largely explained by the shift from dairy calves to suckler calves. Methane from enteric fermentation is the largest source of GHG emissions for both systems, but in year 2, a substantial share of these emissions arose in rearing bought-in calves, i.e., from the mother cows. For the intensive system (2017), purchased concentrate feed and N_2O from manure management and transport were other considerable emission sources, while for the extensive system (2020), other sources were more marginal (SM, Table S12).

Despite the increase in emission intensity per kilogram of meat, agroecological transition lowered the climate impact of beef production in absolute terms by roughly 70%. In 2017, livestock rearing on the farm contributed 6.2 million kilograms of CO_2e, which was reduced to 1.9 million kilograms in 2020 (Fig. 4). It should be noted that we did not model changes in soil carbon following the transition but, judging from the crops grown on the farm and the changes in yields, we concluded that there will likely be a reduction in soil carbon, and hence emissions of carbon dioxide from soils, as a result of the transition (see SM Sect. 1.9).

These results are in line with previous findings that extensively reared ruminants to tend to contribute more GHG emissions per kilogram of product (Clark and Tilman 2017). However, a more holistic perspective is needed for determining the overall sustainability implications of higher emission intensities. In 2019, the average Swedish beef consumption was ~ 24 kg (SW) per person and year (SJV 2020). If that meat had been exclusively sourced from the farm before the agroecological transition, consumption would have given rise to around 570 kg of CO_2e. Limiting intake to ~ 7 kg (SW) as suggested by the EAT-Lancet commission (Willett et al. 2019) and sourcing all beef from the farm in year 2 would have contributed 225 kg of CO_2e and would have simultaneously been "better" for a range of other sustainability areas. This illustrates the potential in the "less but better" strategy; by reducing demand, GHG emissions can be kept at acceptable levels, allowing meat production to realize several other positive values. However, if consumers had replaced meat from the farm in year 1 with beef produced using less sustainable practices than those employed on the farm pre-transition, local environmental gains would have occurred at the cost of increased export of negative environmental impact, either from Sweden to abroad or from one farm to another. The farm has undertaken efforts to couple the on-farm transition with changes in consumer behavior by beginning to sell meat in boxes directly to quality-conscious consumers. Increased attention to quality can be an entry point to more sustainable food practices, but "gourmet" consumers nevertheless often eat diets rich in meat and do not necessarily have de facto more sustainable eating habits than other consumers (Schösler and De Boer 2018). This reinforces the inherent connection between "less" and "better"—choosing a more sustainable meat option must go hand-in-hand with reduced intake in order to transform trade-offs between sustainability areas into synergies (Resare Sahlin et al. 2020).

3.5 A farm-to-food system perspective is needed for assessing how to sustainably feed the world

Despite lower production volumes in year 2 (Table 1), the farm still provided calories for marginally more people per hectare than in year 1 (Table 4), primarily because of abolished use of concentrate feeds, which "imports" land use to the farm. For protein, fewer people could be fed per hectare in year 2 compared with year 1, not primarily because of reduced meat production, but lower yields and changes to sales of crops following organic conversion. Pre-transition (year 1), the farm sold over 600 tons of wheat (providing nearly 65 tons of protein) for human consumption, while in year 2 only oats and rye were sold for human consumption (around 36 tons of protein), because all other crops were awaiting organic certification and could thus only be sold as organic feed. The reduced meat output in 2020, however, explains the fewer number of people fed per hectare in terms of complete protein (containing all amino acids, i.e., either meat or a combination of grain legumes and cereals). Furthermore, a higher number of people could be fed per hectare in terms of fat in year 2, because the total land use was smaller (Table 4) and because a larger share of the land was used to produce crops for food (12.5% of total acreage in year 1 and 25% in year 2). The crop sold for food was mainly oats, which is a fat-rich cereal, thus contributing to the increase in fat per hectare in year 2. Notably, the oat yields reported in year 2 exceeded Swedish organic averages (SCB 2020), impacting the number of people fed per hectare by + 0.7 and + 0.5 per hectare for calories and protein, respectively (Table 4). Should that high oat yield be an (ex-ante)

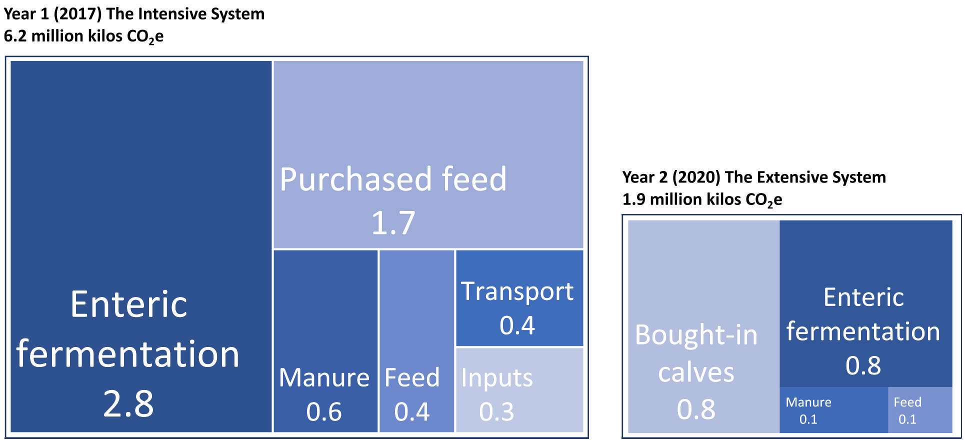


Fig. 4 Total emissions from beef production on the farm in 2017 (left) and 2020 (right), divided by sources of emissions.>

overestimation by the farmers, the number of people fed per hectare for calories would in fact be reduced. These figures should thus be interpreted as the outcomes of an atypical year.

When also considering beef production from sold feed, the results differed slightly and showed a reduction between the assessments in the number of people fed per hectare for calories and protein (Table 4). Lower yields in 2020, resulting in a slight total reduction in cereals sold as feed and thus a corresponding reduction in "virtual" beef production, explain this reduction. Using crops for feed resulted in a greater number of people fed per hectare for protein (comparing version "a" and "b" of the indicator in Table 4), i.e., 4.1 compared with 3.7 persons/ha in year 1 and 3.8 compared with 2.9 persons/ha in year 2. This was expected, because considering meat from sold feed (version "b" of the indicator) meant that on-farm land use for feed crops actually yielded food for human consumption, whereas with version "a" of the indicator, crops for feed only "leave" the farm, thus resulting in land use in the calculation without any food production. The increase occurred despite land use to produce silage being included as "virtual hectares" (required for a complete feed ration) (see SM). Although total meat production (on and off-farm) was substantially lower in year 2, total land use was much higher pre-transition due to purchased feed. In this case, lower production volume and higher land use happened to make both systems equally efficient, providing 2.4 people with complete protein per hectare (Table 4). Similarly, the farm delivered more fat from crops (which produce fat more efficiently per hectare than animals) in 2020, and simultaneously, total land use was lower, thus providing 1.9 people with fat per hectare in year 2 compared with 1.6 in year 1 (Table 4).

Some yield reductions can be expected following agroecological transition, at least initially (Altieri and Rosset 1996; Muller et al. 2018). On the farm, changes in yields varied in magnitude and direction, e.g., grass-clover ley yields more than halved, while decreases were more modest for wheat and triticale, and oat yields even increased (Table 1). As the food security indicators above illustrate, yield is not a good standalone metric of farming performance—what is produced provides a better view of a farm's sustainability in relation to the wider food system (Cassidy et al. 2013), especially concerning organic production (Muller et al. 2018). Since further net expansion of cropland is unsustainable (Steffen et al. 2015), in order for organic production to be a viable option for feeding the world, production and consumption of animal-source foods must be both significantly reduced and transformed to reduce the use of feeds which compete with food (Muller et al. 2018; van Zanten et al. 2018; Willett et al. 2019). This means that how crops and livestock are produced at the farm level, and by extension in the wider food system, is critical for food system sustainability. Ruminant livestock can play a positive role in this regard by transforming inedible biomass into highly nutritious food, but only when limited to land that is unsuitable for cropping (so that arable land can be used for direct food production) or fed waste streams from food production (Mottet et al. 2017; van Zanten et al. 2018). This case study is interesting as it is implementing this avoided feed-food competition in practice. Between years 1 and 2, the farm doubled the area used for crops for direct human consumption (to 25% of total land use). This was possible thanks to downscaling of cattle production to a number compatible with the area of semi-natural pastures and raising cattle on grazing and organic silage only, which eliminated the land use associated with producing concentrate feed. If the farm were to moreover dedicate 15 hectares (3% of its cropland) previously cultivated with wheat to the production of peas and fava beans, this would compensate for the entire loss of protein following the reduced yields and would increase the number of people that could be fed per hectare in terms of calories, complete protein, and fat (scenario 1, Table S21, SM). This could potentially help reduce the need for N fertilizers, that SMART deemed to be problematic on the farm (see Section 3.1) and thus potentially contribute to further environmental improvements. If the farm moreover were

Table 4 Total production and number of people fed per hectare in terms of calories, protein, complete protein, and fat in year 1 and year 2, considering: (a) production occurring on the farm and (b) production occurring on the farm, and the "virtual" beef production from the sold feed. Column 3 shows the percentage change between years 1 and 2. The calculations for energy use are based on a daily energy requirement of 2550 kcal/person, those for protein on a daily protein requirement of 85 g/person, and those for fat on a daily fat requirement of 80 g/person.

	Year 1 (2017): The Intensive System		Year 2 (2020): The Extensive System		Percentage of change between years 1 and 2	
	On-farm production	Including "virtual" production	On-farm production	Including "virtual" production	On-farm production	Including "virtual" production
Total land use (ha)	995	1412	485	850	−14.5%	40%
Total production Energy (Mkcal)	2705	3217.4	1400	1847.7	−48%	−42.5%
Protein (ton)	114.5	178.6	43.9	100	−62%	−44%
Complete protein (ton)	42.4	106.5	8.3	64.4	−80%	−40%
Fat (ton)	35	64.4	20	45.7	−43%	−29%
	a) Number of people fed per hectare	b) The number of people fed per hectare incl. beef from sold feed	a) Number of people fed per hectare	b) The number of people fed per hectare incl. beef from sold feed	a) Number of people fed per hectare	b) The number of people fed per hectare incl. beef from sold feed
Energy	2.9	2.4	3.1	2.3	6.8%	−4%
Protein	3.7	4.1	2.9	3.8	−21.6%	−7%
Complete protein	1.4	2.4	0.6	2.4	−57%	0%
Fat	1.2	1.6	1.4	1.9	16.6%	18.7%

to sell an equivalent amount of the wheat and barley produced in 2020 to human consumption instead of feed, six to seven people could be fed per hectare in terms of calories and protein, compared with approximately three people without this change (scenario 2 Table S21, SM). This would exceed the average figure of five people that should be fed per hectare of arable land globally (considering seven billion people and 1.5 billion hectares of cropland (Röös et al. 2021)). It would also likely contribute positively to farm income, as prices for food crops are generally higher than for feed. Furthermore, introducing "stronger" agroecological practices, such as a more complex crop rotation where 20% of the cereal acreage (about 60 ha) is replaced with e.g., pulses, potatoes, and oilseed rape would provide calories and protein for around nine people per hectare and also significantly increase the farm's production of fat and complete protein (although still not enough to feed five persons per hectare) (scenario 3 Table S21, SM). Greater on-farm diversity is also likely to further increase SMART scores for biodiversity and soil quality.

As it is undesirable to increase meat production from a sustainability perspective (Röös et al. 2017; van Zanten et al. 2018; Willett et al. 2019) and as organic cropping generally produces lower yields (Muller et al. 2018), farm-to-food system interaction is important for sustainability. Value-chain actors and consumers must choose, and be willing to pay for, products which foster transitions to sustainability at the farm level in order for this to be viable. Otherwise, the agroecological transition on the farm will likely stop in this initial stage and never realize its full potential. In another case study of a Swedish farm, Röös et al. (2021) used similar indicators to assess farm sustainability in relation to the wider food system. They found that long-term, reliable, and fair sales outlets for farm products were essential for on-farm transition to more sustainable practices at the local and food system level, including keeping ruminants on pasture and using cropland for production for direct human consumption. Without such buyer–seller relations, farms would not have the financial capacity to make continuous sustainability improvements, as livestock production is currently an avenue to increase the value per hectare of land.

3.6 "Better" meat, a more sustainable farm, and a sustainable food system

The results for our case farm showed that agroecological transition improved sustainability for a range of aspects assessed, which can be interpreted as the farm delivering "better" meat (and crops) in year 2. However, the analysis also highlighted several trade-offs between sustainability themes.

The transition to a more sustainable production system is not necessarily equivalent to sustainable "enough." Since SMART facilitates comparison of farms across the globe, the tool results cannot be used to determine whether the benefits deriving from, e.g., discontinued use of pesticides on the farm accurately match real, marginal improvements in product quality, health, and good governance for the particular

Swedish case. A benchmark for the average performance of Swedish farming would be necessary for a more detailed analysis of the importance of improvements on the farm. Obtaining results for an average farm was not feasible within the scope of this project (the first application of SMART in Sweden) and may not even be possible due to lack of required data on national averages of, e.g., farm sustainability work, crop rotations, animals on pasture, feeding regimes, etc. On the other hand, SMART reflects a common, globally accepted description of sustainable farming, since it operationalizes the SAFA indicators and is judged to be one of the best tools available (Arulnathan et al. 2020). Our complimentary analysis of climate impact, contribution to global food security, working conditions, and economic performance provided additional insights on how the case farm is performing in relation to wider food system sustainability goals, and also quantitatively supported some of the SMART results. For example, the improvement to the SMART theme for atmosphere was reflected in the substantial overall reduction in GHG emissions from beef production and, although the SMART scores for workplace safety and quality of life were high already in year 1, SMART results and staff interviews reflected further positive development. "Better," as in more sustainable, can describe several states along a transition pathway, and beef and crop production on the farm is in different stages of agroecological transition (Fig 2). They contribute differently to farm-level sustainability, e.g., rearing heifers on semi-natural pastures contributed a substantial proportion of the SMART score for biodiversity in both assessments, while abolishing the use of pesticides in crop production had widespread impacts across several SMART themes. There is perhaps no clear answer to whether "better" meat (or crops) is synonymous with more sustainable farming but, based on our case results, it can be concluded that "better" meat production both supports and is dependent on a more sustainable farm. The case results also illustrate that "better" meat and a more sustainable farm cannot be viewed in isolation from the wider food system.

3.7 Challenges and opportunities with the applied research approach

The mixed-methods approach applied here involves challenges, with implications for data quality and reliability of results. For example, SMART requires the interviewer to make an on-site assessment for some indicators, e.g., regarding air quality in animal houses or the dirtiness of animals. The interviewer is inevitably affected by their perception of what a stable or animal should look like, which is in turn largely formed by the context in which the interviewer previously worked. The training required before application of the tool partly remedied this, and the tool provides some rules of thumb (e.g., to base assessment on the worse 10% of the herd) to improve uniformity in assessments. Researcher impact also becomes less relevant when comparing assessments for the same farm, since there are likely "even biases." Nevertheless, it is important to acknowledge the potential impact of the researcher/interviewer when comparing SMART results between farms, years, and farming contexts.

Because the farm had not been in the habit of monitoring all aspects of on-farm operations, during interviews, the farm owner and manager made qualitative estimates of quantitative information. Sometimes the mental models of the interviewees clashed with how the tool and indicators function, so it is possible that the interviewer described and asked about issues that were perceived differently by the interviewees. Moreover, the farm participated in the Swedish UNISECO case study, which i) aimed for on-farm sustainability improvements and ii) was carried out in collaboration with a food industry company. There are clear legal agreements in place separating the roles and involvement of the company and the independent research, but it is still possible that farmers could feel pressured to provide certain information. Effects of this on the results can be minimized by cross-checking information, performing quality checks on SMART assessments, and using internationally acknowledged methods for calculating climate impact, but not all uncertainty relating to this can be ruled out. Some examples of results which stand out were commented upon above.

Moreover, the economic analysis assesses the performance of the farm for a specific year. While this is straightforward for annual crops, the production cycles of livestock are not "completed" (i.e., bought, bred, and sold) within the assessment year, which complicates the analysis. To account for costs and revenues of livestock occurring in different years, change in livestock value is estimated and transferred in the analysis by considering the potential market price, excluding the required rearing costs until the point of sale. As we used the same approach in both assessments of the case farm, temporal comparisons were straightforward, but comparing between different farms or setting the numbers in the context of average FADN indicator values would be more difficult.

It would have been ideal to monitor the farm over many years, to gain a better understanding of the agroecological transition and its motivations and effects. The two assessments made provided snapshots of particular years but, as shown for example by the economic results and analysis, assessment of multiple years is necessary to draw more firm conclusions about outcomes for economic sustainability. However, the study already involved handling large amounts of data and, even with the analysis limited to two assessments, it was beyond the scope of the work to consider all details of the transition. The key contribution of the study is the novel methodological approach employed, the results of which clearly showed that without considering economics, the environment, social well-being, and good governance, one cannot obtain a meaningful understanding of sustainable farming or more sustainable meat options.

4 Conclusions

A novel mixed-methods approach was used in the holistic assessment of the sustainability impacts of agroecological transition by a real-world case study farm extensifying its livestock production and applying organic practices. The analysis investigated whether meat produced in such a system could be a more sustainable option in line with the "less but better" strategy. The results showed improved sustainability for environmental, social, economic, and governance-related aspects, with corroborating results across methods. The case farm is thus an example of the transition to a more sustainable production system, but this is not necessarily equivalent to sustainable "enough." As expected, there were both trade-offs and synergies between sustainability themes, for example in terms of increased emission intensity per kg meat, but with a simultaneous dramatic reduction in overall emissions. This highlights the inherent connection between "less" and "better"; by reducing demand, GHG emissions can be substantially reduced while beef production using "strong" agroecological practices contributes to environmental, social, and economic sustainability. "Better" can also describe several states along a transition pathway, e.g., on the case farm, beef production had transitioned further than crop production. However, "better," i.e., more sustainable, meat production both supports and depends on a more sustainable farm, and a more sustainable farm cannot be viewed in isolation from the wider food system. "Less but better" can thus guide sustainability improvements at the farm level, but it is beyond the control of the individual farm to fully realize these improvements. Involvement by value-chain actors and policymakers is also crucial.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13593-021-00737-5.

Acknowledgements Jan Landert, scientific collaborator in the Department of Socioeconomics, Research Institute of Organic Agriculture (FiBL), is thanked for his invaluable assistance in the application and farm-level sustainability assessment using the SMART Farm-tool. Thanks also to Dr. Gerald Schwarz, Thünen Institute, for facilitating and aiding the study by coordinating the UNISECO project and participating in initial discussions on the conceptualization of this study.

Authors' contributions Kajsa Resare Sahlin and Elin Röös jointly developed the research design and conceptualization. Kajsa Resare Sahlin collected all data except staff interviews, which were conducted by Elin Röös. Johannes Carolus contributed all economic methods and analyses. Karin von Greyerz performed the climate calculations, under supervision by Elin Röös. Ida Ekqvist contributed the calculations of indicators for global food security, under supervision by Elin Röös and Kajsa Resare Sahlin. The first draft of the manuscript was written by Kajsa Resare Sahlin, and Elin Röös and Johannes Carolus commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open access funding provided by Stockholm University. The research was funded by the Horizon 2020 project UNISECO under the European Commission Grant Agree number: 773901.

Availability of data and material The datasets generated during and/or analyzed during the present study are not publicly available since, despite being anonymized, they portray a single farm, so publicly sharing the data can be experienced as sensitive for the case study participants. Datasets are available from the corresponding author on reasonable request.

Code availability The SMART licensed software is not available for public use. It is available for purchase at: https://www.fibl.org/en/index.html.

Declarations

Ethics approval The processes followed in this study were approved for UNISECO by the European Commission and the James Hutton Institute (UK).

Consent to participate Informed consent was obtained from all individual participants in the study.

Consent for publication The authors affirm that human research participants provided informed consent for publication of the anonymous information and descriptions in this study.

Competing interests The authors declare no competing interests.

References

A Greener World (2017) What is better meat? In: www.agreenerworld.org. https://agreenerworld.org/a-greener-world/what-is-better-meat/. Accessed 22 Nov 2018

Altieri MA, Rosset P (1996) Agroecology and the conversion of large-scale conventional systems to sustainable management. Int J Environ Stud 50:165–185. https://doi.org/10.1080/00207239608711055

Arulnathan V, Heidari MD, Doyon M et al (2020) Farm-level decision support tools: a review of methodological choices and their consistency with principles of sustainability assessment. J Clean Prod 256:120410. https://doi.org/10.1016/j.jclepro.2020.120410

Barbieri P, Pellerin S, Nesme T (2017) Comparing crop rotations between organic and conventional farming. Sci Rep 7:1–10. https://doi.org/10.1038/s41598-017-14271-6

Billen G, Aguilera E, Einarsson R, et al (2021) Supplemental information Reshaping the European agro-food system and closing its nitrogen cycle : the potential of combining dietary change , agroecology , and circularity supplemental notes note S1 . Methods and hypothesis for assessing N fluxes. One Earth 4:

Cassidy ES, West PC, Gerber JS, Foley JA (2013) Redefining agricultural yields: from tonnes to people nourished per hectare. Environ Res Lett 8:8. https://doi.org/10.1088/1748-9326/8/3/034015

Chopin P (2021) Avenues for improving farming sustainability assessment with upgraded tools , sustainability framing and indicators . a review. Agron Sustain Dev 41:. https://doi.org/10.1007/s13593-021-00674-3 (2021)

Clark M, Tilman D (2017) Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. Environ Res Lett 12:064016. https://doi.org/10.1088/1748-9326/aa6cd5

Clark MA, Domingo NGG, Colgan K, et al (2020) Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science (80-) 370:705–708. https://doi.org/10.5880/pik.2019.001

de Boer J, Schösler H, Aiking H (2014) "Meatless days; less but better"? Exploring strategies to adapt western meat consumption to health and sustainability challenges. Appetite 76:120–128. https://doi.org/10.1016/j.appet.2014.02.002

de Olde EM, Henrik Moller B, Fleur Marchand B et al (2017) When experts disagree: the need to rethink indicator selection for assessing sustainability of agriculture. Environ Dev Sustain 19:1327–1342. https://doi.org/10.1007/s10668-016-9803-x

de Roest K, Ferrari P, Knickel K (2018) Specialisation and economies of scale or diversification and economies of scope? assessing different agricultural development pathways. J Rural Stud 59:222–231. https://doi.org/10.1016/j.jrurstud.2017.04.013

Dumont AM, Baret P V (2017) Why working conditions are a key issue of sustainability in agriculture? a comparison between agroecological, organic and conventional vegetable systems. https://doi.org/10.1016/j.jrurstud.2017.07.007

Dumont B, Groot JCJ, Tichit M (2018) Review: make ruminants green again - how can sustainable intensification and agroecology converge for a better future? Animal 12:S210–S219. https://doi.org/10.1017/S1751731118001350

Eating Better (2017) Meat and sustainable diets: why we recommend 'less and better.' Eat. Better News,http://www.eating-better.org

Eating Better (2021) Sourcing better framework

EC 834/2007 (2007) Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91 European Council Brussels

European Commission (2020) Farm to fork strategy - for a fair, healthy and environmentally friendly food system Brussels

FADN (2018) Farm accountancy data network. An A to Z of methodology.

FAO (2019) The future of food and agriculture - alternative pathways to 2050. Rome

FAO (2013) SAFA Indicators. Food and agriculture organization of the United Nations, Rome

Tirado R, Thompson KF, Miller KA, Johnston P (2018) Less is more - reducing meat and dairy for a healthier life and planet. Scientific background on the Greenpeace vision of the meat and dairy system towards 2050. Exeter

Harrison H, Birks M, Franklin R, Mills J (2017) Case study research: foundations and methodological orientations. Forum Qual Sozialforsch 18:1–12. https://doi.org/10.17169/fqs-18.1.2655

Hessle A, Kumm KI, Bertilsson J et al (2017) Combining environmentally and economically sustainable dairy and beef production in Sweden. Agric Syst 156:105–114. https://doi.org/10.1016/j.agsy.2017.06.004

HLPE (2019) Agroecological and other innovative approaches - a report by the high level panel of experts on food security and nutrition. Rome

IPCC (2019a) Climate change and land — IPCC. In: IPCC Spec. Rep. Clim. Chang. Desertif. L. Degrad. Sustain. L. Manag. food Secur. Greenh. gas fluxes Terr. Ecosyst. https://www.ipcc.ch/report/srccl/. Accessed 11 Sep 2019

IPCC (2019b) 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories - volume 4 agriculture, forestry and other land use. Switzerland

IPCC (2013) Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA

Karlsson JO, Röös E (2019) Resource-efficient use of land and animals-environmental impacts of food systems based on organic cropping and avoided food-feed competition. Land Use Policy 85:63–72. https://doi.org/10.1016/j.landusepol.2019.03.035

Landert J, Pfeifer C, Carolus J, et al (2019) Deliverable report D3.1 report on environmental, economic and social performance of current aefs, and comparison to conventional baseline. UNIABDN

Landert J, Pfeifer C, Carolus J et al (2020) Assessing agro-ecological practices using a combination of three sustainability assessment tools. J Sustain Org Agric Syst 70:129–144. https://doi.org/10.3220/LBF1612794225000

Moberg E, Karlsson Potter H, Wood A et al (2020) Benchmarking the Swedish diet relative to global and national environmental targets—identification of indicator limitations and data gaps. Sustainability 12:1407. https://doi.org/10.3390/su12041407

Mottet A, De Haan C, Falcucci A et al (2017) Livestock: on our plates or eating at our table? A new analysis of the feed/food debate. Glob Food Sec 14:1–8. https://doi.org/10.1016/j.gfs.2017.01.001

Muller A, Schader C, El-HageScialabba N et al (2018) Strategies for feeding the world more sustainably with organic agriculture. Nat Commun 8. https://doi.org/10.1038/s41467-017-01410-w.DOI:10.1038/s41467-017-01410-w

Ose SO (2016) Using excel and word to structure qualitative data. J Appl Soc Sci 10:147–162. https://doi.org/10.1177/1936724416664948

Poore J, Nemecek T (2018) Reducing food's environmental impacts through producers and consumers. Science (80-) 360:987–992

Poux X, Aubert P-M (2018) An agroecological Europe in 2050: multifunctional agriculture for healthy eating - findings from the ten years for agroecology (TYFA) modelling exercise

Prazan J, Aalders I (2019) UNISECO deliverable report D2.2: typology of AEFS and practices in the EU and the selection of case studies this page is left blank deliberately. REPORT D2.2. Typology of AEFS and Practices in the EU and the Selection of Case Studies 1

Presto Åkerfeldt M, Gunnarsson S, Bernes G, Blanco-Penedo I (2021) Health and welfare in organic livestock production systems-a systematic mapping of current knowledge. Org Agric 11:105–132. https://doi.org/10.1007/s13165-020-00334-y

Resare Sahlin K, Röös E, Gordon LJ (2020) 'Less but better' meat is a sustainability message in need of clarity. Nat Food 1:520–522. https://doi.org/10.1038/s43016-020-00140-5

Röös E, Bajželj B, Smith P et al (2017) Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures. Glob Environ Chang 47:1–12. https://doi.org/10.1016/J.GLOENVCHA.2017.09.001

Röös E, Bajzelj B, Weil C et al (2021) Moving beyond organic – a food system approach to assessing sustainable and resilient farming. Glob Food Sec 28:100487. https://doi.org/10.1016/j.gfs.2020.100487

Rosset PM, Altieri MA (1997) Agroecology versus input substitution: a fundamental contradiction of sustainable agriculture. Soc Nat Resour 10:283–295. https://doi.org/10.1080/08941929709381027

SCB (2020) Skörd för ekologisk och konventionell odling 2019

Schösler H, De Boer J (2018) Towards more sustainable diets: insights from the food philosophies of "gourmets" and their relevance for policy strategies. Appetite 127:59–68. https://doi.org/10.1016/j.appet.2018.04.022

SJV (2020) Statistics database of the Swedish board of agriculture. In: Off. Stat. Sweden. http://statistik.sjv.se/PXWeb/pxweb/sv/Jordbruksverkets statistikdatabas/Jordbruksverkets statistikdatabas__Konsumtion av livsmedel/JO1301K2.px/?rxid=5adf4929-f548–4f27–9bc9–78e127837625

Slow Food (2018) Slow meat. In: www.slowfood.com. https://www.slowfood.com/what-we-do/themes/slow-meat/. Accessed 22 Nov 2018

Steffen W, Richardson K, Rockström J, et al (2015) Planetary boundaries: guiding human development on a changing planet. Science (80-) 347:1259855–9. https://doi.org/10.1126/science.1259855

Tittonell P (2014) Ecological intensification of agriculture-sustainable by nature. Curr Opin Environ Sustain 8:53–61. https://doi.org/10.1016/j.cosust.2014.08.006

Tuck SL, Winqvist C, Mota F et al (2014) Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. J Appl Ecol 51:746–755

van der Ploeg JD, Barjolle D, Bruil J et al (2019) The economic potential of agroecology: Empirical evidence from Europe. J Rural Stud. https://doi.org/10.1016/j.jrurstud.2019.09.003

van Zanten HHE, Herrero M, Van Hal O et al (2018) Defining a land boundary for sustainable livestock consumption. Glob Chang Biol 24:4185–4194. https://doi.org/10.1111/gcb.14321

Willett W, Rockström J, Loken B et al (2019) Food in the anthropocene: the EAT–Lancet commission on healthy diets from sustainable food systems. Lancet 6736:3–49. https://doi.org/10.1016/S0140-6736(18)31788-4

WWF-Germany (2018) Einkaufsratgeber fleisch und wurst. In: www.wwf.de. https://www.wwf.de/aktiv-werden/tipps-fuer-den-alltag/vernuenftig-einkaufen/einkaufsratgeber-fleisch/?fbclid=IwAR2148bI90z5yQb_UM43qhSFFBBn0qIF1EEUKkRVsxWMwXJgx7Zan6yuwbI. Accessed 22 Nov 2018