Supplemental information for Synergies and trade-offs for sustainable food production in Sweden: an integrated approach

Table S1. Search terms used in the systematic literature search. All searches included the general search terms (1), specific search terms for each dimension (2) and search terms for each aspect for the specific dimension (3).

1: General search terms					
(Agricultur* OR farm* OR crop* OR food) AND (Swed* OR Nordic OR Scandin*) AND PUBYEAR > 1999					
2: Dimension-specific search terms					
	Climate	Environment	Animal welfare	Livestock epidemiology	Economy
	Climate	Eutrophic* OR phosphorus OR nitro* OR biodivers* OR divers*	((Animal OR livestock) AND welfare)	Epidem* OR biosecur* OR zoonos*	Business OR "firm strategy" OR profitab* OR "economic sustainability" OR "economically sustainable" OR "economic viability" OR “economically viable” OR "economic output"
3: Aspect-specific search terms					
Transports & supply chain	Transport* OR logistic*	Transport* OR logistic* OR “supply chain”	Transport* OR logistic* OR “supply chain”	Transport* OR logistic* OR “supply chain”	Transport* OR logistic* OR “supply chain”
Production	Production AND (risk* OR vulnerability OR resilience OR mitigation OR adaptation OR “ecosystems services”)	Production AND (risk* OR vulnerab* OR resilien* OR mitigat* OR adapt* OR “ecosystem service*”)	(Production OR slaughter* OR abattoir*) AND (risk* OR vulnerab* OR resilien* OR mitigat* OR adapt* OR prevent* OR limit*)	Production AND (risk* OR vulnerab* OR resilien* OR mitigat* OR adapt* OR prevent* OR limit*)	Production AND (efficiency OR output OR yield)
Scale	Smallholding OR small-holding OR "small holding" OR "small scale" OR "farm size"	Smallholding* OR small-holding* OR “small holding*” OR “small scale” OR small-scale OR “farm size”	Smallholding* OR small-holding* OR “small holding*” OR “small scale” OR small-scale	Smallholding* OR small-holding* OR “small holding*” OR “small scale” OR small-scale OR “farm size” OR land*	SME* OR consolidat* OR "small scale" OR "farm size" OR “economies of scale”

			OR “farm size” OR land*		
Waste	Waste*OR recycl*OR spoilage OR residual*	“Wast* manag*” OR recycl* OR spoilage	Wast* OR recycl* OR spoilage	Wast* OR recycl* OR spoilage	Wast* OR recycl* OR spoilage
Marketing & retail	Market* OR retail*	Market* OR retail*	Market* OR retail*	Market* OR retail*	Marketing OR retail* OR promot* OR communicat*
Public procurement	Procurement	Procurement	Procurement	Procurement	Public procurement
Consumer attitudes	Attitud* OR opinion* OR belief*	Attitud* OR opinion* OR belief*	Attitud* OR opinion* OR belief*	Attitud* OR opinion* OR belief*	Attitud* OR opinion* OR belief*
Policy	Polic* OR incentive* OR politic OR “management control*”	(Polic* OR incentive* OR subsid* OR politic*) AND (sustainab* OR viable)	Polic* OR incentive* OR subsid* OR politic* OR “management control*”	Polic* OR incentive* OR subsid* OR politic* OR “management control*”	Polic* OR incentive* OR politic* OR “management control*” OR regulation
Mapping	Lca OR "life cycle assessment" OR mapping OR "resource flows"	"Lca" OR "life cycle assessment*" OR "life cycle analys*" OR "resource flow*"	"Lca" OR "life cycle assessment*" OR "life cycle analys*" OR "resource flow*"	"Lca" OR "life cycle assessment*" OR "life cycle analys*" OR "resource flow*"	"Lca" OR "life cycle assessment*" OR "life cycle analys*" OR "resource flow*" OR “value chain”

Table S2. Number of articles found in each literature search (a) and number of articles included after the first selection (b). The total represents the total number of unique articles included for the next selection step for each dimension, without duplicates/triplicates of articles that consider more than one aspect.

	Climate	**Environment**	**Animal welfare**	**Livestock epidemiology**	**Economy**
Transports & supply chain	60[a] | 5[b]	158 | 15	17 | 10	62 | 8	62 | 5
Production	56 | 20	115 | 22	36 | 14	51 | 17	46 | 13
Scale	7 | 2	49 | 9	12 | 4	21 | 1	29 | 6
Waste	43 | 9	81 | 26	5 | 2	14 | 3	38 | 9
Marketing & retail	35 | 7	85 | 15	14 | 10	22 | 1	78 | 12
Public procurement	3 | 2	5 | 0	2 | 1	1 | 0	0 | 0
Consumer attitudes	15 | 3	47 | 6	24 | 14	21 | 8	25 | 1
Policy	71 | 14	58 | 11	16 | 9	30 | 2	101 | 10
Mapping	45 | 14	54 | 26	3 | 3	0 | 0	17 | 3
Total	57 (after removal of 19 duplicates/ triplicate)	98 (after removal of 32 duplicates/ triplicates)	67 (after removal of 26 duplicates/ triplicates)	40 (after removal of 13 duplicates/ triplicates)	51 (after removal of 8 duplicates/ triplicates)

Table S3. Interview guide for stakeholder interviews, translated from Swedish. Table 1 is available in the article this supplementary material belongs to.

Step 1	
Short introduction of yourself, the project and the aim of the interview, i.e. how the material will be used.	
Question 1	Do you have any general thoughts after having looked through the results of the literature review and synthesis?
Step 2	
Specify that the interview will mainly consider Table 1, concerning synergies and trade-offs for different sustainability interventions and dimensions. [P*rovide further explanation if needed*].	
Question 2	Looking at Table 1, which **one** intervention do you feel is most important, in terms of solving sustainability issues related to the dimensions? Why this one? How complex (difficult to implement) do you feel this intervention is, e.g. in term of known or unknown negative effects on the dimensions?
Question 3	Specify **two** more interventions that you consider important. Why these two?
Question 4	For the **three** interventions you have chosen, do you agree with the effects of these interventions on the different dimensions, i.e. the colors used in the Table 1? [*If this has not been stated for questions 2 and 3*]
Question 5	The information for Table 1 is based on the current state of knowledge in Sweden. Do you think there are other important aspects or effects that are missing regarding the three interventions you chose, i.e. are there any knowledge gaps? [*If this has not been stated for earlier questions*]
Question 6	What type of research do you feel is necessary to fill the knowledge gaps? [*Related to question 5*]
Question 7	Do you have any other input to provide, e.g. any other knowledge gaps you have identified based on the results?

Table S4. Overview of literature review structured after focus areas and system dimensions.

ReDiReL Focus Area	System Dimension				
	Climate Change	**Environment**	**Animal Welfare**	**Livestock epidemiology**	**Economy**
Transport and localization	The aspect of transport and locality cannot be regarded in isolation from other aspects, such as production operation and characteristics. It could be beneficial to eat locally produced food [46] but the transport constitute a relatively small part of the GHG emissions in agricultural food production – the GHG emissions associated with the production are of greater importance [46,47]. There is although a growing interest in locally produced food, and it is argued to bring benefits to society additional to climate change mitigation [45].	On a landscape scale, a higher heterogeneity of different habitat types or crops does not result in a higher density of migratory or farmland birds [38,39]. However, small-scale farms usually have a higher diversity of birds, insects and plants compared to larger farms, as these farms have higher on-farm heterogeneity. Nevertheless, earning a living on small farms is generally more difficult [40,41].	Mobile abattoirs decrease the need for transports, and also improves animal welfare [35]. Loading animals on and off transports is an important animal welfare consideration, and ideally loading docks should be used for this [37].	Animal transports of different types can cover large areas and many farms, potentially spreading contagious diseases [33].	• Direct selling from farmers to consumers through farmers' markets and on-farm shops entail higher prices, but also higher labor costs, causing most Swedish farmers to focus on the wholesaler marketing channel [122] • The Swedish food system is reliant on imports, especially of animal fodder [42]

Resource utilization within production	• Feed production is a major contributor of GHG emissions in ag. and discussed in relation to aspects such as import, fertilization rates, number of cuts, feedstuff availability, cultivation practices, and possible synergies with energy production [43,50,51,123] • Two discussed mitigation strategies for dairy is production efficiency or shift to vegan milk [48,52,94,104,124] • There is extensive research on lifecycle assessments for various products or systems [46,50,66,67,92,125,126] • The aspect of climate change adaptation is missing [12,58]	Increasing production efficiency, reducing animal density and improving manure handling, integrating crop and animal production, decreasing production of animal products and reducing imports of fodder may decrease environmental impacts and global warming [43,49,52,54,55].	Less intense production systems, lower animal density and more time spent outdoors generally lead to higher animal welfare [59,60]. However, production systems like these may be less profitable and have more negative environmental impacts [99].	Improving animal transports, increasing vaccination and improving general cleanliness within farms can improve farm biosecurity and limit disease spread [62,64,65].	• Organic farming generally shows lower yields, but higher farm gate prices of their products, and there are indications that organic farms are slightly more profitable than their conventional counterparts [122] • Trade-offs appear between economic outcome on the one hand, and animal welfare [99,104,105] and environment on the other [104,106] • Synergies appear when increased efficiency lead to both decreased cost and decreased environmental impact [52]
Scale of production	• The scale of production influence the potential for combined heat and power from agricultural residues [77] • No study was however found that explicitly	No studies found	Animal welfare is generally better with small-scale slaughter, as this generally allows more consideration of animal needs [73].	No studies found	• Smaller scale of production often means lower farm profitability [69,70,127] and creates other efficiency related challenges [71,72] • Cooperative solutions are suggested to increase

	studied this aspect in relation to climate change.				efficiency of small scale farms [72,76]
Waste utilization	• There are climate change mitigation potentials in using agricultural residuals (e.g. straw, manure) to produce biogas but the financial aspect is currently a barrier for implementation [77–79,83,123,128]. • The treatment and use of organic food waste and sewage sludge to recycle nutrients back to the agricultural fields, generally involves synergies with reduced GHG emissions, but it is method dependent [32,85,88,89,129]	Improving resource and waste utilization through source separation of food waste, wastewater and blackwater, and using the resulting sewage sludge as a fertilizer has the potential to decrease both eutrophication and global warming [85–87]. In addition, directly recycling N and P from sewage sludge or from ash from incineration of sewage sludge also results in lower environmental impacts, but often a higher energy consumption [88,90].	No studies found	No studies found	Even though results are inconsistent, several articles in this review claim that subsidies are required for biorefineries based on food waste to be economically feasible [77,80,128]. Having small-scale biorefineries is especially challenging [80] and require even more subsidies than large-scale dittos to be economically feasible [77,83].
Marketing, labelling and consumption of sustainable food	• Consumers are generally positive to climate labelling but consider e.g. transport and waste as more important than a protein shift [93,97]. It is the consumers' demands that drive the retailers to provide options but these options must coincide	Consumer actions are as or more important than food industry actions to decrease environmental impacts, e.g. through decreasing household wastage and consumer home transports [100].	A higher animal welfare is a quality some consumers are willing to pay more for when buying meat, e.g. in the form of meat slaughtered in mobile abattoirs [35,36,134]. However, there is a need to communicate the value of high animal welfare to consumers and change public procurement	No studies found	• Buying locally sourced food is the most common sustainability promoting activity among consumers [98] • Willingness to pay is higher for products with animal welfare enhancing attributes [35,36], but there are large differences between consumer groups [36]

	with financial goals [96]. • There are synergies between nutritious diets and meals that provide low GHG emissions [130–133] • Generally a shift towards more vegetable products and less dairy and meat produces is the most effective way to reduce the carbon footprint of meals [31,47,66,92] but energy profiles should be compared before recommending all vegetables in favor of all types of meat [66]	practices, to increase sales of Swedish meat with a high animal welfare [95].	• Labelling [95] and storytelling [135] are two ways to increase the consumer-perceived attractiveness of sustainable food • Local authorities can and do act proactively as customers to encourage production of sustainable food [45]