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The sustainable farm – does it exist?

Elin Röös

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Preface

This report is written within the framework of two research projects at the Swedish University of Agricultural Sciences (SLU). The first is entitled *What is sustainable Swedish agriculture?* and funded by the research platform Framtidens Lantbruk (Future Agriculture) at SLU. The purpose of this project is to study different strategies for identifying, measuring, and managing sustainability in agriculture and the rest of the food chain. The second project is entitled *The Sustainable Oat Farm - Theory Meets Reality* and is funded by the company Oatly. The purpose of this project is to analyze various sustainability dimensions at farm level during the expansion of production of food crops for human consumption.

I would like to thank Jan Bengtsson and Pernilla Johnsson at Framtidens Lantbruk for their invaluable comments on this report. I would also like to thank Adam and Thomas Arnesson at Jannelund's Farm as well as Carina Tollmar at Oatly for our inspirational discussions about sustainable agriculture for the future.

Uppsala 05/19/2017

Elin Röös

Note: The questions dealt with in the research platform Future Agriculture, have since July 2017 moved to a new research platform, Future Food*, also at SLU.*

Contents

1. Introduction

All human activity, including agriculture and food production, affects the environment. Food production accounts for 20–30 percent of global greenhouse gas emissions (Vermeulen *et al.*, 2012). Agriculture lies behind the majority of emissions of eutrophying substances to the sea and other watercourses. Expansion of agricultural land and structural changes of agriculture leading to more monotonous landscapes have had a negative impact on farm land biodiversity. Further, agriculture and the subsequent stages in the food chain are highly dependent on fossil fuels.

From a global perspective, Swedish agriculture has a number of advantages. EU regulation ensures that manure is used as a fertilizer and spread on arable land. In Sweden, many pesticides are banned, and soil fertility and water supply are, for the most part, good. Animal health is relatively good and antibiotic use is very low. Agriculture contributes with safe foods and renewable energy, it preserves cultural landscapes and threatened plant and animal species in semi-natural pastures, as well as creates jobs in rural areas (SBA *et al.*, 2012).

However, Swedish agriculture is also struggling with a number of sustainability issues. For example, agriculture accounts for 40 percent of the net nitrogen load to sea and 85 percent of total ammonia emissions. Even though much of the food is imported to Sweden, agriculture accounts for 13 percent of Sweden's total greenhouse gas emissions. Pesticide residue levels in watercourses have been found to exceed the safe limits. Many farmers are struggling with profitability issues, administration and regulations, and an uncertain future. It is clear that Swedish agriculture, as it stands today, is not sustainable and that sustainability must increase. But what do we actually mean by sustainable agriculture?

The purpose of this project was to study what the concepts of sustainable farming and sustainable agriculture can mean in reality, and how sustainability can be measured at farm level. This project was undertaken in close cooperation with farmers at Jannelund's Farm, outside Örebro. Jannelund's Farm is run by people with a strong interest in sustainability and how to manage a farm sustainably. But what does it mean and how can it be measured? The purpose of this project was to look into that question. Sweden and Swedish agriculture have been the focus of this project. However, the reasoning can be useful for other regions where the agricultural structure is similar to Sweden's. The situation can also be very different elsewhere, for example in developing countries.

2. Sustainable agriculture - what is it?

There is no established general definition of sustainability, sustainable development or sustainable agriculture. Some believe that this may be an advantage; the term's vagueness has led to it being widely spread and accepted. It is easy to agree that society and agriculture need to develop sustainably – but what sustainability actually means and how sustainable development is viewed are very different from one individual to another, from one organization to another. On the other hand, the term is in danger of becoming meaningless and unusable if it is interpreted too freely (Robert *et al.*, 2005).

2.1 Definition of sustainability and sustainable development

A widely disseminated definition of sustainable development comes from the Report of the World Commission on Environment and Development. The commission was led by former Norwegian Prime Minister, Gro Harlem Brundtland, hence the report is often referred to as the Brundtland Report. The definition reads:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987, p. 43)

The Swedish Parliament adopted a goal, the generational goal, which resembles the Brundtland definition. It is defined as follows: ”The overall goal of the Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders.”

The Brundtland Report laid the foundation for three different sustainability pillars: environmental, economic and social. It is commonly accepted that all three pillars are important to creating a sustainable society. But what exactly is meant by the different pillars and whether all three are equally important is largely open to interpretation.

The UN's 17 Sustainable Development Goals, adopted by 194 states in the fall of 2015, imply a further realization of the objective of sustainable development at global level. Several of the goals relate to food security and sustainable agriculture. There are also goals to reduce climate change and protect ecosystems and biodiversity. However, a more concrete definition of sustainable agriculture or sustainable food supply is not provided.

2.2 The term ”sustainable agriculture”

For example, FAO, the Food and Agriculture Organization of the United Nations, gives the following definition of sustainable agriculture, which can be applied to all levels:

”Sustainable development involves the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.”

This definition is also broad and non-specific. For example, what is meant by ”human needs”? Does it mean having access to large amounts of different foodstuffs every day at low prices, like in the Western world? Or does ”human needs” mean a diet that provides us with the essential, basic nutrition? And what does environmentally degrading mean? Can we – must we – accept a certain level of emissions and negative environmental impact? If so, how much? What is meant by ”technically appropriate”? And by ”economically viable”? What is a reasonable salary for farmers? And what should the working conditions be?

By taking a closer look at how the concept of sustainable agriculture is used in scientific literature and in social debate, it is possible to distinguish a number of different perspectives. Hansen (1996) describes three different approaches:

SUSTAINABILITY AS AN IDEOLOGY. Sustainability in relation to agriculture is interpreted as a strategy for agriculture in response to its negative effects. This can be expressed in different ways, but one example is the development of organic farming in Europe, which arose as a counter reaction to the industrial agriculture that emerged during the post-war period with a high level of pesticide and mineral fertilizer use. Thus, the organic principles aim at reducing the use of external inputs and utilizing local resources and biological processes as much as possible.

SUSTAINABILITY AS GOAL ACHIEVEMENT. According to this approach, sustainable agriculture is one that meets a number of goals. Conflicts regarding goals are common and thus goals need to be balanced in some way. The goals vary between different systems and depending on who defines them.

SUSTAINABILITY AS A MEANS FOR AGRICULTURE TO CONTINUE. Here, the focal point is the means for agriculture to maintain production in the event of different types of changes. Hence, sustainable agriculture is one that can continue despite changes in external conditions including economic, social and environmental changes.

All these approaches are represented in the debate about sustainable agriculture and how to define it. However, seeing sustainability as achieving a number of goals has had a great impact through the development of the UN's global Sustainable Development Goals, and also in Sweden through the work on the country's environmental goals. Sweden's environmental work is based on 16 environmental quality objectives. For each area (climate, eutrophication, acidification etc.), there are objectives for desirable statuses and indicators that measure if development is going in the right direction. Regarding the environmental objective No eutrophication for example, the goal is that levels of nutrients in soil and water should not have a negative impact on human health or biodiversity. By following up on a number of indicators, such as the release of ammonia and the flows of nitrogen and phosphorus to the coast, an assessment is made to ascertain whether the objective will be achieved within the specified time or not. However, there is no specification regarding the responsibility of different sectors in their work towards meeting the various environmental objectives. Does agriculture, for example, hold a greater responsibility for contributing to the reduction of climate impact due to the fact that crops/plants can absorb carbon from the atmosphere through photosynthesis? Or can agriculture, on the contrary, be allowed to emit a higher proportion of emissions than other sectors because food is necessary for human life?

2.3 A sustainable diet

Earlier research into sustainable agriculture has shown that it is difficult to isolate agriculture from the wider food system because the environmental impact of food is determined by three factors:

1. The number of persons to feed
2. The amount of food consumed (eaten and discarded)
3. The environmental impact caused by the production of foodstuffs

How much and *what* we eat then affects the environmental impact of agriculture. Hence, it is difficult to deal with the issue of sustainable agriculture in isolation from what we eat. Animal food has a significantly greater impact on the environment than the majority of plant-based foods, so it is very important to consider how much meat, milk, eggs and fish we consume. The current dietary habits of Swedes contribute greatly to the country's greenhouse gas emissions: nearly two metric tons of CO2e per person per year. To produce the average Swedish diet, 0.34 hectares of arable land is needed per person, which is more than what is available per person globally (Röös, *et al.*, 2015). About 70 percent of greenhouse gas emissions comes from the production of animal products. Therefore, decreasing animal product consumption in the world's richer regions where consumption of animal products is high and has increased significantly over the last 20 years is an important step for reducing the environmental impact of agriculture (Swedish Board of Agriculture, 2012; Swedish Institute for the Marine Environment, 2016). Reducing food wastage at consumer level is also important.

Does that mean that Swedish meat and milk *production* also needs to decrease? Not necessarily. Today, a large proportion of meat consumed in Sweden is imported, which means that there's room for a significant reduction in meat consumption without reducing Swedish production. There may also be advantages in producing meat and milk in Sweden: access to water is good in most parts of the country, ley grows good, and current production is efficient with relatively low environmental impact compared to global averages. If Swedish produce could be exported and replace meat and milk production that has a higher environmental impact elsewhere, this would be beneficial from an environmental point of view.

2.4 Sustainable food production in the future

Since animal foods have a significantly greater environmental impact than most plant-based foods, is a universal vegetarian or vegan diet the best for the environment? Not necessarily. When milk and eggs are produced, meat is inevitably produced by the slaughter of dairy cows and chickens. If everyone ate eggs and dairy products but excluded meat from their diet, this meat would have to be discarded. In addition, there are a lot of residues from the food industry that we don't consume but that can be used as animal feed. There is also land which is not suitable for crops but ideal for grassland and grazing animals. Pasturelands can constitute valuable habitats for many threatened plant and animal species. In the case of a vegan diet, these resources and lands could not be utilized. One can argue that animals play a role in the sustainable food production of the future. But the number of animals and type of breeding systems that can be considered sustainable are still open question.

Science cannot provide a simple and clear answer of what sustainable agriculture is - it depends on what aspects are included in the term, how they are valued, and what goals we believe we should meet through their implementation. However, the huge environmental impact caused by agriculture, in addition to the economic and social challenges faced by many farmers, show that current agricultural methods are not sustainable. Researchers agree to a large extent on a number of measures that need to be taken in order to address several of the issues (Foley *et al.*, 2011). These are:

- To halt the continued expansion of agricultural land. Globally, deforestation is a major problem with catastrophic consequences for biodiversity and the climate.
- Yields needs to increase in regions that currently have very low levels, such as certain areas in Africa, Latin America and Eastern Europe.
- More resource efficient use of water, fertilizers and chemicals, i.e. a lower usage of these per product produced.
- Wastage and other losses throughout the entire food chain need to be reduced.
- A change to our diets whereby we're consuming a smaller proportion of animal foods and a greater proportion of plant-based foods.

How we prioritize these measures is largely determined by how we look at the future and what we consider is feasible to change. And we need to look at where Swedish agriculture and Swedish farmers stand in relation to these measures. This is discussed in sections 3 and 4.

Deforestation in the Amazon. (Photo: Istockphoto)

3. Measuring sustainability

In order to estimate how sustainability is affected by different decisions in relation to production (what is produced and how), it is necessary to measure different aspects of sustainability. We must find ways of moving from a general and diffuse definition (see section 2.1) to something more concrete and measurable.

By using indicators and measuring/monitoring how environmental, economic and social aspects change over time, we get a clearer picture of where development is heading. For example, the climate impact caused by a particular production system can be estimated by calculating the greenhouse gas emissions emitted as a result of that system. But even when something that can be measured and counted is perceived as objective and ”true”, there are still values behind what and how one chooses to measure, how results are interpreted and what results are compare to. There are also things that are difficult to measure and that are therefore not measured regularly and hence risk not being recognized, e.g. aesthetic values, biodiversity and social aspects.

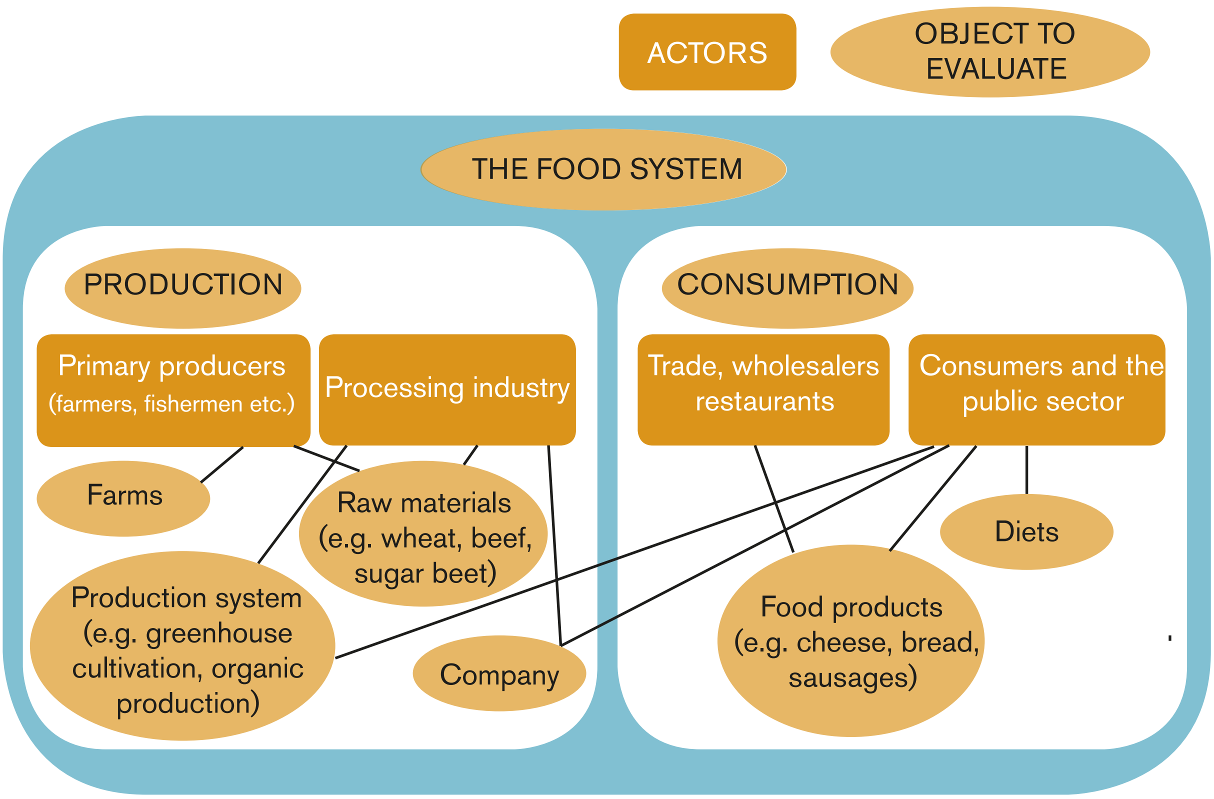


Figure 1. *Food system actors and different objects to evaluate.*

The food system is extremely complex, consisting of many activities and actors, so the term ”sustainability” comprises many different aspects. The challenge lies in selecting a sufficient number of indicators so as to capture this complexity and not overlook important conflicting objectives. Too many indicators mean data collection is costly and results are difficult to understand. It is important that the selection of indicators is done in cooperation with the actors to whom the information is relevant (Rasmussen *et al.*, 2017). Depending on the issue you are seeking an answer to, it may be necessary to evaluate the sustainability of the food system in different ways. Figure 1 shows an overview of food system actors and various ”objects” that can be evaluated. In this study, we focus on ”the farmer” and look at how ”the farm” and the ”raw materials” produced on it can be evaluated.

3.1 What one chooses to focus on is also based on one's vision of the future.

Many studies published in recent years show that a more resource-efficient food production system, reduced wastage and a change in consumption habits are needed to achieve a more sustainable food system (Bajželj *et al.*, 2014; Röös, *et al.*, 2015; Röös, *et al.*, 2015). How we prioritize these measures is largely determined by the values we set and what we consider is feasible to change. For example, if you don't think it's possible to change people's eating habits (e.g. reducing meat consumption) or if you think this constitutes a restriction on personal freedom, then you are left with a measure that focuses on reducing, as much as possible, the environmental impact per kilo of produce. However, if you think it is possible to change people's eating habits, increasing resource efficiency will not be as crucial. Hence, the overall environmental impact can be reduced by the consumption of smaller amounts of resource-intensive foods. Garnett (2014) has developed three perspectives on sustainable food security:

The efficiency perspective is based on the fact that significantly more food must be produced globally for a growing and richer population. New technology and better management will streamline production so that emissions per kilo of produce will decrease. This perspective takes the Western lifestyle as the ”good life” and assumes that it is possible to reduce environmental impact enough through increased efficiency of production. Here, increased efficiency is also considered as a means of ”saving” land by making cultivation more effective, which means that less land is needed for food production and more land can then be used for nature conservation, for example.

The demand restraint perspective, on the other hand, highlights the role of the consumer in reducing the environmental impact of food. The focus is on reducing the consumption of resource-intensive foods such as meat and dairy products. The aim is to reduce both emissions of greenhouse gases and nutrients by reducing the number of animals. Here, too, there are opportunities to ”save” land, in this case by reducing feed production and cultivating more crops for human consumption.

The food system transformation perspective sees the imbalances and injustices in the food system to be at the heart of the problem. In this perspective, the challenge is neither purely technical (more efficient production) or down to the individual (restrained consumption). Instead, a major structural change to the food system is considered to be essential. There are various views regarding what this transformation means and what it will lead to, but it is common for advocates of this perspective to highlight alternative production approaches such as organic farming, permaculture and local, small-scale food systems.

Garnett's perspectives clarify how different perspectives on food security and values affect the way we look at different types of solutions. This in turn affects how we view and measure sustainability. Life cycle assessment (LCA) that measures the environmental impact per kilo of produce, e.g. per kilo of milk, is a tool that is highly relevant in the *efficiency perspective.* Here, it is used to identify which stages in the product life cycle that have the greatest environmental impact and to discuss how these can be lowered. In *the demand restraint perspective*, LCA is also relevant, but more in order to compare different foodstuffs, e.g. the difference between the environmental impact of one kilo of meat and one kilo of beans. Here, it is also important to take into account the environmental impact of the entire diet as it is the impact from the diet, rather than individual food products, that determine the final impact from food consumption. This can be done by using LCA data for individual foods and multiplying it by the consumption of various foodstuffs. Representatives of the food system transformation perspective often criticize LCA for having an overly one-sided focus on increased efficiency[1], and that, as such, it overlooks the socio-economic context that governs the food system. With *the food system transformation perspective*, tools that take into account the numerous economic, social and environmental aspects in order to assess sustainability at field, farm or national level, rather than at product level, are put forward. It is frequently emphasized that the system should be resilient and the focus is often on small-scale producers in vulnerable situations.

Although Garnett's three perspectives are illustrative in pointing out the underlying assumptions in the debate on sustainable food production, in the food system debate they are blurred. Many actors in the food system move between these various approaches and believe that more efficient production, less resource intensive consumption habits and the partial transformation of the food system are all needed. Different actors in the food chain also have varying possibilities to influence different areas. For example, an individual farmer has little possibility to influence wider consumption habits, but a greater possibility to influence production methods. A retailer can affect what is consumed by choosing how to label, price and market products, and, to some extent, influence production by making demands on suppliers and manufacturers. The state decides on instruments for both the production side (e.g. different types of targeted agricultural support) and the consumption side (e.g. imposing taxes).

The focus of this study is the sustainable farm. How do these perspectives and the tools advocated for measuring sustainability relate to sustainability at farm level? We investigate this in section 5 by applying these tools to an actual farm.

3.2 Life Cycle Assessment - the environmental impact per unit produced

Life Cycle Assessment (LCA) is a methodology that calculates the environmental impact per unit produced. In an LCA, all emissions and resource consumption at all stages of production, usage and disposal of a product or service are identified. For a foodstuff, emissions from agriculture such as land, animals and manure, as well as the consumption of resources involved in the production and transport of input materials, mainly fertilizer and energy, and the resulting emissions, are included. The processing, packaging, storage, transportation, cooking and waste management are also included in a full life cycle assessment of a foodstuff. System boundaries can, however, be adapted to the purpose of the study. If the purpose is to compare different agricultural production systems, such as the impact of different types of maintenance rations of fodder on the same farm and for the same product, e.g. one kilo of pork, the boundary can be set at the farm gate because the following stages are the same and do not affect the comparison. With the help of an LCA, the "hot spots"[2] in the production chain can be identified and different foods compared.

1 Efficiency is an inherent characteristic of the LCA methodology because environmental impact is measured per unit produced.

2 Hot spots are processes in the production chain that cause major environmental impact in relation to other processes.

The environmental impact of different products, in this case foodstuffs, can be compared per production of one kilo of foodstuff. It may also be relevant to study the environmental impact in relation to energy content (per kcal) or per kilo of protein. There are also more advanced ways of measuring different nutritional values and comparing the environmental impact based on a ”nutrient index”. Traditionally, LCA has been used to calculate environmental impact, but, in recent years, methods have been developed to also calculate the social impact and cost during a product's lifetime. Here, too, the impact is calculated in relation to a produced unit. LCA is thus a measure of efficiency that answers the question: what is the environmental impact *per product*? For example, increasing the crop yield without changing anything else (e.g. no increase in fertilizer) will definitely reduce the environmental impact as the impact per hectare can be divided among a larger quantity of products.

3.3 Indicators for global food responsibility

By using the LCA data for different foodstuffs, one can calculate the environmental impact of different

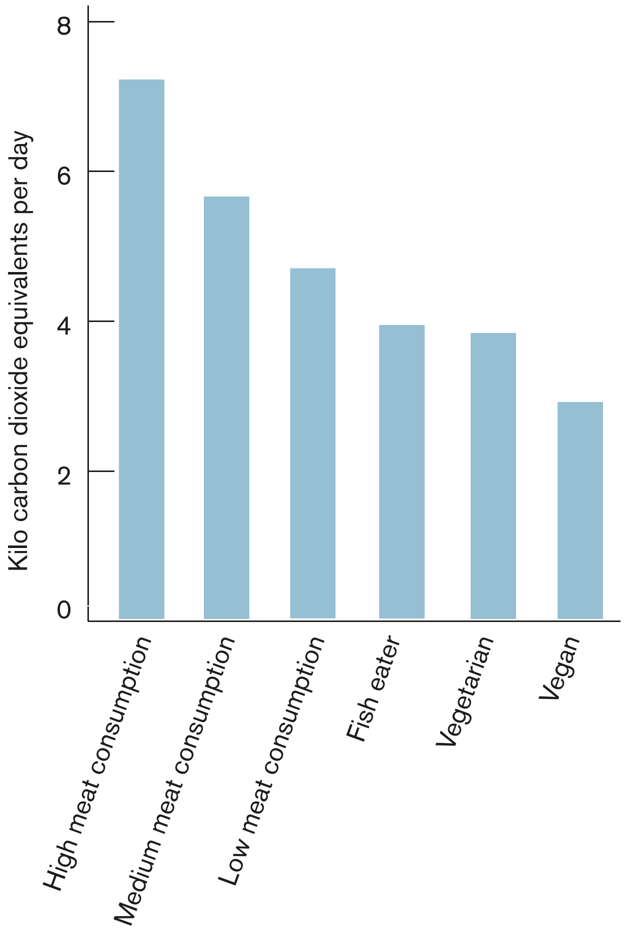


Figure 2. *The Climate Impact of Different Diets (Scarborough et al., 2014).*

diets. This way, one can see how resource-intensive or environmentally-friendly different dietary habits are. Figure 2 shows a UK dietary study in which participants were divided according to the amount of meat they were consuming. The average climate impact of these groups was then calculated using LCA data. For a person consuming between 18-36 kilos of meat per year, the climate impact is about twice that of a person on a vegetarian or vegan diet.

We then have to think about what indicators we can use to measure how farm production contributes to the global food equation, in other words the need to increase food production and lower the environmental impact. It is difficult to give a complete picture of how a single farm that produces only a limited number of products can contribute to global food security. Such an assessment also greatly depends on how the food system is to be organized (by mainly local supply or by global trade etc.). One aspect that may be interesting to study is "the number of persons that can be fed by what is produced on the farm" (Cassidy *et al.*, 2013). In this case, the indicator may be: produced kcal per hectare or kilo of protein per hectare. More sophisticated measures can be developed which take into account not only energy and protein, but a whole range of different nutrients. However, measuring energy or protein per hectare can provide interesting and easy-to-understand information about how much food a farm produces. For fruit and vegetables, supplementary measures are required as these supply the diet with vitamins, minerals and other important micronutrients, and not primarily energy and protein.

3.4 Sustainability assessment frameworks for agriculture

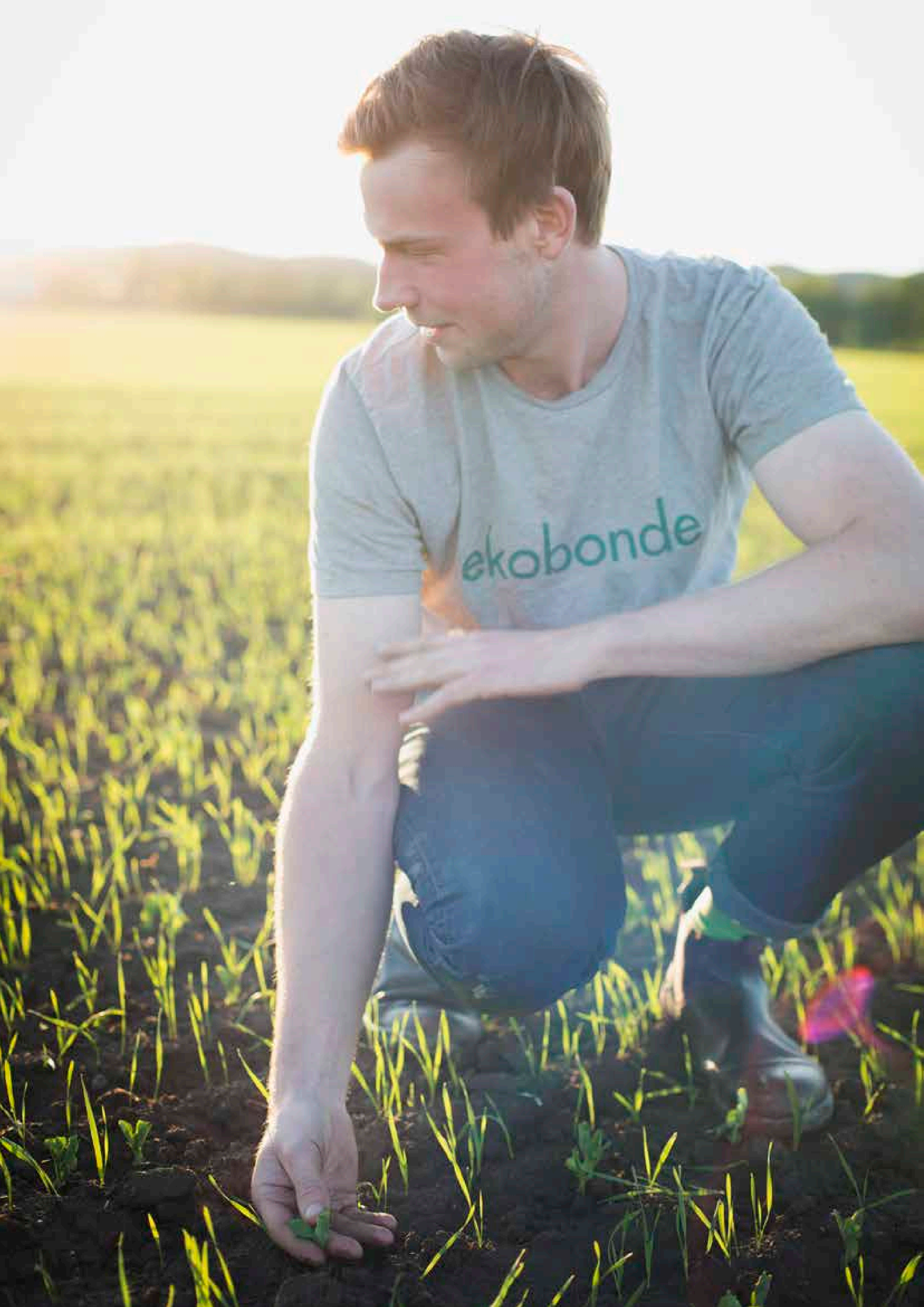
Sustainability assessment frameworks are tools that use a large number of indicators that quantitatively and/or qualitatively measure social, environmental and economic aspects. For agriculture, a number of different sustainability assessment frameworks have been developed, primarily in research (Marchand *et al.*, 2014; Schader *et al.*, 2014). Often, the sustainability assessment frameworks are built around a large number of indicators that are grouped within a number of themes, which in turn are grouped under the general economic, social and environmental sustainability dimensions. The results of a sustainability assessment are often displayed in a spider diagram, which shows how the farm scored in a number of themes. The purpose of such sustainability assessments is to assess the farm from a broad sustainability perspective, to highlight conflicting objectives and also follow changes over time.

In the past few years, FAO has developed a sustainability assessment framework entitled SAFA, which is largely based on previous tools. SAFA is characterized by four dimensions of sustainability: good governance, environmental integrity, economic resilience and social well-being. Under these, there are 21 high-level sustainability themes applicable to all types of sustainable development (Figure 4). And under these, there are 58 sub-themes that specifically deal with agriculture and food. SAFA describes in detail the sustainability objectives for all the sub-themes. SAFA also proposes a number of indicators for each subtheme in order to be able to measure progress towards the objective.

SAFA has been designed as an assessment tool for the many different types of farms and agricultural holdings worldwide. To be applicable to a particular site, we must first contextualize the indicators (i.e. make the indicators relevant) in relation to the site to be studied. Each indicator should be rated according to a five-point scale (red, orange, yellow, light green and dark green). The SAFA framework contains a description of what the red and dark green levels are (and in some cases yellow), but it is up to the assessor to determine criteria for the other levels. Even SAFA's descriptions of red and dark green require concretizing in order to be useful. For example, for the dark green level, the indicator "Connectivity of Ecosystems" states that "All areas at all sites used can be considered to be ecologically well-connected", however no definition of "well-connected" is provided as this will be context specific. Using SAFA in a detailed way, and contextualizing and concretizing all the indicators is therefore very labor-intensive. In addition, the assessment of the actual farm requires a large amount of data to be collected.

SAFA is also available in a simplified version aimed at small farms and companies - SAFA Smallholders App. This tool is structured around a number of issues in each area and offers a much broader assessment with only three performance score levels: green for "good", yellow for "limited" and red for "unacceptable."

SAFA is one of several sustainability assessment frameworks for agriculture. RISE is a tool used by advisors in many countries, e.g. Denmark. IDEA is another framework that has been used in France, among other places. In Sweden, these sustainability assessment frameworks have only been used in a limited number of research projects.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4. Jannelund's Farm

What can the different tools say about the sustainability of a Swedish farm? Can they help us get closer to understanding what sustainable agriculture is? The various tools were tested at Jannelund's Farm, outside Örebro, during a two year period to see how they captured the farm's sustainability as it evolved from mainly lamb production to an increase in crop production for human consumption. The results are reported in this section.

4.1 About Jannelund's Farm

Jannelund's Farm is located between Mullhyttan and Fjugesta, outside Örebro. In the country's agricultural statistics, this area belongs to the forest districts of central Sweden. Jannelund's Farm has been owned by the Arnesson family since 1960 and was taken over by Thomas and Berit Arnesson in 1990. Operations were then transferred to organic production. In 2007, they decided to focus on lamb farming of an indigenous Swedish breed.

In 2015, 67 hectares of land was used with the main activity being KRAV[3]-certified lamb farming with a total of 100 ewes giving birth to 250 lambs each year. All feed is produced on the farm, except mineral feed and a small amount of concentrates. The lambs were born in the spring and grazed throughout the summer and autumn. The ewes were fed with cereals and concentrates before and after giving birth, however the main feed was coarse fodder also known as roughage. Since 2007, the farm has gone from slaughtering their animals solely at Scan[4] to slaughtering them at a local slaughterhouse and, to a large extent, selling the meat directly to the customer. Some of the lambskin is prepared by Tranås Skinnberedning (tannery) and also sold at the farm.

In 2015, Thomas' and Berit's son Adam began to get involved in the day-to-day management of the farm and wondered how a farm such as Jannelund's could develop. One option was to continue in the same way as before. But this would not be financially viable and would mean seeking work beyond the farm. As there is a demand for Swedish lamb, a natural alternative would be to expand lamb production as the farm already has the prerequisites for the increase, in addition to knowledge about lamb production.

However, Adam has an ambition to operate the farm as sustainably as possible, and from a wider perspective. On their website, he explains:

"In order to develop sustainable food production, we believe that meat consumption must generally decrease. We're also convinced that this will be the case in the near future. Animals are at the centre of Jannelund's Farm today, and will continue to be so in one way or another. But instead of intensifying and expanding our animal husbandry, we see the cultivation of plant protein for human consumption as a great opportunity. During 2016, we will carry out several test cultivations that will result in the long-term conversion of the farm. The ratio between the amount of meat protein and plant protein leaving the farm will change."

Thus, during 2016, several changes took place at the farm. The production of crops was significantly increased by the introduction of new ones such as the oat cultivar SOL II, gray peas and the test cultivation of different types of beans (Table 1). Through leasehold, the amount of land cultivated

3 KRAV is the certification body for organic production in Sweden.

4 Scan is the major slaughtering house in Sweden.

Adam Arnesson, Jannelund's farm. Photo: Bianca Brandon-Cox

Table 1. *Crop cultivation at Jannelund's Farm in 2015 and 2016.*

	Year 2015			Year 2016		
	Area (hectares)	Crop yield (kilo/ hectare)	Fertilizer (kilo nitrogen/ hectare)	Area (hectares)	Crop yield (kilo/ hectare)	Fertilizer (kilo nitrogen/ hectare)
Grassland for silage	21	4000	0	20	5500	0
Pasture	30	4000	0	28	3500	0
Oats, feed	2.8	3000	32	8	2800	50
Oats/peas, feed	6.2	2500	21	3	3800	20
Peas, feed				2	2300	0
Spring wheat	6.5	2500	44	9.6	2400	60
Oat variety SOL II				8.4	2500	60
Rye				2	2250	0
Gray pea-spring wheat				1	5200/ 3400	25
Broad beans				0.5	800	0
Colored beans				0.1	800	0
Gray pea, fresh				0.1	2000	0
Turnip				0.005	60000	0
Bee forage				1		0
Total	67		506	83		1554

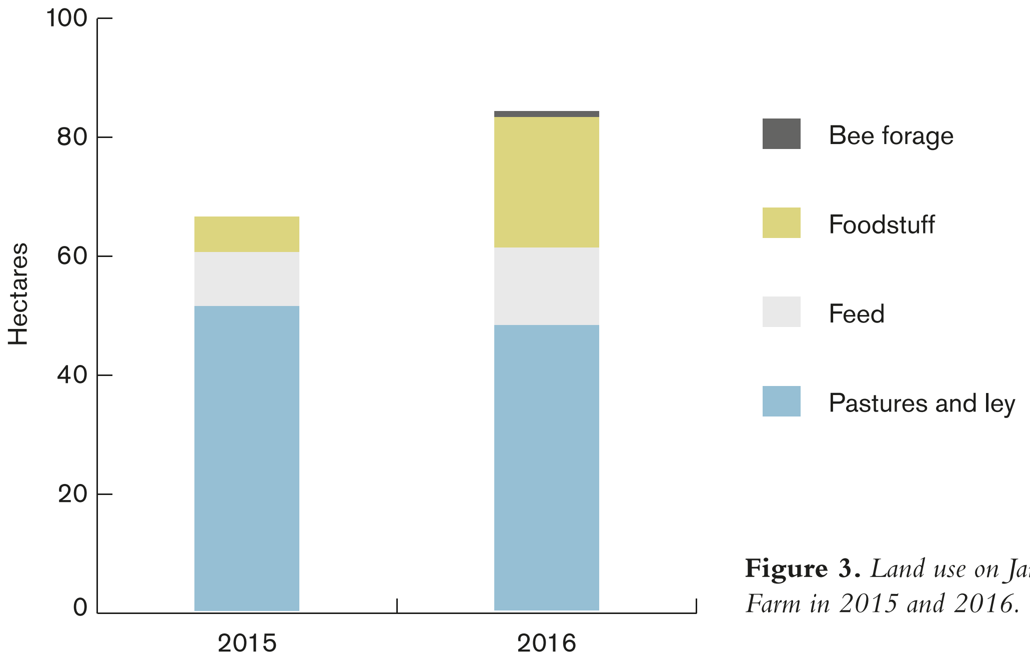

Figure 3. *Land use on Jannelund's Farm in 2015 and 2016.*

increased to 83 hectares. Instead of manure from conventional farms, biogas digestate[5] was purchased from the biogas plant in Örebro in which food waste and other organic wastes are digested. On half a hectare, bee forage was also grown: a mixture of flowering herbs that provide bees and other insects with a food supply for most of the season. The direct sales of lamb increased significantly, and even some legumes were sold directly to consumers. The marketing was mainly done via Twitter. The SOL II oats were sold to the company Oatly, who produced an oat drink which they called Gammeldags Hafvredryck (Old-Fashioned Oat Drink). The rye was sold to a local mill. The sheep and lamb were supplemented with a number of heifers. Adam and his parents also began building a farm shop and new stables. Was the farm more sustainable as a result of these changes?

5 Digestate is the nutrient rich residue from biogas production.

4.2 Method - what we did in this study

The sustainability of Jannelund's Farm was assessed according to the three perspectives described in chapter 3.1: efficiency, demand restraint and food system transformation. With the help of LCA, the climate impact per kilo was calculated for the products produced on the farm in 2016: crops, lamb and beef[6]. The amount of food produced on the farm in 2015 and 2016 was calculated and com-

6 LCA can also be used to calculate other environmental effects such as eutrophication, acidification, land and energy use. Here, however, we have chosen to focus solely on climate impact. Most importantly, we want to show that an LCA calculates the impact per kg of product.

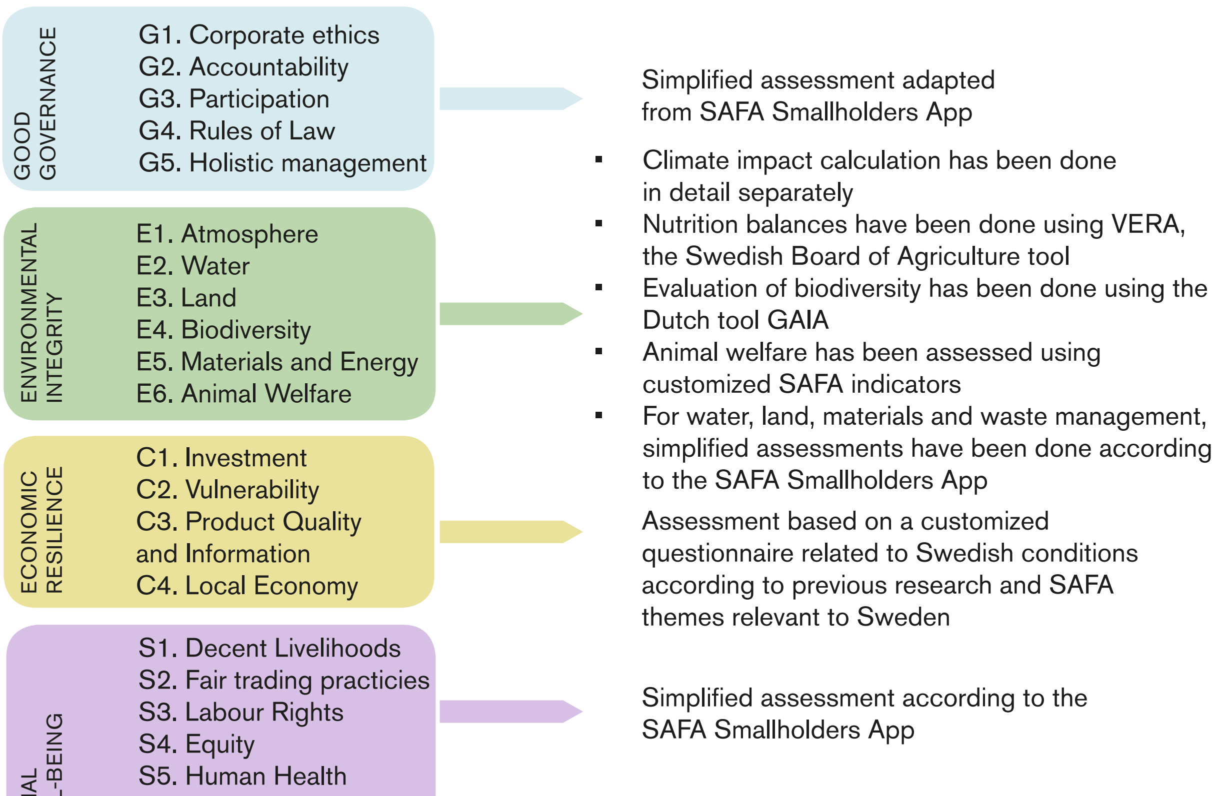

Figure 4. *An overview of SAFA adjusted to Swedish conditions that was used in this project.*

pared to see how the farm contributes to global food responsibility. The results are reported as kcal and kilo of protein per hectare and the number of persons fed per hectare, and then this was compared to the Swedish average. In order to analyze the environmental impact of production, we also calculated emissions of greenhouse gases per kcal, per kilo of protein and per person fed. Finally, a broad study of the farm's sustainability was carried out using a simplified version of SAFA (Figure 4).

4.3 Climate impact from the farm products

The climate impact from the crops grown in 2016 is shown in Figure 5 a). There are essentially two parameters that determine the climate impact per kilo of product: the yield and the amount of fertilizer. With a higher yield, emissions from land use, manure production, transport and tractor diesel are divided between a greater number of products, thereby emissions per product will be lower. Greater amounts of fertilizer give rise to higher emissions from the soil (nitrous oxide), fertilizer production and transport.

Emissions from turnip production are significantly lower than from other crops because the yield is high (60 metric tons per hectare). Also, it was not fertilized and all the processing was done by hand. However, it should be remembered that turnips have a high water content in comparison with cereals and legumes (pulses), and that a proportion of the previous years' environmental impact from fertilization should ideally be allocated to the turnip.

When compared with the average Swedish production, the climate impact of the farm's products is approximately the same as for the average. Emissions from fertilizer production are

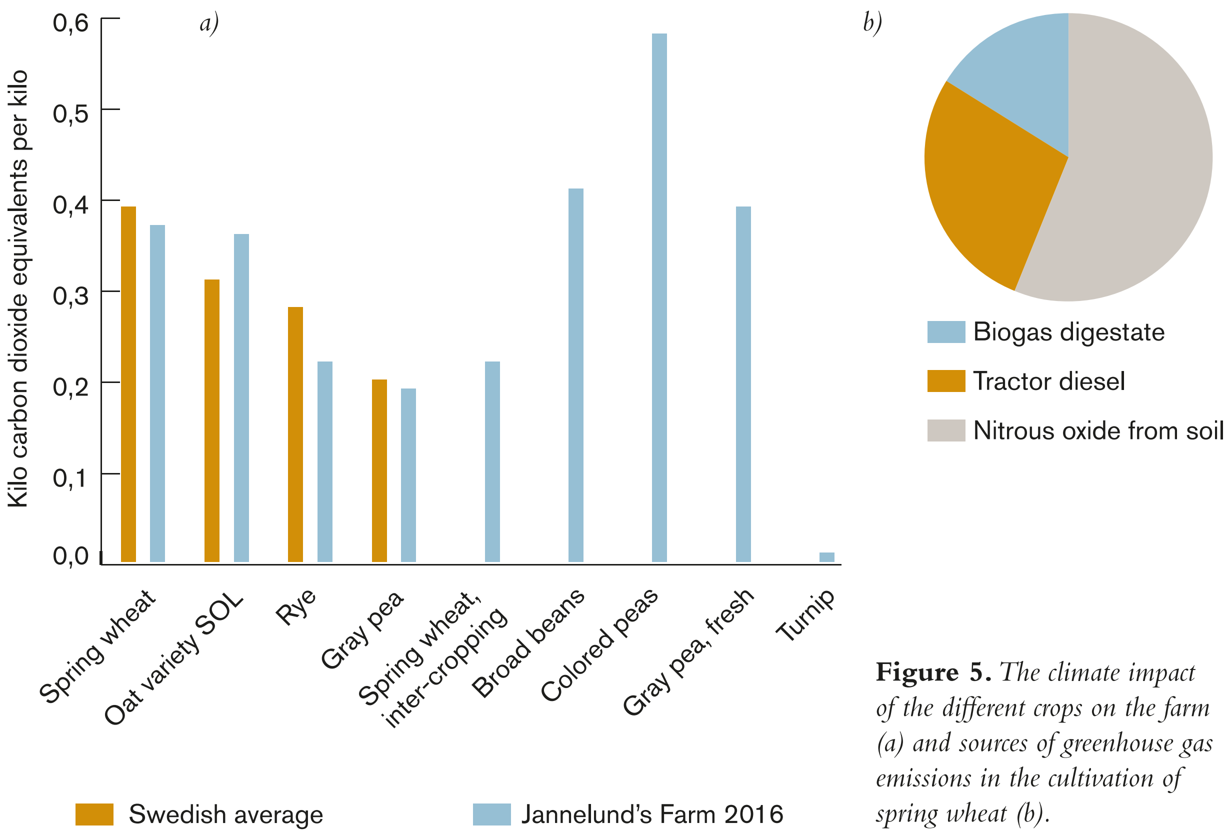

Figure 5. *The climate impact of the different crops on the farm (a) and sources of greenhouse gas emissions in the cultivation of spring wheat (b).*

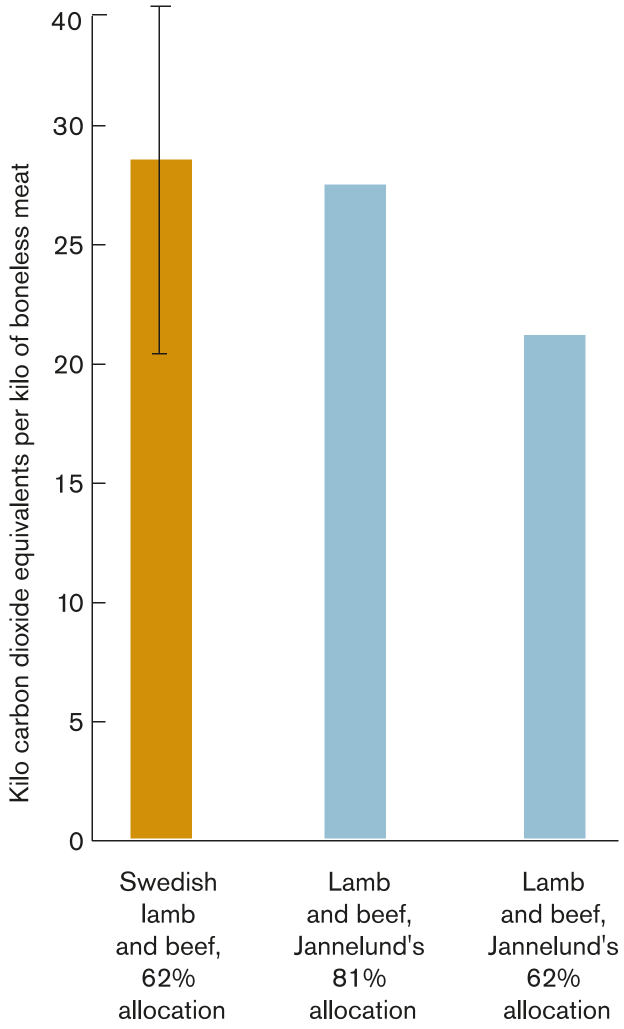

Figure 6. *The climate impact from lamb and beef production at Jannelund's Farm in 2016 compared with the average Swedish lamb and beef production. The allocation factor indicates how much of the emissions from lamb meat production are added to the meat (the remaining part is added to the sheepskin). The allocation factor is based on the revenue from meat and sheepskin respectively.*

Beans that Adam has grown. Photo: Bianca Brandon-Cox

lower for Jannelund's Farm's products because of the use of digestate instead of mineral fertilizer. However, the yield is lower than the national average, so the climate impact will be about the same.

The climate impact of the farm's lamb and beef production compared to that of the national average is shown in Figure 6[7]. In the farm's lamb production, both meat and hide/skin are produced. Emissions are divided between the two products based on the revenue from each. At Jannelund's Farm, 81 percent of revenue from lamb and beef production comes from the meat, so 81 percent of

7 13% of the total meat production at Jannelund's Farm is beef and the rest is lamb and sheep. To compare this with the average Swedish production, we have taken 13% of the climate impact from the average Swedish beef production (Cederberg et al., 2009) and added 87% of the climate impact from Swedish lamb production (Wallman et al., 2011). However, there is no reliable data for the climate impact from the average Swedish lamb production. Therefore, we have used average data from an LCA study of 10 different types of lamb production (Wallman et al., 2011).

emissions from lamb and beef production is added to the meat. For the average Swedish production, the corresponding figure is 62 percent. Therefore, the climate impact of lamb and beef production at Jannelund's Farm is also shown for a case in which 62 percent of the emissions are allocated to the meat.

Figure 6 shows that the climate impact from lamb and beef on Jannelund's Farm is approximately the same as the Swedish average. However, the result should be interpreted with caution as reliable data about average Swedish lamb production is lacking. Differences from one farm to the next are also considerable. If Jannelund's Farm could sell more lambskin - only half of it is sold today - the climate impact from the meat would decrease because the allocation factor (emissions added to the meat) would be lower. Instead, if one uses an allocation factor of 62 percent for Jannelund's Farm (the same as for average Swedish meat), emissions are reduced by just over 20 percent and are significantly lower than the Swedish average. The main factor contributing to the lower climate impact on Jannelund's Farm is that every ewe gives birth to an average of 2.5 lambs per year. In this way, methane emissions are divided between the ewes and lambs, hence the climate impact per kilo of meat decreases.

4.4 Global food responsibility

During 2016, when the farm increased its proportion of crops being sold directly to consumers in relation to animal products, the amount of kcal produced for human consumption per hectare increased by 150 percent and the amount of protein by 116 percent (Table 2)[8]. It was a big change and a direct consequence of the fact that more land was being used to produce crops for human consumption rather than animal feed. Thus, in 2016, the farm could feed 2.3 persons instead of 0.9 as was the case in 2015.

In order to take into account protein quality differences[9], complete protein per hectare was also calculated, which increased by 127 percent between 2015 and 2016. This includes all animal protein (contains all the essential amino acids), all protein from legumes, and the same amount of protein from cereals as from legumes. This is because a mixture of legumes and cereals are required to get a complete protein profile.

8 As the land leased to the farm had previously been conventional farmland, it prevented the entire crop production from being sold for human consumption due to the rules regarding the conversion to organic production. However, the calculations here are based on the fact that all the crops are destined for human consumption.

9 Animal products contains all amino acids essential for humans while for plant protein a combination of cereals and legumes are needed to provide all essential amino acids.

Table 2. *Contribution to global good responsibility from Jannelund's Farm in 2015 and 2016 compared to the average for the forest districts of central Sweden and Sweden as a whole.*

	Jannelund's Farm 2015	Jannelund's Farm 2016	Average for the forest districts of central Sweden	Swedish average 2015
Energy per hectare, million kcal	0.84	2.1	2.7	5.0
Protein per hectare, kilo	31	68	86	148
Complete protein per hectare, kilo	11	25	40	71
Number of persons that the energy per hectare can feed	0.9	2.3	3.1	5.8
Climate impact, kilo carbon dioxide equivalents per kcal	1.8	0.83	-	0.78

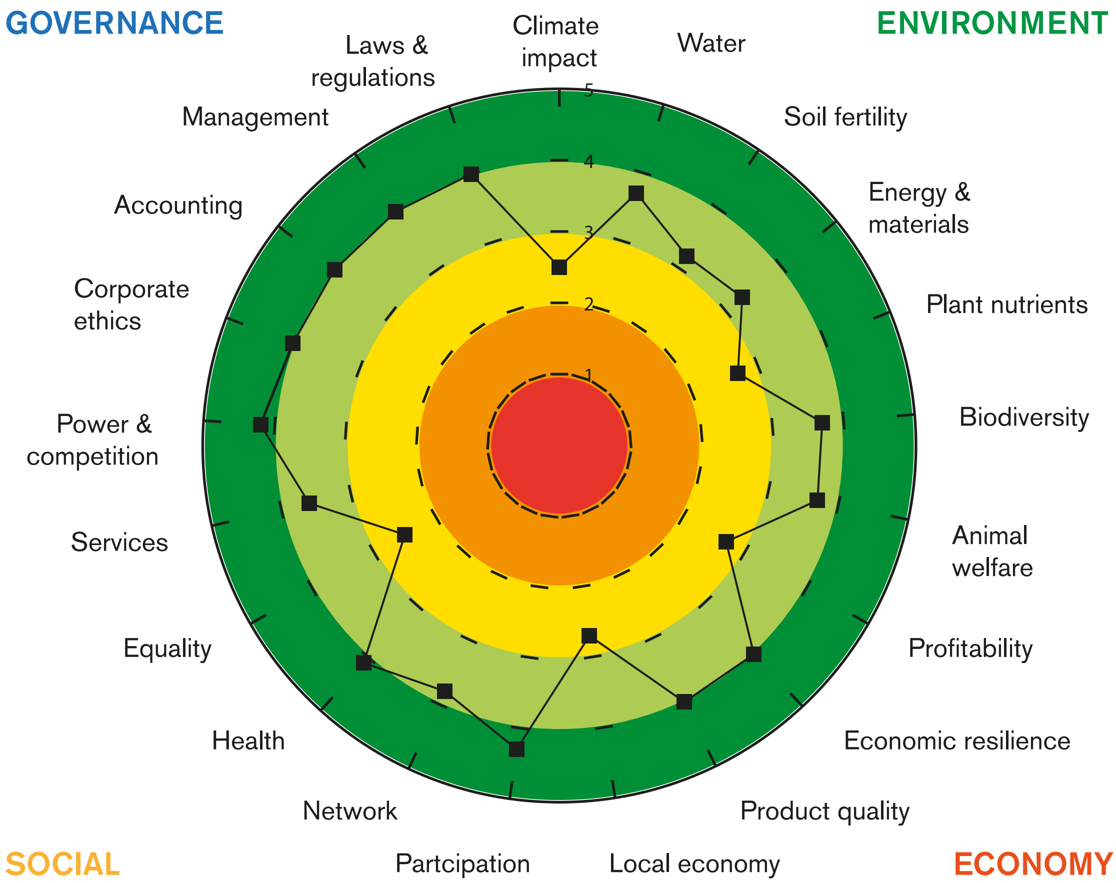

Figure 7. *Results of the sustainability assessment of Jannelund's Farm 2016 using a simplified version of SAFA.*

But does the farm take enough responsibility for global food supply? If we compare with Sweden in general, and also with the production in the agricultural area where the farm is situated – the forest districts of central Sweden, where cultivation conditions for cereals and other crops are not as favorable as in Sweden's plain districts – we see that Jannelund's Farm has a bit to go before it reaches the Swedish average (Table 2). The question is: what is good enough? This will be discussed further in section 5.1.

4.5 Sustainability assessment according to SAFA

Figure 7 shows the results of the sustainability assessment of Jannelund's Farm in 2016 using a simplified version of SAFA's sustainability framework (see Figure 4 for an overview of the contextualization of SAFA done in this project). Green level in the SAFA Smallholders App (best level in this version of SAFA; see section 3.4 for a description of the difference between the SAFA Smallholders App and the complete SAFA tool) was interpreted to be at the top of the light green level (level 4 of 5). SAFA sets high standards for an indicator to be able to get the highest rating (dark green). For example, when it comes to climate impact, the farm would be required not to have any net emissions of greenhouse gases.

The farm receives high ratings for all themes under the sustainability dimension Governance. It reflects the company's thoughtful business development plan and ethical attitude, which is also conveyed on the company's website and through participation in social media and in a diverse set of events in society. In terms of the Environment dimension, the farm lies at average in the themes of Climate Impact and Plant Nutrients, and this is a result of animal husbandry, which contributes both to the emission of greenhouse gases and losses of nutrients to the environment. In the other environmental themes, the farm lies above average. Animal Welfare is also in the higher part of the scale because the animals have a low disease rate and are given significant room for species-specific natural behaviors. However, the rating is lowered somewhat due to the stress animals are subjected to in during transportation to slaughter and during the actual slaughter itself.

The farm's economy improved considerably between 2015 and 2016 as a result of the increase in direct sales of lamb and also good crop prices. During 2016, an annual salary corresponding to a farm worker salary could be paid to the Arnesson family, which, however, does not correspond to all the work done or the return on capital, and therefore Profitability is rated yellow. In terms of Economic Resilience, the rating is positive due to the high number of products and customers. The organic certification, which is verified by a third party, helps to give a high rating for Product Quality. When it comes to contributions to the Local Economy, the rating is average: despite contributing to the local economy through local suppliers and customers, the farm is currently lacking employees.

The social themes reflect how the farmer responded in the questionnaire, which was designed to highlight the social situation of a Swedish farmer. For most themes, the situation looks relatively good, but in terms of Network (social and contextual), Equality (freedom from discrimination) and Services, there is a lot that could be improved. However, it is difficult for those running the farm to do much more about it.

Adam with his sheep. Photo: Bianca Brandon-Cox

5. Discussion and conclusions

5.1 Is Jannelund's Farm a sustainable farm?

In this study, Jannelund's Farm has been assessed in different ways in order to better understand what constitutes sustainable agriculture. Three different perspectives on food security have provided guidance in this assessment (section 3.2). Taking the efficiency perspective as the starting point, the climate impact per kilo of farm products was measured. We see that the efficiency of Jannelund's Farm in terms of climate impact per kilo is approximately the same as the Swedish average, with lamb production being slightly better.

Is the farm's production then efficient enough to be called ”sustainable”? This is difficult to answer because, when it comes to climate impact, it is the total absolute emissions that are important and how high these will be depend on how much of the different produce is consumed in the total population (section 2.3), i.e. a high consumption of something that has low emissions per kilo gives large absolute emissions. However, one can say that the lower the emissions per kilo of produce, the better the rating in relation to this perspective. For example, reducing the farm's fossil fuel consumption per kilo could further increase efficiency. Or by trying to raise the yield per hectare with an unchanged or only limited amount of additional fertilizer.

With regards to global food responsibility, a significant change was made on the farm in 2016 with the increase in crops for human consumption. In 2015, the farm was feeding 0.9 persons per hectare compared to 2.3 persons in 2016 (Table 2). However, the farm has a considerably lower figure than the Swedish average of 5.8 persons, and even a bit lower than the average for the district, 3.1 persons per hectare, which may be fairer comparison[10]. A major change took place between 2015 and 2016, but the farm's contribution to global food responsibility has the potential to improve even further. With the population as it is today, the world's existing arable land needs to feed an average of 5 persons per hectare if the land is to feed the entire global population. And in 2050, with the arable land we have available today, one more person will require feeding per hectare[11].

SAFA's sustainability assessment is broad and captures many aspects (Figure 7). Jannelund's Farm performs well (green) in the majority of the themes in this assessment, but there is a bit to go to reach the dark green level. For some indicators in SAFA's dark green can be interpreted as an ”absolute sustainability limit” (for example, greenhouse gas emissions should be zero or negative, and nitrogen balances should only go over the limit by a tiny fraction). So to claim ”sustainability” there is where the farm would need to be.

Despite contextualizing SAFA to Swedish conditions, the assessment is arbitrary in many ways, for example, where to place the boundaries for the green, yellow, orange and red levels. More work is needed to make the tool more robust, e.g. by basing the thresholds on existing agriculture statistics on how agriculture performs in general and how to define the absolute ”sustainability limit” (dark green) for different indicators. In addition to

10 However, this figure is uncertain as there is no reliable data on the amount of crops being used for human consumption and animal feed respectively.

11 This is a rough comparison to be used with caution. Production capacities around the world differ greatly due to the length of the growing season, climate, temperature, precipitation, soil quality etc.

the actual outcome of the sustainability assessment, a positive experience of working with SAFA has been the process of defining indicators and thresholds, which gave rise to many interesting discussions.

To conclude, we can say that according to the efficiency perspective (LCA), Jannelund's Farm lies at average, possibly slightly better than average for lamb and beef. With regards to the demand restraint perspective, a significant improvement was made between 2015 and 2016, with an increase in the production of crops for human consumption, but there is potential for improvement so that more people can be fed per hectare. SAFA's broad evaluation from the food system transformation perspective gave the farm high ratings in most areas, but average in some. In the SAFA assessment, the implementations which come closest to the absolute limit for sustainability are the dark green level for several (but not all) of the indicators due to very strict requirements.

5.2 Is a sustainability assessment useful to a farmer?

Previous studies have shown that different types of sustainability assessments have commonly been perceived as not relevant to the farmer (Olde *et al.*, 2016). Tools and methods are often developed by researchers who decide what to include and how to measure (Slätmo *et al.*, 2017). Often, the focus is on what is measurable, in other words aspects that have defined measurement and data collection methods, and not on other, more complex aspects.

What are the farmers at Jannelund's Farm saying about the different sustainability assessments of this study? Have they been useful? If so, how?

Adam replies:

"As an individual farmer, it's very difficult to define what sustainable farming is and therefore know what to do to work towards sustainable agriculture for the future. Even though we've decided to do what we can to save the planet, it requires a lot of work to understand the wider picture of sustainability. Collaborating with researchers and having been assessed according to SAFA and the various tools has provided us with exactly that - the wider picture. Now we know where we stand, what we're good at and less good at. It is possible to measure ecosystem services in relation to climate impact, economic and social factors. It motivates us to continue. After just one year, we can feed almost three times as many people and have more than halved our climate impact per produced calorie: it shows that we're on the right track. We regard ourselves as carers of this planet as we offer ecosystem services as our primary product, and to maintain a healthy planet with good conditions for human life, we must produce food that has minimal climate impact. Now we know how to become even better."

5.3 Agriculture's responsibility for what is produced

An effective way to reduce the environmental impact of our food system is to change eating habits, especially to reduce meat consumption in the western world. But where does the individual farmer stand in relation to this? To what extent should and can an individual farmer be responsible for what is produced on the farm?

What is absolutely crucial to an individual farmer is to sell his products at a price that covers his costs. If nobody wants to buy the more sustainable and resource-efficient products, then there's no point in producing them. So far, so good.

According to the mainstream economic theory, it is most efficient to produce different types of products for which the relative benefits are greatest. According to the efficiency perspective, this also contributes to increased environmental and economic sustainability because the environmental impact per product falls and competitiveness increases as costs decrease. Based on this, one may ask if it's a good idea to cultivate legumes and cereals in Sweden's central district? Is it not much more

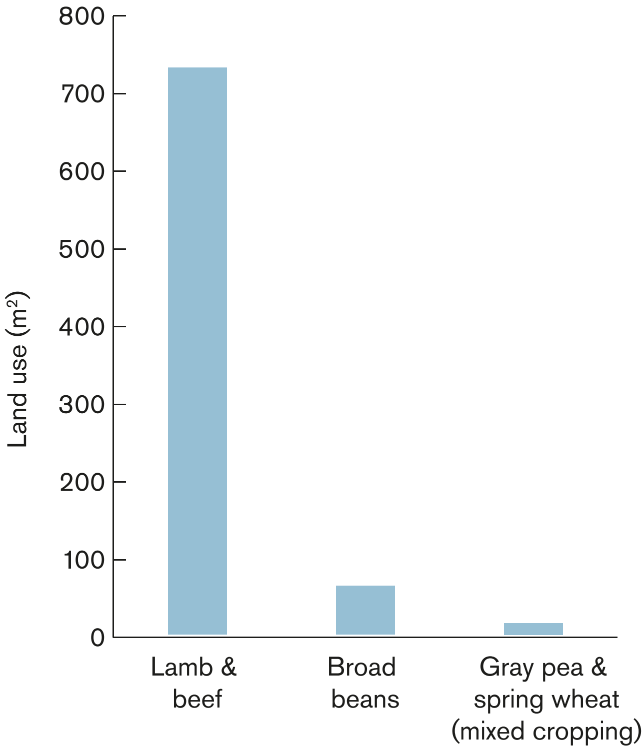

Figure 8. *Land use for the production of 1 kilo of protein from various products on Jannelund's Farm 2016.*

"efficient" to produce ruminant meat from grasslands there? Or even to produce forest and import food from more productive areas? Once again, the answer depends on what one believe is possible to change, how "efficiency" is defined (Garnett *et al.*, 2015) and what we are aiming for.

For example, if the goal is to produce protein for human consumption, the efficiency of land use, i.e. how much land is used to produce one kilo of protein, can be measured. Figure 8 shows the results for land use in the production of one kilo of protein from lamb/beef, broad beans, and the combined cultivation of gray pea and spring wheat on Jannelund's Farm in 2016.

It appears that the crops are significantly more land "efficient" than the lamb and beef. At Jannelund's Farm, a yield of 70 kilos of legumes per hectare is sufficient to produce the same amount of protein per hectare as for the lamb[12].

But is it reasonable to expect the individual farmer to work according to all this? If so, how? Again, there are different ways of approaching the matter. One way is to see oneself as an actor who supplies the market with what is being demanded here and now. Thus, one can look at what consumers are buying today and at what price, and then try to produce these products at that price. For example, imported meat forms a large proportion of lamb and beef consumption today in Sweden, so there is room for increasing Swedish production if we exchange imported for Swedish. The goal would be to sell meat at the same low price as the imported meat or to compete by using added value (e.g. locally produced). Responsibility for sustainability then lies in carrying out production in the best possible way, e.g. with minimal environmental impact, however the producer's responsibility ends here. This reasoning is linked to the efficiency perspective.

One can also see oneself as an actor who, based on his position, has the opportunity to influence the market and consumption. One might ask the question: What should agriculture be producing in a more sustainable food system and how can production be more sustainable? What can I produce that will result in a greater amount of food being produced with a lower environmental impact, i.e. what can I produce that contributes to global food responsibility? So instead of producing more lamb and beef in Sweden, one can, like Adam, consider producing something else, since lamb and beef consumption should be lowered, both for environmental and health reasons. The farmer can ask:

12 At the same time, it is not possible to grow legumes on the same piece of land more than once every five years because they cause problems with plant diseases. So legumes must form part of crop rotation. Grass and legumes in crop rotation is necessary on an organic farm to supply the crops with nitrogen and to deal with weeds.

Should I produce other foods or should I try to raise the value of my products so that there is no need to produce more? Can I influence my buyers to purchase these products? Can I contribute to creating a market for these more sustainable products?

Ultimately, however, it's not a black and white choice between these two perspectives. One should not assume that there already exists a market for what one eventually decides to produce. Obviously, there are numerous other aspects that determine how a farmer chooses to carry out his business: traditions, local conditions, interest in and knowledge of different production methods, environmental, engineering and animal interests, whether agriculture should be the main source of livelihood or a side activity, the capacity to invest, the willingness to take risks and beliefs about the future.

5.4 How do we proceed? Continued research and development.

Sustainability and sustainable agriculture are complex concepts that can be interpreted in many different ways. How one chooses to concretize, measure and set goals for sustainability and sustainable agriculture depends on one's values and on what is possible to quantify or describe.

At global level, researchers have developed what can be regarded as absolute limits for a variety of sustainability aspects. For example, with regards to the environment, the concept of "planetary boundaries" (Rockström *et al.*, 2009; Steffen *et al.*, 2015) defines quantitative limits for nine environmental issues such as climate, biodiversity and land use. An interesting area for further research is how these global boundaries can be linked to activities on a smaller scale such as on national or farm level. Another interesting area to look at is how to link a farm's footprint to Sweden's environmental goals and to the global sustainable development goals.

There is also the need for an increased understanding of how different types of assessments can lead to a change towards a more sustainable future. What kind of assessments and analyses provide the farmer with meaningful information and knowledge? How should these be conducted and how should the results be presented in order to inspire greater sustainability work? More social science research is required, which focuses on change processes and the opportunities and challenges that a farmer faces.

Something we know with certainty is that the future is uncertain. To create a resilient food system, we should not focus on a limited number of systems; we should look at production systems and farms in many different ways. Perhaps we can define some scientifically robust sustainability goals at farm level and allow the road to sustainability to look very different (Broman *et al.*, 2017). Should we set a vision for sustainable agriculture and gradually move towards it? How can that be combined with working with improving the systems we already have today?

Values and social norms will always play a role in how we look at the future and what solutions we suggest – they are important for guiding us in complex situations when we don't know what is best. But science plays a very important role; our normative decisions must be based on facts. However, as this study shows, there are many ways to measure sustainability. An open, fact-based and constructive discussion, more interdisciplinarity, and a willingness to challenge old truths are crucial if we are to succeed in making agriculture more sustainable.

References

Bajželj, B., Richards, K. S., Allwood, J. M., Smith, P., Dennis, J. S., Curmi, E., & Gilligan, C. A. (2014). Importance of food-demand management for climate mitigation. Nature Climate Change, 4(10), 924-929. DOI:10.1038/nclimate2353

Broman, G., Robèrt, K.-H., Collins, T. J., Basile, G., Baumgartner, R. J., Larsson, T., & Huisingh, D. (2017). Science in support of systematic leadership towards sustainability. Journal of Cleaner Production, 140, Part 1, 1-9. DOI:http://dx.doi.org/10.1016/j.jclepro.2016.09.085

Cassidy, E. S., West, P. C., Gerber, J. S., & Foley, J. A. (2013). Redefining agricultural yields: from tonnes to people nourished per hectare. Environmental Research Letters, 8(3), 034015.

de Olde, E. M., Oudshoorn, F. W., Sørensen, C. A. G., Bokkers, E. A. M., & de Boer, I. J. M. (2016). Assessing sustainability at farm level: Lessons learned from a comparison of tools in practice. Ecological Indicators, 66, 391-404. DOI:http://dx.doi.org/10.1016/j.ecolind.2016.01.047

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., . . . Zaks, D. P. M. (2011). Solutions for a cultivated planet. Nature, 478(7369), 337-342. DOI:http://www.nature.com/nature/journal/v478/n7369/abs/nature10452.html#supplementary-information

Garnett, T. (2014). Three perspectives on sustainable food security: efficiency, demand restraint, food system transformation. What role for life cycle assessment? Journal of Cleaner Production, 73, 10-18. DOI:http://dx.doi.org/10.1016/j.jclepro.2013.07.045

Garnett, T., Röös, E., & Little, D. (2015). Lean, green, mean, obscene…? What is efficiency? And is it sustainable? Retrieved from Oxford, UK:

Hansen, J. W. (1996). Is agricultural sustainability a useful concept? Agricultural Systems, 50(2), 117-143. DOI:http://dx.doi.org/10.1016/0308-521X(95)00011-S

Marchand, F., Debruyne, L., Triste, L., Gerrard, C., Padel, S., & Lauwers, L. (2014). Key characteristics for tool choice in indicator-based sustainability assessment at farm level. Ecology and Society, 19(3). DOI:10.5751/ES-06876-190346

Rasmussen, L. V., Bierbaum, R., Oldekop, J. A., & Agrawal, A. (2017). Bridging the practitioner-researcher divide: Indicators to track environmental, economic, and sociocultural sustainability of agricultural commodity production. Global Environmental Change, 42, 33-46. DOI:http://dx.doi.org/10.1016/j.gloenvcha.2016.12.001

Robert, K. W., Parris, T. M., & Leiserowitz, A. A. (2005). What is Sustainable Development? Goals, Indicators, Values, and Practice. Environment: Science and Policy for Sustainable Development, 47(3), 8-21. DOI:10.1080/00139157.2005.10524444

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., . . . Foley, J. A. (2009). A safe operating space for humanity. Nature, 461(7263), 472-475.

Röös, E., Bajželj, B., Smith, P., Patel, M., Little, D., & Garnett, T. (2015). Land use and climate impacts of food in 2050 under different potential livestock futures. Food Policy. Manuscript to be submitted.

Röös, E., Karlsson, H., Witthöft, C., & Sundberg, C. (2015). Evaluating the sustainability of diets – combining environmental and nutritional aspects. Environmental Science & Policy, 47(0), 157-166. DOI:http://dx.doi.org/10.1016/j.envsci.2014.12.001

SBA, SEPA, SS, & SFA. (2012). Hållbarhet i svenskt jordbruk 2012. ("Sustainability in Swedish Agriculture 2012"). Retrieved from Örebro, Sweden:

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. Climatic Change, 125(2), 179-192. DOI:10.1007/s10584-014-1169-1

Schader, C., Grenz, J., Meier, M. S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. Ecology and Society, 19(3). DOI:10.5751/ES-06866-190342

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science. DOI:10.1126/science.1259855

Vermeulen, S., Campbell, B., & Ingram, J. (2012). Climate Change and Food Systems. Annual Review of Environment and Resources, 37, 1-496. DOI:10.1146/annurev-environ-020411-130608

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