Acta Universitatis Agriculturae Sueciae

SLU

Doctoral Thesis No. 2024:93
Faculty of Veterinary Medicine and Animal Science

How to make money

Profitability in pasture and forage based Swedish beef production

Kristina Holmström

How to make money

Profitability in pasture and forage based Swedish beef production

Kristina Holmström
Faculty of Veterinary Medicine and Animal Science
Department of Applied Animal Science and Welfare
Skara

SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES

DOCTORAL THESIS
Skara 2024

Acta Universitatis Agriculturae Sueciae
2024:93

Cover: It is raining money over grazing beef cattle on semi-natural pasture. AI-generated with Adobe Firefly
(by: Helena Falkman, 2024)

ISSN 1652-6880
ISBN (print version) 978-91-8046-420-8
ISBN (electronic version) 978-91-8046-428-4
DOI: https://doi.org/10.54612/a.2pr67a17dk
 https://orcid.org/0000-0002-4681-534X
Swedish University of Agricultural Sciences, Department of Applied Animal Science and Welfare , Skara, Sweden

Print: SLU Grafisk service, Uppsala 2024

How to make money – profitability in pasture and forage based Swedish beef production

Abstract

Profitability in Swedish beef production is low, predominantly because of its small scale and the Nordic climate. The aim of this thesis was to find ways to improve profitability in Swedish beef production. The first study investigated the profitability of creating large pasture enclosures by including adjacent marginal fields and forest to pastureland. The second study examined, aside from different herd sizes, if either indoor bulls or grazing steers were the most profitable in different parts in Sweden. The third study focused on workload in beef cow operations. The fourth study compared profitability when feeding silage based on two different types of grasses to dairy cows, slaughter beef bulls, and beef cows during three different weather scenarios and in different parts of Sweden.

The results show that there are economies of scale. Larger pasture enclosures decrease costs per animal. Although the restoration of pastures was expensive and timber production was lost, the action in all investigated cases was profitable overall. Depending on geographic area and natural conditions, bull or steer production were the most profitable. A more profitable steer needs larger incomes and/or less costs linked to the grazing period. Larger beef cow herds generally had a lower workload per cow and year, but there was a massive variation within herd size especially in smaller operations. The relative competitiveness of grass changes in response to more extreme weather conditions that are caused by climate change. Therefore it is important to choose the correct grass species. The results show that beef bulls were profitable with different grasses in different weather conditions. Contrary, profitability in dairy production was highest with traditional grasses under almost all studied weather conditions and profitability was highest with beef cows when their feed contained much fibre. Thereby, this thesis shows different ways to improve profitability in beef production.

Keywords: profitability, economies of scale, herd size, pasture enclosure, bull, steer, beef cow, labour demand, grass, climate change

Hur tjäna pengar – lönsamhet i svensk betes- och vallfoderbaserad nötköttsproduktion

Sammanfattning

Lönsamheten i svensk nötköttsproduktion är låg, bland annat på grund av småskalighet och vårt nordiska klimat. Syftet med denna avhandling var att hitta vägar för ökad lönsamhet i svensk nötköttsproduktion. Första studien undersökte om det är lönsamt att skapa större betesfållor genom att inkludera intilliggande små svårbrukade åkrar samt skog till befintlig naturbetesmark. Den andra studien undersökte, förutom olika besättningsstorlekar, även om tjurar uppfödda på stall eller stutar på naturbetesmark var mest lönsamma i olika delar av Sverige, medan fokus för den tredje studien var arbetstid i dikobesättningar. I den fjärde studien jämfördes lönsamhet vid utfodring av ensilage baserat på två olika typer av gräs till mjölkkor, köttrastjurar och dikor under tre olika väderscenarier och i olika delar av Sverige.

Resultaten visar att det finns storleksfördelar. Större betesfållor minskade kostnaderna per djur. Även om betesrestaureringen var kostsam och virkesproduktion förlorades, var åtgärden i samtliga undersökta fall lönsam. Beroende på geografisk belägenhet och naturgivna förutsättningar, var tjur- eller stutproduktionen mest lönsam. För att stuten skulle bli än mer lönsam behövdes större intäkter och/eller lägre kostnader kopplade till betesdriften. Stora besättningar med dikor hade generellt mindre arbetstid per ko och år än mindre besättningar, men det var stor variation i arbetstid, speciellt i mindre besättningar. Med ett förändrat klimat med mer frekvent extremväder kan olika vallväxters relativa konkurrensförmåga förändras. Därför är det av vikt att välja rätt gräsart. Resultaten visade att för tjurar var olika gräs bäst i olika situationer medan mjölkkor nästan alltid har bäst lönsamhet med traditionell timotej och dikorna har högst lönsamhet med hög fiberhalt i fodret. Denna avhandling visar att det går att öka lönsamheten i nötköttsproduktion.

Nyckelord: lönsamhet, stordriftsfördel, besättningsstorlek, betesfålla, tjur, stut, diko, arbetstid, vallgräs, klimatförändring

Dedication

Till mitt drömlag

Vi har alla lantbruket i vårt DNA.
CO Holmström

My grandfather used to say that once in your life you need a doctor, a lawyer, a policeman and a preacher, but every day, three times a day, you need a farmer.
Brenda Schoepp – Farmer

Contents

List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I. Holmström K., Hessle A., Andersson H. & Kumm K. - I. (2018). Merging small scattered pastures into large pasture-forest mosaics can improve profitability in Swedish suckler-based beef production. Land, 7 (2). https://doi.org/10.3390/land7020058

II. Holmström K., Kumm K. - I., Andersson H., Nadeau E., Arvidsson Segerkvist K. & Hessle A. (2021). Economic incentives for preserving biodiverse semi-natural pastures with calves from dairy cows. Journal for nature Conservation, 62. https://doi.org/10.1016/j.jnc.2021.126010

III. Holmström K., Kumm K. - I., Andersson H. & Hessle A. (2023). Labour in suckler cow herds – a study on enterprises in southern Sweden. Acta Agriculturae Scandinavica, Section A — Animal Science, 73 (1-2). https://doi.org/10.1080/09064702.2023.2245400

IV. Holmström K., Kumm K. - I., Andersson H., Jardstedt M., Sousa D. & Hessle A. In a changing world – an economical comparison between traditional and wet-and-drought resistant grasses in Swedish cattle production under different weather scenarios. (Submitted).

All published papers are published open access.

Contributions of the thesis

The contribution of Kristina Holmström to the papers included in this thesis was as follows:

I. Holmström was the main author. She participated in planning the study, conducted the main part of the work, did most of the analysis, summarised the results, presented it as a poster at conference, drafted, and submitted the manuscript together with co-authors.

II. Holmström was the main author. She participated in planning the study, conducted the main part of the work, did most of the analysis, summarised the results, presented the results at a conference, drafted and submitted the manuscript together with co-authors.

III. Holmström was the main author. She participated in planning the study, performed the fieldwork, conducted the main part of the work, did most of the analysis, summarised the results, drafted and submitted the manuscript together with co-authors.

IV. Holmström was the main author. She participated in planning the study, conducted the main part of the work, did most of the analysis, summarised the results, drafted and submitted the manuscript together with co-authors.

List of figures

Abbreviations

CM	Contribution margin
CMC	Contribution margin calculation
Gns	Plain districts in northern Götaland
Gsk	Forest districts in Götaland
LFA	Less favoured area
Nn	Lower parts of Norrland
PCA	Principal component analysis
TR	Traditional grasses
WD	Wet-and-drought resistant grasses

1. Introduction

The low or even non-existent profitability of Swedish beef production is the starting point for this thesis (Swedish Board of Agriculture 2022; FADN 2023). Indeed, 20 years ago the Swedish Government carried out a competition investigation which concluded that Swedish beef enterprises had several disadvantages compared to other countries (Government Offices of Sweden 2004). Some of the listed disadvantages included small herd size, Nordic climate, extensive legislation on animal welfare, fragmentation, and long transports. These disadvantages are still listed in the similar, recently report, which also includes e.g. damage from wildlife, low profitability, and climate change (Swedish Parliament 2023). In addition, Swedish beef production is characterised as being sensitive for political decisions and forced into high operations costs, low prices, and reduced payments and supports (Manevska-Tasevska et al. 2024).

Almost 75% of all Swedish farm operations are part-time farmers. Contrastingly, 75% of all agricultural land is used by the 25% full-time farm operations and almost all cattle are located in full-time farm operations (Swedish Board of Agriculture 2023a). The large number of part-time farmers affects competitiveness (Swedish Parliament 2023) but is important for the keeping scattered agricultural land maintained. Nevertheless, farm enterprises need services from, in average, at least two other non-farming full-time jobs. By living in the countryside, farmer households inquire for other services, such as school and retail, which contribute to increased employment (Swedish Board of Agriculture 2008). All of this combined contributes to an attractive and living countryside which is in line with the national food strategy (Government Offices of Sweden 2017).

In this thesis, I introduce possible ways for greater profit-making in beef enterprises. By doing so, this thesis also provides hope to endangered species in semi-natural pastures. With more national beef production we are closer to self-sufficiency with beef and creating an attractive countryside. Accordingly, this thesis begins in a critical area for future agriculture: sustainable and profitable cattle enterprises. Based on my findings I will argue that the remunerability in beef production can increase in various ways.

To approach the disadvantage of small, scattered pastures I investigated if it was worthwhile to create larger, coherent pasture enclosures that include marginal land and forest, which is described in Paper I. In some cases, studies on the farms also examined if no replanting after the final cut was a viable alternative when creating larger enclosures.

The second focus of the thesis was to investigate how it differs between profitability in enterprises. Therefore, in Paper II, I investigated profitability of bulls compared to steers. Calculations were undertaken for, not only bulls and steers, but also for different regions in Sweden and different herd sizes.

Economies of scale is likewise discussed in Paper III, where labour demand of beef cow herds was examined for different herd sizes in Sweden. This study was conducted on farms with help from farmers and their employees.

Another serious threat that the Swedish Parliament (2023) has highlighted is climate change. Paper IV, which reflects on the impact of climate change, explores how weather scenarios would affect the different cattle systems (dairy cow, beef breed bull, and beef cow) in different parts of Sweden when feeding different grass silages.

1.1 Aim

The overall aim of this thesis was to contribute to beef enterprises profitability, by investigating different economical pathways. Lucrative beef enterprises are important for e.g. a living and attractive countryside, Swedish degree of self-sufficiency, consumers, and maintained biodiversity. Considering this, the aim with this thesis is summarised in two research questions:

- Are there economies of scale?
- Are there differences in profitability between different cattle production systems?

1.2 My point of departure

My journey with this thesis started on a journey, in a hotel room looking out over an area of a slaughterhouse in Herning, Denmark. The question I received over the phone was if I was the person to take this project into its harbour. Such an inquiry needs to be thought of for a while, but after then it has never been a question anymore. Coming from an advisory organisation with a focus on both cattle and nutrition to create more profitable enterprises, my step towards even more business calculations was minimal. Rather, it was to find pathways for sustainable profitable beef enterprises. Finishing this thesis has taken several years, largely because of other work that demanded attention, particularly my role as an advisor and discussion partner to farmers, but also other projects that are not included in this thesis. Working closely with farmers renders this PhD-journey even more important, by witnessing the struggle with long workdays and low reward. My motto has been, for a long time, to make a difference, and I hope this paper really will make difference.

My journey has now arrived at its harbour and one of the final products is this thesis, which is important in many ways. Swedish beef enterprises are under significant economic pressure and if they do not gain profitability, there will be a lack of Swedish beef in the future. Swedish beef enterprises produce more than just meat. Beef production involves other companies that obtain their providing from beef enterprises, such as carpenters, people working on farms, machine shops, and all the logistics around cattle. Cattle are also an important factor for biodiversity on semi-natural pastures. If we lose those pastures, many species will be gone forever. Moreover, not only will flora and fauna disappear, but the landscape will alter, and we will forfeit a heritage from our ancestors and an important social and cultural value.

By explaining all of this, I provide reasoning for why I have:

- investigated the profitably of changing from small, scattered pasture paddocks to large, coherent enclosures (Paper I)
- examined the difference in profitability when raising purebred or cross-bred steers or intact bulls in different regions and herd sizes (Paper II)
- inquired into labour in Swedish beef cow production (Paper III)
- compared the profitability of forage-based cattle production in three intensity levels with diets composed of silages of traditional

versus alternative wet-and-drought resistant grass species during different weather conditions (Paper IV)

Paper I, II, and III investigated the research question if there are economies of scale. Paper II and IV explored the research question if there are differences in profitability between different cattle systems.

In the next chapter I provide background information regarding enterprises structure and challenges in Swedish beef production with the aid of earlier research and other reports. Therefore, this chapter presents the background for understanding the research question. The following chapter describes the different materials and methods that were used in this thesis for analysing economies of scale and profitability in different cattle systems. Due to the different issues in the Papers, chapter 3 describes some different methods that were used. Results of Paper I-IV are summarised in chapter 4. Chapter 5 begins by summarising the answers to the research questions and then discusses them in a larger context. The main conclusions and practical implications are stated in chapter 6, and this thesis ends with future perspectives and issues to be solved in chapter 7.

2. Background

Chapter 2 discusses the important aspects for the background of this thesis. The chapter begins with section 2.1, where the low profitability in Swedish beef production is described. Profitability in business is a result of both incomes and costs. In section 2.2 a short description of incomes in beef production are reviewed and thereafter, in section 2.3 different costs in beef production are presented. The degree of self-sufficiency of human food in Sweden today is a big question. Therefore, section 2.4 reflects on the important work that beef farm enterprises do for domestic food production. The importance of grazing cattle to maintain biodiversity is discussed in section 2.5. We currently live with climate change, and this will impact the beef sector even more in the future. Thus, there is a glance on how climate change can affect, and is effected by, Swedish cattle production in section 2.6. Finally, section 2.7 briefly describes the analysing methods for different scenarios to find conditions for greater profitability in Swedish beef production and create better conditions for economically sustainable beef operations, self-sufficiency, and preserved biodiversity.

2.1 Weak profitability in Swedish beef production

Farmers in Sweden are under serious threat. Both pasture-based and indoor beef production have low or even no financial gain in Sweden (Swedish Board of Agriculture 2022; LRF 2023). The profitability of beef production is approximately half of what the profitability is for Swedish dairy production when profit is measured as farm net value added and is described as equals sum of revenues incl. current subsidies and taxes minus intermediate consumption and depreciation. Both Swedish crop production and dairy production have greater competitiveness compared to other

European countries than Swedish beef production (FADN 2023; Manevska-Tasevska et al. 2024). Comparing revenues and costs in several Swedish beef farm operations shows that, especially smaller herds, do not have enough profitability to pay ordinary farm worker wages (Swedish Board of Agriculture 2022). The report from the farm economic survey 2014 – 2021 showed that, in addition to a generally low profit in beef production, large enterprises had higher gain than smaller ones and operations located in forest areas and northern parts of Sweden had lower gain than the ones on the plains (Swedish Board of Agriculture 2023b).

Figure 1 shows the family farm income for businesses with dairy cows, field crop production, or grazing beef cattle in Sweden throughout the last decade. The line with ordinary Swedish farm workers' wages reveals that income from enterprises with grazing beef cattle for every year has been greatly below this and below enterprises with dairy cow or field crop operations for most years.

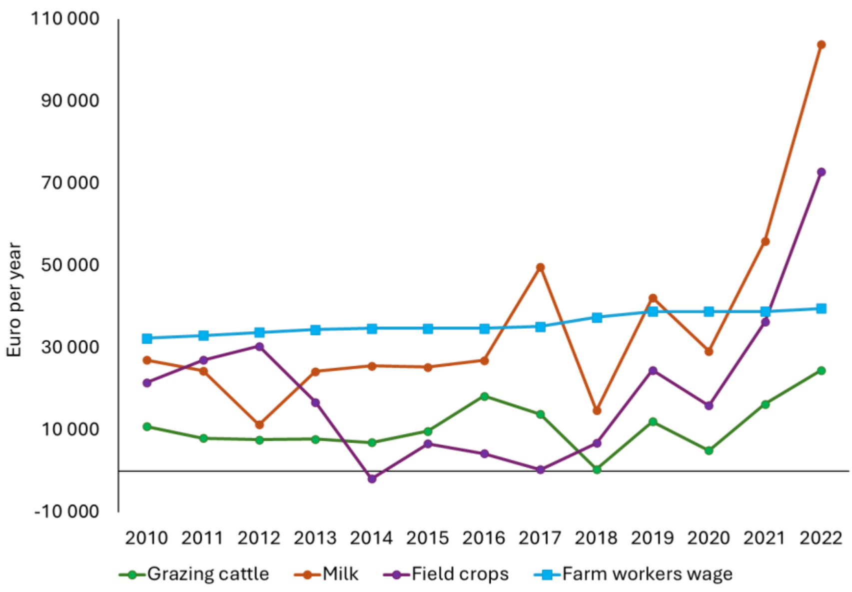

Figure 1. Family farm income, expressed as Euro per annual full time equivalent farm worker in operations with dairy cows, field crops, and grazing beef cattle, as well as ordinary farm work wages in Sweden, from 2010 − 2022 (FADN 2023; Länsstyrelsen Västra Götaland 2023).

Throughout the last decades, the number of beef farm enterprises has dramatically decreased. In the early1990's, Sweden had 21 000 farms with beef cows and/or finishing cattle farms but today there is less than 12 000 enterprises left (Swedish Board of Agriculture 2023a). Two reasons for this decrease is the low financial gain (Swedish Board of Agriculture 2022) and the prerequisite of having a large capital to be able to start a beef operation.

Low, or even lack of, profit for beef enterprises can be partially explained by the fact that it has several competitive disadvantages against many other countries in the common EU market. Some of Sweden's disadvantages are small herd sizes, wherein fixed costs will be spread over few animals, but also large fragmentation of land which is time-consuming and results in more expensive feed costs. A shorter growing season, due to our climate, affects the length of grazing period and the costs for winter feed is consequently expanded. Due to the natural climate in Northern Europe and Swedish animal welfare regulations, expensive barns are needed (Government Offices of Sweden 2004). Further, Sweden has high wages compared to many other countries (OECD 2018).

Resilient and competitive businesses must be able to handle challenging conditions for long-term survival. The Swedish Board of Agriculture listed factors that can affect the survival of businesses. Such factors can be the handling of abandoned or loss of land, climate change, price on products, and availability of labour force (Swedish Board of Agriculture 2023d).

This perspective of the weak profitability in Swedish beef production is the starting point of this thesis.

2.2 Incomes in beef production

One way to make beef production more lucrative is to increase the revenues. In this thesis I discuss different ways to increase revenues, such as making larger pasture enclosures, additional payments for carcasses, and importance on payments and supports. Beside income from animal products and agri-environmental payments and supports, income from other enterprises of production, e.g., off-farm work, entrepreneur, field crop production, and forestry, are all important parts of the farm business, particularly for smaller operations (Swedish Board of Agriculture 2022).

Almost half of the income in contribution margin calculations (CMC) with steers, and more than half of the income with beef cows, is associated with different payments and supports, while calculations with bull payments and supports is just a small part of the total income (Fig. 2). Agri-environmental payments are paid for the work with maintenance of semi-natural pastures with biological and cultural values, which the Swedish government and EU provides (Swedish Board of Agriculture 2023c). Agri-environmental payments are important for the profitability in pasture-based beef production as I show particularly in Paper II, but also in Paper I and IV.

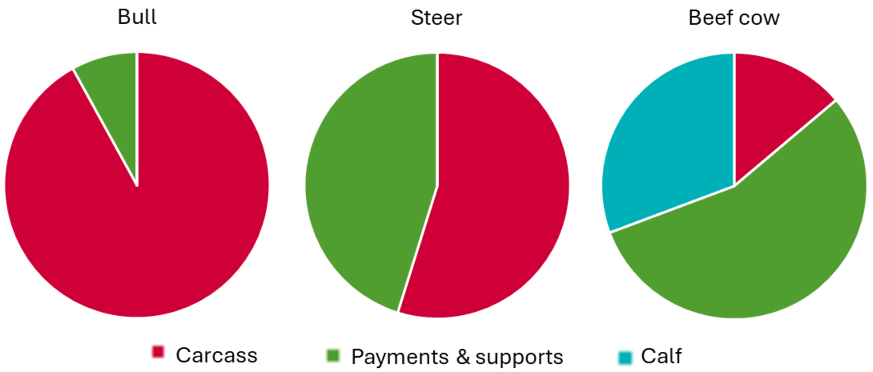

Figure 2. Distributions of revenues in different beef production systems in Sweden, indoor slaughter bulls, grazing steers, and beef cows, bulls and steers originating from dairy production (Paper II and IV).

Depending on the region, support for less favoured area (LFA) can have a large impact on the economic results (Paper II and IV). Support for LFA and agri-environmental payments and supports are also significant regarding the competitiveness of pasture-based beef production compared to indoor beef production (Hessle & Kumm 2011) and for beef production compared to afforestation on marginal agricultural land (Kumm & Hessle 2020).

Additional national support for milk production in northern Sweden can further increase the income for this production (Paper IV). Other important payments and supports, as displayed in paper I, II, and IV, are investment support, single farm payments, and animal premium. Those direct payments for beef production enable better conditions for beef enterprises and likely lead to increased, or at least maintained, production levels.

Another way of increasing incomes is by increasing the price paid for carcasses at the abattoir. Paper II shows that a higher carcass weight is not only associated with a payment for more kg's, but also to higher carcass conformation, rendering an increased price, which is also reported in other studies (Keane 2010; Huuskonen et al. 2013, 2014; Hessle et al. 2019; Wetlesen et al. 2020).

Hence, insemination of dairy cows with beef breed semen can increase the revenue and the profit in beef production due to an increased weight gain and conformation of the finishing offspring (Paper II). Although offspring of dairy × beef crosses has become more common they are less usual in Sweden (Växa 2024) than in other countries (Department of Agriculture 2021; Agriculture and Horticulture Development Board 2022). Increasing the number of crossbreds results in a win-win situation for the dairy farms. When a suitable number of pure-bred replacement dairy heifers in dairy farms has been achieved, the remaining cows can be inseminated with semen from a beef breed sire, and the calves will later be sold at a higher price when entering beef production systems.

2.3 Costs in beef production

Depending on the type of beef production, the distribution of costs varies (Fig. 3). However, the four largest costs in Sweden are feed, building, labour, and purchase of calf/replacement heifer (Agriwise 2023). I have primarily focused on economies of scale, labour demand and choice of forage in this thesis for reduction of costs.

During the indoor winter period, harvested feed is a large cost. Costs for silage is dependent on the grass yield, natural conditions, and size of the farm, as shown in Paper II and IV. During the grazing season the agri-environmental payment for semi-natural pastures is important for keeping the costs down. Due to low yield, small and scattered pastures with long fence per hectare, and labour-intensive production, grass from semi-natural pasture can be significantly expensive, as seen in Paper II and IV. Gross costs for silage and grazed grass are seen in Figure 3. However, net costs (gross cost – single farm payment and agri-environmental payment for semi-natural pastures) for silage and, particularly, grazed grass on semi-natural pastures are low, especially the latter which can even have a negative net cost.

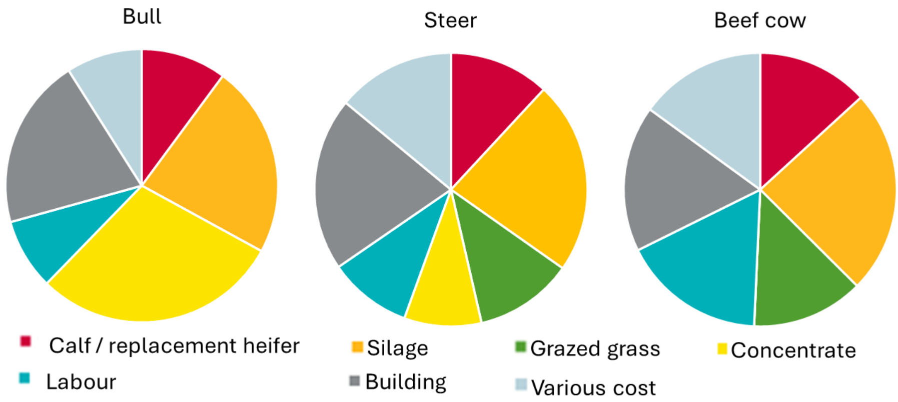

Figure 3. Distribution of costs in different beef production systems in Sweden, slaughter indoor bulls, grazing steers, and beef cows, where bulls and steers originate from dairy production. All costs are derived from Agriwise (2023) except building costs (Lindman Larsson 2019; Hedlund et al. 2023), where various cost includes bedding, veterinary, control & advice, insemination/bull, electricity, maintenance inventories, interest of working, interest of animal capital, and other costs.

Sweden's soil, climate, and tradition means that most cattle are kept indoors during winter, which can be a significant part of the year. The calculations given in Paper II and IV, as well as in other studies (Agriwise 2023; Kumm & Hessle 2023), show that building costs during winter are high. In Paper II, the building cost in a herd with 100 slaughtered steers per year is at least 10% higher compared to 18 months bulls when building costs are divided with income from carcass. This difference in building cost is due to cattle that having a shorter retention time using buildings for less time and therefore have a lower building cost. For a beef cow, Paper IV, 60% of the income from a calf will cover her building costs, and for a beef breed bull 15% of the slaughter income corresponds to his building costs. Nevertheless, there is economies of scale for larger herds in building cost (Short 2001) when fixed costs can be distributed over more animals, also demonstrated in Paper I and II.

If the beef production in Sweden will be sustainable long-term, proper payments for farmers' labour time is significant. It has been shown for both finishing cattle (Nelson 2002; Bostad et al. 2011) and beef cows (Paper III) that cattle husbandry is time consuming, especially in smaller herds. Labour demand may be dependent, not only on herd size, but also on fragmentation of farm and pasture, degree of mechanisation (Fallon et al. 2006; Bostad et al. 2011; Veysset et al. 2015; Paper III), and length of calving period (Paper

III). In contrast to dairy production, a high degree of mechanisation is not common in beef production, particularly not in older buildings (Bostad et al. 2011).

Finneran et al. (2012) reported that under Irish conditions, grazed grass is the cheapest feed, but in Nordic countries (Swedish Board of Agriculture 2007; Bratli et al. 2012; National Resources Institute Finland 2019), it is common to have time consuming, small, and scattered pastures. Sweden's characteristic semi-natural pastures affect the cost of grazing, both because of the workload for supervision of livestock and maintenance of the pasture, largely due to the Swedish regulation of compulsory daily supervision (Swedish Board of Agriculture 2019b). This becomes an extra cost when applied in a fragmented landscape with small, scattered pastures (Swedish Parliament 2023). Marginal arable fields and semi-natural pasture enclosures have higher production costs; the smaller the area the higher the cost (Cederberg et al. 2018; Kumm & Hessle 2020). Paper I discusses the economics of creating larger pasture enclosures in beef cow enterprises. It has been previously shown that by creating large pasture-forest mosaics of small, scattered, semi-natural pastures, marginal and abandoned agricultural land, and adjacent forest land, the cost of grazed grass can decrease and profitability in beef production can improve (Kumm & Hessle 2020).

2.4 Self-sufficiency

The receding three sections dealt with the low profitability in beef enterprises. This section also discusses the potential of more beef production in Sweden.

In 2017, the Swedish Parliament decided upon a national food strategy (Government Offices of Sweden 2017), aimed at increasing Swedish food production to 2030, to become globally competitive, innovative, sustainable, and attractive. Relevant environmental goals should be achieved simultaneously and the strategy ought to contribute to a sustainable development throughout Sweden (Government Offices of Sweden 2017).

The present level of self-sufficiency is just below 60% of all beef consumed (Fig. 4), compared to almost 90% at Sweden's entry to the European Union in 1995 (Swedish Board of Agriculture 2023a). Low profitability in beef production and a high proportion of cheap beef available on the common EU market are likely reasons for the low self-sufficiency of beef in Sweden. As the food strategy aims to increase food production and achieve the relevant environmental goals, the low profitability is a threat to the Swedish food strategy (Swedish Parliament 2023). In this thesis I suggest different ways to promote the profitability in beef production, outlined in Paper I-IV.

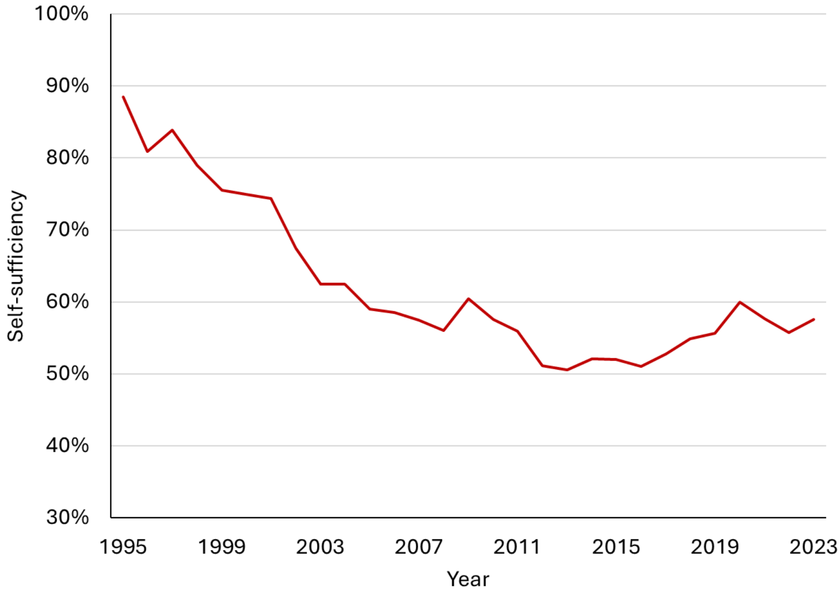

Figure 4. Swedish self-sufficiency of beef, expressed as domestic beef produced : beef consumed (Swedish Board of Agriculture 2023a).

2.5 Biodiversity

The biodiversity in the world is also under significant threat. More than 20% of native species have become extinct, and majority of them during the last century. Maintaining biodiversity involves the preservation of multifunctional landscapes including maintenance of species and ecological functions and conservations of the diversity of genes, varieties, breeds, and species (IPBES 2018). In Sweden, the most species-rich habitats, and also the most threatened ones, are natural and semi-natural grasslands (Toräng & Jacobson 2019; Swedish Species Information Centre 2020). European natural and semi-natural grasslands are remains of the prehistoric heterogeneous open-wood landscape created by wild large herbivores (Vera

2000). After mankind had exterminated a majority of the wild grazers, the domesticated herbivores have maintained the ecological functions and preservations of their biodiversity (Jacquemyn et al. 2011; Eriksson 2021, 2022).

Only 1-2.5% of the semi-natural grasslands managed in Sweden in the 19th century are still managed for fodder production (Dahlström et al. 2008), from 2 000 000 hectares in 1870 (Swedish Board of Agriculture 2005) to only 450 000 hectares (Swedish Board of Agriculture 2023a) and all of them are defined as semi-natural pastures in this thesis. In addition to this areal of semi-natural pastures and meadows, a high proportion of Swedish forest has been grazed on (Steen 1958) and even in 1927 still 750 000 hectares of forest grazing remained (Lothigius 1945). Today, there is nearly none (Swedish Board of Agriculture 2019a).

The rapid decrease in grazed area is due to a diminished Swedish cattle stock during the last century from 2 700 000 to only 1 440 000 (Swedish Board of Agriculture 2023a). There has also been an increased proportion of indoor feed harvested on arable land along with higher production levels (Swedish Board of Agriculture 2023a). More grasslands are at risk of being abandoned if future pasture-based beef production will not be viable because cattle graze on 80 % of Swedish semi-natural grasslands (Spörndly & Glimskär 2018). Those grasslands are predominantly threatened by abandonment with accomplished spontaneous overgrowing, but also by forest planting and conversion into arable land, forest, or urban land (WallisDeVries et al. 2002; Rockström et al. 2009).

It is likely that distant, small, and fragmented pastures will be abandoned first, and their biodiversity subsequently erased. The cost for fencing, pasture management, and the supervision of animals is high, as investigated in Paper I – III. Thereby this thesis is of importance for showing cost-effective pasture-based beef production.

2.6 Climate change and beef production

The forecasted climate change, which will cause more extreme weather conditions such as heat, flooding, drought, and reduced snow cover in winter (IPCC 2023; SMHI 2024), will affect cattle production (Gauly & Ammer 2020; Bunning & Wall 2022), as well as cultivated crops and permanent grasslands (Roth 2023), in different ways across the world. Climate change directly affects cattle enterprises, in terms of the animals' health, welfare, and reproduction as well as their production level as heat-stressed cattle give less milk and/or meat (Gauly & Ammer 2020; Bunning & Wall 2022). Moreover, climate change can also affect the enterprises indirectly through the productivity on cultivated crops and pastures. Agriculture will strive to adapt to the new climate, for instance, by changing crops to increase, or at least maintain, the yields (Wreford & Topp 2020). Higher, or maintained, fodder yields results in a lower cost for silage and grazed grass, as described in Paper IV and others (Finneran et al. 2012; Agriwise 2023). Nevertheless, if the new grass is of lower nutritional quality with less digestibility or palatability, climate change might have a negative effect on cattle performance and profit.

In areas where climate change is less dramatic, such as Nordic countries, the major negative effect on the potential gain for beef farm enterprises will most likely be the indirect effects on feed production, which is discussed in Paper IV, and was also investigated by Bunning and Wall (2022). For future resilient farm enterprises, decision-making that incorporates tomorrow's climate is of importance (Wreford & Topp 2020). For Nordic cattle operations, decisions concerning what species to use for silage making and how to adapt their use of agricultural land might be the most important, Paper I and IV provide significant guidance on this.

Climate change will not only affect beef production, but vice versa as the greenhouse gas methane is emitted in the ruminant feed digestion process. (Searchinger et al. 2018). However, trees that are growing in silvopastoral systems can partially compensate for these emissions through carbon dioxide absorption and carbon storage in the wood as long as they grow (Swedish Board of Agriculture 2011), and after they are felled, through wood that is substituted for climate-affecting materials such as concrete and steel in building construction (Lundmark et al. 2014). Surveys on Swedish citizens' valuation of landscapes also show silvopastoral agroforestry in such a mosaic are valued higher than treeless pastures, especially by respondents who have been informed on the positive climate effect from the trees (Kumm & Hessle 2023). In Paper I, the economic potential of creating silvopastoral mosaics of agricultural land and forests is investigated.

2.7 Analysing methods

To uncover if the enterprise is moneymaking, it had to be counted. This counting can be completed in different ways due to the question. Thus, this thesis includes different measuring and calculation techniques. To investigate if a change is worthwhile, a partial budgeting technique is a simple analysis, however, it only considers the parameters that are changed, using historical and estimated information, and not the whole business, as was the question in Paper I. If costs and benefits occur in different time periods, discounting is necessary. Partial budgeting uses four items: additional income, reduced costs, additional costs, and reduced income. When benefits exceed the costs, the change is an advantage. Partial budgeting is mostly used for considering the economic value of a change.

In Paper II and IV the question was to find the most profitable alternative in each situation. This was done by CMC which subtracts the variable costs from the revenues, and profitability is defined as contribution margin (CM), hence calculated as Σ revenues – Σ variable costs = money generated to cover common costs and profits. Common costs include e.g. planning, labour management, administration, and accounting. CMC is a tool for budgeting, typically for one year for beef cows or one reared animal, and ease to identify the most remunerative alternative or break-even price. CM can only be compared to enterprises with a similar basis and production system (Olson & Westra 2022). To adapt the calculations, sensitivity analyses are common. In Paper II, sensitivity analyses were done for e.g. higher payments by increasing the proportion of semi-natural pastures rendering a higher level of agri-environmental payments. In Paper IV, a sensitivity analysis was done wherein price paid at rent for land instead of opportunity cost for land was used.

To obtain background information and an important face-to-face interaction with the enterprises, Paper I and III started with interviews. Questions included e.g. the number of hectares and cattle, changes in land use, and labour demand.

Smartphones are a part of most people's everyday life. Thus, in Paper III an application for time logging in smartphones was used. Combining time logging data with background information composes a large amount of information. Principal Component Analysis (PCA) is a useful tool when there is a need to reduce variables (Hair et al. 2014), therefore it was used in Paper III. To summarise data and make it easily visible, I chose a correlation matrix. Correlation matrix shows correlation coefficients between variables, and each cell in the matrix shows the correlation between two variables (Hair et al. 2014). The methods used in Paper III are not methods that are used in calculations for profitability but rather for sampling data and displaying it more clearly.

This chapter has described different aspects of the low profitability in Swedish beef operations and various analysing methods. The next chapter discusses the materials and how the analysing methods were used in the four studies of the thesis.

3. Materials and methods

This chapter provides an overview of the different materials and methods used in the different studies in Paper I – IV, for more details please see each paper. My thesis is organised around ways to improve profitability in beef enterprises, both grazing and indoor reared cattle, and this is explored through four different studies. In order to answer the aim of this thesis different methods were used due to the different research questions in the studies. My study investigations have been interviews complemented with farm visits (Paper I and III), different economic calculation methods (Paper I, II and IV), and records of workload followed by analyses (Paper III).

- Paper I started with farm visits and interviews on five study farm enterprises to understand the background of changing from small, scattered pastures to large, coherent pasture enclosures. Thereafter the profitability of this change was calculated, using partial budgeting technique, as (Additional income + Reduced costs) – (Additional costs + Reduced income).
- Paper II used experimental data from the rearing of indoor bulls and grazing steers, both offsprings from dairy cows. The profitability was defined as CM, calculated as Σ revenues – Σ variable costs.
- Paper III investigated the workload in enterprises with beef cows. After initial farm visits with interviews, farmers and employees recorded their labour time every 8th day for a year in their smartphones. The data was investigated by PCA and correlation analysis.
- Paper IV, based on data from three experimental studies of dairy cows, beef breed bulls, and beef cows, respectively, compared the impact on farm profitability when feeding different grass silages. Profitability was calculated under three different weather

conditions. Profit was defined as CM and calculated as Σ revenues – Σ variable costs.

3.1 Paper I – Large coherent pastures

Study I was based on data from five farmers with beef cow enterprises who had recently made a transformation from small, scattered pasture paddocks to large, coherent paddocks. Participants were found through advertisements in two national Swedish farm journals. Out of twenty replies five farms across the country were chosen for the study (Fig. 5, yellow triangles). The five farmers were visited once for interviews. The questions asked were related to the changes in income and costs due to the larger coherent mosaic pasture enclosures that are created from the original small, scattered pastures and intermediate marginal arable land and forest land. Thereby, the aim of this study was to investigate how profitability was affected by this rationalisation action. The profitability was calculated by partial budgeting as:

(Additional income + Reduced costs) – (Additional costs + Reduced income)

Additional income included revenues from additional weaned calves, carcasses, and agri-environmental payments and supports. Reduced costs were related to less labour due to fewer livestock transports between paddocks and animal supervision in fewer paddocks, and in one case an outdoor wintering in the protection of woodland created in the pasture-forest mosaic instead of expensive indoor wintering. Additional costs included fencing and work with fencing, along with the extra cost related to having outdoor wintering animals, and the cost of having more animals. Reduced incomes were related to premature clearcutting of forest and lost future timber production. One farm also had less income from rent, due to arable land that was previously rented out now being used by the farm itself. There was also a loss of supports, due to grazing animals being moved from leased pasture far from the farm to new mosaics pasture with a lower agri-environmental payment close to the farm centre.

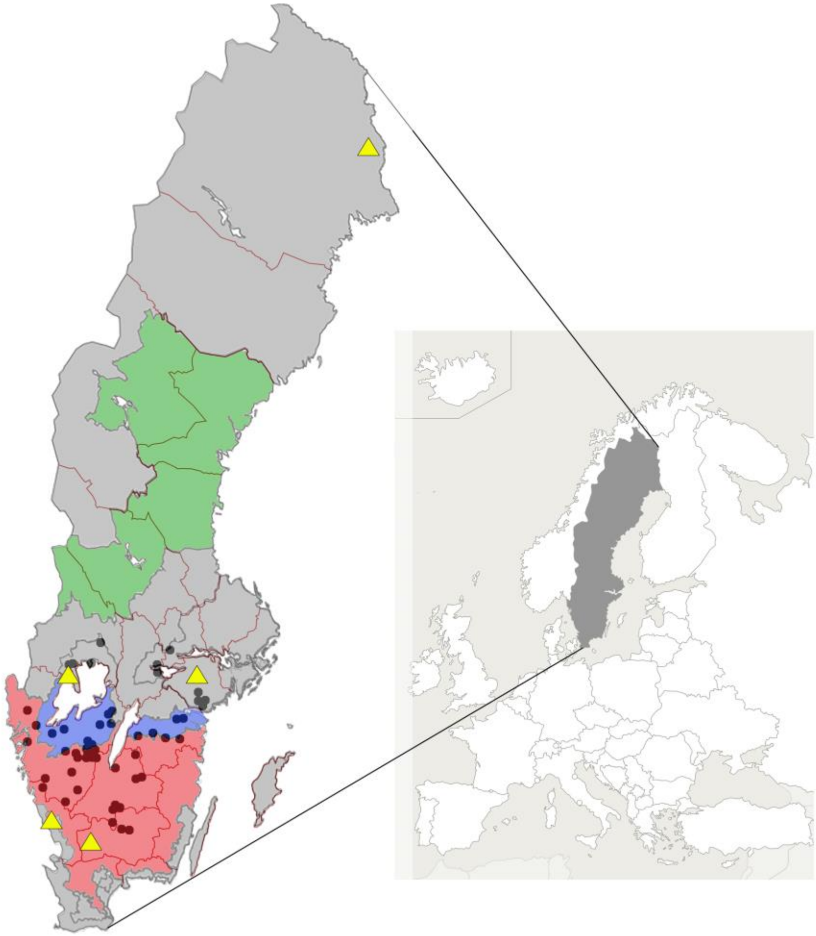

Figure 5. Map over Sweden that shows where the different studies took place. Yellow triangles display the five (Farm 1-5) beef cow enterprises in Paper I, black plots are the beef cow enterprises in Paper III, and three different regions in Paper II and IV are painted in the background (the forest district of Götaland (Gsk) is red, the plain districts in northern Götaland (Gns) is blue, the lower parts of Norrland (Nn) is green).

After basic calculations, sensitivity analyses were conducted for situations without agri-environmental payments, for decreases in prices paid for carcasses and weaned calves by €0.5 per kg, for a decrease in the interest rate in forestry from 4% to 2%, and for a market decrease in the price of timber.

Factors affecting the profitability on the farms were grouped into five categories:

- Agri-environmental payments and supports
- Economies of scale
- Improved consolidation
- Net rent
- Forestry

3.2 Paper II – Bulls or steers?

Study II used biological data from two experiments of bulls and steers, reared from weaning until slaughter in southwestern Sweden, to examine the profitability of different production systems. Half of the bulls and half of the steers were of purebred dairy breed, and the other half were dairy × beef breed crosses. Half of the animals of each breed type were allocated into one out of two production systems, intensive or extensive. All bulls were reared indoors where the intensive system implied more concentrate in the feed ration combined with slaughter at 15 months of age and the extensive system implied less concentrate and slaughter at 18 months of age. All steers were grazed on semi-natural pastures during summers, but during winter the intensive steers were offered more nutrient-dense feed and slaughtered after only one summer on grass at 21 months of age. The extensive steers grazed for two summers and were slaughtered at 28 months of age.

From those biological results, CMC were conducted for rearing bulls and steers in three different regions in Sweden (Fig. 5): the forest district of Götaland (Gsk), the plain districts in northern Götaland (Gns), and the lower parts of Norrland (Nn). The profitability was defined as CM, calculated as Σ revenues – Σ variable costs. CM was calculated for all combinations of gender, breeds, production systems, and regions, and for herds with 50, 100, and 150 animals slaughtered per year. Basic calculations were based on average prices from 2014 – 2018, to consider price variations over a longer time, and 2018 levels of agri-environmental payments and supports.

Finally, sensitivity analyses for six other situations were computed:

- Higher payment by increasing the proportion of semi-natural pasture area rendering a high, not basic, level of agri-environmental payment for high biological and cultural values from 30 % to 70 %

- Higher carcass revenues due to production of certified pasture beef with a premium of + €0.29 per kg
- Decreased labour cost due to reduced frequency of animal surveillance on pasture from once a day to once a week
- Decreased cost for grass-clover silage with €0.02 per kg dry matter due to e.g. higher herbage yield and/or lower cost for machines
- Decreased size of pasture enclosures from 8 – 16 ha in the basic calculation to 2 ha, independent of herd size
- Use of existing buildings without opportunity cost for winter housing

3.3 Paper III – Labour time

The aim of this study was to examine the current labour demand in Swedish beef cow operations. An invitation letter was sent to a random selection of beef cow enterprises with ≥ 20 beef cows in southwestern Sweden. Enterprises with a loose house or outdoor wintering systems, that were willing to participate in the study (response rate 20%), were visited and background farm data was collected with a questionnaire. Questions related to the structure of the farm, i.e. area of pasture, distances to pastures, feeding and cleaning systems, calving time, herd size, etc. Of all the farms visited, 49 completed the whole study (Fig. 5, black dots). All individuals working in the enterprise logged their labour time with the cows, breeding bulls, and replacement heifers during one whole day every 8th day for 12 months. The respondents were asked to log their time into one of eight animal-related labour categories using an application on their smartphone. Thereafter, the person sent the information to me by email for further compilation. The eight labour categories were:

- Administration
- Bedding
- Cleaning
- Feeding
- Fencing
- Maintenance
- Supervision indoor
- Supervision on pasture

To obtain accurate estimates of the labour consumption for tasks that are seldom undertaken, farmers were asked to separately estimate the labour time for such tasks. These tasks could involve emptying straw beds, or the time required for turning-out cattle to pasture. If both the time log and estimate were lacking for such a seldom task, a prediction was made for the individual farm by applying multilinear regression based on the workload on the other farms with similar conditions.

In the data analyses, the study year was divided into three periods: calving period, grazing period, and indoor non-calving period. Correlations between variables were investigated using PCA and correlation analysis. A regression model on herd size and total labour time per cow, including replacement, was estimated using a logarithmic model $y = \log10(x)$, where y = labour time and x = number of cows. Finally, a further case-selected analysis was done based on the farms with ≤ 100 cows and with residuals in each end that diverged the most from the regression line described above. The five farms most below the regression line had the lowest labour time and the five farms above the line had the greatest labour time per cow. These two groups were compared to reveal possible differences in management and natural conditions between them.

3.4 Paper IV – Competitive grasses

Study IV investigated if alternative wet-and-drought resistant grasses (WD) were more competitive than traditional grasses (TR) when produced and fed as silages to cattle under different weather conditions. Biological data from three previous feeding experiments with various animal categories, conducted in southwestern Sweden was used, representing three levels of production intensity: dairy cow as high-intensive, slaughter beef bulls as semi-intensive, and beef cows as low-intensive. In each of the three systems cattle were fed two different types of silages, TR or WD. In economical calculations, each of the three cattle production systems was supposed to be located in three alternative geographical regions of Sweden, Gsk, Gns, and Nn (Fig. 5). Economic consequences of using TR or WD in these systems and regions were conducted for three different weather scenarios. Those weather scenarios were composed of historical normal climate (reference) and supposed future climate with increased frequency of drought (dry conditions), and more frequent and heavier precipitation (wet conditions) during cropping season.

The profitability was defined as CM, calculated as Σ revenues – Σ variable costs using a modified model of Agriwise (Agriwise 2023), to find the most profitable alternative in each weather scenario for the different production system and region. Average prices for 2019 – 2023 were used in the calculations to reflect prices over a longer time. Grass silage production costs used in the CMC reflected the different yields and field configurations in the regions.

In the basic calculation the cost for arable land was calculated as CM in grain production (opportunity cost). In a sensitivity analysis the cost for arable land was instead set as regional average rent cost incl. free rents in the region. The rent cost is lower than the opportunity cost, especially on the plains where CM in grain production is very high in many areas. Rent cost is a relevant cost for land in the areas with less suitable conditions for grain production, where cattle production often is located.

4. Main findings

The profitability of Swedish beef production is under immense pressure (Swedish Board of Agriculture 2022; FADN 2023; LRF 2023). In my thesis I have examined different ways to increase the profit and thus create a sustainable and increasing beef production which contributes to fulfil both the national food strategy (Government Offices of Sweden 2017) and the national environmental goals of a rich biodiversity and varied agricultural landscape (Swedish Environmental Protection Agency 2023). I have found several ways to increase the income and decrease the costs. This chapter presents the findings and results of this thesis through an executive summary of each paper. More detailed results can be found in Paper I – IV.

4.1 Paper I – Large coherent pastures

By merging small, scattered pastures into large coherent pasture-forest mosaics all five beef cow operations studied obtained a higher efficiency in grazing management and this contributed towards improved financial gain, expressed per farm and per hectare.

The improved remunerability had different sources. Farm 4 had the highest increase in profitability, due to improved consolidation combined with enlarging the herd size. Increased agri-environmental payments and supports were the primary sources for increased profitability on Farm 1 and 3. With more cows in each individual enclosure, Farm 3 also required fewer sires which further reduced the costs. However, Farm 3 lost income from previously rented-out arable land that was converted into pasture, and there was an additional loss from semi-natural pastures rendering high payments. Lost payments were due to grazing animals being moved from leased pasture far from the farm to new mosaics pasture with lower payment close to the farm centre. Farm 2 included some forest area in the pastureland and the cows were therefore able to spend winter outdoors which resulted in less costs associated with indoor wintering. There was a reduced income in the crop cultivation for Farm 2, since handling the manure was a problem on pasture. For Farm 5 the improved profitability was entirely due to the replacement of rented pasture far away with its own pastures closer to the farm centre.

Notably, I found that making a larger, coherent pasture that included forestry land (Fig. 6) was more profitable than replanting after final felling. Even premature felling was economically motivating on Farm 4 to quickly gain access to more consolidated pasture.

Figure 6. Forest that has been restored to pasture (photo: K. Holmström).

4.2 Paper II – Bulls or steers?

In basic calculations I found that indoor bulls were more lucrative than grazing steers on semi-natural grasslands, regardless of gender, breed, production systems, herd size, and region. CM above zero were obtained for all crossbred bulls in herds with 150 slaughtered animals per year, and in some cases purebred dairy bulls also had CM above zero. Further, for herds with 100 slaughtered bulls per year, six calculations out of twelve cases in total had a positive bottom line, with CM above zero. Steers in herds with 150 slaughtered animals per year, had a CM above zero in six cases, mostly in Gns which had low feed costs, but no steers were more competitive than bulls. No steers in herds with less than 150 slaughtered animals per year had a CM above zero. In general, the most economically sustainable steers were pure dairy steers found in extensive systems, grazing two summers on grass and slaughtered at 28 months of age.

The different sensitivity analyses showed that there are ways of making steers more profitable than bulls. If 70% of the semi-natural pastures received the high level of agri-environmental payments, instead of 30% as in the basic calculation, steers in the largest herd size were more competitive than bulls in Gns and Gsk. This is especially the case for extensive steer grazing 1.6 ha semi-natural pastures per head, whereas the intensive steer only grazed 0.9 ha. For the remining 13 cases with a high level of payment for semi-natural pastures, bulls were still more competitive than steers or there were no CM above zero.

Additional payments for premium-priced pasture beef increased the revenues for steers and made them more profitable than bulls in most cases, mostly in larger herds.

Decreasing labour demand on pasture from daily to weekly supervision on animals, had the largest positive effect on extensive steers and they became more profitable than bulls in three more cases compared to basic cases.

A decreased cost for grass-clover silage made steers more competitive in three cases in the largest herd size with 150 slaughtered animals per year, whereas the bulls continued to be more competitive in most calculations.

A decrease in the size of pasture enclosure to two hectares drastically decreased the profitability and competitiveness of steers compared to bulls and showed CM below zero for all steer systems.

Using existing buildings that have no fruitful alternative use was the most important factor to reduce total cost. In 10 of 18 cases steers were more profitable than bulls. With existing buildings, CM above zero was obtained for all cases of gender, breed, production system, herd size, and region.

The result of basic calculation and two sensitivity analyses is displayed in Figure 7, showing intensive and extensive steers and bulls in Gsk in herds with 100 animals slaughtered per year. As shown, only steers that have a combination of premium for certified pasture beef, less labour on pasture, and lower cost for silage have a positive result, however bulls almost have a positive result with less cost for silage. Furthermore, when steers graze on a large amount of semi-natural pasture rendering high level of agri-environmental payment, steers are close the black bottom line. Thereby, combining more grazing on pastures rendering high level of agri-environmental payments, certified premium, and less costs would make steers gainful in Gsk.

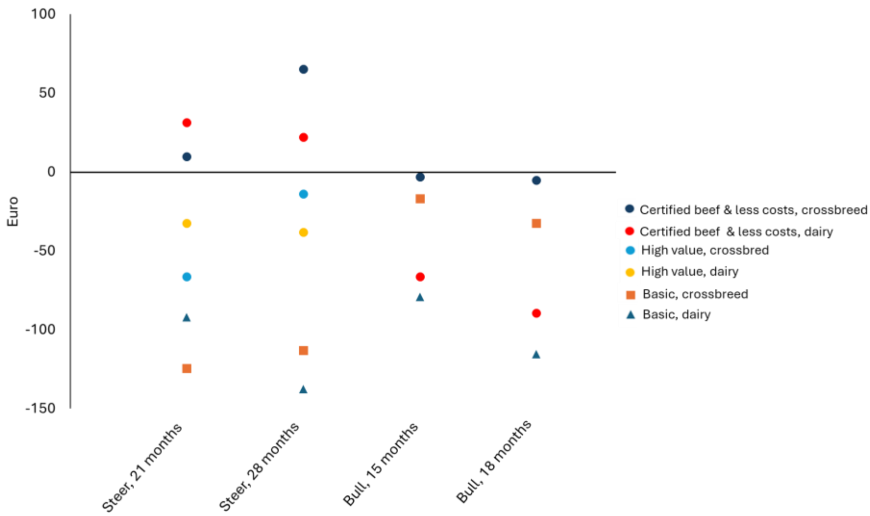

Figure 7. Contribution margin for grazing steers slaughtered at 21 or 28 months of age and indoor bulls slaughtered at 15 or 18 months of age, all groups of either pure dairy breed or dairy x beef crossbreed, result in basic calculation and different sensitivity analyses; 1) grazing 70% of high valued semi-natural pastures instead of 30%, 2) additional revenues for certified pasture beef (steer), and less costs for less labour on pasture (steer) and lower cost for silage (steer and bull), in the forest district of Götaland (Gsk) with herd size of 100 slaughtered animals per year, expressed per reared head.

4.3 Paper III – Labour time

There was a large variation among labour time for the studied beef cow herds with an annual median labour time of 17 hours per cow incl. replacement, corresponding to 2.8 minutes per day. According to the regression function, labour input per cow decreased with herd size, largely because some small herds had a very high labour demand. A significant result that I found in this study was that some small herds with 20-50 cows were as labour-efficient as herds with 200-300 cows.

Largest labour demand per cow and day occurred during the calving period (from 1.77 to 5.26 min.) and the lowest demand during the indoor non-calving period (from 1.23 to 4.78 min) for all herd sizes investigated. Generally, the most time-consuming task across the year was the supervision of animals and water supply on pasture (example seen in Fig. 8), except for the smallest herds (20 – 50 cows) with highest workload (75th percentile) where manure handling was the most time-consuming task across the year. The most important factor for reducing daily labour time per cow, aside from herd size, was using equipment for mechanical bedding.

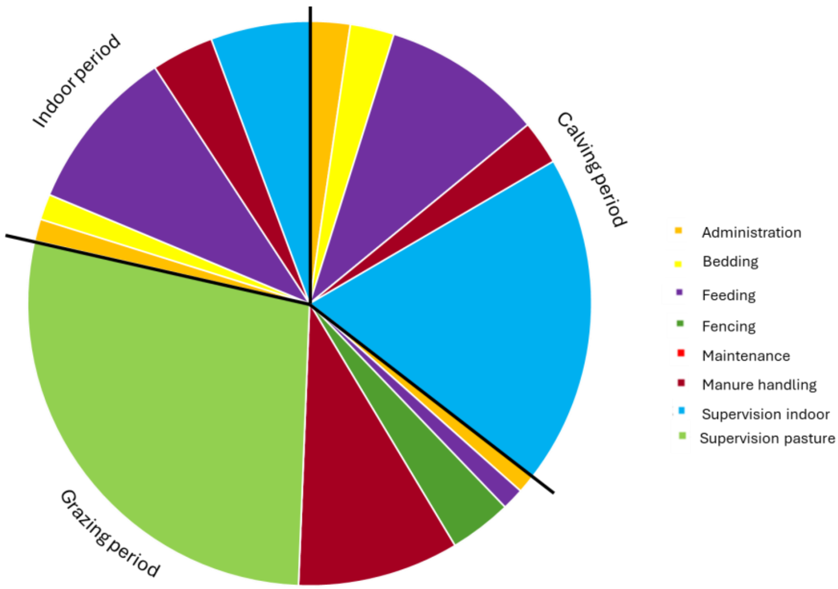

Figure 8. Yearly distribution of labour demand into various categories during calving period, grazing period, and indoor non-calving period expressed as median values for herds with 20 - 50 beef cows.

During calving and indoor non-calving periods, and across all farms, labour time was negatively correlated with herd size. During indoor non-calving period, labour time was also negatively correlated to number of employees and use of mechanical bedding, whilst it was positively correlated to manual bedding. There was a positive correlation between herd size and number of barns during calving period.

When I separately analysed the grazing period across all farms, I could not find the negative correlation between herd size and time spent on supervision on pasture, which was found on a yearly basis.

When comparing the five farms with ≤100 cows having the least and most labour time per cow I found that farms with a large labour time spent more time on every task but particularly on maintenance of buildings and machinery, feeding, and bedding. There were more farmers that worked off-farm on the farms with low workload. Furthermore, farms with a low workload had one barn, compared to a median of two barns for farms with high workloads and they also had just half as long of a calving period as the farms with high workloads. Even if the farms with low workloads had more animal groups on pasture, their maximum distance from pasture to the farm centre was shorter.

4.4 Study IV – Competitive grasses

When comparing TR with WD grasses, evidence illustrates that TR was more competitive when fed to dairy cows and slaughter beef bulls in all regions under both normal and wet weather conditions (Fig. 9). Under drought conditions, TR still was more competitive than WD in dairy production, while WD was more competitive in beef bull production (Fig. 9). For beef cows, the alternative with WD-reed canary grass always had a higher CM than both TR and WD-festulolium, independent of normal, wet or dry weather.

All alternatives for dairy production showed CM above zero. For beef bull production all combinations of grasses and weather conditions in Gns, and for TR under dry conditions in Gsk, showed negative CM. In beef cow production all combinations of grasses and weather conditions showed a positive CM in Nn, and for WD-reed canary grass also in the Gsk. For beef cows in Gns, WD-reed canary grass still showed a less negative CM than the other grasses. The results are displayed in Figure 9 showing the difference in CM between WD and TR for the different cattle systems.

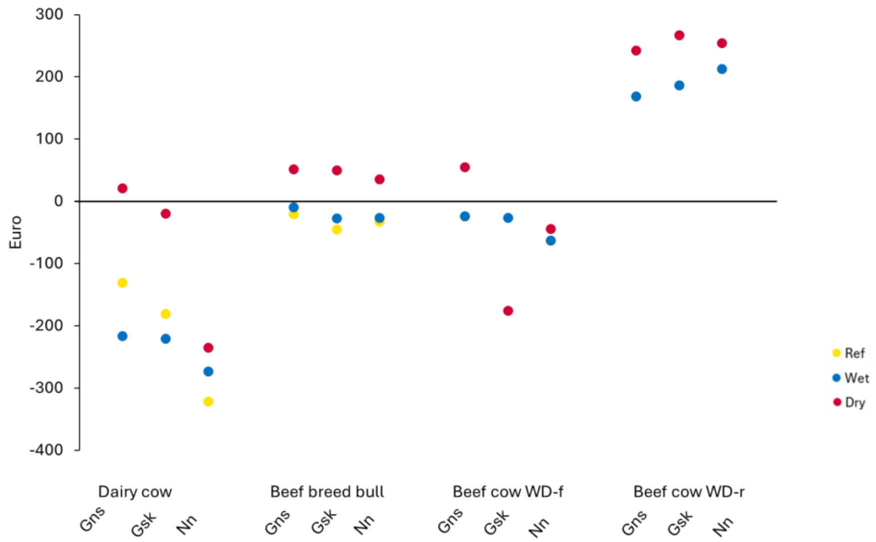

Figure 9. Comparison of the competitiveness of feeding silage of wet-and-drought resistant (WD) *versus* traditional (TR) grasses by subtracting contribution margin (CM) for WD by CM for TR for three cattle production systems (dairy cow, slaughter beef bull, beef cow), in three geographical regions: the plain districts in northern Götaland (Gns), the forest district of Götaland (Gsk), the lower parts of Norrland (Nn) under normal (Ref), wet (Wet) and dry (Dry) weather conditions. The difference is expressed per head and year for dairy and beef cows, and per reared head for bulls. For beef cows, Ref and Wet implies the same harvest date and other conditions. Based on basic calculations.

Not even with yearly droughts, WD was more profitable than TR for dairy cows in Gsk and Nn. Beef bulls differed with grass species depending on which gave highest CM between different weather scenarios. Supposing drought scenarios every second year or more, WD resulted in a higher CM than TR. For beef cows, WD-reed canary grass had higher CM than TR and so did WD-festulolium, independent of proportion of different weather conditions and region.

Changing from opportunity cost of land to rent cost including free rents, had the most positive effect on CM for dairy production in Gns where CM in grain production is very high.

5. Discussion

The starting point of this thesis is the urgent need to increase economic sustainability in Swedish beef enterprises and contributes with suggestions to achieve this. More profitable beef farms will increase self-sufficiency, and areas of biodiverse semi-natural grasslands can be maintained and even extended.

Several aspects of profitability can be discussed, as seen from the results in Paper I – IV, but in this discussion, I focus on results that are vitally important to increase profitability. For a more detailed discussion about the results in each study, please see Paper I – IV. To find economic ways for sustainable beef production following two different complementary questions are formulated:

- Are there economies of scale?
- Are there differences in profitability between different cattle production systems?

My thesis leverages different ways to increase financial gain in beef farm enterprises. In four papers, I demonstrate that it is possible to increase the surplus in beef operations. I also show differences between herd sizes, cattle systems, and different Swedish regions, as well as the large demand for grazing cattle. This fifth chapter completes this thesis with a discussion that ties the findings of the paper together and puts them in a larger context.

Below, I start to summarise the answers of the two research questions.

5.1 Are there economies of scale?

The findings of Paper I, II, and III show economies of scale in different ways. In the previous chapter, I discussed how larger pasture enclosures and herd size can affect beef cattle enterprises. Those studies explore how economies of scale can positively affect profitability in beef cattle enterprises.

The findings in Paper I demonstrate positive changes when creating larger pasture enclosures. Increased agri-environmental payments and supports gave the bottom line a positive result compared to the baseline with small, scattered pastures. When transforming forestland into pasture there is a loss of income from future forestry production. Despite this economic drawback, I found that the economies of scale of creating larger enclosures was advantageous.

Economic calculations based on different herd sizes in Paper II clearly show economies of scales with larger herd size. The investigation in Paper III describes labour demand in beef cow herds. The findings highlight, except economies of scale, also the large labour demand during the grazing period in typical Swedish fragmented pastureland. Fragmented pastures with lots of small enclosures must be fenced and maintained and all the small groups of grazing livestock cared for, leading to a large labour demand. For pasture-based cattle systems this poses a challenge. Beside our theory of economies of scale that larger number of beef cows decreases labour time per head, we found that some small herds can be as labour efficient as larger ones.

5.2 Are there differences in profitability between different cattle production systems?

Earlier in this thesis I described various ways to calculate profit depending on the question at hand. Findings from Paper II and IV shows that profitability varies between cattle systems of different intensities. The findings from this thesis also widen the display of various disparities between regions in Sweden, which is predominantly due to natural and geographical conditions. Disparity can be yield of crops, days of grazing, area of semi-natural pastures, and number of payments and supports. All these differences have an impact on profitability. For example, if large areas of semi-natural pastures are available, low-intensive cattle systems are usually the most advantageous, while if there is more arable land with high yields of cereals on the farm, high-intensive indoor cattle systems are more suitable.

Findings from Paper II show large differences between indoor bulls and grazing steers, where bulls have more positive results than steers in basic calculations. Sensitivity analyses, which included e.g. more semi-natural pastures rendering a higher level of payment and premium price for pasture beef, showed scenarios that favoured grazing cattle and, hence, steers became more competitive than bulls, especially in the forest district Gsk.

It is evident from the findings in Paper IV that changing grass species for silage making will result in subsequent changes in profitability in different cattle systems and weather scenarios. The studied semi-intensive system with slaughter bulls of beef breed is most sensitive for wet weather with accomplished delayed cut, which generates fibre-rich forage with lower nutritional value than under normal weather conditions. For the intensively fed dairy cows, traditional nutrient-dense grass was almost always most competitive, independent on weather conditions. On the other hand, the extensive system with beef cows had the highest gain when fed forage with high fibre concentration. It can therefore be concluded that recommendation on what grass to use needs to consider both cattle system and supposed weather.

5.3 Pasture enclosure

As I already mentioned in chapter 2, many Swedish semi-natural pastures are small and scattered, particularly in forest districts where the average size is only two hectares (Swedish Board of Agriculture 2007). Moreover, these districts keep the largest areas of semi-natural pastures that have already been abandoned or are at risk of abandonment (Kumm 2003). The small size of pasture enclosures is an important factor for the lack of profitability in beef operations with grazing cattle. As we claimed in Paper I, merging small, scattered pastures into large, pasture-forest mosaics and by including abandoned pastures, or pastures at risk of abandonment, marginal arable land and adjacent forest can improve profitability.

Creating such large enclosures from small and scattered pastures, fields, and forests can increase profitability in pasture-based beef production and therefore be significant long-term to reach the national goal of increased domestic food production according to the national food strategy (Government Offices of Sweden 2017; Kumm 2021). Although the area of each site is small and scattered (Swedish Board of Agriculture 2007), together they are large areas.

Based on the recent European Nature Restoration law (European Parliament 2024), the Swedish Environmental Protection Agency found that at least 370 000 ha of now generally afforested former natural and semi-natural grasslands must be restored and grazed by at least 160 000 beef cows and their offspring to give medium-high probability to preserve biodiversity of these habits long-term (Swedish Environmental Protection Agency 2024). This area of pastureland and stock of beef cattle are almost doubled compared to today (Swedish Board of Agriculture 2023a). Such increases require the combination of beef production and conservational grazing to be gainful. Hence, the suggested increase in semi-natural grassland area can be a good opportunity for pasture-based beef operations if the political ambitions will be followed by economic incentives to promote grazing. This is chiefly true for farms with the possibility to create large, coherent pasturelands of small and scattered pasturelands and restore abandoned pasturelands, as discussed in Paper I. However, if some of the calves that originate from beef cows are reared as indoor bulls instead of grazing steers, there is a need for even more beef cows to maintain the new pasturelands (Hessle & Danielsson 2024).

From an economic point of view, it is important to find solutions for enlarging pasture enclosures. When we anticipated an enclosure size of two hectares in our calculations (Paper II), no grazing steer alternative resulted in a positive CM. As mentioned above, small enclosures correspond to the average size of semi-natural pastures in forest districts (Swedish Board of Agriculture 2007), therefore many of them are even smaller. These small plots, with high biodiversity values, are important for nature conservation and are thus threatened.

Since larger pasture enclosures are not as expensive to build and maintain as smaller ones, they generate a higher CM for grazing cattle. Additionally, larger enclosures can keep larger cattle groups which decreases labour demand per head compared to having smaller but more groups, thus improving profit per working hour. In Paper III we saw that fragmentation of pastureland increased labour demand per beef cow during the grazing season. Thereby, an ease to create larger pasture enclosures, including changing land with neighbours, is of importance. A newly published official governmental report on improved competitiveness and animal welfare in Swedish livestock production can provide hope of mitigation on these issues (Swedish Parliament 2024a). One example is a suggestion on legally allowing virtual fences, which would favour the creation of larger pasture enclosures, maintain fragmented pastures, or direct the cattle to graze at specific places within a large enclosure.

Cattle kept on pasture for more than one summer, as the extensive steers were in Paper II, render a higher CM due to receiving more agri-environmental payments, and thereby they can be more profitable than indoor bulls and steers grazing for one summer only. This is particularly the case if they are kept on pastures with high biological and cultural values rendering the higher level of payments (Swedish Board of Agriculture 2023c). These findings are also in line with results from a previous study that compared steers with either one, two, or three grazing seasons (Hessle & Kumm 2011). In Paper II, fairly high-yielding semi-natural pastures was supposed (1.5 ton dry matter per ha). With a lower biomass production, every steer would have been able to manage a larger area and hence render more agri-environmental payments. If future general payments and supports to livestock production will decrease, a compensatory increase of environmental payments to semi-natural pastures will be needed to continue the preservation of these pastures. An effect of such a scenario will be pasture-based production systems having a higher competitiveness relative to indoor-based production systems. The increased payment for semi-natural pastures must, however, be significant for a positive result. Design of the payment and support will have a large influence on the future area of maintained semi-natural pastures (Larsson et al. 2020).

5.4 Herd size

Most Swedish beef herds are small, with an average herd size of 20 beef cows and 33 young stock per herd of these two types 2023 (Swedish Board of Agriculture 2023a). As we shown in Paper II, small herds with less than 100 bulls, or 150 steers slaughtered per year do not reach CM above zero. This was also recently shown for small beef cow operations with 20 beef cows (Kumm & Hessle 2020). However, larger herds with finishing cattle originating from dairy (Paper II) or beef cows (Kumm & Hessle 2020) can be fruitful. Therefore, larger herd sizes can improve economically sustainable profitability in beef production systems. The rapid increase in herd size in Swedish dairy cow operations is far from the slow size rationalisation in herd size for beef operations, where the average beef cow herd size even decreased a little last year (Swedish Board of Agriculture

2023a). Economies of scale connected to herd size was seen in Paper I, where an enterprise expanded production, and more finishing cattle contributed to the additional income. Profitability was not measured in Paper III, but we saw that labour demand in general decreased with herd size. However, there were some small operations with 20-50 beef cows that were as labour effective as operations with 200-300 beef cows.

5.5 Payments and supports

An important part of the revenues in Swedish beef production is payments and supports (Fig. 2), and in Paper I payments and supports were an important factor to achieve increased profitability by creating large coherent pastures. In Paper II, we show that steers are highly dependent on payments and supports because just a little more than half of the income derives from carcasses and the remaining part from payments and supports. Contrary for bulls, the share of income from carcass is over 90%. It is therefore important to have a long-term understanding of keeping and increasing agri-environmental payments and supports, if the price paid for carcasses does not increases drastically to achieve sustainable and economic pasture-based beef production.

The Swedish Parliament have included a goal in their strategic plan for the implementation of the common agricultural policy in Sweden to prevent the loss of biodiversity (Swedish Parliament 2023) and has resultingly increased support for the management of semi-natural pastures, which positively affects the profitability of grazing cattle. In Paper II, we show that an increased proportion of semi-natural pastures rendering the high instead of basic level of agri-environmental payment increased the income by 12 – 100 Euro per head, which made the grazing steers more profitable than indoor bulls in several rearing alternative situations. Support to LFA is also prioritised in the strategy (Swedish Parliament 2023) and is of importance for continued agriculture in areas with less competitiveness as described in Paper II and IV.

5.6 Buildings

Possibilities to use existing buildings that have no beneficial alternative use, i.e. buildings without opportunity cost are the most important factor to reduce cost in beef production systems, as we shown in Paper II and already seen by (Johnsson et al. 2004). The problem with existing buildings, in addition to finding usable ones, is that they often need more maintenance than newer barns and eventually must be replaced.

5.7 Labour demand

As I discussed in chapter 2.3, cost for labour is one of the biggest expenses in beef production (Fig. 3). If there are possibilities to reduce labour time, profitability will increase. In comparison to dairy production, which has undergone a large increase in both herd size and degree of mechanisation, beef cow herds and finishing of beef operations in Sweden are still small (Swedish Board of Agriculture 2023a). Economies of scale is one way to decrease labour demand per head of animal cattle. Nevertheless, as stated in Paper III, small beef cow operations, can be as efficient as larger ones. For some farmers balancing small efficient herds along with other income-generating activity can be more satisfactory than building larger herds for full time work on farm (Short 2001). Those small, efficient herds could be gainful.

Notably, I found that during the grazing season larger beef cow herds did not have a lower workload per head for animal supervision on pasture than smaller herds (Paper III). Pastures far away, especially in larger herds, with high fragmentation are the reasons for high workload with grazing beef cattle. On the studied farms there were many enclosures and flocks that each required daily supervision in accordance with Swedish animal welfare regulations (Swedish Board of Agriculture 2019b). Hence, in pasture-based livestock production, opportunities for labour efficiency in large compared to small herds is therefore limited during grazing period. As mentioned in Paper III, changing from daily supervision to once a week would decrease labour input between 26% and 39% per cow during the grazing period. Also, in Paper II, an alternative with decreased animal supervision during grazing period was calculated. We found higher CM for steers with less supervision, but the change in supervision frequency alone did not make these steers as competitive as indoor bulls. In the ongoing technological age, greater use of digital monitoring would have favoured economic sustainability of beef operations. It is possible to further reduce the time spent on animal supervision by using new digital sensors with remote surveillance of animal behaviour and welfare (Högberg 2021) if it was legally allowed by regulation as a replacement of manual supervision. According to the official governmental report on improved competitiveness and animal welfare in Swedish livestock production (Government Offices of Sweden 2017; Swedish Parliament 2024a) I can see solutions for the question raised above, e.g. further development of digitalised solutions for supervision of animals and legalisation of virtual fence.

In beef cow operations, we show that a short calving season and mechanical bedding decreased labour demand (Paper III). Unsurprisingly, mechanisation is shown to also decrease the workload in other herds with beef cows and young stock (Fallon et al. 2006; Bostad et al. 2011; Veysset et al. 2015).

5.8 Price for carcass

There is a disparity between the official price lists from different slaughter companies (Swedish Board of Agriculture 2023a) and the price actually paid for carcasses from statistics (LRF 2023), with the latter being much higher. This discrepancy reveals the possibility to negotiate higher prices, and this possibility would, for the single farmer, be greater along with availability and the more animals that can be supplied. As the calculations in this thesis are based on official list prices, it may be possible, especially for larger producers, to obtain higher prices and thus increase profitability.

There are several certification schemes on the market which can provide a premium price and thereby extra income. One type of certification is for organic production, which gains extra income from payments and supports for organic farming (Swedish Board of Agriculture 2023c) and also extra income for the carcass. Organic production is associated with less crop yields, which give higher production costs for silage and grains (Finneran et al. 2012). Another more recent type of premium price available in Sweden is paid for certified pasture beef, a concept which guarantees that the animal has been grazing on semi-natural pastures for at least half of the grazing season and has been forage fed during the indoor period (Naturbeteskött 2024). This premium price, in addition to the support system, further strengthens the competitiveness of grazing semi-natural pastures. Both certified pasture beef and organic production are well adopted by grazing steers but not allowed for all-year-round indoor bulls. Premium price for the carcass can fill the gap of required extra payments for grazing steers originating from dairy production to be more profitable than indoor bulls (Paper II).

Even if dairy × beef crossbreds generate a higher income from slaughter than purebred dairy breed, they are also more expensive to buy as calves due to their higher weight and the premium price for calves after beef breed sires (KLS 2024; Scan Sverige AB 2024; Skövde slakteri 2024). Nonetheless, cross-bred cattle more frequently generated a higher CM than pure dairy cattle in Paper II, due to higher carcass weight and better conformation score, which has also been reported by others (Keane 2010; Huuskonen et al. 2013, 2014; Hessle et al. 2019; Wetlesen et al. 2020). Li and Cabrera (2019) created a model for dairy farmers using beef semen, where they showed that when the calf price and price paid at the abattoir are high, use of beef semen is beneficial. Regarding Swedish enterprises I am convinced that an increase in the proportion of dairy × beef crossbred offspring from dairy cows is a valuable opportunity.

5.9 Winter feed cost

According to Paper II and IV, reduced cost for silage is positive for the bottom line in cattle systems, where herbage yield is the most important factor for the production cost of winter feed. As we claimed in Paper IV, reed canary grass was always the best of the studied alternatives for beef cows and can contribute to a more advantageous cow-calf production. The superiority of reed canary grass is due to a combination of, firstly, a high concentration of fibre with low nutritional value that suits beef cows (Jardstedt et al. 2020). Secondly, a high forage yield which keeps production cost of silage low, as seen in Paper IV and also reported by Finneran et al. (2012). Depending on weather situations, species of TR or WD grasses are most competitive in beef bull operations (Paper IV). Under dry conditions WD are more drought tolerant (Casler et al. 2020; Joel et al. 2023) and therefore have higher yields than TR (Mäkinen et al. 2018). Accordingly, I recommend that farms with beef bulls in regions with frequent droughts use WD in their leys, as stated in Paper IV. Animal performance level varies along with the intensity of the cattle production system and influence of the nutritional requirement. The nutrient supply is crucial for high-intensive dairy cows, which require digestible, nutritious forage as TR to maintain milk yield (Sousa et al. 2021). A decrease in milk yield from replacing TR with WD would cost more than the gain from growing high-yielding WD instead of TR also under dry weather conditions (Paper IV), why I recommend dairy farmers to continue feeding TR.

5.10 National food strategy

The ongoing work with a national food strategy is complex. The first version of a food strategy was determined in 2017 (Government Offices of Sweden 2017), and recently the Swedish Parliament presented a budget proposal with an increased budget for food production (Swedish Parliament 2024b). This means that there e.g. will be increased investment supports to farmers, decreased tax on diesel, and a revised national food strategy. If this strategy comes to fruition, the competitiveness of Swedish beef operations will increase.

At present, vast areas are being abandoned or are at risk of being abandoned, due to poor field layout in high-yielding land compared to forestland, that is low-yielding. An enlargement of beef production would contribute to both a higher degree of self-sufficiency and more land, both arable and permanent grasslands, being used. There are only two beneficial alternatives for the vast area of land that is currently being abandoned, or is at risk for being abandoned, namely beef production and afforestation (Kumm 2021).

An evaluation of the food strategy (Government Offices of Sweden 2017), conducted by the Swedish Board of Agriculture, indicates that there is a small increase in the area of semi-natural pastures during 2016 and 2022 but a decrease in the number of grazing cattle. Therefore, it will be difficult to achieve the national environmental goals of a rich flora and fauna and a rich and varied agricultural landscape (Swedish Board of Agriculture 2023d).

Consumers appear to prefer Swedish beef over imported beef, according to statistics from 2017 until 2023 (Swedish Board of Agriculture 2023a), when consumption of beef decreases but consumptions of Swedish produced beef increases. However, Sweden’s self-sufficiency in beef for 2023 was only 57.6%. With more profitable beef enterprises and consumers that are willing to buy the products it will be possible to reach the national food strategy´s goal of increased food production as well as the environmental goal to preserve biodiversity of semi-natural pastures.

The new Nordic nutritional recommendations (Livsmedelsverket 2024) argues that consumption of red meat must decrease, for both health and environmental reasons. If Swedes consumed only domestic produced beef, current beef consumption levels would almost half and beef production would still be maintained. With an increase in beef production to meet goals in the national food strategy (Government Offices of Sweden 2017) and the restoration law (European Parliament 2024), low-intensive pasture-based beef production could be useful for export to other countries. Therefore, the pasture-based beef production must increase.

5.11 Methodological considerations

In Paper I we sought out farmers who had made a change in their pasture management and of twenty replying farmers we used five enterprises. The extensive data collection on each farm and limitations in time resulted in a small number of farms for the study. The profitability in this study was calculated with partial budgeting technique using historical and projected production data. It is important to note that partial budget does not determine the enterprise's profitability, but rather the profitability of a specifical change. Accuracy of a partial budget analysis is dependent on the reliability of the estimated data used (Olson & Westra 2022).

Use of sensitivity analyses shows the effect on profitability if input parameters are changed. In Paper I we used five different sensitivity analyses to demonstrate these effects. If repeating the study in Paper I there are two aspects that can be done differently. Firstly, increasing the number of investigated enterprises across Sweden will give more well-founded results. Secondly, including enterprises that have not voluntarily replied to a call will engage farmers who might not be so satisfied with their change, and this will influence the result.

In Paper II and IV CMC, including different sensitivity analyses, were done. CMC are useful when comparing similar basis's and production systems but they do not take into account common costs (Olson & Westra 2022). Therefore, CM in an advantageous alternative must be above zero to cover common costs such as planning, administration, and accounting. To further illustrate results in Paper II and IV, there could have been sensitivity analyses completed for more levels of revenues and costs.

The enterprises used for studying labour demand in beef cow herds (Paper III) voluntarily participated. The replying enterprises that were willing to participate represented 20% of the total number asked. Voluntary participation was, of course, necessary, but it had also been interesting to investigate the enterprises which rejected the offer to participate to see if this had influenced the results. This study was undertaken in southern Sweden. The result may be different if repeated in northern Sweden where the grazing period is somewhat shorter (Ahlgren et al. 2024). We were also dependent on farmers' and employees' accuracy in this study, both for time logging and for the estimated time for seldom tasks. A drawback is that the study did not include the labour conducted of people other than farmers and employees. Letting neighbours or people outside the enterprise keep an eye on grazing livestock is common when grazing on other people's pastures. This limitation may have resulted in significant time not being recorded during the grazing period.

The time logging data in Paper III was investigated with a correlation analysis. Factors that were not included in the correlation analysis might have influenced the result, such as number of veterinary visits or age of the newest building. In an correlation analysis it is also suggested that only linear correlations occur (Hair et al. 2014), and more complicated measures of the correlations are needed if there is a curved line expressing the relationship. If repeating this study, more enterprises will be welcome, especially operations with larger herds.

Regardless of these limitations in the work, it can be claimed that important knowledge was discovered which is in line with earlier presentations of the findings. In addition, all four papers are peer-reviewed and three of them have been, so far, published in scientific journals.

5.11.1 Practical experiences

I have familiarity with the research area. Due to my long experience, more than 20 years of working as an advisor to beef and dairy enterprises, experience of farm-work in dairy herds, and a short period at a county administration board, I would claim a respectable level of validity between calculated results and reality, even if I do not claim to be an expert in all agricultural fields. I have provided written descriptions of the work, but it is not possible to judge if it is repeatable until someone else has conducted a similar study. During this thesis work, my own perspective has changed in different ways. For instance, I have learned to think in figures to make results more visible and use my thoughts even more outside the box. Nowadays, I always see an issue that can be calculated.

Finally, this thesis claims that there can be economically sustainable beef enterprises in Sweden. This thesis also claims that there are economies of scales and differences in profitability between various cattle systems. Accordingly, I hope this thesis makes an important difference regarding financial gain in beef enterprises. Nevertheless, these beef enterprises need help to reach economic sustainability, from both policymakers and consumers.

6. Concluding remarks

We found that there are several ways to make Swedish beef production more profitable and thus economically sustainable. Many factors affect profitability and therefore each production system needs to be optimised based on its own conditions. The main conclusions of this thesis are listed below.

- Creating larger, coherent pastures for cow-calf enterprises is profitable

- Steers grazing on semi-natural pastures can be profitable

- Certain small beef cow herds can be as labour efficient as larger ones

- Reed canary grass is economically outstanding winter forage for beef cows

Furthermore, we conclude that:

- Agri-environmental payments and support are necessary for all beef production

- There is a reduction in costs with less fragmentation on agricultural land

- Cost for premature final felling and opportunity costs of forests are of minor economic importance when creating large pasture-forest mosaics

- Indoor bulls are more profitable than grazing steers under normal Swedish conditions

- Bulls of dairy × beef crossbreed are more profitable than dairy bulls, whereas breed is of less importance for steers

- Beef cows have a median labour demand of 17 hours per cow per year

- Herd size of beef cow operations has decrease labour demand per head during indoor periods

- Supervision of cattle on pasture is the most time-consuming task across the year in beef cow herds

- Mechanical bedding and a short calving period reduces beef cow labour demand

- Relative competitiveness of grass types is more sensitive to weather conditions for indoor bulls than for dairy and beef cow systems

- In high-intensive cattle production systems traditional grasses are often more competitive than wet-and-drought resistant ones

6.1 Practical implications

The results from Paper I-IV provide deeper knowledge of ways to increase profit-making in Swedish beef production. These results can be used in planning processes for e.g. creating coherent pasturelands or identifying optimisation measures in beef production. Distinction among various cattle systems and regions in the studies provides possibilities to analyse diverse beef operations. This thesis can also be used by policymakers when deciding better conditions for beef operations.

The results of merging small, scattered land to large, coherent pastures improves profitability in beef operations. By evaluating how changes affect production using a partial budgeting technique, enterprises can easily calculate their own transformations.

Findings from the comparison of bulls and steers, shows evidence for rearing indoor bulls of dairy × beef crossbreed. The results also display diverse ways of making steers competitive to bulls.

The results from beef cow workload can be used for analysing if and where labour demand can be possibly decreased. The large variation in labour demand between and within herd size can encourage beef cow enterprises to adjust their workload.

Findings from comparing traditional grasses with wet-and-drought resistance ones for silage provides guidance for diverse cattle systems in future climates. Based on the profitability results, various grasses are optimal in the different cattle systems.

7. Future perspectives

To further develop this area of profitability in beef production the following aspects could be studied:

- Identify practical opportunities to merge small, scattered pastures into large pasture-forest mosaics which, according to Paper I, can improve remunerability. Challenges in this research include the fact that such mosaics can affect many landowners and that careless cattle grazing in forests can result in forest damage.

- Investigate the combined profitability of dairy and beef herds using beef breed semen for dairy cows. This would complement Paper II wherein only the profitability in beef herds was investigated.

- Evaluate if beef cow operations with low workload per cow have greater profitability.

- Identify more characteristics of relatively small beef herds which, according to Paper III, can have as low of a labour input per animal as larger herds. Such small labour-efficient herds may enable profitable beef production where limited access to land or capital makes building up large herds impossible.

- Investigate profitability when using grass-clover mixtures in different weather scenarios as this is the most common forage type in Sweden. This is a complement to Paper IV where only different pure leys of grasses were studied.

References

Agriculture and Horticulture Development Board (2022). *Beef & Lamb | AHDB*. https://ahdb.org.uk/beef-lamb [2024-08-20]

Agriwise (2023). *Agriwise - Smart kalkylering*. https://www.agriwise.se/web [2024-01-18]

Ahlgren, S., Wirsenius, S., Toräng, P., Carlsson, A., Seeman, A., Behaderovic, D., Kvarnbäck, O., Parvin, N. & Hessle, A. (2024). Climate and biodiversity impact of beef and lamb production – A case study in Sweden. *Agricultural Systems*, 219, 104047. https://doi.org/10.1016/j.agsy.2024.104047

Bostad, E., Swensson, C. & Pinzke, S. (2011). Labour input in specialist beef bull production in Sweden. *Agricultural Engineering International: CIGR Journal*, 13 (3). http://cigrjournal.org/index.php/Ejounral/article/view/1920 [2018-05-09]

Bratli, H., Jordal, J.-B., Norderhaug, A. & Svalheim, E. (2012). *Bioforsk rapport 2012-193 Naturfaglig grunnlag for handlingsplan naturbeitemark og hagemark*. http://www.bioforsk.no/ikbViewer/Content/123168/Bioforsk%20rapport%202012-193%20faggrunnlag%20naturbeitemark%202012.pdf [2017-12-11]

Bunning, H. & Wall, E. (2022). The effects of weather on beef carcass and growth traits. *animal*, 16 (11), 100657. https://doi.org/10.1016/j.animal.2022.100657

Casler, M.D., Kallenbach, R.L. & Brink, G.E. (2020). Cool-Season Grasses for Humid Areas. In: *Forages*. John Wiley & Sons, Ltd. 297–311. https://doi.org/10.1002/9781119436669.ch16

Cederberg, C., Henriksson, M. & Rosenqvist, H. (2018). *Ekonomi och ekosystemtjänster i gräsbaserad mjölk- och nötköttsproduktion*. Instutitionen för rymd-. geo- och miljövetenskap.

Dahlström, A., Lennartsson, T., Wissman, J. & Frycklund, I. (2008). Biodiversity and Traditional Land Use in South-Central Sweden: The Significance of Management Timing. *Environment and History*, 14 (3), 385–403

Department of Agriculture, Food & the Marine. (2021). *Bovine statistics Ireland*. https://www.gov.ie/en/organisation/department-of-agriculture-food-and-the-marine/ [2024-08-20]

Eriksson, O. (2021). The importance of traditional agricultural landscapes for preventing species extinctions. *Biodiversity and Conservation*, 30 (5), 1341–1357. https://doi.org/10.1007/s10531-021-02145-3

Eriksson, O. (2022). Coproduction of food, cultural heritage and biodiversity by livestock grazing in Swedish semi-natural grasslands. *Frontiers in Sustainable Food Systems*, 6. https://www.frontiersin.org/articles/10.3389/fsufs.2022.801327 [2022-10-28]

European Parliament (2024). *Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869*. http://data.europa.eu/eli/reg/2024/1991/oj/eng [2024-10-03]

FADN (2023). *FADN Public Database*. https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FarmEconomyFocus.html [2024-08-22]

Fallon, R.J., Leahy, H., O'Riordan, E.G. & Ruane, D. (2006). *A study of time and labour use on Irish suckler beef farms*. (5084). Teagasc. https://t-stor.teagasc.ie/handle/11019/1133 [2022-02-28]

Finneran, E., Crosson, P., O&#39, P., KIELY, Shalloo, L., Forristal, D. & Wallace, M. (2012). Stochastic simulation of the cost of home-produced feeds for ruminant livestock systems. *The Journal of Agricultural Science*, 150 (1), 123–139. https://doi.org/10.1017/S002185961100061X

Gauly, M. & Ammer, S. (2020). Review: Challenges for dairy cow production systems arising from climate changes. *Animal*, 14, s196–s203. https://doi.org/10.1017/S1751731119003239

Government Offices of Sweden (2004). *Genomförandet av EU:s jordbruksreform i Sverige/ Implementation of the EU agricultural reform in Sweden.* http://www.regeringen.se/rattsdokument/departementsserien-och-promemorior/2004/01/ds-20049/ [2017-11-16]

Government Offices of Sweden (2017). *Livsmedelsstrategin fram till 2030*. *Regeringskansliet*. https://www.regeringen.se/informationsmaterial/2017/01/mal-for-livsmedelsstrategin-fram-till-2030/ [2024-08-21]

Hair, J.F., Black, W.C., Babin, B.J. & Anderson, R.E. (2014). *Multivariate data analysis*. 7th. ed. Pearson Education Limited.

Hedlund, S., Lindqvist, S. & Andersson, S. (2023). HS Västra, Karlstad, Sverige. Personal communication.

Hessle, A. & Danielsson, R. (2024). Cattle population required for favorable conservation status of management-dependent semi-natural grasslands and forests, and associated increase in enteric methane emissions. *Journal for Nature Conservation*, 78, 126571. https://doi.org/10.1016/j.jnc.2024.126571

Hessle, A. & Kumm, K.-I. (2011). Use of beef steers for profitable management of biologically valuable semi-natural pastures in Sweden. *Journal for Nature Conservation*, 19 (3), 131–136. https://doi.org/10.1016/j.jnc.2010.10.002

Hessle, A., Therkildsen, M. & Arvidsson-Segerkvist, K. (2019). Beef Production Systems with Steers of Dairy and Dairy × Beef Breeds Based on Forage and Semi-Natural Pastures. *Animals*, 9 (12), 1064. https://doi.org/10.3390/ani9121064

Högberg, N. (2021). *Sensing the worms - automated behaviour monitoring for detection of parasitism in grazing livestock*. (Diss.). Swedish university of Agricultural Sciences. https://publications.slu.se/?file=publ/show&id=111607

Huuskonen, A., Pesonen, M., Kämäräinen, H. & Kauppinen, R. (2014). Production and carcass traits of purebred Nordic Red and Nordic Red×beef breed crossbred bulls. *The Journal of Agricultural Science*, 152 (3), 504–517. https://doi.org/10.1017/S0021859613000749

Huuskonen, A.K., Pesonen, M., Kämäräinen, H. & Kauppinen, R. (2013). A comparison of purebred Holstein-Friesian and Holstein-Friesian × beef breed bulls for beef production and carcass traits. *Agricultural and Food Science*, 22 (2), 262–271

IPBES (2018). *Nature's Dangerous Decline Unprecedented; Species Extinction Rates Accelerating*. https://ipbes.net/news/Media-Release-Global-Assessment [2020-03-03]

IPCC (2023). *IPCC: Summary for policymakers*. (Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change). doi: 10.59327/IPCC/AR6-9789291691647.00. https://www.ipcc.ch/report/ar6/syr/longer-report [2024-01-18]

Jacquemyn, H., Mechelen, C.V., Brys, R. & Honnay, O. (2011). Management effects on the vegetation and soil seed bank of calcareous grasslands: An 11-year experiment. *Biological Conservation*, 144 (1), 416–422. https://doi.org/10.1016/j.biocon.2010.09.020

Jardstedt, M., Nadeau, E., Nielsen, M., Nørgaard, P. & Hessle, A. (2020). The Effect of Feeding Roughages of Varying Digestibility Prepartum on Energy Status and Metabolic Profiles in Beef Cows around Parturition. *Animals*, 10, 496. https://doi.org/10.3390/ani10030496

Joel, A., Nilsdotter-Linde, N. & Wesström, I. (2023). *Går det att höja vallskördarna med enstaka bevattningsgivor – vad händer med kvaliteten? L1-0268 och L1-0269*. (Försöksrapport Sverigeförsöken). www.sverigeforsoken.se

Johnsson, S., Kumm, K.-I., Jeppsson, K.-H., Lidfors, L., Lindén, B., Pettersson, B., Ramvall, C.-J., Schönbeck, P. & Törnquist, M. (2004). *Production systems for beef. Housing systems, working environment, animal welfare, nutrient cycling, feeding, economy*. (5). Department of Animal Environment and Health, Swedish University of Agricultural Sciences.

Keane, M.G. (2010). A comparison of finishing strategies to fixed slaughter weights for Holstein Friesian and Belgian Blue × Holstein Friesian steers. *Irish Journal of Agricultural and Food Research*, 49 (1), 41–54

KLS (2024). *KLS notering*. https://www.kls.se/sv-se/foer-lantbrukare/notering/ [2024-09-13]

Kumm, K.-I. (2003). Sustainable management of Swedish seminatural pastures with high species diversity. *Journal for Nature Conservation*, 11 (2), 117–125. https://doi.org/10.1078/1617-1381-00039

Kumm, K.-I. (2021). *Betesbaserad köttproduktion och kolinlagrande virkesproduktion på nedlagd och nedläggningshotad jordbruksmark/Grazing-based meat production and carbon-storing timber production on abandoned and in risk of being abandoned agricultural land*. (53). Department of Animal Environment and Health, Swedish University of Agricultural Sciences. https://pub.epsilon.slu.se/22425/1/kumm_k_i_210218.pdf

Kumm, K.-I. & Hessle, A. (2020). Economic comparison between pasture-based beef production and afforestation of abandoned land in Swedish forest districts. *Land*, 9 (2), 42. https://doi.org/10.3390/land9020042

Kumm, K.-I. & Hessle, A. (2023). The Decline and Possible Return of Silvipastoral Agroforestry in Sweden. *Land*, 12 (5), 940. https://doi.org/10.3390/land12050940

Larsson, C., Bode Olén, N. & Brady, M. (2020). *Naturbetesmarkens framtid - en fråga om lönsamhet*. (2020:1). AgriFood Economics Centre. https://agrifood.se/Files/AgriFood_Rapport20201.pdf [2021-03-17]

Li, W. & Cabrera, V.E. (2019). Dairy × Beef: Fad or Sustainable Future? in Proceeding Dairy Cattle Reproduction Council Conference.

Lindman Larsson, S. (2019). HS konsult AB, Uppsala, Sverige. Personal communication.
Livsmedelsverket (2024). *Nordic nutritional recommendations*. https://www.livsmedelsverket.se/om-oss/press/nyheter/pressmeddelanden/idag-lanseras-nya-nordiska-naringsrekommendationer [2024-10-03]
Lothigius, W. (1945). *Sveriges skogsvårdsstyrelser 1905-1944.* Föreningen Sveriges skogsvårdsstyrelser.
LRF (2023). *Statistik från köttbranschen*. https://www.lrf.se/om-lrf/lrfs-branschavdelningar/lrf-kott/statistik-fran-kottbranschen/ [2024-08-22]
Lundmark, T., Bergh, J., Hofer, P., Lundström, A., Nordin, A., Poudel, B.C., Sathre, R., Taverna, R. & Werner, F. (2014). Potential Roles of Swedish Forestry in the Context of Climate Change Mitigation. *Forests*, 5 (4), 557–578. https://doi.org/10.3390/f5040557
Länsstyrelsen Västra Götaland (2023). Bidragskalkyler 2023 - Konventionell produktion. https://www.lansstyrelsen.se/vastra-gotaland/om-oss/vara-tjanster/publikationer/2023/bidragskalkyler-2023---konventionell-produktion.html [2024-01-18]
Mäkinen, H., Kaseva, J., Virkajärvi, P. & Kahiluoto, H. (2018). Gaps in the capacity of modern forage crops to adapt to the changing climate in northern Europe. *Mitigation and Adaptation Strategies for Global Change*, 23. https://doi.org/10.1007/s11027-016-9729-5
Manevska-Tasevska, G., Nylén, H. & Pupp, J. (2024). Konkurrenskraft inom svensk jordbruksproduktion. *AgriFood economics centre*. (2). www.agrifood.se
National Resources Institute Finland (2019). *Statistics Finland*. http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/?rxid=dc4b7bdc-243a-449b-8ce5-83e2ea40a7e8 [2020-04-27]
Naturbeteskött (2024). *Naturbeteskött i Sverige*. https://www.naturbete.se/ [2024-10-01]
Nelson, B.-O. (2002). *Kalkylmodell för nötköttsproduktion*. Skogs- och lantarbetsgivareförbundets analysgrupp.
OECD (2018). *Innovation, agricultural productivity and sustainability in Sweden*. *oecd-ilibrary.org*. https://read.oecd-ilibrary.org/agriculture-and-food/innovation-agricultural-productivity-and-sustainability-in-sweden_9789264085268-en [2022-05-12]
Olson, K. & Westra, J. (2022). *The economics of farm management | A global perspective*. 2nd. ed Routledge. https://doi.org/10.4324/9781003280712

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. & Foley, J.A. (2009). A safe operating space for humanity. *Nature*, 461 (7263), 472–475. https://doi.org/10.1038/461472a

Roth, N. (2023). *Grasslands in a changing climate - Summer drought and winter warming effects on grassland vegetation*. (33). Department of Physical Geography, Stockholm University. https://su.diva-portal.org/smash/get/diva2:1805650/FULLTEXT01.pdf

Scan Sverige AB (2024). Scan Sverige notering. https://www.scanagri.se/notering/ [2024-10-01]

Searchinger, T.D., Wirsenius, S., Beringer, T. & Dumas, P. (2018). Assessing the efficiency of changes in land use for mitigating climate change. *Nature*, 564 (7735), 249–253. https://doi.org/10.1038/s41586-018-0757-z

Short, S.D. (2001). *Characteristics and Production Costs of U.S. Cow-Calf Operations. Statistical Bulletin No. 974-3. U.S. Department of Agriculture. Economic Research Service. November. www.ers.usda.gov/publications/ sb974-3/.* https://www.ers.usda.gov/webdocs/publications/sb9743/16084_sb974-3_1_.pdf?v=41063 [2017-04-24]

Skövde slakteri (2024). *Skövde slakteri notering*. https://www.skovdeslakteri.com/noteringssidan.php [2024-10-01]

SMHI (2024). *Klimat – statistik, forskning och vägledning | SMHI*. https://www.smhi.se/klimat [2024-02-29]

Sousa, D.O., Murphy, M., Hatfield, R. & Nadeau, E. (2021). Effects of harvest date and grass species on silage cell wall components and lactation performance of dairy cows. *Journal of Dairy Science*, 104 (5), 5391–5404. https://doi.org/10.3168/jds.2020-19362

Spörndly, E. & Glimskär, A. (2018). *Betesdjur och betestryck i naturbetesmarker / Grazing animals and stocking rates in Swedish semi-natural pastures*. (297). Department of Animal Nutrition and Management Uppsala 2018 Swedish University of Agricultural Sciences.

Steen, E. (1958). *Betesinflytelser i svensk vegetation*. (89). Statens Jordbruksförsök.

Swedish Board of Agriculture (2005). *Svenskt jordbruk i siffror 1800 - 2004*. http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/S tatistik,%20fakta/Annan%20statistik/Statistikrapport/20056/20056_inEnglish.htm [2020-03-03]

Swedish Board of Agriculture (2007). *Jordbrukets miljöeffekter 2020 - en framtidsstudie/Agricultures' environmental impacts 2020 - a future study. Jönköping, Sweden*. http://webbutiken.jordbruksverket.se/sv/artiklar/jordbrukets-miljoeffekter-2020.html [2017-05-22]

Swedish Board of Agriculture (2008). *Jordbruket och landsbygden i en förändrad global miljö*. (35). https://webbutiken.jordbruksverket.se/sv/artiklar/jordbruket-och-landsbygden-i-en-forandrad-global-miljo.html [2024-09-23]

Swedish Board of Agriculture (2011). *Den svenska kött- och mjölkproduktionens inverkan på biologisk mångfald och klimat – skillnader mellan betesbaserade och kraftfoderbaserade system*. (21)

Swedish Board of Agriculture (2019a). *Plan för odlingslandskapets biologiska mångfald - ett samverkansprojekt inom miljömålsrådet*. (2019:1). https://www2.jordbruksverket.se/download/18.36d57baa168c704154d46f04/1549611543321/ra19_1.pdf

Swedish Board of Agriculture (2019b). *SJVFS 2019:18: Statens jordbruksverks föreskrifter och allmänna råd om nötkreaturshållning inom lantbruket/The regulations and general advice of the Swedish Board of Agriculture about cattle farming in agriculture. Jönköping, Sweden*. https://lagen.nu/sjvfs/2019:18 [2023-04-06]

Swedish Board of Agriculture (2022). *The farm economics surveys (JEU) 2022*. https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2024-02-27-jordbruksekonomiska-undersokningen-2022 [2024-08-22]

Swedish Board of Agriculture (2023a). *Agricultural statistics*. https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksstatistisk-sammanstallning [2024-01-18]

Swedish Board of Agriculture (2023b). *Jordbruksekonomiska undersökningen 2014 - 2021, nyckeltal och standardiserade intäkter*. https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2023-09-27-

jordbruksekonomiska-undersokningen-2014---2021-nyckeltal-och-standardiserade-intakter [2024-09-29]

Swedish Board of Agriculture (2023c). *Stöd till lantbrukare och verksamma på landsbygden*. https://jordbruksverket.se/stod [2024-01-18]

Swedish Board of Agriculture (2023d). *Uppföljning och utvärdering av livsmedelsstrategin – Årsrapport 2023*. (6). https://www2.jordbruksverket.se/download/18.20acff251875291a9bef173/1680768433318/ra23_6v3.pdf

Swedish Environmental Protection Agency (2023). *Sveriges miljömål*. https://www.sverigesmiljomal.se/ [2024-09-12]

Swedish Environmental Protection Agency (2024). *Översyn av referensarealer för livsmiljötyper i art- och habitatdirektivet. Redovisning av regeringsuppdrag*. (NV-11038-22)

Swedish Parliament (2023). *Strategisk plan för genomförande av den gemensamma jordbrukspolitiken i Sverige 2023-2027*. (3.1). https://www.regeringen.se/contentassets/bd779fd2cf644e7baec4d9bed12b9b61/strategisk_plan_inom_gjp/ [2024-09-17]

Swedish Parliament (2024a). *Animalieproduktion med hög konkurrenskraft och gott djurskydd*. (56). https://www.riksdagen.se/sv/dokument-och-lagar/dokument/statens-offentliga-utredningar/animalieproduktion-med-hog-konkurrenskraft-och_hcb356/html/#page_17 [2024-09-13]

Swedish Parliament (2024b). *Omfattande satsningar för att stärka det civila försvaret*. Regeringskansliet. https://www.regeringen.se/pressmeddelanden/2024/09/omfattande-satsningar-for-att-starka-det-civila-forsvaret/ [2024-09-16]

Swedish Species Information Centre (2020). *Rödlistade arter i Sverige 2020 (Redlisted Species in Sweden 2020)*. *www.artdatabanken.se*. https://www.artdatabanken.se/ [2020-04-27]

Toräng, P. & Jacobson, A. (2019). *An assessment of favourable reference areas for grassland habitat types in the 2019 reporting under Article 17 of the Habitats Directive*. SLU Swedish Species Information Centre, Uppsala, Sweden.

Växa (2024). *Cattle statistics*. https://www.vxa.se/fakta/styrning-och-rutiner/mer-om-mjolk/statistik/ [2024-08-20]

Vera, F.W.M. (2000). *Grazing Ecology and Forest History*. CABI Publishing.

Veysset, P., Lherm, M., Roulenc, M., Troquier, C. & Bébin, D. (2015). Productivity and technical efficiency of suckler beef production systems: trends for the period 1990 to 2012. *Animal*, 9 (12), 2050–2059. https://doi.org/10.1017/S1751731115002013

WallisDeVries, M.F., Poschlod, P. & Willems, J.H. (2002). Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna. *Biological Conservation*, 104 (3), 265–273. https://doi.org/10.1016/S0006-3207(01)00191-4

Wetlesen, M.S., Åby, B.A., Vangen, O. & Aass, L. (2020). Estimation of breed and heterosis effects for cow productivity, carcass traits and income in beef × beef and dairy × beef crosses in commercial suckler cow production. *Acta Agriculturae Scandinavica, Section A — Animal Science*, 69 (3), 1–15. https://doi.org/10.1080/09064702.2020.1746825

Wreford, A. & Topp, C.F.E. (2020). Impacts of climate change on livestock and possible adaptations: A case study of the United Kingdom. *Agricultural Systems*, 178, 102737. https://doi.org/10.1016/j.agsy.2019.102737

Popular science summary

The profitability of Swedish beef production is under severe pressure and 40% of all beef consumed in Sweden is imported. The low profitability is due to several different factors such as small pastures, predominantly small herds, unfavourable climatic conditions, and expensive regulations. Both the number of beef operations and cattle stock in Sweden is decreasing, whilst there is also much arable land and semi-natural pastureland, that could be used for increased production, being abandoned. A reduction in area of semi-natural pastures negatively affects the flora and fauna associated with these habitats. An increased gain in Swedish beef production is therefore important from many reasons, such as an increased degree of self-sufficiency, and achieving the environmental goals of a rich flora and fauna and a rich and varied agricultural landscape. In addition, agricultural enterprises provide a living countryside.

The overall aim of this thesis was to positively contribute to beef farmers profitability, by investigating different pathways to get there. The doctoral project consisted of four different studies which investigated whether there are economies of scale regarding both pasture enclosures and animal herds, and whether there are differences in profitability between different animal categories and rearing systems.

The purpose of the first study was to see if there are economies of scale in creating larger pasture enclosures by including, not only existing semi-natural pasture, but also adjacent marginal fields and forests. The purpose of the second study was to examine both the benefits of larger herds with male animals, and the possible difference in profitability between indoor bulls and grazing steers kept on semi-natural pasture during summers. The purpose of the third study was to look at economies of scale in beef cow herds regarding labour input. The purpose of the fourth study was to evaluate the economic

differences between different grass species fed to dairy cows, slaughter beef bulls, and beef cows. Profitability of these grasses were calculated under three different weather scenarios: normal weather, drought, or very wet weather with delayed harvest.

The economical calculations in this thesis were made with partial budgeting technique and contribution margin calculations. Additionally, farmers were interviewed, data was collected via an application in their mobile phones, and multivariate statistical methods was used.

The results showed that there were economic benefits to larger pasture enclosures and herd sizes, as well as differences between animal categories and rearing systems. In the first study, we found that the change from small, scattered pasture enclosures to larger coherent pastures was profitable. Larger pasture enclosures reduced the labour time for supervision and the cost of fencing materials. The most important aspect in the change from small to large pasture enclosure was the additional or increasing support and payments when forest was transformed to pasture.

The second study showed that natural conditions, for example the proportion between arable and pasture area, as well as the farms location in Sweden, determines whether bulls or steers are most profitable. There was also a difference between breeds, as dairy x beef breed bull was more often profitable, compared to a purebred dairy bull, while breed did not affect the steer's profitability. To make the steer more profitable than the bull, greater income linked to grazing was needed, such as a larger area of semi-natural pasture that provided agri-environmental payment for high natural values or an additional payment for certified beef. With enclosures less than two hectares, all steers, regardless of herd size, were unprofitable. The use of buildings with no other profitable alternative use made all herds with bull and steer profitable, even the smallest ones. In most cases, the steer became more profitable than the bull.

The results of the third study showed that larger herds with beef cows generally have less workload per cow and year than smaller herds, but also some of the relatively small herds had as low of a labour input per cow as the largest ones. The most workload per day was during the calving period, while the indoor period prior to calving required the least workload per day. Supervision of animals during the grazing period was the most time-consuming task across the year. A reduction in labour time during the indoor period was seen with increased mechanisation of bedding, and a short calving period.

In the fourth study wet-and-drought resistant reed canary grass was the most profitable winter feed for beef cows, of all studied grass species. Dairy cows were almost always more profitable if fed traditional timothy compared to more wet-and-drought resistant tall fescue. Beef bulls typically had the best profitability with traditional meadow fescue, but if drought becomes common, wet-and-drought resistant tall fescue is recommended.

This doctoral thesis has shown that it is possible to achieve profitability in Swedish beef production, which in turn contributes to an increased degree of self-sufficiency, open landscapes with rich biodiverse semi-natural pastures, and a living countryside.

Populärvetenskaplig sammanfattning

Lönsamheten inom svensk nötköttsproduktion är hårt pressad och 40% av det nötkött vi konsumerar är importerat. Den låga lönsamheten beror på ett flertal olika faktorer såsom små betesmarker, övervägande små besättningar, ogynnsamma klimatförhållanden och fördyrande regelverk. Såväl antalet nötköttsföretag som nötkreatur minskar i Sverige, samtidigt som det finns mycket nedlagd åker- och naturbetesmark som skulle kunna användas för ökad produktion. En minskning av arealen naturbetesmark påverkar den flora och fauna som är kopplad till dessa habitat. En ökad lönsamhet för den svenska nötköttsproduktionen är därför viktig ur många synvinklar, såsom ökad självförsörjningsgrad och uppfyllande av miljömålen ett rikt odlingslandskap och ett rikt växt- och djurliv. Dessutom ger lantbruksföretag en levande landsbygd.

Det övergripande syftet med denna avhandling var att hitta vägar till bättre lönsamhet för nötköttsproducenter. Doktorandprojektet bestod av fyra olika delstudier där det undersöktes om det finns ekonomiska storleksfördelar avseende både beteshagar och djurbesättningar samt om det finns skillnader i lönsamhet mellan olika djurkategorier och uppfödningsformer.

Den första studiens syfte var att se om det finns storleksfördelar med att skapa större betesfållor genom att inkludera inte bara befintlig naturbetesmark utan också närliggande svårbrukad åker och skog. Den andra studiens syfte var att undersöka dels fördelar av större besättningar med handjur, dels eventuell skillnad i lönsamhet mellan tjurar uppfödda på stall och stutar som hålls på naturbetesmark under sommaren. Syftet med den tredje studien var att titta på storleksfördelar i dikobesättningar med avseende på arbetsåtgång. Den fjärde studiens syfte var att utvärdera den ekonomiska skillnaden när olika gräsarter odlas och utfodras till mjölkkor, köttrastjurar och dikor. Lönsamheten beräknades under tre olika väderscenarier: normalt väder, torka eller mycket blött väder med försenad skörd.

Avhandlingens ekonomiska beräkningar gjordes med partiell budgetering och bidragskalkylering. Dessutom intervjuades lantbrukare, data samlades in via en applikation i deras mobiltelefoner och multivariata statistiska bearbetningar gjordes.

Resultaten visade att det fanns ekonomiska fördelar med större beteshagar och besättningar, samt skillnader mellan djurkategorier och uppfödningsformer. I den första studien fann vi att förändringen från små spridda betesmarker till större sammanhängande betesmarker blev lönsam. Större betesfållor minskade arbetstiden för tillsyn och kostnaderna för stängselmaterial. Det som hade störst betydelse vid förändringen från liten till stor betesfålla var de stöd och ersättningar som tillkom eller ökade när skogsmark restaurerades till betesmark.

Den andra studien visade att naturliga förutsättningar avseende åkermarks- och betesmarksareal samt var i Sverige gården ligger avgör om tjurar eller stutar är mest lönsamma. Det var även skillnad mellan raser då tjuren oftare var lönsam när den var en korsning mellan mjölkras och köttras, än av ren mjölkras, medan ras inte spelade någon roll för stutens lönsamhet. För att stuten skulle bli mer lönsam än tjuren behövdes större intäkter kopplade till betesdriften såsom en stor andel av naturbetesmarken gav ersättning för så kallade särskilda naturvärden eller en tilläggsbetalning för certifierat naturbeteskött. Med beteshagar på mindre än två hektar var alla stutar, oavsett besättningsstorlek, olönsamma. Användandet av byggnader utan annan lönsam användning gjorde samtliga tjur- och stutbesättningar lönsamma, även de minsta besättningarna. I de flesta fall blev då stuten mer lönsam än tjuren.

Den tredje studiens resultat visade att större besättningar med dikor generellt har mindre arbetstid per ko och år än mindre besättningar, men det fanns relativt små besättningar som hade lika låg arbetsåtgång per ko som de största. Mest arbetstid per dag lades under kalvningsperioden medan den dräktiga kon på stall innan kalvning krävde minst arbete per dag. Tillsyn av djur under betesperioden var det arbetsmoment som tog mest tid under året. En minskning av arbetstiden under vintern sågs med ökad mekanisering vid ströarbete liksom en kortad kalvningsperiod.

I den fjärde studien var, utav de undersökta fodren, rörflen det lönsammaste vinterfodret till dikor. Mjölkkor var nästan alltid mer lönsamma om de utfodrades med traditionell timotej jämfört med mer vädertålig rörsvingel. Köttrastjurar hade oftast bäst lönsamhet med traditionell ängssvingel men om det var torka vartannat år eller oftare var rörsvingel mest lönsam.

Denna doktorandsavhandling har visat att det går att uppnå lönsamhet i svensk nötköttsproduktion vilket i sin tur bidrar till ökad självförsörjningsgrad, öppna landskap med mångfaldsrika naturbetesmarker och en levande landsbygd.

Acknowledgements

Firstly, I would like to thank the funders of the projects in this thesis, which were Region Västra Götaland, the Rural Economy and Agricultural Society Sjuhärad, Swedish University of Agricultural Sciences, Formas, Nötkreatursstiftelsen Skaraborg, and Bröderna Jonssons forskningsfond. Further, the experiments behind Paper II and IV would not be what they are without Agroväst, Lantmännen Research Foundation, Interreg ÖKS, European Union's Horizon 2020, and Swedish farmers' foundation for agricultural research.

Without funding it would not been possible to carry out this project. However, it is the people around that I would like to acknowledge most.

I would like to thank my supervisors for their continuous input during my doctoral education. Thank you for believing in me. You have all generously contributed with your specialist knowledge within your area. Thank you for always have the door open, **Anna Hessle**, my main supervisor, who never find problems just solutions and who can see a new figure when I thought all was developed. We are a great complement to each other with different views on the question but always with the best interests of the farmers in focus. Thank you, **Karl-Ivar Kumm**, my assistant supervisor, for your never-ending helpfulness, for your critical hawk eye that can find an error in a formula, and your kindness in reading and discussing all this. Thank you to my assistant supervisor **Hans Andersson**, for your broad knowledge from interest rate to the league in English football, the latter of which was useful during my studies at Gothenburg University. The last paper would not have been what it is without you **Dannylo Sousa**, my extra assistant supervisor during the last year of this PhD-project, thank you.

I received the first call about this employment whilst standing in a hotel in Herning, Denmark, looking out over an abattoir, so thank you to

Margareta Helander who believed in me and introduced this work. Sorry **Jonas Bodenhem** for not giving a clear answer to your question, but now this book is finished. Thank you for letting me have my time. I am here partly because of you **Ola Hallin**, I guess, thank you for that. Also, thank you for all discussions that are outside of my field and for explaining how to calculate animal premium (yearly). Let's see what project we will be into next.

Thank you, **Elisabet Nadeau**, rest in peace. I remember a warm and curious person with much knowledge, who believed that it is vitally important to do something useful for the farmers. That is a real good point of departure.

Linda Söderberg Gradén, you are a lady with one of the warmest and generous hearts I have ever met. Thank you for all those talks about life and cows, football and horses, and sometimes a potato or big survival-box(es), that can easily make my day 😂.

I do not know what Rådde would be without you **Helena Falkman**, probably a place without structure, a colour poorness and mess in our posters. I would probably not get Svenskjävlar on my desk either, which would be a pity. It would be even more of a pity to not have your creativeness for this thesis, the front page is really nice 😃.

Thank you to **Caroline Dahrén**, for your curiosity and your skill to solve a problem with a smile (and you always smoothly solve them). Thank you also, along with **Dan Claesson, Stefan Wallin, Nathalie Kärrman** and **Göran Schelin**, for taking care of my bulls and other things, and always giving a helping hand. Stefan, sorry for the blood but not for a thesis without blood, sweat and tears. Göran, I appreciate our talks during different fika and dinners.

Ann Hjalmarsson and **Rose-Marie Andersson**, for all these administration things and fika, thank you! I just wonder if at some point I will be able to solve how to stamp an envelope. Thank you **Åsa Andersson** for your patience, I will do my best with your Excel files.

Thank you, **Hanna Nyberg**, for how many times you rescued me! From all kinds of issues such as how the farm economic surveys are built up to what is meant in the salmonella assurance. Looking forward to your "glögg-fika" in the new house, I am sure it will be very soon 😉

Katarina Berlin-Thorell, I will miss you during your stay in the other building but during the meantime I will continue to talk about timothy and meadow fescues' superiority compared to tall fescue with **Daniel Muregård**. Thank you to both of you for interesting talks, particularly those during our field walks with farmers (**Matilda Wilson**, I will tell you the truth of tall fescue).

Thank you, **Jenny Löfstrand,** and **Kajsa Ståhlberg**, for being great colleagues and letting me work on my own for a while. I will soon join you again.

Linnea Ryrvik, Cecilia Hermansson and **Margareta Bendroth** thank you for being inspiring colleagues outside my own field.

This thesis would not have this brilliant name without you **Frida Dahlström**, now we all know how to make money! A further thanks to you and **Karin Wallin**, for your never-ending smile and book tips.

Mikaela Jardstedt, thank you for all discussions about simple things and more complicated things, for always have a door (and a lovely garden) open for me. We are a great team!

Thank you, **Katarina Arvidsson Segerkvist**, for being a great colleague with the best honeybees in the corridor. Thanks, **Elin Stenberg** for good patience to explain different meat associated things and, most importantly, the best suggestion for hiking boots. I guess the kindest person in Skara is you **Qasim Mashood**, and by now I know that you can give an unprepared speech 😉. Thank you, **Jenny Lans**, for being a smiling and cheerful colleague. **Anders Karlsson**, thank you for statistical advice, your capacity to untangle differences between meat, and other strange things that the media often tells us (often not the whole story, but that you easily complement). Thank you, **Annelie Carlsson**, it is good to have someone with a great ability to plan close by. **Carl Helander**, thank you for spreading joy in the corridor. **Dan-Axel Danielsson**, thank you for your patience, now I will start to clean up in other common projects. Thank you to **Jonas Dahl** and **David Johansson**, for being great colleagues with more or less ironic humour. Thank you, **Johanna Friman** for being a nice co-worker. I will soon start to calculate on your project with dry cows.

Gunilla Jacobsson, thank you for all your help! You put places on the map, and you are deserving of a big box of liquorice and grynkorv.

Linda Rydén Engström, Annika Holm and **Susanne Lindvall**, thank you for always being so kind and helpful with all kinds of questions.

A big thanks to you **Andrea von Essen**, taking care of issues around our other projects. It is a big advantage to share this project's questions with you.

Thank you, **Karin Andersson** for your inspiring talks throughout the last year. When you read this, you will have almost reached the goal.

Emelie Wickström and **Karin Ahlström Eliasson**, thanks for being cheerful and supportive co-workers of the past.

Thank you to **all other staff at Rådde** and **SLU Skara**, for meeting me with a smile in the corridor, making a lunch or fika a pleasure, and being great colleagues.

Thank you for your careful and comprehensive editing of this thesis and paper manuscript, **Lauren Gormley, Anna Jamieson** and **Mary McAfee**.

I am so grateful to **all farmers** that have given me their time, both in the first study of large, coherent pastures and the third study of labour time in beef cow operations, thank you. Also, thank you to all farmers and employees that I meet during my advisory job, you are all extremely valuable for the ongoing discussions, and you all provide energy and new questions. Especially thank you to **Åke, Göran, Jörgen, Samuel, Hanna, Robin, Tobias, Erika, Jan, Morgan, Eva-Lena, PM, Alexander, Christer, Martin, Svante, Johan, Rikard, Björn, Jimmy, Martin, Mattias, Anders, Magnus, Björn,** and **Berith**.

Tack **Linda**, för att du är en fantastisk vän och underbar konsertkamrat (samt privatchaufför 😊). Alla vattenfilmer, både med kor och hästar, lättar upp den gråaste dag, ja en fölunges första steg i hagen är fel det heller! **Håkan, Martin, Mia, Jörgen** och **Maria**, tack för att ni försiktigt frågat men framför allt pratat på om allt annat vanligt förekommande. Förstår dock inte varför vi alltid ska ses så nära solnedgång.

Nu måste vi ta en ordentlig fika **Frida**! Diskutera vad som ska sås nästa år och om vi ska samla på något annat än pelargonier, tack för att du lyckats hitta en stund då och då för en stor kopp te. Säg något som inte en kopp te kan lösa.

Thérèse och **Hilma** med familj, tack för att ni alltid har en liten stund över till mig. Jag kommer snart igen och fikar både sommarkaka och sandkaka. Thérèse, en dag sitter vi där på ålderdomshemmet och spelar kort.

Stort tack till mina blomster- och hundpratarvänner med familj **Lotta, Lotta** och **Ann-Kristina** det är alltid ett nöje att prata med er. Resorna österut känns mer meningsfulla om vi får en liten stund tillsammans.

Karin, tack för att du, och familjen, alltid är där med en kaka och en sängplats om det skulle behövas vid mina vistelser i Uppsala. Jag hoppas att vi kommer ses oftare framöver.

Tack **Eva**, för att du och din familj (både äldre och yngre generationer) finns där. Att få insyn inom andra områden än lantbruk samt andra vardagliga saker är en stor ynnest och jag är väldigt tacksam för att jag får ta del av detta. Vår Winnerbäckkväll kommer jag sent att glömma!

Tack **Robert** för alla gånger som du tagit hand om djuren, hämtat barnen och sett till så vi fått våfflor. Det är ovärderligt. Det är bara dig jag och växterna litar på när jag inte är hemomkring.

Allas vår farmor **Maj**, tack för all god mat och hjälp längs vägen, otaliga matlådor har jag njutit av under åren. Tack **Britt**, för god mat och roliga historier, speciellt tror jag att hundarna tackar för leverpastej och köttbullar.

Mamma, tack för allt stöd. Att du alltid låtit mig vara den jag är. Nu när den här boken är klar vi kan åka och fika. **Pappa**, jag vet att du är med – vila i frid. Jag ska ta hand om väggen så utsikten från kojan blir god åt båda håll!

Mitt Drömlag ❤️, ni är det bästa team jag någonsin kan ha! **Carl**, nu har jag uppfunnit pengar men kanske inte på det sätt som du frågade om när du var 7 år. **Gustaf**, nu får du lära mig svarva för jag har inget att skriva på i snickeriet på en stund och det blir långtråkigt att bara sitta och titta. **CO**, min livskamrat, tack för allt. Låt oss nu leta efter ett annat vindskydd! Eller vill ni att jag ska boka ett hotellrum 😉?

I

land

Article

Merging Small Scattered Pastures into Large Pasture-Forest Mosaics Can Improve Profitability in Swedish Suckler-Based Beef Production

Kristina Holmström [1,2,*], Anna Hessle [1], Hans Andersson [3] and Karl-Ivar Kumm [1]

1 Department of Animal Environment and Health, Swedish University of Agricultural Sciences, PO Box 234, 53223 Skara, Sweden; anna.hessle@slu.se (A.H.); karl-ivar.kumm@slu.se (K.-I.K.)
2 Rural Economy and Agricultural Society Sjuhärad, PO Box 5007, 51405 Länghem, Sweden
3 Department of Economics, Swedish University of Agricultural Sciences, PO Box 7013, 75007 Uppsala, Sweden; hans.andersson@slu.se
* Correspondence: kristina.holmstrom@slu.se; Tel.: +46-325-618-646

Received: 26 March 2018; Accepted: 28 April 2018; Published: 3 May 2018

Abstract: A scattered structure of small pastures has negative effects on profitability in beef enterprises because small enclosures result in high labor costs per livestock unit. Moreover, larger enterprises distribute the costs across more livestock units and hence achieve lower operating costs. Creating larger coherent pastures makes it easier to increase herd size and yields positive effects due to economies of scale. This study on five Swedish organic cow-calf enterprises examined how profitability is affected by creating larger pastures from small scattered pastures and adjacent forest land. Additional income, additional costs, reduced income and reduced costs were taken into account using a partial budgeting technique. A change to larger coherent pastures was found to be profitable for all enterprises examined. Agri-environmental payments and supports were the most important benefit from creating larger pastures, followed by income increases and cost reductions resulting from economies of scale and improved consolidation. Income reductions due to premature final felling (clearcutting of forest land) and the opportunity cost of forest land did not have a major influence. To conclude, creating large coherent pasture-forest mosaics by merging small scattered enclosures is profitable for Swedish organic cow-calf enterprises.

Keywords: pasture; semi-natural grassland; pasture-forest mosaic; cow-calf; beef; cattle; cow; economic; profitability; consolidation

1. Introduction

North European pasture is frequently scattered in structure, with small separate pasture areas [1,2], as is the case in Sweden [3]. Small scattered areas for pasture and forage harvesting can be expected to have negative effects on the profitability of farm enterprises, as managing these scattered plots separately results in expensive grazing with high fencing and labor costs, especially if the pastures are located far from the main farmyard. Fragmentation increases travel time between plots and results in higher cost for transport, animal supervision and water supply. Swedish animal welfare regulations state that all livestock must be checked daily [4], which results in high costs especially if pastures are small and scattered. Fencing in forest-dominated districts is assessed to be particularly expensive, due to smaller pasture areas and more irregularly shaped pasture compared to areas on open plains. There may also be an increase in the cost of fencing if many electric power units have to be used [5]. An additional effect of small pastures is the difficulty in expanding enterprise size, which impairs the competitiveness of Swedish beef enterprises compared with in other countries [6,7].

In North European beef production, small cow-calf enterprises are over-represented, with the majority of enterprises having less than 30 suckler cows [8,9]. When cow-calf enterprises are expanding, it is common practice to rent a number of small scattered pasture areas far from the farm itself, which increases the costs of transport, animal supervision and fencing. Achieving profitability in such small herds requires use of existing resources with low or no opportunity costs. Existing buildings, fences and machinery capital will ultimately reach the end of their economic lifespan and, moreover, small herds are often owned by old farmers. Hence, re-investment and full coverage of labor costs in small suckler beef enterprises are difficult to achieve [7,10–12].

Economies of scale by distributing the costs across more livestock units have been reported in cow-calf enterprises in the northern hemisphere, e.g., in the United States [13–15] and Sweden [16]. Creating larger coherent pastures facilitates an expansion of the herd size and provides an accompanying positive effect due to economies of scale in feeding, buildings and labor [16]. When herd size increases, the costs of breeding [14,15] and labor per livestock unit also decrease [16]. Hence, the larger farm, the higher the net income per animal [14–16].

Low profitability in suckler-based beef production, caused e.g., by small herd size, is a threat not only to farming but also to the social values of semi-natural pastures. Semi-natural pastures are a feed resource, but they also preserve biodiversity and represent a cultural heritage with substantial and amenity values [17–19]. Suckler cows and other grazing livestock provide an important function in preserving these values, as grazing management is a prerequisite for the values to prevail. The decreasing number of grazing livestock in Sweden over the past century and subsequent abandonment and fragmentation of grasslands have resulted in a trend towards disappearance of threatened plant and animal species [20,21]. To promote preservation of semi-natural pastures, the government provides agri-environmental payments for regular grazing of these areas and also for individual measures, such as restoration of overgrown or afforested former pasture land. These payments are important for achieving profitability in Swedish beef production [16,22,23]. Another factor important for profitability is organic farming, as it results in higher product prices and is also eligible for agri-environmental payments, both in Sweden [24,25] and in the rest of Europe [24,26–29].

Due to natural circumstances, most Swedish semi-natural pastures are small and scattered, especially in forest districts [3]. One way to increase profitability could therefore be to create large pasture-forest mosaics that combine small scattered semi-natural pastures and adjacent marginal arable and forest land [30]. However, when forest is included in pasture areas grazing livestock may damage trees, affecting future income from the forest [31–33]. Therefore, it is vital to consider the economics of beef production and the economics of forest production in the same analysis.

Knowledge of production costs and efforts to minimize these are also important, irrespective of herd size. Under Swedish conditions, it might be preferable not to replant forest after a regular clearcutting, but instead transform the forest land into pasture. At normal interest rates used in Swedish agriculture (3–4%) [34], replanting after final clearcutting gives a negative or poor return to land at timber production below eight cubic meter over bark per hectare (ha) and year [35]. Timber production capacity is below that threshold for nearly 60% of the forest land in southern and central Sweden and for all forest land in northern Sweden [35,36]. Given higher requirements on return to assets from forest production, a more profitable option may be to transform forest into pasture [10]. If forest land were not replanted after final harvesting, it would be possible to develop larger coherent pasture-forest mosaics that decrease the cost of fencing and labor compared with small scattered pastures. It is not well documented in the literature whether the resulting loss of forest income is compensated for by the benefits of more rational pasture size.

The aim of this study was, therefore, to compare profitability on a number of Swedish farms before and after changing from small to large pastures by merging small scattered enclosures of semi-natural pastures with adjacent, marginal arable land and forest into large coherent enclosures.

2. Material and Methods

Farmers with cow-calf enterprises who had recently created large coherent pastures from small, scattered pastures, and adjacent forest and/or transformed forest to pasture, were recruited for the study through advertisements in two national farming journals in Sweden, *Nötkött* (*Beef*) and *Ekologiskt Lantbruk* (*Organic Agriculture*). Twenty enterprises responded and were visited.

Out of the 20 farms, those who had suckler-based organic beef production with more than 20 cows, experience of major changes in pasture management and able to provide substantiated data were selected for the study. This resulted in a sample of five farms with varying herd size from different geographical locations across Sweden. This method is similar to the approach taken by Frankwick and co-workers [37] in their study of strategic decision making in high technology firms. The enterprises selected had 30–280 suckler cows and most kept their calves until slaughter. After the initial interview, the five farms were visited once more for a complementary interview regarding changes in their pasture management (Table 1), and the consequences of the changes (Table 2), based on the farmers' estimates and accounting records.

Table 1. Conditions before and after merging small scattered pastures into large coherent pasture-forest mosaics in five Swedish cow-calf enterprises.

Farm No., Geographical Location	Herd Size (No. of Cows) and Area of Arable and Pasture Land (Hectare, ha) before/after Change	Before Change: Small and Scattered Pastures	After Change: Large Coherent Pasture
Farm 1, forest district in Götaland	160 cows/160 cows; 221 ha/245 ha	Several rented small pastures far away.	Converted 24 ha of wind thrown forest causing premature final felling near the barn to pasture, replacing rented pastures far away.
Farm 2, plain districts in Götaland	30 cows/30 cows; 46 ha/63 ha	Own farmland divided into many small paddocks by internal fences. Cows kept in a labor-intensive stanchion barn in winter.	Created a large coherent pasture by merging semi-natural pasture, arable land and some forest through removing internal fences. Keeps the cows outside on pasture all year round, using forest as a form of weather protection.
Farm 3, plain districts of Svealand	280 cows/280 cows; 540 ha/545 ha	Several rented relatively small pasture areas far away. Own poorly consolidated arable land rented to other farmer.	Converted own arable land, including scattered semi-natural pastures, groves and 5 ha forest to large coherent pasture and stopped renting small, scattered pastures far away.
Farm 4, plain districts in Svealand	270 cows/295 cows; 800 ha/840 ha	Wetland pasture where cattle had to be removed during rainy periods, which required labor and fields for grazing and as a reserve.	Created a large coherent pasture from the wetland. Forest land was converted, so the livestock can graze during wet and dry periods. The change released land for growing forage and made it possible to increase the herd by 25 cows.
Farm 5, upper parts of Norrland	50 cows/50 cows; 80 ha/80 ha	Several rented small pasture areas far away.	Stopped renting some pastures far away and rented 16 ha pasture closer to the farm. Arable land in this area of Sweden has no or low opportunity costs and therefore no positive rent exists.

Table 2. Descriptions and calculations of items when creating large coherent pasturelands from small scattered pastures in five Swedish cow-calf enterprises.

Item	Description
Additional income	
Agri-environmental payments and supports	Agri-environmental payment per hectare (ha) [38] * no. of ha on farm
Higher survival of calves	Price for weaned calf at 300 kg [39] * percentage increase in calf survival on farm
Slaughter income	Price for carcass per kg [39] * carcass weight (kg) according to farmer's statement
Stumpage value of final felling	Stumpage value per ha [40,41] * annualized at 30 years and 4% interest rate
Reduced income	
Cost of premature final felling	Cost of premature final felling per ha [42,43] * annualized at 30 years and 4% interest rate
Opportunity cost of forestry land	Opportunity cost for forestry land [40,41] * interest rate
Loss of rent for agricultural land	Rent cost on arable land in the area per ha [38] * no. of ha on farm
Loss of value of manure	Net value of manure after cost for spreading + soil compaction [44]
Additional costs	
Restoration and fencing costs [a]	Restoration (wages per h and tractor cost per h) [11] * farmer's time estimate * (annualized at 30 years and 4% interest rate). Fences (wages per h [11] * farmer's time estimate) + cost for materials 2016, tax depreciation five years
Animal transports and supervision [a]	(Wages per h and tractor cost per h) [11] * farmer's time estimate (h).
Feeding cost at pasture [a]	(Wages per h and tractor cost per h) [11] * farmer's time estimate (h)
Outdoor housing	Outdoor housing systems for cattle [45]
Building cost of barn	(Material costs + wages per h) [11] * farmer's time estimate (h). Tax depreciation 20 years for the building structure and five years for the building equipment
Feed for more animals [a]	Feed quantity (kg dry matter) [11] * price per kg dry matter [11]
Labor for more animals	Wages per h [11] * farmer's time estimate (h)
Interest rate, animal and working capital	4% interest rate at increased animal capital and increased working capital
Reduced costs	
Animal transports, supervision and feed [a]	(Wages per h and tractor cost per h) [11] * farmer's time estimate (h)
Costs of pasturing [a]	(Wages per h and tractor cost per h) [11] * farmer's time estimate (h) in maintenance, land clearing and removal of deciduous trees from mixed stands
Costs of sires	Feed cost per sire [11] + (purchase price for sire - slaughter income per kg carcass weights) [39]
Rent of agricultural land	Rent cost on arable land in the area per ha [38] * no. of ha on farm
Indoor housing cost	Farmer statement and Agriwise [11]
Indoor feeding cost [a]	(Wages per h and tractor cost per h) [11] * farmer's estimate

[a] The cost of tractor and machinery in the table includes only fuel and maintenance and not capital costs, since the examined conversions studied on the farms did not change the need for new machinery investments.

The profitability of changing from small to large pastures by converting intermediate marginal arable land and forest land was calculated using partial budgeting techniques [46]. The change in profitability was calculated as:

(Additional income + Reduced costs) − (Additional costs + Reduced income).

The partial budgeting technique took into account the revenues and cost items that changed as a result of increasing pasture size by including intermediate, marginal arable and forest land. As a result, only the effects of the changes were examined, not the financial results for the whole farm.

The model included reduced income attributable to premature harvesting of forest land due to conversion of forest land into pasture. Reduced income also included the opportunity cost of forest land, given that the original value of land remains constant although the standing volume has been harvested. The annual reduced income was calculated as the annuity of the discounted value of future revenues from forest land in the event that premature harvesting is not enacted. The discounted present value (PV) of future net benefits originating from planned forestry activities in the event that the forest land is not transferred into pasture at time t, here denoted H_t, is given by the equation:

$$PV = \sum_{t=1}^{T} H_t (1 + r)^{-t}$$

The equation was calculated for each of the five farms using Plan33 [40]. In accordance with theoretical developments reported by Lagerkvist and Andersson [47], *r* is an after-tax interest rate calculated at 4% in the basic calculation. It is important to note that all calculations were conducted "after tax", which means that applicable tax provisions were used both the investment in beef production and in forestry. All results are presented as Euros (€) per year.

In a second step, sensitivity analysis was enacted for a situation without agri-environmental payments and supports. Sensitivity analysis was also undertaken for changes in beef prices and price payed for weaned calf by decreasing the price with €0.5 per kg, for a decrease in the interest rate in forestry from 4% to 2%, and for a decrease in the market price of timber.

Finally, the factors affecting the farms were grouped into five categories defined by the impact on profitability:

(1) Agri-environmental payments (agri-environmental payments for grazing of semi-natural pasture, restoration of semi-natural pasture, and organic production) and supports (single farm payment, enterprise support, support for less favoured areas, and animal premium).
(2) Economies of scale (additional slaughter income with increasing number of animals minus additional costs for feed, building, labour, and interest).
(3) Improved consolidation (reduced costs of animal transport, supervision, feeding, pasturing, and sire due to the fact that small pastures far away from the farm centre were replaced by new pastures and removal of old internal fences).
(4) Net rent (reduced rent costs for former rented pastures far from the farm minus loss of income from high agri-environmental payments on these pastures and loss of rent for land previously rented out but now transferred to pasture).
(5) Forestry (additional income from final felling and loss of future forestry production).

3. Results

Arrangements designed to create larger coherent pasture areas contributed towards improved profitability on all farms studied (Table 3). The increase in profitability, expressed per farm and per ha, is highest for Farm 4, due to improved consolidation in combination with enlarging herd size.

On Farms 1 and 3, agri-environmental payments and supports are the primary source of increased profitability. On Farm 3, rent is a negative item due to the loss of income from previously rented-out arable land that is now converted into pasture. Farm 3 also loses some income from high agri-environmental payments associated with the smaller areas of rented pastures far away. Due to larger coherent pastures, and hence more cows in each enclosure, Farm 3 requires fewer sires which reduces costs.

Table 3. Change in profitability, Euro (€) per farm and year, according to the partial budgeting model, summing up additional income, reduced income, additional costs and reduced costs, attributable to the creation of larger coherent pasturelands from small scattered pastures in five Swedish cow-calf enterprises (1–5).

Farm	1	2	3	4	5
Additional income					
Agri-environmental payments and supports	7526		16,464	18,945	
Higher survival of calves		1045			
Slaughter income				18,804	
Stumpage value of final felling				7662	
Sum	**7526**	**1045**	**16,464**	**45,411**	**0**
Reduced income					
Cost of premature final felling	148			1887	
Opportunity cost of forestry land	8		−50	−277	
Loss of rent for agricultural land			26,233		
Loss of value of manure		1028			
Sum	**157**	**1028**	**26,183**	**1610**	**0**
Additional costs					
Restoration and fencing costs	12	721	280	190	145
Animal transport and supervision			2132		
Feeding cost at pasture		4400			
Outdoor housing		681			
Building cost of barn				2646	
Feed for more animals				7673	
Labor for more animals				289	
Interest rate, animal and working capital				1158	
Sum	**12**	**5802**	**2411**	**11,956**	**145**
Reduced costs					
Animal transports, supervision and feed	744	84	4315	777	2336
Costs of pasturing		882		544	
Costs of sires			1155		
Rent of agricultural land			14,380		
Indoor housing cost		4465			
Indoor feeding cost		1 366			
Sum	**744**	**6796**	**19,849**	**1321**	**2336**
Total sum per farm	**8102**	**1011**	**7719**	**33,166**	**2191**
Total sum per ha	**33**	**16**	**28**	**39**	**27**

Creating a larger enclosure including some forest on Farm 2 enables keeping cows outdoor all year round. Compared with using the former stanchion barn in winter, Farm 2 thus has reduced labor costs as a result of the change due to abandoning the indoor housing during winter. Furthermore, the survival rate of calves increased on changing housing system, providing additional income. However, when wintering the suckler cows outdoors Farm 2 had problem to handle all the manure, which causes a reduced income in its organic crop cultivation. On the other hand, after the change to an enclosure including forest, the suckler cows forage a lot of verges and also some brushwood, which reduced costs for land clearing that previously required farmer's labor.

Due to the increase in herd size, Farm 4 receives additional income not only from agri-environmental payments and supports, but also from slaughter livestock. Additional income from the animals exceeded the additional costs for feed, building, labor and interest, resulting in economies of scale. The final felling of the forest converted to pasture at Farm 4 provided a high stumpage value, due to the fact that the forest was cut at a period of high timber prices. The actual stumpage value was higher than the reduced income due to premature clearcutting and loss of future forest production. Consequently, conversion of forest land gives a net benefit.

The improved profitability on Farm 5 is entirely due to the replacement of rented pastures far away with 16 ha of pasture close to the farm, resulting in lower costs for animal transport and supervision.

The sensitivity analysis (Table 4) reveals that when agri-environmental payments and supports are excluded, the increase in profitability is, compared with baseline, halved for Farm 4 and drastically reduced for Farm 1. Moreover, without agri-environmental payments and supports the result is actually negative for Farm 3, due to loss of rent for arable land converted to pasture and loss of income from high agri-environmental payments on formerly rented pasture. On Farms 2 and 5, the creation of large pasture enclosures is profitable irrespective of payments and supports. Reducing the price paid for weaned calves and carcasses by €0.5 per kg respectively does not have any major effect on profitability on Farms 2 and 4. Halving the interest rate in forestry from 4% to 2% decreases profitability marginally on Farms 1, 3 and 4 on converting forest to pasture.

Table 4. Sensitivity analysis for profitability, € after tax per farm and year, when changing five variables relevant in creation of large coherent pastures from small scattered pastures in five Swedish cow-calf enterprises (Farms 1–4, Farm 5 not affected).

Farm	1	2	3	4
Total sum per farm, basic calculation	8102	1 011	7719	33,166
Excluding agri-environmental payments and supports	576		−8745	14,221
Reduced price paid for weaned calves, by €−0.5 per kg		825		
Reduced price paid for carcasses, by €−0.5 per kg				31,169
Interest rate in forestry, 2% instead of 4%	7393		7543	31,867
Missing the highest peak of timber price				29,986

If Farm 4 would have missed the highest peak of timber prices when the forest was harvested, the profitability increase is reduced only marginally. Thus, even when changing the variables in the sensitivity analysis, the measures undertaken are still profitable for all four farms except when taking agri-environmental payments and supports away from Farm 3.

It is apparent, as can be noted when five stated causes are allocated (Figure 1), that consolidation contributes to improved profitability on all five farms. Consolidation is the sole cause of increased profitability on Farms 2 and 5, due to large coherent pastures close to the farm enabling more rational housing and pasture management, respectively. Agri-environmental payments and supports is the major reason for the positive results of the changes on Farms 1, 3 and 4. As seen for Farm 4, forestry and economies of scale gave similar additional income. On Farm 3, the increase in agri-environmental payments and improved consolidation exceeded the loss of net rent (left-hand bar in Figure 1) due to the missed income from formerly out-rented arable land converted to pasture. In addition, Farm 1 displays an inconsiderable negative bar caused by reduced income in forestry.

4. Discussion

In this study of the effects of creating larger, coherent pastures, all organic cow-calf enterprises studied profited from the change, as additional income and reduced costs exceeded reduced income and additional costs. The increase in profitability is mainly due to higher agri-environmental payments and supports when forest land (Farms 1, 3 and 4) and arable land (Farm 3) is transformed into pasture eligible for agri-environmental payments and supports. Available statistics [38] shows that the agri-environmental payments and supports generally appears to have promoted an increase in beef herd size and conversion of arable land and abandoned farmland into pasture at national level in Sweden. Agri-environmental payments and supports are major factors affecting the profitability in cow-calf production. An important contribution on transforming forest land back to pasture being the payment for pasture restoration.

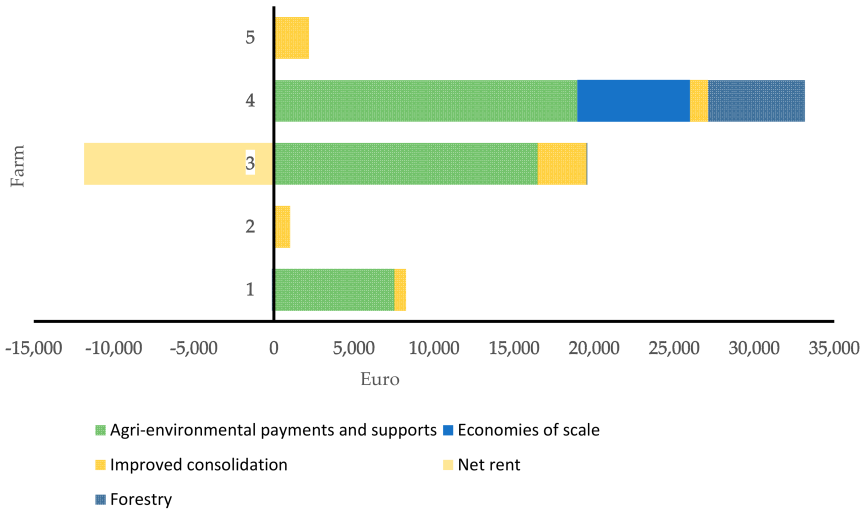

Figure 1. Magnitude, € after tax per farm and year, and reasons for profitability increases due to creation of large coherent pastures on five Swedish cow-calf enterprises.

In general, half the income in Swedish cow-calf enterprises derives from the agri-environmental payments for semi-natural pastures and organic farming and a variety of supports [11,38]. The sensitivity analysis in this study reveals that agri-environmental payments and supports are of crucial importance for the profitability of three of the farms studied. Depending on the enterprises situation, the agri-environmental payments and supports are more or less critical for the profitability.

Farm 4, which could increase its herd size when transforming forest to pasture, showed the highest profitability increase without agri-environmental payments and supports of all farms studied, due to economies of scale. Since the year 2000, average herd size in Swedish cow-calf production has increased by 60% [41]. Nevertheless, the average size remains at only 19 suckler cows per farm [38] and 78% of the farms have 1–25 suckler cows [48]. Thus, most Swedish cow-calf enterprises are smaller than those examined in this study (30–280 cows). It is well known, that distributing costs across more cattle reduces the costs per animal unit [13–16]. With larger herds, Short [14] found that the operating costs per animal in cow-calf production for feed, veterinary services, bedding and also some custom operations such as fuel and electricity declined with enterprise size. There was also a positive effect on capital costs for tractors, equipment and insurance. In contrast, Langemeier and co-workers [15] concluded that production costs are not always affected by the size of the enterprise and that the variation between farms is substantial. Similar findings are made in the present study, e.g., there is a substantial variation in costs between farms depending not only on herd size but also farm layout, rented pastures, transports etc. The results from this study show that there is potential on both small and large cow-calf enterprises, irrespective of location in Sweden, to achieve improved profitability by creating larger coherent pastures.

The results in this study are due to several factors. Time required for transport and supervision constitutes a major part of the reduced costs. Better consolidation has also been reported to increase profitability in other countries. For example, on dairy farms in Spain, profitability increased when the farm was less fragmented [49], while in Finland land consolidation decreased enterprise costs [50]. However, most Swedish pastures are small, especially in forest districts where there is much abandoned and marginal arable land with low or no opportunity cost, but which would be appropriate for beef production if better consolidated. In typical Swedish forest districts, where less than 10% of the area consists of farmland and the average farm only has 30 ha arable land and pasture, the average size of pasture enclosures is only two ha [3]. Even if increasing the size of these pasture units would be profitable, it is not always possible due to different land owners and thus difficulty in acquiring enough land, intersecting roads and scattered habitations [30].

Cattle kept outdoors all year round may be healthier than cattle reared indoor [51]. It is known that a good air supply promotes calf health, with less respiratory diseases [52]. Hence, there exists a risk of increased infection pressure from crowding cattle indoors. It has also been found that the formation of cow-calf bond can be disturbed when calving occurs in groups, especially in crowded situations [53]. Creating a large pasture with forest to protect the animals from the weather on Farm 2 meant that calving occurs on pasture instead of indoors, resulting in higher survival rate of calves. A higher proportion of weaned calves implies more additional income due to the change. The price paid for weaned calves is positively correlated with the price paid for beef carcasses. In recent years, the price paid for beef carcasses at Swedish abattoirs has been high [38], Hence, the price of weaned calves has also increased [39]. A few years ago, the additional income from weaned calves on Farm 2 was not as high as at present.

A vital issue for Farm 3 was the termination of rented pastures far away from the farm, which required a lot of labor and fencing. When a larger pasture was developed on the farm's own land, the enterprise stopped renting distant pastures. Even though the farm's own pasture was of lower biological and cultural heritage value, resulting in a lower agri-environmental payment, creating a more coherent pasture enclosure by including marginal arable land produced more forage than the former rented land, so the change was profitable. Large pasture enclosures require shorter fence lengths per ha pasture. Furthermore, larger but fewer enclosures implies that fewer watering facilities are needed, less transports of cattle between enclosures and fewer stops on the daily cattle inspection tour.

Farm 5 faced problems with land tenure that made it difficult to merge pastures closer to the farm. The farm is situated along a river, with a multitude of owners with small land properties. Despite previous repeated attempts by the farmer, some of the landowners would not allow any cattle on their land. When Farm 5 was given the opportunity to rent a larger coherent pasture closer to the farm, it achieved a positive consolidation effect due to less transports.

Sweden consists of three million ha of farmland, 23 million ha forest, 13 million ha of mountains, and one million ha of built-up areas and related land. The southern and central parts of Sweden up to the southern border of the mountain area are dominated by coniferous and deciduous forest in which there is scattered farmland [54]. A few defined plain districts with economically sustainable crop production are located in southern and central parts. Large area of farmland in the forest districts has been abandoned during the past century, while the remaining arable land is becoming even more concentrated to the plains, where larger enterprises are possible. Less productive, often smaller, patches of arable land are abandoned and overgrown, or actively transformed to forest by planting.

In large parts of Sweden, farm enterprises often have both production of beef and forest [3,54]. Creating large coherent pasturelands, embracing both pastures and forests, is thereby possible on such mixed enterprises. With return requirements normally facing the agriculture and forestry sector (4% real interest rate in the present study), replanting after final felling has low profitability on much of Swedish forest land [35]. On Farms 1, 3 and 4, it proved profitable not to replant and instead transform the forest land to pasture after final felling, in order to improve the consolidation and/or get pasture for a larger herd. On Farm 4, even premature felling motivated by quickly obtaining access to more consolidated pasture was profitable. However, felling on this farm to transform forest to pasture was undertaken in 2010 when the prices of forest products were very high [43]. Furthermore, the logging was large-scale (40 ha) which might have had a positive effect when the farmer was bargaining on price, and there are good roads nearby for transport of the timber. Taken together, the stumpage value of final felling in this study might be higher than in an ordinary year and another situation. However, the sensitivity analysis reveals only marginal effects on profitability of decreasing the stumpage value to a more normal price.

There are a number of governmental environmental quality objectives in Sweden. Two of these, "a varied agricultural landscape" and "a rich diversity of plant and animal life", are dependent on continuously managed semi-natural pastures [55]. Grazing livestock serve an important function in the preservation of semi-natural pastures. Abandonment and fragmentation are the major threats to biodiversity, where short-lived plants can easily disappear if grazing management ceases and fragmentation and increasing distance between small scattered species-rich pastures obstruct seed dissemination to other grasslands [56]. Opening up fences around separate semi-natural pastures to create large coherent pastures embracing adjacent forest and ex-arable land increases connectivity between species-rich plots and thereby promotes the preservation of vulnerable grassland species. After restoration of abandoned grassland, the number and frequency of species increase with time, but the final outcome is dependent on presence of species in the neighborhood [56]. Re-colonization of biodiversity was not investigated in the present short-term study. However, systematic inventories of vascular plants were undertaken on Farm 3 before and after creation of large coherent pastures from a mosaic of managed and previously abandoned semi-natural pastures, arable land and forests. This revealed that some vascular plants have spread greatly from the managed semi-natural pastures to the other land [57]. Varying grazing system alter the composition and structure of pasture vegetation where species sensitive to continuous grazing are more frequent in rotationally grazed paddocks whereas less competitive species tend to increase in continuous grazing systems [58]. As a large part of the Swedish semi-natural pastures are less than 2 ha [3] they are too small to be part of a rational rotational grazing management. Rotational grazing among some large connected pastures, which are created from small scattered pastures, could therefore enable rational rotational grazing systems. Various rotational grazing systems is provided at Farm 1, 3 and 4 to promote biodiversity. Farm 2 and 5 do not have areas with high biodiversity values as continuous grazing is satisfying.

Farms 2 and 3 have both expanded pastures that include forest. Experience from the early 1900s, when forest grazing was common in Sweden, shows that excessive forest grazing can cause major damage to trees [32]. However, careful forest grazing at appropriate times and stocking rates causes insignificant forest damage [59,60], especially if the livestock also have access to lush open pasture [61]. Livestock grazing in coniferous replanting may even provide silvicultural benefits by removing deciduous vegetation [62], which competes with the young trees for nutrients, water and light [63]. Such positive effects have been noted on Farm 2. Grazing and trampling livestock may also be associated with decreased soil water storage and increased runoff. The effects of grazing on forest vary with rainfall, slope, soil stability and vegetation type, and also with animal density and stocking rate, as well as season and duration of use [62]. Forest damage due to grazing animals may not become apparent for decades and therefore it was not possible to assess this problem in the present study.

5. Conclusions

A scattered structure of small pastures has negative effects on profitability in cow-calf enterprises since small enclosures result in high labor costs per livestock unit. Creation of larger coherent pastures facilitates an increase of herd size, which yields positive effects due to economics of scale. This study examined how additional income, additional costs, reduced income and reduced costs affects the profitability, by using a partial budgeting technique, when creating larger coherent pastures from small, scattered pastures and adjacent forest land on five Swedish cow-calf enterprises. Decreased labor costs for animal transports and supervision as well as other cost reductions due to improved consolidation contributes to improved profitability on all five cow-calf enterprises examined. Consolidation is the sole cause of increased profitability for two of the farms, due to larger coherent pastures close to the farm, which enables more rational housing and pasture management, respectively. Agri-environmental payments and supports is the major reason for increased profitability on the other three farms. When agri-environmental payments and supports are excluded, two out of the three farms still display positive results, due to consolidation effects on one farm and economies of scale, forestry and consolidation on the other. For the latter farm expanding enterprise, economies of scale and forestry gave similar additional income. A reduction of price paid for weaned calves or reduced price paid for carcasses did not have any major effect on profitability. Costs for premature final felling and opportunity costs for forestry land were of quite minor importance.

Improving the profitability, and thereby promoting the economic sustainability of beef production by creating large coherent pasture including e.g., semi-natural pasture, marginal arable land and former forest land, is of interest not only for the involved farmers. It is also socio-economically important because it improves the international competitiveness of Swedish beef production, creates employment opportunities in rural areas and enables the conservation of semi-natural pastures with high amenity and biodiversity values.

Author Contributions: Karl-Ivar Kumm did the conceptualization. Kristina Holmström conducted the major part of the study including literature review, study design, collection, preparation and analyze of data under supervision of primarily Karl-Ivar Kumm, but also Anna Hessle and Hans Andersson. Kristina Holmström prepared the manuscript, which was reviewed and edited by Karl-Ivar Kumm, Hans Andersson and Anna Hessle. Anna Hessle was responsible for project administration and funding acquisition, assisted by Karl-Ivar Kumm.

Funding: This research was funded by Region Västra Götaland (Grant No. RUN 610-0789-13), the Rural Economy and Agricultural Society Sjuhärad, Swedish University of Agricultural Sciences, Formas (Grant No. 221-2014-287) and Bröderna Jonssons forskningsfond.

Acknowledgments: We gratefully acknowledge the managers of the beef enterprises studied for sharing their time, thoughts and figures. We also thank Hans Ekvall and Johan Gradén for basic data and discussions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bratli, H.; Jordal, J.-B.; Norderhaug, A.; Svalheim, E. *Naturfaglig Grunnlag for Handlingsplan Naturbeitemark og Hagemark/Natural Science Foundation for Action Semi-Natural Pastures and Meadows*; Bioforsk: Ås, Norway, 2012; p. 91.
2. Natural Resources Institute Finland. Statistics Database. Available online: http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/?rxid=001bc7da-70f4-47c4-a6c2-c9100d8b50db (accessed on 26 February 2018).
3. Swedish Board of Agriculture. Jordbrukets Miljöeffekter 2020—En Framtidsstudie/Agricultures' Environmental Impacts 2020—A Future Study. Available online: http://webbutiken.jordbruksverket.se/sv/artiklar/jordbrukets-miljoeffekter-2020.html (accessed on 22 May 2017).
4. Swedish Board of Agriculture. SJVFS 2017:24 Statens Jordbruksverks Föreskrifter Och Allmänna Råd Om Nötkreaturshållning Inom Lantbruket/The Regulations and General Advice of the Swedish Board of Agriculture about Cattle Farming in Agriculture. Available online: http://www.jordbruksverket.se/forfattningar/forfattningssamling/2017.4.5a0cf638159e8f8740777936.html (accessed on 15 March 2018).
5. Kumm, K.-I. *Profitable Grazing by Large Connected Pastures*; Department of Animal Environment and Health, Swedish University of Agricutural Sciences: Skara, Sweden, 2007; p. 43.
6. Regeringskansliet. Genomförandet av EU:s Jordbruksreform i Sverige/Implementation of the EU Agricultural Reform in Sweden. Available online: http://www.regeringen.se/rattsdokument/departementsserien-och-promemorior/2004/01/ds-20049/ (accessed on 16 November 2017).
7. Deblitz, C. Beef and Sheep Report 2017. Available online: http://www.agribenchmark.org/beef-and-sheep.html (accessed on 10 February 2018).
8. European Commission Database—Eurostat. Available online: http://ec.europa.eu/eurostat/data/database (accessed on 20 November 2017).
9. Statistics Norway. Statistics Norway. Available online: http://www.ssb.no/ (accessed on 20 November 2017).
10. Kumm, K.-I. Scenarios for Profitable Beef and Lamb Production. Available online: https://www.researchgate.net/publication/242112192_Vagar_till_lonsam_not-_och_lammkottsproduktion_Scenarios_for_profitable_beef_and_lamb_production (accessed on 15 May 2017).
11. Agriwise. Agriwise—Verktyg för Ekonomisk Planering Och Analys/Agriwise—Tools for Financial Planning and Analysis. Available online: http://www.agriwise.org/ (accessed on 28 June 2017).

12. LRF Konsult Lantbrukets Lönsamhet—LRF Konsult. Available online: https://www.lrfkonsult.se/Global/Lantbrukets%20lönsamhet%20-%20höst%202017/Lantbrukets%20lonsamhet%20host%202017.pdf (accessed on 20 December 2017).
13. Boggs, D.; Hamilton, E. Cow/Calf Analysis: Key Indicators of Profitability. In Proceedings of the Range Beef Cow Symposium XV, Rapid City, SD, USA, 9–11 December 1997.
14. Short, S.D. *Characteristics and Production Costs of U.S. Cow-Calf Operations*; U.S. Department of Agriculture, Economic Research Service: Washington, DC, USA, 2001; p. 26.
15. Langemeier, M.R.; McGrann, J.M.; Parker, J. Beef Cattle Handbook: Economies of Size in Cow-Calf Production. Available online: http://www.iowabeefcenter.org/bch/CowCalfEconomySize.pdf (accessed on 24 April 2017).
16. Salevid, P.; Kumm, K.-I. Searching for economically sustainable Swedish beef production systems based on suckler cows after decoupling EU income support. *Outlook Agric.* **2011**, *40*, 131–138. [CrossRef]
17. Drake, L. The Swedish agricultural landscape—Economic characteristics, valuations and policy options. *Int. J. Soc. Econ.* **1999**, *26*, 1042–1062. [CrossRef]
18. Cousins, S.A.O.; Eriksson, O. The influence of management history and habitat on plant species richness in a rural hemiboreal landscape, Sweden. *Landsc. Ecol.* **2002**, *17*, 517–529. [CrossRef]
19. Dahlström, A.; Cousins, S.A.O.; Eriksson, O. The history (1620–2003) of land use, people and livestock, and the relationship to present plant species diversity in a rural landscape in Sweden. *Environ. Hist.* **2006**, *12*, 191–212. [CrossRef]
20. Pykälä, J. Cattle grazing increases plant species richness of most species trait groups in mesic semi-natural grasslands. *Plant Ecol.* **2005**, *175*, 217–226. [CrossRef]
21. Kohyani, P.; Bossuyt, B.; Bonte, D.; Hoffmann, M. Grazing impact on plant spatial distribution and community composition. *Plant Ecol. Evol.* **2011**, *144*, 19–28. [CrossRef]
22. Kumm, K.-I. *Cost of Roughage Production to Beef Cattle*; Department of Animal Environment and Health, Swedish University of Agricutural Sciences: Skara, Sweden, 2009; p. 49.
23. Hessle, A.; Kumm, K.-I. Use of beef steers for profitable management of biologically valuable semi-natural pastures in Sweden. *J. Nat. Conserv.* **2011**, *19*, 131–136. [CrossRef]
24. Offerman, F.; Nieberg, H. *Economic Performance of Organic Farms in Europe*; Organic farming in Europe: Economics and Policy; University of Hohenheim: Stuttgart, Germany, 2000.
25. Salevid, P.; Kumm, K.-I. Profitability of organic and conventional cow-calf operations under Swedish conditions. *Org. Agric.* **2012**, *2*, 205–217. [CrossRef]
26. Deblitz, C.; Ballie, U.; Krebs, S.; Rump, M. *Extensive Grünlandnutzung in den Östlichen Bundesländern: Entwicklung Standortangepaßter Verfahren der Extensiven Grünlandnutzung für Ausgewählte Regionen in den Östlichen Bundesländern*; Landwirtschaftsverlag: Renningen, Germany, 1994.
27. Hrabalová, A.; Zander, K. Organic beef farming in the Czech Republic: Structure, development and economic performance. *Agric. Econ.* **2006**, *2*, 89–100.
28. Zander, K.; Nieberg, H.; Offermann, F. Financial relevance of organic farming payments for western and eastern European organic farms. *Renew. Agric. Food Syst.* **2008**, *23*, 53–61. [CrossRef]
29. Doucha, T.; Foltýn, I.; Humpál, J. Profitability of dairy and suckler cows breeding on Czech farms. *Agric. Econ.* **2012**, *58*, 397–408. [CrossRef]
30. Kumm, K.-I. Conditions for profitable organic beef production using abandoned and marginal farmland in Sweden. *Org. Agric.* **2018**. under review.
31. Mayer, A.; Stöckli, V.; Konold, W.; Kreuzer, M. Influence of cattle stocking rate on browsing of Norway spruce in subalpine wood pastures. *Agrofor. Syst.* **2006**, *66*, 143–149. [CrossRef]
32. Kardell, L. *Om Skogsbete I Allmänhet och det i Klövsjö i Synnerhet/On Forest Pasuring in General and that in Klövsjö in Particular*; Swedish University of Agricultural Sciences, Dep. of Forest Landscaping: Uppsala, Sweden, 2008; p. 144.
33. Histøl, T.; Hjeljord, O.; Wam, H.K. *Storfe og Sau på Skogsbeite i Ringsaker—Effekter på Granforyngelse og Elgbeite/Cattle and Sheep on Forest Pasturing in Ringsaker—Effects on Spruce Rejuvenation and Browsing Moose*; Bioforsk: Ås, Norway, 2012; p. 19.
34. Krokeus, C. Rural Economy and Agricultural Society Sjuhärad, Länghem, Sweden. Personal communication, 2018.
35. Skogskunskap. Skogskunskap/Forest Science. Available online: https://www.skogskunskap.se/rakna-med-verktyg/ (accessed on 12 December 2017).

36. Swedish Forest Agency. Official Statistics of Sweden. Available online: https://www.skogsstyrelsen.se/globalassets/statistik/historisk-statistik/skogsstatistisk-arsbok-2010-2014/skogsstatistisk-arsbok-2014.pdf (accessed on 9 January 2018).
37. Frankwick, G.L.; Ward, J.C.; Hutt, M.D.; Reingen, P.H. Evolving patterns of organizational beliefs in the formation of strategy. *J. Mark.* **1994**, *58*, 96–110. [CrossRef]
38. Swedish Board of Agriculture. Agricultural Statistics 2017. Available online: http://www.jordbruksverket.se/swedishboardofagriculture/engelskasidor/statistics/agriculturalstatistics.4.2d224fd51239d5ffbf780001098.html (accessed on 7 March 2018).
39. HKScan Agri. HKScan Agri Notering/HKScan Agri Listing. Available online: http://www.hkscanagri.se/notering/notering-arkiv/ (accessed on 12 December 2017).
40. Ekvall, H. *Plan33—A Tool for Economic Analysis of Timber Production in the Forest Company*; Report No. 123; Dept of Forest Economics, Swedish University of Agricultural Sciences: Umeå, Sweden, 2001.
41. Ekvall, H. Swedish University of Agricultural Sciences, Umeå, Sweden. Personal communication, 2017.
42. Gradén, J. Gradéns skogskonsult, Alingsås, Sweden. Personal communication, 2017.
43. Swedish Forest Agency. Forest Statistics. Available online: www.skogsstyrelsen.se/statistik (accessed on 12 December 2017).
44. Länsstyrelsen Västra Götaland. Bidragskalkyler/Contribution Calculations. Available online: http://www.lansstyrelsen.se:80/VastraGotaland/Sv/lantbruk-och-landsbygd/Radgivning-kurser/ditt-foretags-ekonomi/bidragskalkyler/Pages/index.aspx (accessed on 8 June 2017).
45. Gård & Djurhälsan. Utegångsdjur Utan Ligghall—Nöt | Kontrollprogram/Housing Animal without Shelter—Cattle Control Program. Available online: http://www.gardochdjurhalsan.se/sv/kontrollprogram/utegangsdjur-utan-ligghall-not/ (accessed on 8 March 2018).
46. Olson, K.D. *Economics of Farm Management in a Global Setting*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2011.
47. Lagerkvist, C.-J.; Andersson, H. Taxes, inflation and financing—The rate of return to capital for the agricultural firm. *Eur. Rev. Agric. Econ.* **1996**, *23*, 437–454. [CrossRef]
48. Grönvall, A. Swedish Board of Agriculture, Jönköping, Sweden. Personal communication, 2017.
49. del Corral, J.; Perez, J.A.; Roibas, D. The impact of land fragmentation on milk production. *J. Dairy Sci.* **2011**, *94*, 517–525. [CrossRef] [PubMed]
50. Hiironen, J.; Riekkinen, K. Agricultural impacts and profitability of land consolidations. *Land Use Policy* **2016**, *55*, 309–317. [CrossRef]
51. Hegrestad, O.M. Veterinary, Murum, Sweden. Personal communication, 2018.
52. Lago, A.; McGuirk, S.M.; Bennett, T.B.; Cook, N.B.; Nordlund, K.V. Calf respiratory disease and pen microenvironments in naturally ventilated calf barns in winter. *J. Dairy Sci.* **2006**, *89*, 4014–4025. [CrossRef]
53. Illmann, G.; Špinka, M. Maternal behaviour of dairy heifers and sucking of their newborn calves in group housing. *Appl. Anim. Behav. Sci.* **1993**, *36*, 91–98. [CrossRef]
54. Statistics Sweden. Land Use in Sweden 2010. Available online: http://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/land-use/land-use-in-sweden/pong/tables-and-graphs/land-use-in-sweden-2010/ (accessed on 20 December 2017).
55. Swedish Environmental Objectives. Miljömål.se—Om Hur Miljön Mår Och Arbetet Med Sveriges Miljömål Går/Environmental Objectives. Available online: http://www.miljomal.se/ (accessed on 4 December 2017).
56. Lindborg, R.; Eriksson, O. Effects of restoration on plant species richness and composition in Scandinavian semi-natural grasslands. *Restor. Ecol.* **2004**, *12*, 318–326. [CrossRef]
57. Emanuelsson, U. Swedish University of Agricultural Sciences, Uppsala, Sweden. Personal communication, 2018.
58. Pavlů, V.; Hejcman, M.; Pavlů, L.; Gaisler, J. Effect of Rotational and Continuous Grazing on Vegetation of an Upland Grassland in the Jizerské Hory Mts., Czech Republic. *Folia Geobot.* **2003**, *38*, 21–34.
59. McLean, A.; Clark, M.B. Grass, trees and cattle on clearcut-logged areas. *J. Range Manag.* **1980**, 213–217. [CrossRef]
60. Pitt, M.D.; Newman, R.F.; Youwe, P.L.; Wikeem, B.M.; Quinton, D.A. Using a grazing pressure index to predict cattle damage of regenerating tree seedlings. *J. Range Manag.* **1998**, *51*, 417–422. [CrossRef]
61. Geete, E.; Grinndal, T. *Anvisningar i Skogsbruk/Instructions for Forestry*; Svenska skogsvårdsföreningens förlag: Stockholm, Sweden, 1923.

62. Belsky, A.J.; Blumenthal, D.M. Effects of livestock grazing on stand dynamics and soils in upland forests of the interior west. *Conserv. Biol.* **1997**, *11*, 315–327. [CrossRef]
63. Zimmerman, G.T.; Neuenschwander, L.F. Livestock grazing influences on community structure, fire intensity, and fire frequency within the Douglas-Fir/Ninebark habitat type. *J. Range Manag.* **1984**, *37*, 104–110. [CrossRef]

II

Journal for Nature Conservation 62 (2021) 126010

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc

Economic incentives for preserving biodiverse semi-natural pastures with calves from dairy cows

Kristina Holmström[a,b,*], Karl-Ivar Kumm[a], Hans Andersson[c], Elisabet Nadeau[a,b], Katarina Arvidsson Segerkvist[a], Anna Hessle[a]

[a] Department of Animal Environment and Health, Swedish University of Agricultural Sciences, PO Box 234, 53223 Skara, Sweden
[b] Research and Development, Rural Economy and Agricultural Society Sjuhärad, PO Box 5007, 51405 Länghem, Sweden
[c] Department of Economics, Swedish University of Agricultural Sciences, PO Box 7013, 75007 Uppsala, Sweden

ARTICLE INFO

Keywords:
Economy
Profitability
Semi-natural pasture
Grazing
Cattle
Steer

ABSTRACT

Economical profitability of pasture-based beef production is necessary for continued maintenance of semi-natural pastures. In a situation of decreased cattle stocks, there is a potential to castrate male calves from dairy cows and raise them as grazing steers instead of intact bulls reared indoors, which is the common way in the Nordic countries. We examined the profitability in model enterprises with either grazing steers or indoor bulls. Within the two genders (steer and bull), there were animals of two breed types (pure dairy breed and dairy × beef crossbreed), which were divided into an intensive or extensive production system. The intensive steer system had one summer on grass and slaughter at 21 months of age whereas the extensive steer system had two summers on grass and slaughter at 28 months of age. All bulls were reared indoors and slaughtered at 15 or 18 months of age. The profitability was calculated as contribution margin (CM; Σ revenues – Σ variable costs) in three different herd sizes (50, 100 and 150 slaughtered animals per year) and in three different regions in Sweden (the southern forest districts Gsk, the southern plain districts Gns, and the lower parts of the northern Nn). In the basic calculation, CM for all steers in large herds with 150 slaughtered animals per year was above zero for all cases in Gns, and for one case in Nn and in Gsk respectively. However, all steer cases had lower CM than the comparable bull system in the basic calculation. Sensitivity analyses demonstrate several possible ways of increasing the competitiveness of the grazing steers, compared to the bulls. Utilization of buildings without opportunity cost resulted in a CM above zero for all cases. Increasing the proportion of semi-natural pastures rendering high agri-environmental payment and support was another effective mean. Decreasing the winter feed cost and labour demand on pasture reduced the costs, whereas producing premium-price certified pasture beef increased the revenue, all measures further contributing to an improved profitability. Pasture-based beef production from dairy-born steers can be economically viable, especially in large herds and with extensive production systems. Thereby, we conclude this system to has a potential to graze large areas of semi-natural pastures and thereby conserve their biodiversity and cultural values.

1. Introduction

Globally, grazing cattle have both negative and positive environmental effects (Steinfeld et al., 2006). There are environmental risks with grazing livestock, e.g., soil erosion (Blake et al., 2018), loss of biodiversity (Davidson et al., 2020) and poor water quality (Hansen et al., 2020), all of it mainly because of to high grazing intensity. Cattle do also contribute to greenhouse gas emissions due to their enteric production of methane (FAO, 2017). At the same time, natural and semi-natural grassland habitats are dependent on grazing livestock (Steinfeld et al., 2006). Without the disturbance of grazing, the grasslands become overgrown. Hence, cessation of traditional grazing regimes is the main threat to the habitats (Luoto et al., 2003).

About 90 % of the European semi-natural pastures have been lost during the last century, which negatively affect biodiversity (Lindborg & Eriksson, 2004; Swedish Species Information Centre, 2020; WallisDeVries et al., 2002). In Sweden, the semi-natural pastures and meadows have decreased even more drastically. Only 1–2.5 % of these

* Corresponding author at: Department of Animal Environment and Health, Swedish University of Agricultural Sciences, PO Box 234, 53223 Skara, Sweden.
E-mail address: kristina.holmstrom@slu.se (K. Holmström).

https://doi.org/10.1016/j.jnc.2021.126010
Received 8 April 2021; Received in revised form 28 April 2021; Accepted 28 April 2021
Available online 3 May 2021
1617-1381/

lands managed in the 1800th century are still managed (Dahlström et al., 2008). During the last century the number of cattle has decreased from 2 900 000 (Swedish Board of Agriculture, 2005) to only 1 500 000 heads (Swedish Board of Agriculture, 2020a). Due to this decrease in numbers of cattle a large proportion of pastures with high biodiversity have been, or are, at risk of discontinued grazing.

Most cattle in Sweden originate from the dairy production. Of the young male calves, a majority is reared as intact bulls whereas only a few are castrated and reared as steers (Swedish Board of Agriculture, 2020a). Intact dairy bulls are kept indoor all year round, whereas steers are grazed during the summers. Thus, there is a potential to have more grazing cattle if a higher proportion of male dairy calves would be reared as steers. Extensive steer production systems with high slaughter ages imply that the steers are grazing during more than one summer, which results in a large area of managed semi-natural pastures per animal. On a national level, an increasing number of steers slaughtered at a high age would most likely result in an increased area of semi-natural pastures.

A basic goal for beef enterprises is maximized profits or at least achievement of a satisfactory profitability. To reach the profitability goals, choice of production system, gender, breed, and the combinations of these are important. Profits also vary among geographical regions e. g., due to cropping conditions and availability of various environmental and agricultural payments and supports. Costs in beef production often exceeds the revenues, in Europe as well as in big parts of the world (Deblitz, 2019). This is also a fact in Sweden (Statistics Sweden, 2018; Swedbank et al., 2019). Pasture-based cattle production is more common in countries with large coherent grazing areas, while in northern Europe indoor feeding with grass-clover silage and concentrates is more frequent (European Commission, 2001). Steers is an example of cattle suitable for low intensive grazing systems, common in regions with some of the larger European grasslands (European Commission, 2001, 2019). Farmers with low intensive grazing livestock systems have one of the lowest farm incomes. Low incomes, as well as increasing age of farmers and small farm sizes represent a risk factors for farmland abandonment (Terres et al., 2015). In many European countries, including Sweden, semi-natural pastures are often expensive to utilize as a feed resource due to fragmentation (Isselstein et al., 2005; Kumm & Hessle, 2020; Terres et al., 2015) and a low biomass yield (Isselstein et al., 2005).

To stimulate more grazing of livestock on semi-natural pastures, the Swedish government and EU provides agri-environmental payments for grazing of these land (Swedish Board of Agriculture, 2021b). As these payments constitute a large part of the revenues in pasture-based beef production, they serve as a prerequisite for maintained management of these land and hence preservation of their biodiversity (Hessle & Kumm, 2011; Swedish Board of Agriculture, 2020a; Terres et al., 2015). Available for the farmers are also support for less favoured area (LFA), which varies among regions and animal densities, and a range of direct payments (Swedish Board of Agriculture, 2021b).

In addition to agri-environmental payments and support, there is also a possibility for increased revenues in pasture-based beef production. By using the management of semi-natural pasture for biodiversity as an added value and selling the product with a premium-price as certified pasture beef.

The conditions on a specific farm determine which production system is most profitable. Indoor bulls are eligible for lower agri-environmental payments and supports compared to grazing steers. However, instead bulls have lower costs for e.g. building and labour, due to their higher growth rate and lower slaughter age (Agriwise, 2020). For beef breed male calves born by suckler cows, intensive indoor rearing as intact bulls is more profitable than rearing them as grazing steers if no semi-natural pastures with high levels of environmental payments are available whereas steers are more profitable on farms with such pastures (Hessle & Kumm, 2011). However, there is to the best of the authors knowledge no Swedish comparison conducted on the profitability of young male livestock with dairy origin.

Profitability, and hence the opportunities to increase the area of grazed semi-natural pastures by steers, may also be affected by animal genetics. Calves from dairy cows entering the beef system are most often of pure dairy breed (Växa, 2019), while offspring of dairy × beef crosses are more common in other European countries (Agriculture & Horticulture Development Board, 2019; Department of Agriculture, 2018). The dairy × beef crosses have a higher weight gain and hence a higher carcass weight at a specific slaughter age compared to pure-bred dairy cattle (Eriksson et al., 2020) rendering an increased revenue. The superiority of the dairy × beef crosses is, however, more pronounced in intensive than in extensive production systems (Eriksson et al., 2020).

The aim of this study is to examine the profitability of steers in two grazing systems and intact bulls in two indoor systems, both genders of pure dairy breed and dairy × beef crossbreed, at three different herd sizes in three regions of Sweden. Thus, the economic opportunities to increase the area of grazed semi-natural pastures with high biodiversity by castrating bull calves born from dairy cows and use them for managing, and conserving, these valuable areas is determined.

2. Material and method

2.1. Biological data

One group of steers and one group of intact bulls were reared from weaning until slaughter at Götala Beef and Lamb Research Centre, the Swedish University of Agricultural Sciences, Skara, in south-western Sweden (long 13°21'E, lat 58°42'N; elevation 150 m) during the years 2016–2019. The rearing conditions reflected commercial beef production systems with steers reared extensively, grazing one or two summers, whereas the bulls were fed more intensively and kept indoors the entire rearing period. Half of the steers and half of the bulls were of pure dairy breed (Holstein and Swedish Red), whereas the other half were dairy × beef crossbreeds. Charolais was used as the beef breed sire for the steers while Angus was used for the bulls. Within gender and breed, animals were allocated into one of two production systems. The two production systems differed in indoor feed intensity, where feed rations, non-equal to steers and bulls, were formulated to reach market-oriented carcass weights at 21 and 28 months of age for steers and at 15 and 18 months for bulls (Table 1). Steers reared with high indoor feed intensity and slaughtered at 21 months of age, grazed semi-natural pastures for one summer. The low indoor intensity reared steers, slaughtered at 28 months of age, were grazed for two summers. Taken together, there were eight combinations of gender, breed, and production system, where data was obtained from 15 to 18 animals per group.

Details of biological data for the animals, feed rations and slaughter characteristics is found in Hessle et al. (2019) for the steers and in

Table 1
Gender, breed, indoor feed intensity, slaughter age and numbers of summers grazing semi-natural pastures for eight groups of male cattle originating from dairy cows.

Group	Gender	Breed	Indoor feed intensity[a]	Slaughter age (months)	No. of summers grazing
d 21	steer	dairy	high	21	1
d × b 21	steer	dairy × beef	high	21	1
d 28	steer	dairy	low	28	2
d × b 28	steer	dairy × beef	low	28	2
d 15	bull	dairy	high	15	0
d × b 15	bull	dairy × beef	high	15	0
d 18	bull	dairy	low	18	0
d × b 18	bull	dairy × beef	low	18	0

[a] Feed intensity not comparable between gender.

Nadeau et al. (2020) for the bulls. Arithmetical means of feed consumption and carcass characteristics were calculated for the eight animal groups. The calculations were supposed to represent continuous rearing with calves evenly born all year round. As feed consumption is not affected by season in indoor rearing, the original data from the bulls was used (Table A1). Data from the steers were converted from the original all-in-all-out rearing to represent a system with continuous rearing with 1/12 of the herd born each month (Table A1). Original carcass characteristics were used for both steers and bulls (Table A1).

2.2. Geographical regions

Sweden is situated in the northern hemisphere, with humid snow climate with cool summers in the northern part of the country and humid warm temperate climate with warm summers in the southern part (Kottek et al., 2006). Based on the biological results from the steer and bull trials, economic calculations were conducted for anticipated rearing of steers and bulls in three geographical regions in Sweden (Fig. 1). These regions were chosen due to their varying natural and economic conditions and large cattle populations (Swedish Board of Agriculture, 2020a, 2021b). One region was a LFA in forest districts in Götaland (Gsk) with grazing 100 % semi-natural pastures. Another region was the plain districts in northern Götaland (Gns) situated outside LFA, but still with 100 % semi-natural pastures. The third region was a LFA in lower parts of Norrland (Nn), where proportion of semi-natural pastures are low, assuming steers grazing 20 % semi-natural pastures and 80 % arable land (Swedish Board of Agriculture, 2020a).

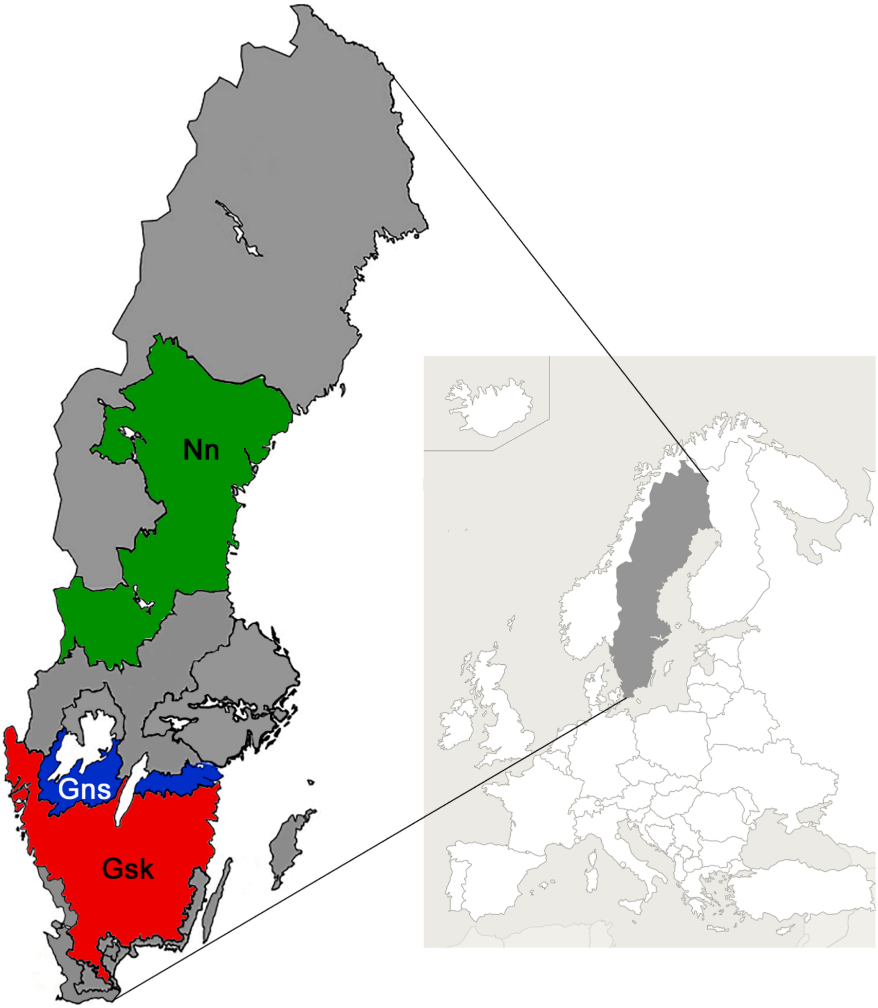

Fig. 1. Localization of three geographical regions in Sweden, forest districts in Götaland (Gsk), plain districts in northern Götaland (Gns), and lower parts of Norrland (Nn) (Swedish Board of Agriculture, 2020a).

2.3. Economical calculations

The profitability was defined as contribution margin (CM), calculated as ∑ revenues – ∑ variable costs, which represents the money generated to cover common costs and profits. Common costs include e.g. planning, labour management, administration, and accounting. Revenues are including carcasses, agri-environmental payment, animal premium, LFA, single farm payment, green direct payment, support to permanent grassland and investment support (Table A2a). Variable costs are associated with the production and those costs will disappear if production ceases e.g. calf purchase and feeds (Table A2b). Common costs include management that is common to all branches of production at the holding such as planning, accounting and administration. Risk includes biological risks, e.g. severely bad feed harvests, market risks, e.g. sharply lowered beef price, and political risks, e.g. lowered or abolished farm supports.

Contribution margins for all 24 combinations of genders, breeds, production systems and regions were computed. The calculations were made for herds with 50, 100 and 150 slaughtered animals per year. The calculations were based on average prices years 2014−2018. This period was chosen because it reflects averages prices over a longer time, which is not the case for later years (HKScan Agri, 2021; Swedish Board of Agriculture, 2020b). Initially, basic calculations based on present conditions were calculated.

An important revenue for pasture-based beef production is agri-environmental payment for management of semi-natural pastures. Semi-natural pastures with high biodiversity and cultural values are paid approximately 270 Euro per ha, whereas pastures with general values are paid approximately 100 Euro per ha (Swedish Board of Agriculture, 2021b). In the basic calculations, 30 % of the semi-natural pastures were supposed to render the high level of agri-environmental payment and the remaining 70 % of the land was supposed to render the low level of payment. In Gsk and Nn, support for LFA is an important revenue especially for the steers that demand large area per head. This support varies between regions and animal density.

Grass-clover silage cost used in the contribution calculations (Table A2b) were calculated for different field configurations in the different regions. Gns was supposed to have large fields with rectangular shape while Gsk and Nn had small scattered and irregular fields (Table A3). The cost of grass-clover silage was calculated as (∑ variable costs - ∑ supports and payments)/net yield of silage. Variable costs of grass-clover silage included machinery and labour costs (Neuman, 2019), cropping costs (Länsstyrelsen Västra Götaland, 2020) and opportunity cost of land, i.e. CM in spring barley cropping including LFA. Larger scale silage production in the presence of larger beef units will create a more efficient use of machinery and labour but will also increase the average distance between the field and the cattle barn. This creates higher transport costs while using contract machinery services may limit the cost for small farms (Errington, 1998). The cost of silage was therefore calculated at the same level for all herd sizes. When calculating the opportunity cost of the field, varying sizes of the farm was anticipated in the regions (Table A3).

The cost for pasture included costs for fencing, clearing and water supply where topography and enclosure size varied among the regions (Table A3). The opportunity cost for semi-natural pasture was set to zero (Kumm & Hessle, 2020).

Investment in a new building (Table A2b) was supposed where the expense for the building (stanchion barn) was estimated from cost calculations for 50, 100 and 150 reared 21-month-old steers (Lindman Larsson, 2019). This estimation was done by applying linear relationship from these calculations to all other rearing alternatives, based on the length of their rearing period.

Labour demand per reared animal included all work associated to the animals during indoor and grazing periods, but not work connected to feed cropping and maintenance of pasture (Table A2b). Labour demand was computed by using a model (Nelson, 2002) which produces estimates based on recorded labour data from beef herds of varying size (Bostad et al., 2011; Nelson, 2002). The model is constructed as $t = a / x + b$ where t is the labour needed per head and day of a specific type of animal, a is the fixed labour needed per day for a herd of a specific size, x is the number of the specific animals (calves and young cattle during the indoor period and young cattle on pasture) and b is the variable time needed per head and day.

2.4. Sensitivity analyses

In addition to the basic calculations CM for six other situations was calculated. Those sensitivity analyses were:

- Higher payment and support by increasing the proportion of semi-natural pastures rendering high level of agri-environmental payment to 70 %
- Higher carcass revenues due to production of certified pasture beef with a premium of +0.29 Euro/kg
- Decreased labour cost due to decreased frequency of animal surveillance on pasture from once a day to once a week
- Decreased costs for grass-clover silage with 0.02 Euro/kg dry matter due to e.g. higher yield of grass-clover and/or lower cost for machines
- Decreased size of pasture enclosures from 8−16 ha in the basic calculation to 2 ha, independent of herd size
- Use of existing buildings without opportunity cost for winter housing

3. Results

3.1. Basic calculations

The revenues in the beef enterprise compose of two parts, payment for carcasses and agri-environmental payments and supports. The payments and supports compose 10–15 % of the revenue for bulls and 30–47 % of the revenue for steers where the largest proportion is derived for the extensive steers with two summers on semi-natural pastures (d 28 and d × b 28). The largest cost is winter feed (40–75 % of this is silage costs), followed by costs for building, labour and calf (Table A4). Building and labour costs show positive responses from economy of scale, where these costs are diminished more sharply between 50 and 100 animals slaughtered per year than between 100 and 150 animals slaughtered per year (Table A4).

In all regions, the highest CM is obtained for crossbreed bulls in herds with 150 slaughtered animals per year (Fig. 2). Also, herds with 100 slaughtered bulls per year have a CM above zero in all four cases in Gns and in two cases in Nn (Fig. 2, Table A4).

For grazing steers to be competitive, CM must be higher than CM for the corresponding indoor bulls. As a result of lower feed costs in Gns and Nn compared to Gsk, steers have CM above zero in herds slaughtering 150 animals per year in all four cases in Gns and in one case in Nn (Fig. 2, Table A4). In Gsk, d × b 28 has a CM above zero in the largest herd size due to high amount of LFA (Fig. 2, Table A4). However, steers have lower CM than comparable bulls for all breeds, regions and herd sizes studied (Fig. 2, Table A4). Steers are less competitive compared to indoor bulls mainly due to higher costs for labour and buildings, where the costs are 8–143 and 34–148 Euro higher per reared animal respectively (Table A4). Steers also have higher feed costs due to higher consumption, especially in Gsk where feed costs are higher than in Gns and Nn (Table A4).

Small herds with 50 reared animals per year have a CM below zero regardless of gender, breed, or region due to high costs for labour and buildings (Fig. 2, Table A4).

3.2. Sensitivity analyses

Results from the sensitivity analyses in Table 2 show the beef

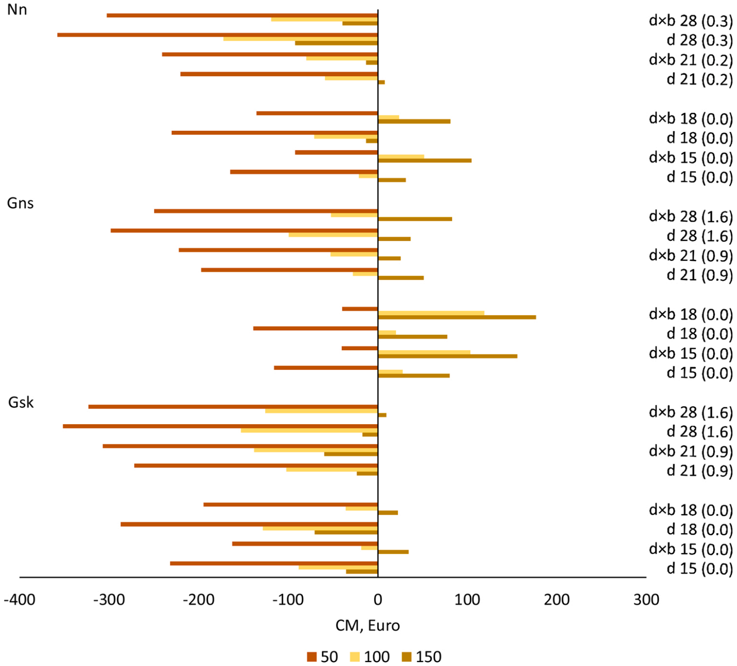

Fig. 2. Basic calculation of contribution margin (CM = contribution to management and risk) in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system (15, 18, 21, 28 is age at slaughter in months with ha grazed semi-natural pastures per animal within parenthesis), and herd sizes (50, 100, 150 is number of heads slaughtered per year), in northern districts Nn, plain districts Gns, and forest districts Gsk, Euro per reared animal.

production system that yield the highest CM when CM is above zero, where grazing steer alternatives are marked in bold. Compared to the basic calculation, the sensitivity analyses demonstrate several possible ways of increasing the competitiveness of grazing steers, both the result as such and compared to indoor bulls (Table 2).

Steers compete better with bulls when purebred dairy cattle are used compared to situations with dairy × beef crossbreeds, although the crossbreds in general have higher CM than purebred dairy cattle (Tables 2 and A4). The most economically sustainable steer production system is more often from the extensive systems (d 28, d × b 28) than from the intensive systems (d 21, d × b 21; Table 2).

If 70 % of the semi-natural pastures render payments for high biodiversity and cultural values, instead of 30 % as in the basic calculations, the CM of the steers increase with 65–111 Euro per steer, whereas the CM of the bulls is not affected (Table A5). Hence, the competitiveness of steers compared to bulls is increased with steers being more profitable than bulls in several cases. Steers in large herds with 150 slaughtered animals per year in Gns and Gsk have CM above zero with the highest results for the extensive steers grazing the most semi-natural pastures (d 28 and d × b 28). The intensive steer d 21 in Gns has the highest CM in herds with 100 slaughtered animals per year. In the other calculated alternatives, bulls are more profitable than steers and/or there is no CM above zero (Table 2).

Also, premium-priced pasture beef (+ 0.29 Euro/kg carcass) increases the revenue and the CM of the steers, whereas the CM of the bulls is unchanged. The increase in revenue for the steers is 66–97 Euro compared to the basic calculation, depending on carcass weight, making the steers more profitable than the bulls in most calculations (Table A6). Most steers in large herds with 150 slaughtered animals per year and also some steers in herds with 100 slaughtered animals per year have CM above zero and somewhat higher than CM for the corresponding indoor bulls (Table 2).

Decreasing labour demand on pasture from daily to weekly animal surveillance has a slightly lower impact on the CM, 20–66 Euro per steer depending on slaughter age and time spent on pasture (Table A7). Nevertheless, the extensive steers (d 28 and d × b 28) become the most profitable alternative in most calculations in Gns and Gsk in large herds (Table 2).

Decreased cost for grass-clover silage by 0.02 Euro per kg of dry matter reduces the costs and increase the CM for both steers and bulls, but the extensive steers benefit most as they consume the largest amount of silage (Table A8). Steers become most profitable in three calculations of large herds with 150 slaughtered animals per year, whereas the bulls continue to have the highest CM in most calculations (Table 2).

Small pasture enclosures of 2 ha, compared to 4.5−18 ha in the basic calculation, increase the costs of fencing and management with 10–165 Euro per steer (Table A9). The profitability and competitiveness of steers compared to bulls is drastically decreased and all steer alternatives have a CM below zero (Tables 2 and A9).

The most important factor to reduce the total costs is if there are possibilities to utilize existing buildings that have no profitable alternative use, i.e. buildings without opportunity cost. Depreciation and interest on new buildings are calculated to 263–377 Euro per reared animal and thereby represent a substantial cost in beef enterprises. As shown in Tables 2 and A10, steers outcompete bulls in a majority of alternatives (10 out of 18 calculations). A CM above zero is obtained for all combinations of gender, feed intensity, breed and region, also for small herds.

When combining premium-priced pasture beef, decreased labour on pasture and reduced silage cost, steers in herds with 100 and 150 slaughtered animals per year have a positive CM in all regions (Table A6–8). All steer alternatives have a higher, or similar, CM compared to bulls in these herds. Bulls are only favoured by a decreased cost of silage, 14–30 Euro per bull, whereas steers both get an additional revenue for

Table 2
Beef production with highest positive contribution margin (CM) in the basic calculation and six sensitivity analyses in enterprises with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production systems (15, 18, 21, 28 is age at slaughter in months), and herd sizes (50, 100, 150 is number of heads slaughtered per year), in northern districts Nn, plain districts Gns, and forest districts Gsk. Situations where positive and highest CM is obtained with grazing steers are marked bold. Empty cells imply no alternatives reach CM above zero.

	Dairy			Dairy × beef		
	Nn 50	Nn 100	Nn 150	Nn 50	Nn 100	Nn 150
Basic calculation			d 15		d × b 15	d × b 15
Pasture 70 % high value			d 15		d × b 15	d × b 15
Certified pasture beef		**d 21**	**d 21**		d × b 15	d × b 15
Decreased labour			d 15		d × b 15	d × b 15
Decreased silage cost			**d 21**		d × b 15	d × b 15
Pasture size 2 ha			d 15		d × b 15	d × b 15
Existing building	**d 21**	**d 21**	**d 21**	d × b 15	d × b 18	d × b 18
	Gns 50	Gns 100	Gns 150	Gns 50	Gns 100	Gns 150
Basic calculation		d 15	d 15		d × b 18	d × b 18
Pasture 70 % high value		**d 21**	**d 28**		d × b 18	**d × b 28**
Certified pasture beef		**d 21**	**d 21**		d × b 18	**d × b 28**
Decreased labour		d 15	**d 28**		d × b 18	d × b 18
Decreased silage cost		d 18	d 18		d × b 18	d × b 18
Pasture size 2 ha		d 15	d 15		d × b 18	d × b 18
Existing building	d 18	d 18	**d 28**	d × b18	d × b 18	**d × b 28**
	Gsk 50	Gsk 100	Gsk 150	Gsk 50	Gsk 100	Gsk 150
Basic calculation						d × b 15
Pasture 70 % high value			**d 28**			**d × b 28**
Certified pasture beef			**d 28**			**d × b 28**
Decreased labour			**d 28**			**d × b 28**
Decreased silage cost			**d 28**			**d × b 28**
Pasture size 2 ha						d × b 15
Existing building	d 21	**d 28**	**d 28**	d × b 18	**d × b 28**	**d × b 28**

the carcasses and less costs for labour and silage, totally 137–198 Euro per steer.

In a situation with small-sized (2.0 ha) pasture enclosures, the extra costs can be overridden by an improvement from premium-priced pasture beef, less labour and silage costs in some calculations, especially in Gns (Table A6–9). Also, utilization of buildings with no opportunity cost as a single measure of improvements override the extra cost of small pasture enclosures for all steer alternatives in large herds, irrespective of region (Table A9–10).

4. Discussion

4.1. Large advantages for biodiversity with profitable steer production

Maintained and preferably expanded grazing of semi-natural pastures is important for preserving biodiversity and cultural values in Sweden as stated in the introduction. These values are threatened by the fact that the number of cows in Sweden has decreased from 639 000 in 1995 to 506 000 in 2019 because of rapidly decreasing numbers of dairy cows and a lower increase in numbers of suckler cows. There is a risk that the numbers of suckler cows also will decrease in the next decade, e. g. as a result of changes in EU's coming Common Agriculture Policy (CAP) (Swedish Board of Agriculture, 2021a,b). It is therefore important, from a nature conservation point of view, that the calves born to the remaining cows graze as much as possible during their lifetime. This can be done by rearing bull calves as grazing steers instead of intact indoor bulls. During the years 2015–2019, slaughter of bulls in Sweden was, on average, 175 000 animals per year and steers only 35 000 animals. If 100 000 of these bulls were raised in a 28 months steer production system in the future, the area of grazed semi-natural pastures would increase with 160 000 ha, which corresponds to more than one third of the pastures of today (Swedish Board of Agriculture, 2020a). Thus, there is a great biological potential to be realized by increasing the number of grazing steers. But this requires a profitable steer production.

The number of cattle enterprises in Sweden has decreased from 42 000 enterprises in 1995 to only 15 000 enterprises in 2019 (Swedish Board of Agriculture, 2020a). To ensure grazing on the increasing number of farms, which no longer have cattle of its own, and on small and scattered pastures, a solution could be grazing-entrepreneurs who rotate grazing livestock around several farms and sites. A grazing entrepreneur may operate a large herd, hence benefitting from economies of scale, and manage many otherwise not grazed pastures (Kumm, 2014) thereby maintaining the biodiversity of the land. Steers are well suited for this type of activities, as they are easy to handle and without need of any reproductive procedures. If the number of cattle herds continues to decrease, the importance of steers will increase for grazing-dependent nature conservation purposes.

4.2. Profitable steer production requires large herds and large pastures

Our results show grazing steers are profitable, i.e. they result in CM above zero and at the same time having CM higher than the corresponding bulls, almost exclusively in the largest herds with 150 slaughtered animals per year, as large herds distribute their fixed costs across more animal units (Short, 2001). The only exceptions are the sensitivity analysis using existing buildings without opportunity cost, where also smaller steer herds can be profitable, and in the sensitivity analyses with 70 % semi-natural pasture with high values and premium-priced pasture beef where steers in herds with 100 animals are profitable in some calculations. The problem with existing buildings is finding a suitable barn in the neighbourhood, and since existing buildings are older, they need more maintenance. Furthermore, as existing buildings eventually become worn out or outdated and in need of replacing with new ones, our calculations indicate that in the long run large herds are required for grazing steers to be able to compete economically with indoor bulls.

Extensive steers with large pasture herbage consumption and thus great nature conservation benefits (d 28 and d × b 28) in herds with 150 slaughtered animals per year give CM above zero. This is also higher than bulls' CM in the forest district Gsk in all calculations, except in the basic calculation and the sensitivity analysis with 2 ha pasture enclosures. The same applies in the plain district Gns in the sensitivity analyzes with 70 % semi-natural pasture with high values as well as for extensive dairy calves (d 21 and d × b 28) with premium-priced pasture beef and for extensive dairy calves (d 28) at decreased labour demand on pasture. In Nn, where only 20 % of the grazing occurs on semi-natural pasture, these extensive steers are not competitive even when grazing 70 % semi-natural pasture with high values. In the present study, rather high-yielding semi-natural pastures was supposed (1.5-ton dry matter per ha). With a lower biomass production, every steer would have been able to manage a larger area and hence render more agri-environmental payments (Hessle and Kumm, 2011). The demand of semi-natural pasture for 150 steers slaughtered at 21 months of age, grazing one summer, is 150 × 0.9 = 135 ha and for the same herd size steers reared to 28 months of age, grazing two summers, require 150 × 1.6 = 240 ha. In most forest districts, such as Gsk, it is difficult, or even impossible, to gather such large pastures areas within a reasonable distance.

In an area representative for Gsk, the farm enterprises have on average only 10 ha semi-natural pastures, and the average size of pasture enclosure is only 2 ha (Swedish Board of Agriculture, 2007). Among particularly biologically valuable pastures included in a national meadow and pasture inventory, the average pasture enclosure area is 2.8 ha, and the median size is 1.5 ha in Gsk (Larsson et al., 2020). In plain districts, pastures are generally much larger than in forest districts (Larsson et al., 2020; Swedish Board of Agriculture, 2007), which points to better conditions for economically sustainable steer production in these areas.

4.3. Pasture-forest mosaics preserve semi-natural pastures in forest districts

Previous studies show that suckler-based beef production can be profitable in forest districts if large coherent pasture enclosures are made from existing small scattered semi-natural pastures together with intermediate and adjacent marginal arable land and forests, which in many cases are abandoned and forested agricultural land (Kumm and Hessle, 2020). Likewise, post-calculations of beef suckler holdings in forest districts resulted in better profitability after having created large coherent pastures (Holmström et al., 2018). This suggests that also steers from dairy origin may become economically sustainable if there are possibilities to create large coherent pasture-forest mosaics. Creating such large coherent pasture-mosaics can, however, be difficult due to intersecting roads and scattered habitations.

4.4. Grazing in forest district and wintering in plain district

Extensive steers (d 28 and d × b 28) can be profitable in large herds with 150 animals in forest district Gsk, as well as intensive steers (d 21) in northern Sweden Nn, as seen in the sensitivity analysis with decreased silage cost but otherwise the same conditions as in the basic calculation. This cost reduction can possibly be achieved if the silage is not grown on the small fields in the forest districts but on large rational fields in the plains. For beef enterprises in the areas between plain and forest district, steers could be wintered in the plains and graze during summer in the forest district. In addition to economic benefits for the cattle rearing, more grass-growing and available manure in the grain-dominated plains would be beneficial for the environment and the crop production.

A combination of the on-farm measures premium-priced pasture beef, decreased labour on pasture and decreased silage cost, result in competitiveness for the grazing steers in Gsk and Nn, also in herds with only 100 animals slaughtered per year. Animal surveillance could be achieved by a combination of contracted neighbours and digital sensors if the Swedish animal welfare regulation will allow (Swedish Board of Agriculture, 2019a) partly replacing manual supervision with remote digital means.

4.5. Seasonal variation in slaughter age

The present study was based on calves born from dairy cows evenly distributed throughout the year. The steers therefore reached the slaughter ages of 21 and 28 months evenly distributed over the year, including in spring just before the start of the grazing period. If steers planned to be slaughtered close to a new grazing period instead are provided for an additional grazing season, they very likely will be more profitable as they both increase their weight and also receive further agri-environmental payments and supports for the increased pasture area. The additional costs during such an additional grazing period are limited to pasturing, labour and interest rate on working and animal capital for a few months. This hypothesis is supported by the fact that suckler beef steers slaughtered at 30 months of age in the autumn were more profitable than steers slaughtered five months earlier in the spring (Hessle & Kumm, 2011). Such a seasonal postponement of the slaughter would improve the profitability of the steer production and thereby the competitiveness against indoor bulls indicated in Table 2. In addition, larger areas of semi-natural pasture would be grazed, especially in early summer when there is a general surplus of grazing.

4.6. Combination of steers and bulls

Another interesting combination for a profitable beef enterprise with semi-natural pastures could be a combination of steers and bulls. Using calves born in the second half of the year as steers, they spend as much as possible of their lifetime on pasture while calves born in the first half of the year are kept as intact bulls and reared indoors. Such an arrangement would provide economies of scale also when the area of available semi-natural pastures is limited. The present results indicate that, if possible, dairy breed calves would preferably be reared as steers and dairy × beef breeds as intact bulls.

4.7. Rationalization, political means and market support to preserve pastures

Results show that large herds and large areas of semi-natural pastures are required for steer production to be profitable. Sensitivity analyses also show that higher agri-environmental payment and support for semi-natural pastures, additional payment for premium-priced pasture beef, and lower requirements for frequent animal supervision on pasture may be needed for grazing steers to be able to compete with indoor bulls if fewer and fewer calves are born. Those arrangements presume political decisions, actions from the market, and adaptation of the production system. Without those arrangements, there is a great risk that steer production and maintenance of semi-natural pastures decrease as existing buildings with no alternative use and old cattle farmers with low profitability demands exit farming.

5. Conclusion

The basic calculation shows that under current normal Swedish conditions indoor bulls are more profitable than grazing steers, regardless of breed, herd size, and geographical region. Steers in large herds grazing on semi-natural pastures can also be profitable, especially in extensive systems and when rearing purebred dairy cattle, but not as profitable as bulls in the basic calculation. However, the sensitivity analyses show a range of measures resulting in grazing steers becoming more profitable than bulls. Decreasing the cost by utilizing buildings without profitable alternative use, or increasing the revenue by grazing a large proportion of semi-natural pastures rendering payment for high biodiversity and cultural values, are ways of obtaining both positive economic results and outcompeting the bulls. Lowering the winter feed cost, reducing the labour demand on pasture and increasing the revenue by producing certified premium-priced pasture beef can further improve the profitability. Taken together, these suggestions contribute to an economically sustainable beef production with grazing dairy-born steers, which enables management and hence conservation of large areas of semi-natural pastures with high biological and cultural values.

Funding

This study was funded by Västra Götalandsregionen (grant number RUN 2018-00137), the Rural Economy and Agricultural Society Sjuhärad, Nötkreatursstiftelsen Skaraborg and the Swedish University of Agricultural Sciences.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgements

We thank Lars Neuman, Spirina consult, for showing his calculations of costs for silage production during different conditions such as shape of field and distance to farm centre. We also thank Sofia Lindman Larsson, HS Konsult AB, for great work with building costs calculations.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnc.2021.126010.

References

Agriculture & Horticulture Development Board. (2019). *Agriculture & Horticulture Development Board*. AHDB Beef & Lamb. http://beefandlamb.ahdb.org.uk/.
Agriwise. (2020). *Agriwise—Smart kalkylering*. https://www.agriwise.se/web.
Blake, W. H., Rabinovich, A., Wynants, M., Kelly, C., Nasseri, M., Ngondya, I., Patrick, A., Mtei, K., Munishi, L., Boeckx, P., Navas, A., Smith, H. G., Gilvear, D., Wilson, G., Roberts, N., & Ndakidemi, P. (2018). Soil erosion in East Africa: An interdisciplinary approach to realising pastoral land management change. *Environmental Research Letters, 13*(12), Article 124014. https://doi.org/10.1088/1748-9326/aaea8b.
Bostad, E., Swensson, C., & Pinzke, S. (2011). Labour input in specialist beef bull production in Sweden. *Agricultural Engineering International: CIGR Journal, 13*(3). http://cigrjournal.org/index.php/Ejounral/article/view/1920.
Dahlström, A., Lennartsson, T., Wissman, J., & Frycklund, I. (2008). Biodiversity and traditional land use in South-Central Sweden: The significance of management timing. *Environment and History, 14*(3), 385–403.
Davidson, K. E., Fowler, M. S., Skov, M. W., Forman, D., Alison, J., Botham, M., Beaumont, N., & Griffin, J. N. (2020). Grazing reduces bee abundance and diversity in saltmarshes by suppressing flowering of key plant species. *Agriculture, Ecosystems & Environment, 291*, Article 106760. https://doi.org/10.1016/j.agee.2019.106760.
Deblitz, C. (ed). (2019). Agri benchmark. http://www.agribenchmark.org/beef-and-sheep/publications-and-projects.html.
Department of Agriculture, F. & the M. (2018). *Bovine statistics Ireland (Ireland)*. Ireland: Department of Agriculture, Food & the Marine. https://www.agriculture.gov.ie/animalhealthwelfare/animalidentificationmovement/cattle/.
Eriksson, S., Ask-Gullstrand, P., Fikse, F. W., Jonsson, E., Eriksson, J.-Å., Stålhammar, H., Wallenbeck, A., & Hessle, A. (2020). Different beef breed sires used for crossbreeding with Swedish dairy cows—Effects on calving performance and carcass traits. *Livestock Science, 232*. https://doi.org/10.1016/j.livsci.2019.103902.
Errington, A. (1998). The increasing flexibility of machinery and labour inputs to UK farming. *Études et Recherches Sur Les Systèmes Agraires et Le Développement, INRA Editions* (pp. 371–385).
European Commission. (2001). *The welfare of cattle kept for beef production (Sanco.C2/AH/R22/2000)* (p. 150). https://ec.europa.eu/food/sites/food/files/safety/docs/sci-com_scah_out54_en.pdf.
European Commission. (2019). *Eurostat*. https://ec.europa.eu/eurostat/data/browse-statistics-by-theme.
FAO. (2017). *Livestock solutions for climate change*. Food and Agriculture Organization of the United Nations. http://www.fao.org/home/en/.
Hansen, S., Messer, T., Mittelstet, A., Berry, E. D., Bartelt-Hunt, S., & Abimbola, O. (2020). Escherichia coli concentrations in waters of a reservoir system impacted by cattle and migratory waterfowl. *The Science of the Total Environment, 705*, Article 135607. https://doi.org/10.1016/j.scitotenv.2019.135607.
Hessle, A., & Kumm, K.-I. (2011). Use of beef steers for profitable management of biologically valuable semi-natural pastures in Sweden. *Journal for Nature Conservation, 19*(3), 131–136. https://doi.org/10.1016/j.jnc.2010.10.002.
Hessle, A., Therkildsen, M., & Arvidsson-Segerkvist, K. (2019). Beef production systems with steers of dairy and dairy × beef breeds based on forage and semi-natural pastures. *Animals, 9*(12), 1064. https://doi.org/10.3390/ani9121064.
HKScan Agri. (2021). *HKScan Agri notering | HKScan Agri*. http://www.hkscanagri.se/notering/.
Holmström, K., Hessle, A., Andersson, H., & Kumm, K.-I. (2018). Merging small scattered pastures into large pasture-forest mosaics can improve profitability in swedish suckler-based beef production. *Land, 7*(2), 58. https://doi.org/10.3390/land7020058.
Isselstein, J., Jeangros, B., & Pavlu, V. (2005). Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe – A review. *Agronomy Research, 3*(2), 139–151.
Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the köppen-geiger climate classification updated. *Meteorologische Zeitschrift, 15*, 259–263. https://doi.org/10.1127/0941-2948/2006/0130.
Kumm, K.-I. (2014). Rädda naturbetesmarkerna med stutar och naturvårdsentreprenörer. *Svensk botanisk tidskrift, 108*(6), 334–337.
Kumm, K.-I., & Hessle, A. (2020). Economic comparison between pasture-based beef production and afforestation of abandoned land in Swedish forest districts. *Land, 9*(2), 42. https://doi.org/10.3390/land9020042.
Länsstyrelsen Västra Götaland. (2020). *Bidragskalkyler för konventionell produktion 2020*. Länsstyrelsen Västra Götaland. https://www.lansstyrelsen.se/download/18.52ea1660172a20ba65cd6ac/1594195115891/Bidragskalkyler-konv-2020.pdf.
Larsson, C., Bode Olén, N., & Brady, M. (2020). *Naturbetesmarkens framtid—En fråga om lönsamhet (2020:1)*. AgriFood Economics Centre. https://agrifood.se/Files/AgriFood_Rapport20201.pdf.
Lindborg, R., & Eriksson, O. (2004). Effects of restoration on plant species richness and composition in Scandinavian semi-natural grasslands. *Restoration Ecology, 12*(3), 318–326. https://doi.org/10.1111/j.1061-2971.2004.00334.x.
Lindman Larsson, S. (2019). *HS konsult AB, Uppsala, Sverige. Personligt meddelande [Personal communication]*. February 11.
Luoto, M., Rekolainen, S., Aakkula, J., & Pykälä, J. (2003). Loss of plant species richness and habitat connectivity in grasslands associated with agricultural change in Finland. *Ambio, 32*, 447–452. https://doi.org/10.1579/0044-7447-32.7.447.
Nadeau, E., Wallin, K., Dahlström, F., Stenberg, E., Johansson, M., & Hessle, A. (2020). Performance of dairy x beef bulls and dairy bulls. In *Book of abstract, 33944*.
Nelson, B.-O. (2002). *Kalkylmodell för nötköttsproduktion. Skogs- och lantarbetsgivareförbundets analysgrupp*.
Neuman, L. (2019). *Spirina Consult, Timmele, Sverige. Personligt meddelande [Personal communication]*.
Short, S. D. (2001). *Characteristics and production costs of U.S. cow-calf operations (Statistical Bulletin No. 974–3)* (p. 26). U.S. Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/publications/pub-details/?pubid=47151.
Statistics Sweden. (2018). *The farm economics survey 2018*. Statistics Sweden. http://www.scb.se/hitta-statistik/statistik-efter-amne/jord-och-skogsbruk-fiske/jordbrukets-ekonomi/jordbruksekonomiska-undersokningen/pong/publikationer/jordbruksekonomiska-undersokningen-2018/.
Steinfeld, H., Gerber, P., Wasswnaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). *Livestock's long shadow* (p. 390).
Swedbank, Sparbankerna, & LRF Konsult. (2019). *Lantbruksbarometern 2019*. https://online.swedbank.se/ConditionsEarchive/download?bankid=1111&id=WEBDOC-PRODE30743892.
Swedish Board of Agriculture. (2005). *Svenskt jordbruk i siffror 1800—2004*. http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Annan%20statistik/Statistikrapport/20056/20056_inEnglish.htm.
Swedish Board of Agriculture. (2007). *Jordbrukets miljöeffekter 2020—En framtidsstudie/Agricultures' environmental impacts 2020—A future study*. Jönköping, Sweden http://webbutiken.jordbruksverket.se/sv/artiklar/jordbrukets-miljoeffekter-2020.html.
Swedish Board of Agriculture. (2019a). *Regulations and general advices by the Swedish Animal Welfare Agency for animal husbandry in agriculture*. http://djur.jordbruksverket.se/amnesomraden/djurhalsopersonal/veterinaraforfattningshandboken/ldjurskydd/jordbruksverketsforfattningarinomomrade ldjurskydd.4.5fa25aa016d179872d24e5c5.html#h-L104notkreaturshallninginomlantbruketmm.
Swedish Board of Agriculture. (2020a). *Agricultural statistics [Text]*. https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksstatistisk-sammanstallning.
Swedish Board of Agriculture. (2021a). *CAP-reformen hotar betesmarkerna men ger också möjligheter—Resultat från modellberäkningar*. Swedish Board of Agriculture. https://jordbruksverket.se/download/18.1a74af1a177a8cbc6f8758d3/.
Swedish Board of Agriculture. (2020b). *Priser och marknadsinformation för livsmedel [Text]*. https://jordbruksverket.se/mat-och-drycker/handel-och-marknad/priser-och-marknadsinformation-for-livsmedel.
Swedish Board of Agriculture. (2021b). *Stöd till lantbrukare och verksamma på landsbygden [Text]*. https://nya.jordbruksverket.se/stod.
Swedish Species Information Centre. (2020). *Rödlistade arter i Sverige 2020 (Redlisted Species in Sweden 2020)*. https://www.artdatabanken.se/ www.artdatabanken.se.
Terres, J.-M., Scacchiafichi, L. N., Wania, A., Ambar, M., Anguiano, E., Buckwell, A., Coppola, A., Gocht, A., Källström, H. N., Pointereau, P., Strijker, D., Visek, L., Vranken, L., & Zobena, A. (2015). Farmland abandonment in Europe: Identification of drivers and indicators, and development of a composite indicator of risk. *Land Use Policy, 49*, 20–34. https://doi.org/10.1016/j.landusepol.2015.06.009.
Växa. (2019). *Cattle statistics 2019*. https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2019.pdf.
WallisDeVries, M. F., Poschlod, P., & Willems, J. H. (2002). Challenges for the conservation of calcareous grasslands in northwestern Europe: Integrating the requirements of flora and fauna. *Biological Conservation, 104*(3), 265–273. https://doi.org/10.1016/S0006-3207(01)00191-4.

Appendix

Table A1. Feed consumption of grass-clover silage in dry matter (DM), concentrates, and grazed grass per animal from weaning until slaughter, as well as the carcass traits carcass weight, conformation, and fatness for eight groups of male cattle originating from dairy cows of varying breeds (d is dairy, d x b is dairy x beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months)

Group	Feed consumption			Carcass traits		
	Silage[a], ton DM	Concent-rate[b], ton	Grass[c], ton DM	Carcass weight, kg	Confor-mation[d]	Carcass fat[e]
Grazing steers						
d 21	3.07	0.18	1.41	283	4.0	7.6
d×b 21	3.27	0.13	1.38	315	5.0	7.9
d 28	3.77	0.20	2.36	305	3.8	6.7
d×b 28	4.20	0.17	2.36	355	6.4	7.0
Indoor bulls						
d 15	1.07	2.04	0.00	321	5.4	8.0
d×b 15	1.11	2.14	0.00	371	7.2	9.2
d 18	2.14	1.84	0.00	365	5.7	8.2
d×b 18	2.24	1.90	0.00	410	7.3	10.1

[a]Partly late cut silage for d 28 and d×b 28, all other silages early cut. [b]Concentrate containing, in tons, 0.05-0.07 barley, 0.01-0.03 peas, 0.01-0.03 rape seed meal, 0.05-0.09 minerals for the steers and 1.73-1.96 barley, 0.05-0.13 peas, 0.02-0.03 rape seed cake and 0.05 minerals for the bulls. [c]Consumed amount of grass estimated from growth rate and days on pasture. [d]Scored according to the EUROP-system 1-15 where 1 is thin and 15 well developed. [e]Scored according to the EUROP-system 1-15 where 1 is lean and 15 fat (EC, 2006; Swedish Board of Agriculture, 2002).

Reference

EC, 2006, Council Regulation (EC) No 1183/2006 of 24 July 2006 concerning the Community scale for the classification of carcasses of adult bovine animals.

Swedish Board of Agriculture. 2002. SJVFS 2002:14: Föreskrifter om ändring i Statens jordbruksverks föreskrifter (SJVFS 1998:127) om klassificering av slaktkroppar | lagen.nu [Internet]. [accessed 2021 Mar 17]. https://lagen.nu/sjvfs/2002:14

Table A2a. Method and data used for calculating revenues when comparing the profitability of various combinations of gender, breed, production system, and geographical region in Swedish beef cattle originating from dairy cows; calculated in average price 2014 - 2018 for beef. Other revenues are collected from sources with prices originating from different years. Those sums are index calculated to an average price level of 2014-2018 by using series of indexes for different means of production (Swedish Board of Agriculture, 2019a); 10.25 SEK = 1 Euro; ha = hectare

Revenues	*Description*
Carcass	Carcass weight × average price paid at abattoir for steers and bulls at different classifications (HKScan Agri, 2018; Swedish Board of Agriculture, 2017)
Animal premium	Days >1 year/365 × 96 Euro (Swedish Board of Agriculture, 2019)
Single farm payment	No. of ha semi-natural pastures × 131 Euro/ha (Swedish Board of Agriculture, 2019)
Green direct payment	No. of ha semi-natural pastures × 49 Euro/ha (Swedish Board of Agriculture, 2019) × 54.04%
Agri-environmental payment	No. of ha semi-natural pastures × 98 Euro/ha for ordinary semi-natural pasture and 273 Euro/ha for especially valuable semi-natural pasture (Swedish Board of Agriculture, 2019)
Support to less-favoured area	No. of ha arable land and semi-natural pastures × depending on livestock density 98-205 Euro/ha (Gsk) or 380 Euro/ha for permanent grassland and 117 Euro/ha for grain (Nn) (Swedish Board of Agriculture, 2019)
Support to permanent grassland	No. of ha for permanent grassland (Gns) × 49 Euro/ha (Swedish Board of Agriculture, 2019)
Investment support	40 % of cost for new building but not more than 0.17 MEuro/per farm (Swedish Board of Agriculture, 2019) × annuity for 30 years and 4% interest rate

References

HKScan Agri. 2018. HKScan Agri notering/HKScan Agri listing. [Internet]. [accessed 2017 Dec 12]. http://www.hkscanagri.se/notering/notering-arkiv/

Swedish Board of Agriculture. 2017. Priser för kött och ägg [Internet]. [accessed 2017 Dec 12]. /amnesomraden/handelmarknad/kottmjolkochagg/priserforkottochagg.4.459982ee152aeb2b7653dd61.html

Swedish Board of Agriculture. 2021. Stöd till lantbrukare och verksamma på landsbygden [Internet]. [accessed 2019 Nov 28]. https://nya.jordbruksverket.se/stod

Table A2b. Method and data used for calculating variable costs and contribution margins when comparing the profitability of various combinations of gender, breed, production system, and geographical region in Swedish beef cattle originating from dairy cows; calculated in average price 2014 - 2018 for calf purchase, concentrate and labour. Other prices are collected from sources with prices originating from different years. Those sums are index calculated to an average price level of 2014-2018 by using series of indexes for different means of production (Swedish Board of Agriculture, 2019a); 10.25 SEK = 1 Euro; ha = hectare.

Variable costs	*Description*
Calf	Calf weight × price paid at abattoir for calves including intermediation fee, vaccination, dehorning and castration 2014–2018 (HKScan Agri, 2018)
Grass-clover silage	Kg dry matter (DM) × cost of production for silage in different regions, 0.10-0.17 Euro/kg DM (Neuman, 2019)
Concentrate (grain, protein feed, minerals)	Kg barley × price for barley 0.12 Euro/kg in Gns (selling), 0.16 Euro/kg in Gsk (purchasing) and 0.12 Euro/kg in Nn (selling) (Swedish Board of Agriculture, 2019). Kg rape seed meal × price for rape seed meal 0.32 Euro/kg in Gns/Nn and 0.36 Euro/kg in Gsk (Swedish Board of Agriculture, 2019). Kg peas × price for peas 0.18 Euro/kg in Gns/Nn and 0.22 Euro/kg in Gsk (Swedish Board of Agriculture, 2019). Kg mineral and supplementary mineral × price for minerals 0.56 Euro/kg and supplements 0.14 Euro/kg (Vallberga Lantmän, 2018)
Grazed herbage	Kg DM × 0.02 Euro/kg dry matter grass on permanent grassland and 0.08-0.12 Euro/kg DM grass on semi-natural pasture (Kumm, 2020; Swedish Board of Agriculture, 2005)
Bedding	Amount of wood shaving × 18 Euro/m^3 (Gradén, 2017)
Veterinary, medicine, mortality, various cost	Information from Swedish agricultural economics survey 2017 (Leonardsson, 2019)
Building maintenance cost	Building cost (Lindman Larsson, 2019), 0.5% yearly maintenance (Swedish Board of Agriculture, 2018)
Labour	Labour, hours × 22 Euro per hour average 2014–2018 (Agriwise, 2020)
Building depreciation and interest	Building cost (Lindman Larsson, 2019). Annuity at depreciation 30 years for building structure and 15 years for equipment, 4% interest rate (Swedish Board of Agriculture, 2018)
Interest working capital	Rearing time in year × variable costs exclusive calf purchase, intermediation fee, vaccination, dehorning, castration × 0.55 × 4% interest rate (Agriwise, 2020)
Interest animal capital	Rearing time in year × calf purchase including intermediation fee, vaccination, dehorning, castration × 4% interest rate

References

Agriwise. 2020. Agriwise - Smart kalkylering [Internet]. [accessed 2020 Nov 4]. https://www.agriwise.se/web

HKScan Agri. 2021. HKScan Agri notering/HKScan Agri listing. [Internet]. [accessed 2017 Dec 12]. http://www.hkscanagri.se/notering/notering-arkiv/

Neuman L. 2019. Spirina Consult, Timmele, Sweden. Unpublished data.

Vallberga Lantmän. 2018. Sweden. Personal communication.

Gradén H. 2017. Granareds Gård AB, Hökerum, Sweden. Personal communication.

Kumm, K.-I., & Hessle, A. (2020). Economic Comparison between Pasture-Based Beef Production and Afforestation of Abandoned Land in Swedish Forest Districts. *Land*, *9*(2), 42. https://doi.org/10.3390/land9020042

Leonardsson M. 2019. Jordbrukstekniska undersökningen 2017, SCB, Sverige. Personal communication.

Lindman Larsson S. 2019. HS konsult AB, Uppsala, Sweden. Unpublished data.

Swedish Board of Agriculture. 2005. Ängs- och betesmarksinventeringen 2002-2004 [Internet]. [accessed 2017 May 15]. http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra05_1.pdf

Swedish Board of Agriculture. 2018. Bygg smartare stall [Internet]. [accessed 2020 Jun 9]. https://jordbruksverket.se/utveckla-foretagande-pa-landsbygden/bygg-smartare-stall

Swedish Board of Agriculture. 2019. Agricultural statistics [Internet]. [accessed 2020 Mar 3]. http://www.jordbruksverket.se/swedishboardofagriculture/engelskasidor/statistics.4.68dc110a12390c69dde8000500.html

Table A3. Descriptions of three geographical regions, showing their type, field configuration, silage chain, farm size for opportunity cost calculation, and yields of harvested grass-clover silage and grazed semi-natural pastures and leys, expressed in ton dry matter (DM) per hectare (ha), and size of pasture enclosures for herds of varying size

Item	Gsk	Gns	Nn
Full name	Forest districts in southern Sweden	Plain districts in southern Sweden	Lower parts of northern Sweden
Field structure	Scattered fields, irregular shapes	Large fields, rectangular shape	Scattered fields, irregular shapes
Grass-clover silage chain	Round bale	Silo	Silo
[a]Farm size for opportunity cost calculation, ha	150	500	150
[b,c]Yield harvested grass-clover silage, ton DM	7.0	9.0	7.0
[d]Yield grazed herbage on semi-natural pasture, ton DM	1.5	1.5	1.5
Yield grazed herbage pastured on ley, ton DM	-	-	5.5
[d]Size of enclosures, 50 slaughtered animals per year, ha	4.5	4.5	4.5
Size of enclosures, 100 slaughtered animals per year, ha	8	8	8
Size of enclosures, 150 animals slaughtered per year, ha	18	18	18

References

[a]Agriwise. (2020). Agriwise - Smart kalkylering [Internet]. [accessed 2020 Nov 4]. https://www.agriwise.se/web

[b]Berlin-Thorell K. (2020). Advisor, Rådgivarna i Sjuhärad, Länghem, Sweden. Personal communication.

[c]Bernes G. (2020). Researcher, Umeå, Swedish University of Agricultural Sciences. Personal communication.

[d]Spörndly E. & Glimskär A. (2018). Betesdjur och betestryck i naturbetesmarker. Department of Animal Nutrition and Management, Uppsala, Swedish University of Agricultural Sciences. Report 297, ISSN 0347-9838.

Table A4a. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 50 animals to slaughter per year and located in forest districts of Götaland (Gsk), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	126	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	135	135	206	212	31	33	63	66
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	130	130	130	130	130	130	130	130
Sum revenues	1 749	1 871	2 162	2 401	1 423	1 623	1 653	1 839
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	480	511	588	655	166	174	334	350
Concentrate (grain, protein feed, minerals)	61	48	87	78	352	367	323	332
Grazed herbage	183	179	306	305	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	43	43	50	50	37	37	40	40
Labour	315	314	392	386	248	249	305	305
Building depreciation and interest	478	478	558	558	410	410	444	444
Interest working capital	39	40	70	73	21	21	31	32
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	855	863	1 053	1 062	693	699	801	804
Contribution margin	*-272*	*-307*	*-352*	*-323*	*-232*	*-162*	*-287*	*-194*

Table A4b. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 100 animals to slaughter per year and located in forest districts of Götaland (Gsk), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	126	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	135	135	206	212	31	33	63	66
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	65	65	65	65	65	65	65	65
Sum revenues	1 684	1 806	2 097	2 336	1 358	1 558	1 588	1 774
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	480	511	588	655	166	174	334	350
Concentrate (grain, protein feed, minerals)	61	48	87	78	352	367	323	332
Grazed herbage	174	170	292	291	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	31	31	38	38	25	25	28	28
Labour	237	236	294	289	185	186	228	228
Building depreciation and interest	346	346	425	425	277	277	312	312
Interest working capital	36	37	64	67	19	19	29	29
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	641	649	816	827	497	502	589	593
Contribution margin	*-102*	*-138*	*-153*	*-126*	*-88*	*-19*	*-128*	*-36*

Table A4c. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 150 animals to slaughter per year and located in forest districts of Götaland (Gsk), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	126	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	135	135	206	212	31	33	63	66
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	43	43	43	43	43	43	43	43
Sum revenues	1 662	1 785	2 076	2 315	1 337	1 536	1 566	1 752
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	480	511	588	655	166	174	334	350
Concentrate (grain, protein feed, minerals)	61	48	87	78	352	367	323	332
Grazed herbage	154	151	225	224	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	27	27	34	34	21	21	24	24
Labour	211	211	261	257	165	165	203	202
Building depreciation and interest	297	297	377	377	229	229	263	263
Interest working capital	34	35	60	62	18	19	28	28
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	565	573	730	741	427	432	514	517
Contribution margin	*-23*	*-60*	*-17*	*9*	*-36*	*34*	*-71*	*22*

Table A4d. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 50 animals to slaughter per year and located in plain districts in southern Sweden (Gns), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	0	0	0	0	0	0	0	0
Support to permanent grassland	17	18	20	23	6	6	12	12
Investment support	130	130	130	130	130	130	130	130
Sum revenues	1 631	1 754	1 979	2 213	1 398	1 596	1 602	1 786
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	299	318	366	408	103	108	208	218
Concentrate (grain, protein feed, minerals)	55	45	83	75	276	288	255	262
Grazed herbage	183	179	306	305	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	43	43	50	50	37	37	40	40
Labour	315	314	392	386	248	249	305	305
Building depreciation and interest	478	478	558	558	410	410	444	444
Interest working capital	33	33	60	61	17	18	26	26
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	849	856	1 042	1 050	690	696	795	799
Contribution margin	*-197*	*-222*	*-298*	*-250*	*-116*	*-41*	*-139*	*-40*

Table A4e. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 100 animals to slaughter per year and located in plain districts in southern Sweden (Gns), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	0	0	0	0	0	0	0	0
Support to permanent grassland	17	18	20	23	6	6	12	12
Investment support	65	65	65	65	65	65	65	65
Sum revenues	1 566	1 689	1 914	2 147	1 333	1 531	1 537	1 721
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	299	318	366	408	103	108	208	218
Concentrate (grain, protein feed, minerals)	55	45	83	75	276	288	255	262
Grazed herbage	174	170	292	291	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	31	31	38	38	25	25	28	28
Labour	237	236	294	289	185	186	228	228
Building depreciation and interest	346	346	425	425	277	277	312	312
Interest working capital	30	30	54	55	16	16	23	23
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	635	642	805	815	493	499	583	586
Contribution margin	*-28*	*-53*	*-99*	*-52*	*28*	*103*	*20*	*119*

Table A4f. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs*. dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 150 animals to slaughter per year and located in plain districts in southern Sweden (Gns), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	123	120	206	206	0	0	0	0
Green direct payment	67	65	112	111	0	0	0	0
Agri-environmental payment	142	138	237	236	0	0	0	0
Support to less-favoured area	0	0	0	0	0	0	0	0
Support to permanent grassland	17	18	20	23	6	6	12	12
Investment support	43	43	43	43	43	43	43	43
Sum revenues	1 544	1 667	1 892	2 126	1 311	1 509	1 515	1 699
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	299	318	366	408	103	108	208	218
Concentrate (grain, protein feed, minerals)	55	45	83	75	276	288	255	262
Grazed herbage	154	151	225	224	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	27	27	34	34	21	21	24	24
Labour	211	211	261	257	165	165	203	202
Building depreciation and interest	297	297	377	377	229	229	263	263
Interest working capital	28	28	49	50	15	15	22	23
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	558	566	719	729	423	429	508	511
Contribution margin	*51*	*25*	*36*	*83*	*80*	*156*	*78*	*177*

Table A4g. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 50 animals to slaughter per year and located in lower parts of Norrland (Nn), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	25	24	41	41	0	0	0	0
Green direct payment	13	13	22	22	0	0	0	0
Agri-environmental payment	28	28	47	47	0	0	0	0
Support to less-favoured area	240	249	326	349	0	0	0	0
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	130	130	130	130	130	130	130	130
Sum revenues	1 589	1 726	1 841	2 096	1 392	1 590	1 590	1 773
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	400	426	490	546	138	145	278	292
Concentrate (grain, protein feed, minerals)	56	45	84	76	284	295	262	269
Grazed herbage	64	62	107	107	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	43	43	50	50	37	37	40	40
Labour	315	314	392	386	248	249	305	305
Building depreciation and interest	478	478	558	558	410	410	444	444
Interest working capital	32	33	56	58	18	19	28	28
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	848	856	1 039	1 048	691	697	797	801
Contribution margin	*-221*	*-241*	*-358*	*-303*	*-165*	*-92*	*-230*	*-135*

Table A4h. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs.* dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 100 animals to slaughter per year and located in lower parts of Norrland (Nn), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	25	24	41	41	0	0	0	0
Green direct payment	13	13	22	22	0	0	0	0
Agri-environmental payment	28	28	47	47	0	0	0	0
Support to less-favoured area	240	249	326	349	0	0	0	0
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	65	65	65	65	65	65	65	65
Sum revenues	1 524	1 661	1 776	2 031	1 327	1 525	1 525	1 708
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	400	426	490	546	138	145	278	292
Concentrate (grain, protein feed, minerals)	56	45	84	76	284	295	262	269
Grazed herbage	63	61	105	105	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	31	31	38	38	25	25	28	28
Labour	237	236	294	289	185	186	228	228
Building depreciation and interest	346	346	425	425	277	277	312	312
Interest working capital	29	30	51	53	17	17	25	26
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	634	642	802	813	494	500	585	589
Contribution margin	*-59*	*-80*	*-172*	*-119*	*-21*	*52*	*-71*	*24*

Table A4i. Basic calculation of contribution margin (= contribution to management and risk) in beef production with grazing steers and indoor bulls of varying breed (pure dairy breed *vs*. dairy × beef crossbreed) and in different production systems (15, 18, 21, 28 age at slaughter in months) at a farm sending 150 animals to slaughter per year and located in lower parts of Norrland (Nn), Euro per reared animal

	steers				bulls			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Revenues								
Carcass	1 080	1 211	1 146	1 381	1 238	1 435	1 411	1 594
Animal premium	72	71	128	126	24	24	49	49
Single farm payment	25	24	41	41	0	0	0	0
Green direct payment	13	13	22	22	0	0	0	0
Agri-environmental payment	28	28	47	47	0	0	0	0
Support to less-favoured area	240	249	326	349	0	0	0	0
Support to permanent grassland	0	0	0	0	0	0	0	0
Investment support	43	43	43	43	43	43	43	43
Sum revenues	1 502	1 639	1 754	2 009	1 306	1 503	1 504	1 687
Variable costs								
Calf	347	483	375	519	346	447	380	444
Grass-clover silage	400	426	490	546	138	145	278	292
Concentrate (grain, protein feed, minerals)	56	45	84	76	284	295	262	269
Grazed herbage	55	54	92	91	0	0	0	0
Bedding	7	7	8	8	7	7	8	8
Veterinary, medicine, mortality, various cost	45	45	45	45	55	55	55	55
Building maintenance cost	27	27	34	34	21	21	24	24
Labour	211	211	261	257	165	165	202	202
Building depreciation and interest	297	297	377	377	229	229	263	263
Interest working capital	28	28	48	50	16	16	24	25
Interest animal capital	22	31	33	45	15	19	20	24
Sum variable cost	559	567	718	729	424	430	510	514
Contribution margin	*8*	*-13*	*-93*	*-40*	*31*	*104*	*-13*	*81*

Table A5. Contribution margin when 70 % of the semi-natural pastures render payment for high biodiversity and cultural values in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production systems (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	-206	-243	-241	-213	-232	-162	-287	-194
Gsk 100	-36	-74	-42	-15	-88	-19	-128	-36
Gsk 150	43	5	94	120	-36	34	-71	22
Gns 50	-131	-158	-188	-140	-116	-41	-139	-40
Gns 100	38	12	11	58	28	103	20	119
Gns 150	117	90	147	193	80	156	78	177
Nn 50	-207	-228	-336	-281	-165	-92	-230	-135
Nn 100	-46	-67	-150	-97	-21	52	-71	24
Nn 150	21	-1	-70	-18	31	104	-13	81

Table A6. Contribution margin when steer carcasses are sold as premium-priced certified pasture beef in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system s (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	-206	-232	-279	-236	-232	-162	-287	-194
Gsk 100	-29	-56	-74	-32	-88	-19	-128	-36
Gsk 150	53	26	65	107	-36	34	-71	22
Gns 50	-131	-147	-226	-162	-116	-41	-139	-40
Gns 100	45	29	-20	41	28	103	20	119
Gns 150	127	111	119	180	80	156	78	177
Nn 50	-154	-165	-285	-215	-165	-92	-230	-135
Nn 100	14	2	-93	-25	-21	52	-71	24
Nn 150	84	72	-10	58	31	104	-13	81

Table A7. Contribution margin when labour demand on pasture is decreased to weekly animal supervision in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system s (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	-240	-276	-285	-257	-232	-162	-287	-194
Gsk 100	-80	-115	-106	-78	-88	-19	-128	-36
Gsk 150	-4	-40	29	50	-36	34	-71	22
Gns 50	-166	-190	-232	-183	-116	-41	-139	-40
Gns 100	-5	-30	-52	-5	28	103	20	119
Gns 150	71	45	82	124	80	156	78	177
Nn 50	-189	-209	-291	-236	-165	-92	-230	-135
Nn 100	-36	-57	-125	-72	-21	52	-71	24
Nn 150	27	6	-47	1	31	104	-13	81

Table A8. Contribution margin when cost for grass-clover silage is decreased with 0.02 Euro/kg dry matter in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system s (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	-230	-263	-301	-266	-217	-147	-258	-164
Gsk 100	-61	-94	-102	-69	-74	-3	-99	-6
Gsk 150	18	-16	34	66	-21	49	-42	53
Gns 50	-156	-178	-247	-193	-102	-26	-110	-10
Gns 100	14	-9	-48	4	42	118	49	149
Gns 150	93	70	87	139	95	171	107	207
Nn 50	-179	-197	-307	-246	-151	-77	-201	-105
Nn 100	-17	-35	-121	-62	-7	67	-42	54
Nn 150	49	31	-42	17	46	119	16	112

Table A9. Contribution margin when size of pasture enclosures is decreased to 2 ha independent of herd size in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system s (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	-322	-356	-435	-406	-232	-162	-287	-194
Gsk 100	-161	-196	-251	-224	-88	-19	-128	-36
Gsk 150	-102	-137	-182	-155	-36	34	-71	22
Gns 50	-247	-271	-382	-333	-116	-41	-139	-40
Gns 100	-87	-110	-198	-151	28	103	20	119
Gns 150	-28	-52	-129	-82	80	156	78	177
Nn 50	-231	-251	-374	-319	-165	-92	-230	-135
Nn 100	-70	-91	-191	-137	-21	52	-71	24
Nn 150	-12	-32	-125	-72	31	104	-13	81

Table A10. Contribution margin when existing building without opportunity cost is used in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system s (15, 18, 21, 28 age at slaughter in months), in three regions in Sweden (forest districts in Götaland (Gsk), plain districts in southern Sweden (Gns) and lower part of Norrland (Nn)), and at three herd sizes (50, 100, 150 is number of heads slaughtered per year), Euro per reared animal

	steers				*bulls*			
	dairy 21	dairy × beef 21	dairy 28	dairy × beef 28	dairy 15	dairy × beef 15	dairy 18	dairy × beef 18
Gsk 50	76	41	76	105	48	117	27	120
Gsk 100	178	142	207	235	124	194	118	210
Gsk 150	230	194	316	343	150	220	149	242
Gns 50	151	126	130	178	164	239	175	274
Gns 100	253	228	261	308	240	316	266	365
Gns 150	305	279	370	416	266	341	297	396
Nn 50	128	107	70	125	115	188	84	179
Nn 100	222	201	188	241	191	264	175	270
Nn 150	261	240	241	294	217	290	207	301

III

ACTA AGRICULTURAE SCANDINAVICA, SECTION A — ANIMAL SCIENCE
https://doi.org/10.1080/09064702.2023.2245400

Taylor & Francis
Taylor & Francis Group

Labour in suckler cow herds – a study on enterprises in southern Sweden

Kristina Holmström[a,b], Karl-Ivar Kumm[a], Hans Andersson[c] and Anna Hessle[a]

[a]Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Skara, Sweden; [b]Rural Economy and Agricultural Society Sjuhärad, Länghem, Sweden; [c]Department of Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden

ABSTRACT
This study aimed at examining labour demand in Swedish suckler cow operations grazing biodiverse semi-natural grasslands. Labour time was successfully recorded by 49 randomly selected farmers and their employees using an application in their mobile phone to register time for different labour tasks every 8th day for one year, crop production excluded. Median labour time for all herds was 17 hours/cow/year with a general lower workload per cow for large herds compared to small herds. Labour demand during the grazing period was however more dependent on the structure of pastures than herd size. The calving period was the most labour-intensive period, whereas supervision on pasture was the most time-consuming task both during the grazing period and the entire year. Large variations among herds indicates that there are often great opportunities for achieving a decreased labour time, not the least in small herds.

ARTICLE HISTORY
Received 30 May 2023
Accepted 2 August 2023

KEYWORDS
Labour time; work efficiency; workload; suckler cow; beef production; pasture fragmentation

Introduction

As in many countries in the European Union (EU), Swedish beef suckler cow herds are small (European Commission, 2022; Swedish Board of Agriculture, 2022). The average herd size of suckler cows in Sweden has increased from only 6 to 22 cows from year 1985 to 2022, while the number of herds is relatively unchanged. The labour demand per cow is correlated with herd size where larger herds generally are more labour efficient than smaller ones (Paul et al., 2004; Schrade et al., 2005), at least up to a certain size (Langemeier et al., 2004). Furthermore, farm fragmentation has a negative effect on efficiency (Fallon et al., 2006).

A lot of former Swedish dairy enterprises have changed their operation to suckler cows, which can explain why a lot of Swedish suckler cow herds are small. Of the Swedish suckler herds, 60% have 1–49 cows while only 2% of the enterprises have more than 100 suckler cows (Swedish Board of Agriculture, 2021a). Many suckler cow enterprises, especially the small ones, use buildings, machines, land and manpower which have been released when ceasing the dairy production. Those resources often have low or no opportunity cost, why the profitability can be acceptable even though the working time per cow sometimes is high. However, cheap existing resources will run out sooner or later. When investment in new buildings and machinery and market-related wages are required, then low labour demand per cow is necessary to achieve profitability (Kumm, 2006). In general, labour is one of the largest costs in suckler cow enterprises (Agriwise, 2022).

Labour demand in Swedish indoor beef production with intact bulls has previously been studied by Bostad et al. (2011). They found that labour demand per bull was not significantly affected by unit size from large (450 bulls reared/year; 0.4 min/bull/day) to very large (960 bulls reared/year; 0.3 min/bull/day) but they found that labour demand per animal were higher in smaller herds. Previous studies of labour demand in suckler cow herds are lacking in Sweden. However, based on practical experience from suckler herds, the daily labour requirement per suckler cow and replacement heifer in different herd sizes has been estimated (Nelson, 2002). The result indicates that the labour requirement per cow is halved when the herd size is increased from 20 to 150 cows. In larger herds, the time required per animal decreases with a slower rate than for smaller herds (Nelson, 2002). Production calculations for spring-calving suckler cows in Sweden typically uses labour demand of 12 or 15 hours/cow/year as a rule of thumb, and have done so for decades, while labour demand for dairy production has decreased rapidly (Agriwise, 2000, 2022; Gård & Djurhälsan, 2022).

CONTACT Kristina Holmström kristina.holmstrom@slu.se
Supplemental data for this article can be accessed online at https://doi.org/10.1080/13235818.2022.2036308

Labour demand in suckler cow herds has been measured in other countries with varying results. Fallon et al., (2006) found labour demand per suckler cow and year to be 6.7 hours in Ireland, when including feeding, cleaning, animal husbandry, farm maintenance and farm management. Labour demand was found to be much higher in Switzerland, where the animal husbandry included grassland maintenance, loading and driving cattle to and from alpine pastures, with an average of 66 hours/cow/year (Schrade et al., 2005). The average labour demand for British suckler cows was estimated to be between 10.8 and 34.8 hours/cow/year excluding feed production (Redman, 2020). Another British study distributed suckler cow operations after financial performance. They found the labour time per cow (with calf and 0.2 replacement heifer) including feed production, management of pasture and buildings and administration to be 16.6 hours per cow in the third of herds with the largest labour demand (average 54 cows). The labour time in the average labour demanding herds (90 cows) was 10.9 hours, whereas it was 9.2 hours per cow in the third of the herds having the lowest labour demand (101 cows) (Agriculture and Horticulture Development Board, 2016). These international studies show a huge variation in labour demand per cow, and the last one states work demand is much lower in large, profitable herds than in small herds with lower economic result. These large, profitable herds have significantly lower labour demand per cow than what is assumed in the Swedish suckler cow calculations cited above.

Suckler cows are often kept on biodiverse semi-natural pastures, where their grazing maintain the ecological, culture-historical, recreation and amenity values of these lands (Pykälä, 2005; Hanauer, 2015; Eriksson, 2022). The values of these lands are due to the long-standing continuous grazing-management, and occasional mowing, and they are therefore location-bound. They tend to be small and scattered, and thereby expensive to maintain, not the least due to high labour demand (Cederberg et al., 2018). Small herds in combination with small-scaled, scattered mosaic pastures is one reason for the mearge profitability in Swedish beef cattle production (Government Offices of Sweden, 2004), not the least as Swedish wages and cost of living are generally high compared to many other countries (OECD, 2018).

There is a long-lasting trend of decreasing numbers of small suckler cow enterprises, caused by the retirement of older farmers, while the younger generation at the farm finds profitability too small to continue with this production (Swedish Board of Agriculture, 2021a; Swedish Board of Agriculture, 2022). Many of the small suckler cow operations that still exist are family-based and dependent on off-farm work, which decreases the labour available at the farm. For existing suckler cow herds to carry on and new farmers taking over when older farmers retire, the enterprise must be able to provide acceptable labour remuneration per hour and therefore low labour demand per cow is necessary (Swedish Board of Agriculture, 2022). By adopting good techniques and/or practices, small farms can improve their competitiveness without growing in size (Sheng et al., 2015). Low labour demand per cow also makes it easier to combine a small suckler cow herd with off-farm work. It is therefore important to find working methods that decrease labour demand in suckler cow operations, both to increase the possibility to create larger herds for full-time enterprises, and to facilitate having off-farm employment on small suckler cow enterprises.

The aim of this study was to examine labour demand in Swedish suckler cow operations with different conditions regarding herd size and structure of pasture, and to demonstrate possibilities to reduce labour demand per cow.

Material and method

Selection of farms

Farmers with beef cow operations were recruited for the study by using an official register of all Swedish cattle herds at the Swedish Board of Agriculture. An invitation letter was sent to a random selection of 247 suckler cow enterprises with ≥20 suckler cows, performed by Swedish Board of Agriculture, in a radius 300 km from Skara, southwestern Sweden, in February 2019. All selected herds had to have loose housed or outdoor wintering systems to be part of the study, hence, herds in tied-up systems were excluded. The aim was to find similar numbers of enterprises within the herd sizes 20–50, 51–100 and >100 cows per farm. In the first round, 30 positive responses were received. After a reminder to the initial 247 invited enterprises, contact with a further 100 randomly selected farms from the official register, and one last reminder addressed only to farms with >100 cows were undertaken. After these actions, 68 enterprises (response rate 20%) were willing to participate in the study. Twenty-two of these farms had 20–50 cows, 26 farms had 51–100 cows and 20 farms had >100 cows.

Each of the enterprises were visited by the main author before entering the study and background farm data was collected by the help of a questionnaire (Appendix 1). The questions concerned structure of the farm, i.e area of pasture and arable land, calving time, number of workers etc. Some variables used in the analyses were calculated from those data. One such variable was median distance from the farm to animals on pasture, both on a group level and to individual animals in different pasture enclosures. The other variable was median distance from farm to paddock. Of the 68 visited farms, 51 entered the study and 49 completed the whole study period (Figure 1). The enterprises that participated had 20–280 suckler cows (18 farms with 20–50 cows, 17 with 51–100 cows and 15 with >100 cows) and the overall median herd size was 72 cows.

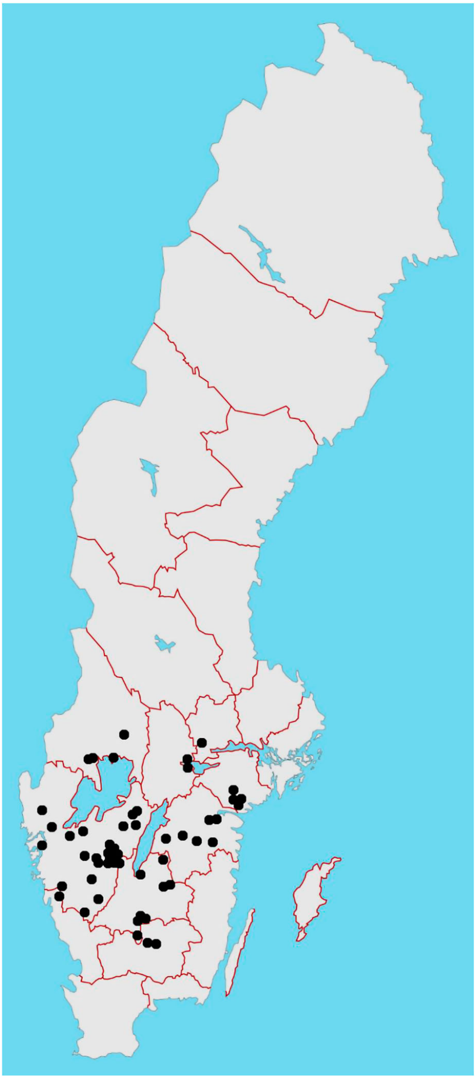

Figure 1. Location of investigated suckler cow enterprises in southern Sweden where labour time was measured.

Time logging of labour

The data collection on each enterprise aimed at measuring the workload during all seasons of the year and all days of the week, including weekends. In agricultural time studies it is important to incorporate weekends because family labour might carry out a disproportionately large part of their farming tasks during weekends (Abeyasekera and Lawson-McDowall, 2001). The starting time of the data collection varied from February 2019 to

Table 1. Definition of categories of work at investigated suckler cow enterprises. Maintenance = maintenance of buildings and machinery.

Category of work	Definition	Recurrent	Seldom
Administration	Planning, accounting, labour management and further education e.g. courses or study visits at other farms. From when you start the activity/arrive at the place until the activity/event is over (not travel time).	X	X
Bedding	From straw is picked up or, if straw is stored far away, when entering the farmyard. Finished when work is done.	X	
Cleaning	Mucking out from barns and cleaning e.g. water bowls, feeding table and wash barn. From entering the barn until the work is done.	X	X
Feeding	From the start of the tractor/feeding equipment until the work is completed. If feedstuff is stored far away the time begins when entering the farmyard.	X	
Fencing	Looking over and maintenance of existing fences, but not fencing new pastures. Starts when picking up equipment and leave the farm and lasts until being back to the farm again.	X	X
Maintenance	Buildings and machinery related to suckler cows. From when you start until the work is done and the equipment is put back again.	X	
Supervision indoor	Supervision and handling of housed cattle in barns, e.g. assistance at calving, marking calves and treatment of sick animals. From entering the barn until the work is done.	X	X
Supervision on pasture	Supervision of cattle at pasture, changing pasture enclosures and oversight of water, salt and mineral supplements. From leaving farmyard until being back again.	X	X

December 2019. All persons working in the enterprise logged their labour time with the cows, breeding bulls and replacement heifers in real-time during one whole day every 8th day for 12 months. Three of the enterprises measured all their animal-related labour on own initiative every day continuously, two of them for 365 days and one enterprise for 180 days. Labour with finishing cattle was not included in the study. The farmers/employees were asked to allocate their time recordings into eight different labour categories (Table 1). The categories were all animal-related tasks. Hence, work with e.g. crop production, maintenance of pasture or forestry was not included. Labour was logged in an application called 'A time logger' (©aLoggers 2019) in the person's smart phone and sent for further compilation by email to the author.

Estimates of labour time of seldom tasks

When using time logging every 8th day there is a risk of both missing or overestimating labour time for labour-intensive work occurring just once or a few times per year, in this study defined as 'seldom tasks'. To correctly incorporate the seldom tasks, the farmers were asked to estimate labour time for such tasks. The defined seldom tasks were study visits, meetings and courses (belonging to work category Administration), emptying straw beds and high pressure washing the barn (belonging to work category Manure handling), repair and inspect existing fence (belonging to work category Fencing), pregnancy test, hoof trimming, deworming, clipping and trade of livestock (belonging to work category Supervision indoor), and time for turning-out cattle to pasture and housing them for the winter-feeding period including transports (belonging to category Supervision on pasture).

Data on common, recurrent, work was analysed as it was collected, but for seldom tasks there was sometimes missing or double data, leading to this work time having to be processed before analysing. At the three farms where all work time was logged continuously everyday (365, 365 and 180 days, respectively), this data was used also for the seldom tasks (data defined as 'true'). If a seldom task at the other farms had been completely covered by every 8th daytime logging, this data was used (defined as 'recorded'). If a seldom task had been partly covered, it was possible to use an estimate based on knowledge of the proportion of work that had been done (for instance if one straw bed was emptied in eight hours, two beds would take 16 hours), this data was used (defined as recorded). If the seldom task had not been covered by the time logging at all, but estimated by the farmer in the questionnaire, this data was used (defined as 'farmer's estimate'). If both time log and estimate were lacking for a seldom task, a prediction was made by applying multilinear regression, using predict model in R version 4.1.3 (R Core Team, 2022) based on the workload on the other farms with similar conditions. In prediction for seldom tasks, number of cows was most often included, whereas the other variables in the model differed among the specific seldom tasks. For estimation of labour time for the seldom task emptying straw beds, labour time in barns with straw beds were included, while the model for estimate of labour time for deworming, trade of livestock and high pressure washing the barn included type of housing system. Models for estimation of time for fencing, turn-out on pasture and housing did not include number of cows. Instead, time for fencing was predicted from number of paddocks, hectares of pastures and median numbers of animals per paddock. Turn-out on pasture and housing of animals included number of animal groups, median number of groups and number of barns. Distribution of seldom tasks, independent of type of time estimate, was in average across farms 1.2 hours per cow, corresponding to 7% of the total labour time.

Periods

In the data analyses, the year was divided into three periods: calving period, grazing period and indoor non-calving period. The ranges of the periods were individually defined for each farm. Calving period was defined as starting on the day the first calf was born and lasting until the day when the last calf was born. Calving during summer grazing was regarded as grazing period, because so few calvings occurred during the grazing period. The start of the grazing period was defined as the day the cattle were turned out to pasture and lasted until the day when the cattle were housed again. For out-wintering cattle the grazing period ended when they were put in to their winter enclosure. The indoor non-calving period started on the day of housing and lasted until the day of turn-out to pasture, except during the period of calving.

Median daily amount of labour per work category and cow in each of the enterprises was calculated as well as the total labour in each of the three periods (calving period, grazing period and indoor non-calving period), and for the entire year.

Statistical data analyses

Statistical analyses were done in R and RStudio (R Core Team, 2022; RStudio Team, 2022). Correlations between variables were investigated using correlations and principal component analysis (PCA) (Le et al., 2008; Kassambara and Mundt, 2020). The correlation graph shows significant correlations from a t-test on the Pearson correlation coefficient at a significance level of 0.05. With the given number of replicates, the cut-off for significance is a correlation below −0.29 or above 0.29. A regression model on herd size and total labour time was done using a logarithmic model $y = \log10(x)$, where y = labour time per cow and year and x = number of cows. Model assumptions were checked using diagnostics graphs for normally distributed residuals and homoscedasticity (equal variance independent of the level of the explanatory variable). Finally, case-selection based on five farms, with ≤100 cows and with residuals in each end that diverged most from the regression line, were picked out for further analysis. The five farms furthest below the line had least labour time per cow and the five farms highest above the line had largest labour time per cow.

Results

Description of labour time

There was a large variation in labour time among suckler cow farms. In herds with 20–50 cows, labour time varied from a minimum value of 11.6 hours/cow/year to a maximum value of 40.6 hours/cow/year. In herds with 51–100 cows, the workload varied in a range from 9.7 to 41.9 hours/cow/year, and in herds with >100 cows the labour time varied from 7.9 to 28.5 hours/cow/year. The large distribution in labour time among farms is shown in Table 2. The annual median labour time was 17 hours per cow, corresponding to 2.8 minutes per cow and day.

Largest daily labour demand was found during the calving period (median 91 days) and least labour time during the indoor non-calving period (median 101 days). Although the animals usually were kept indoor in the same systems during these two periods, labour time for feeding, bedding and manure handling increased during the calving period (Table 2).

The single most time-consuming labour task across the year was supervision of animals and water supply on pasture (Table 2), corresponding to almost half of the total labour time during the grazing period (median 173 days). However, for the 75th percentile in herds with 20–50 cows, manure handling was the most time-consuming task across the year.

The labour time was unevenly distributed over the year, not only among the three studied periods (calving period, grazing period, and indoor non-calving period), but also among single weeks. This is illustrated with data from one of the farms, where the labour time was recorded every day during the investigated year (Figure 2). This enterprise shows a variation in workload from 0.9 minutes per cow during week 24 (on pasture) to 11.9 minutes per cow during week 44 (indoor), when all animals had been housed and, in addition to the daily tasks, pregnancy testing (supervision indoor) and a study visit (administration) was also undertaken.

Correlations and regression

Year

Farms with low daily labour time per cow across the entire year, generally spent less time at every single task whereas farms with large labour time spent more time on every task. The most important factors for the daily labour time per cow across the year, were number of cows (*r*: −0.37) and mechanical bedding (labour time and mechanical bedding *r*: −0.33; labour time and manual bedding *r*: 0.35) (Figure 3(a)). Manual bedding was in turn positively correlated with time spent on manure handling (*r*: 0.34), administration (*r*: 0.31) and maintenance (*r*: 0.29). Number of cows was negatively correlated with time spent on manure handling (*r*: −0.38) and time spent on supervision on pasture (*r*: −0.35).

Calving period and indoor non-calving period

Similar to the labour time across the year, the daily labour time per cow during calving and indoor non-calving periods, was negatively correlated to the number of cows (*r*: −0.36 and −0.33 for calving period and indoor non-calving period, respectively) (Figure 3 (b,d)). During the indoor non-calving period, the labour time per cow was also negatively correlated with number of employees (*r*: −0.31) and mechanical bedding (*r*: −0.31), and positively correlated with manual bedding (*r*: 0.43).

For the calving period, the number of cows was positively correlated with number of barns (*r*: 0.36). For the indoor non-calving period, the number of cows was positively correlated with length of calving period (*r*: 0.47), annual working unit (AWU) (*r*: 0.66) and number of employees (*r*: 0.56).

Grazing period

Although a negative correlation between number of cows and daily labour time spent on supervision on pasture was found on a yearly basis, no correlation between daily labour time and herd size could be

Table 2. Labour time (min) per suckler cow and day (25th, 50th and 75th percentile) of different work categories in Swedish suckler enterprises of three different herd sizes (n = no. of herds) during the calving period, the grazing period, the indoor non-calving period and yearly. Maintenance = maintenance of building and machinery, supervision ind. = supervision of animals indoor and supervision pas. = supervision of animals and water supply on pasture.

	Herd sizes, cows	20–50 (*n* = 16)			51–100 (*n* = 19)			>100 (*n* = 14)		
	Percentile	25	50	75	25	50	75	25	50	75
Period					Work category					
Calving	Administration	0.11	0.14	0.25	0.11	0.16	0.25	0.10	0.15	0.30
	Bedding	0.12	0.31	0.93	0.30	0.67	0.98	0.11	0.19	0.24
	Feeding	0.44	0.90	1.50	0.32	0.60	1.01	0.36	0.67	0.83
	Fencing	0.00	0.00	0.03	0.00	0.00	0.34	0.00	0.01	0.13
	Maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.06
	Manure handling	0.12	0.32	1.18	0.14	0.41	0.73	0.05	0.21	0.42
	Supervision ind.	0.90	1.18	1.66	0.46	0.90	1.28	0.47	0.77	1.30
	Supervision pas.	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04
	Total labour	**3.28**	**4.18**	**5.26**	**2.09**	**3.41**	**3.99**	**1.77**	**2.45**	**3.07**
Grazing	Administration	0.05	0.14	0.38	0.11	0.19	0.27	0.08	0.12	0.14
	Bedding	0.00	0.00	0.01	0.02	0.04	0.11	0.00	0.00	0.02
	Feeding	0.06	0.11	0.34	0.07	0.15	0.25	0.03	0.06	0.14
	Fencing	0.17	0.54	0.90	0.25	0.52	0.97	0.11	0.25	0.36
	Maintenance	0.00	0.00	0.02	0.00	0.03	0.23	0.00	0.02	0.27
	Manure handling	0.44	0.57	1.00	0.29	0.35	0.51	0.23	0.34	0.41
	Supervision ind.	0.00	0.04	0.18	0.02	0.09	0.22	0.01	0.05	0.30
	Supervision pas.	1.33	1.65	2.10	1.17	1.42	1.75	0.81	0.98	1.35
	Total labour	**2.63**	**3.41**	**4.38**	**2.23**	**3.17**	**4.32**	**1.57**	**1.93**	**2.50**
Indoor non-calving	Administration	0.06	0.13	0.22	0.10	0.14	0.22	0.07	0.09	0.13
	Bedding	0.07	0.30	0.51	0.20	0.35	0.63	0.14	0.18	0.23
	Feeding	0.45	0.92	1.33	0.41	0.52	1.00	0.33	0.41	0.83
	Fencing	0.00	0.00	0.02	0.00	0.00	0.13	0.00	0.00	0.12
	Maintenance	0.00	0.00	0.27	0.00	0.02	0.22	0.00	0.01	0.05
	Manure handling	0.17	0.43	0.98	0.16	0.29	0.45	0.04	0.08	0.41
	Supervision ind.	0.27	0.41	0.71	0.17	0.42	0.51	0.13	0.23	0.35
	Supervision pas.	0.00	0.00	0.04	0.00	0.00	0.01	0.00	0.00	0.00
	Total labour	**1.85**	**2.25**	**4.78**	**1.75**	**2.40**	**2.89**	**1.23**	**1.42**	**1.69**
Year	Administration	0.09	0.15	0.27	0.12	0.20	0.30	0.09	0.12	0.19
	Bedding	0.10	0.18	0.39	0.13	0.27	0.46	0.09	0.09	0.13
	Feeding	0.31	0.65	0.80	0.24	0.42	0.65	0.21	0.36	0.49
	Fencing	0.08	0.24	0.43	0.19	0.30	0.57	0.12	0.15	0.26
	Maintenance	0.01	0.06	0.12	0.01	0.08	0.23	0.00	0.02	0.18
	Manure handling	0.29	0.55	0.99	0.26	0.37	0.51	0.17	0.24	0.33
	Supervision ind.	0.34	0.40	0.62	0.24	0.44	0.58	0.24	0.36	0.62
	Supervision pas.	0.63	0.79	0.93	0.52	0.71	0.84	0.37	0.45	0.66
	Total labour	**2.71**	**3.40**	**4.32**	**2.12**	**3.01**	**4.05**	**1.72**	**1.92**	**2.51**

found when analysing this correlation for the grazing period separately.

Total daily labour time during the grazing period was positively correlated to time spent on supervision on pasture (*r*: 0.84), fencing (*r*: 0.73) and manure handling, mostly composing of emptying straw beds (*r*: 0.51) (Figure 3(c)). Some labour time during the grazing period was spent on supervision indoors (Table 2), e.g. of single housed sick cows.

The regression line (Figure 4) shows that the annual total labour time per suckler cow generally decreased with increasing herd size, but the distribution around the regression line was large, and largest in the herds with fewer cows. The variability explained by the model (17%) is in the range what can be expected in this kind of studies. For a tenfold increase in herd size from 20 to 200 cows, labour time decreased from 25.0 to 13.5 hours per cow. Nonetheless, in herds with more than 250 cows the decline in labour time per cow and year tended to cease. It should also be noted there were several small herds which had less labour demand per cow and year than larger herds.

Comparisons between farms with particularly low and particularly high labour consumption

Comparison of the five farms with ≤100 cows having least and most labour time (Figure 4) showed that farms with large labour time spent time on most tasks, compared to farms with least labour time, but especially on maintenance of buildings and machinery, feeding and bedding (Figure 5). The median of the daily workload of the farms with the least labour time was 23, 48, 40 and 36% of the workload at the five farms with the largest labour time during calving period, grazing period, indoor non-calving period, and across the entire year, respectively.

At the five farms with the low workload, four of the farmers worked off-farm, whereas only two farmers worked off-farm in the group with the high workload.

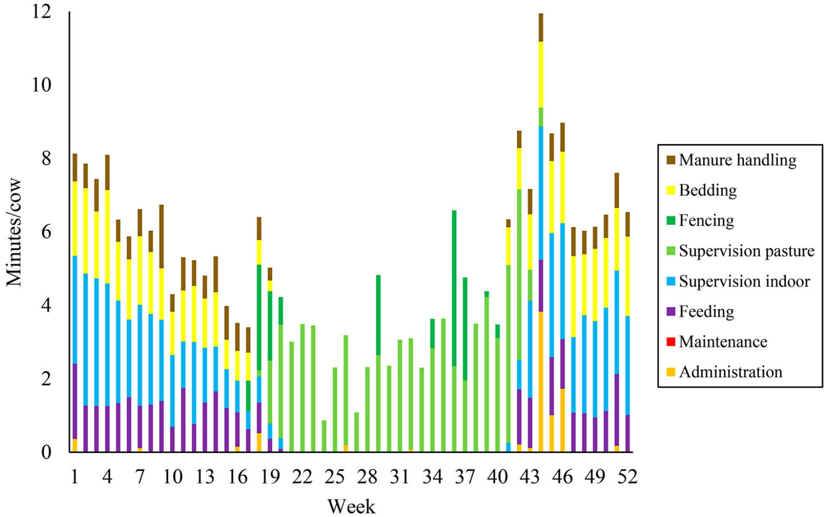

Figure 2. Labour time (min) per cow and week during a year logged continuously every day in a Swedish beef suckler cow farm with 69 cows, representative of the studied farms. Maintenance = maintenance of building and machinery, supervision pasture = supervision of animals and water supply on pasture.

Farms with low workload had one barn as a median, whereas farms with high workload had two barns. Both farm groups had cubicle housing as well as straw bed barns where the most common feeding strategy was to put silage bales on the feeding table. The median length of calving period was 61 days on the farms with low workload and 121 days on the farms with high workload.

Farms with a low workload had a median of five animal groups on pasture whereas farms with a high workload had three groups. The median value of the maximum distance from the farm centre to the pasture paddocks was four kilometres for farms with a low workload and seven kilometres for farms with a high workload (Appendix 2).

Discussion

The results of this study show that there is a large distribution in labour demand per cow and year (from 7.9 to 41.9 hours) among beef suckler cow herds in southern Sweden (Table 2 and Figure 4). A similar large distribution has also been found in Irish suckler cow production (Leahy et al., 2004; Fallon et al., 2006) and in Swedish indoor finishing bull production (Bostad et al., 2011). The five small farms (≤100 cows) with the least labour time per cow and day (furthest below the regression line, Figure 4) diverged most in workload compared to the five small farms with the largest labour time during the grazing period (Figure 5). In spite of having more animal groups on pasture, the farms with the least labour spent only 23% of the labour time that the farms in the high labour group spent during the same period.

Short SD (2001) categorized suckler cow operations both as being 'retirement and residential/lifestyle farms' and family farms of various sizes. These lifestyle farms studied by Short SD (2001) were part-time operations with small herds, less than 50 cows and having relatively high labour demand per cow. Nevertheless, these farms were generally profitable due to low total operating costs per cow stemming from having owned pasture resources to feed the animals. Short SD (2001) stated that suckler cow production tends to fit well into lifestyle farming compared to finishing cattle. The motivation for a lifestyle farmer in a Swedish context might not always be to achieve high labour efficiency, but rather an interest in animals and traditions, to be able to use existing resources or keeping biodiverse semi-natural grasslands around the residence open (Setten, 2002; Nitsch, 2009). A possible higher proportion of lifestyle farms in the present study on suckler cows than in the study on indoor finishing cattle of Bostad et al. (2011) might explain the larger dispersion in labour time in the suckler cow study.

Even in situations where labour efficiency is desirable, minimizing labour time is not the only goal. How the labour is distributed across the year and hence can be

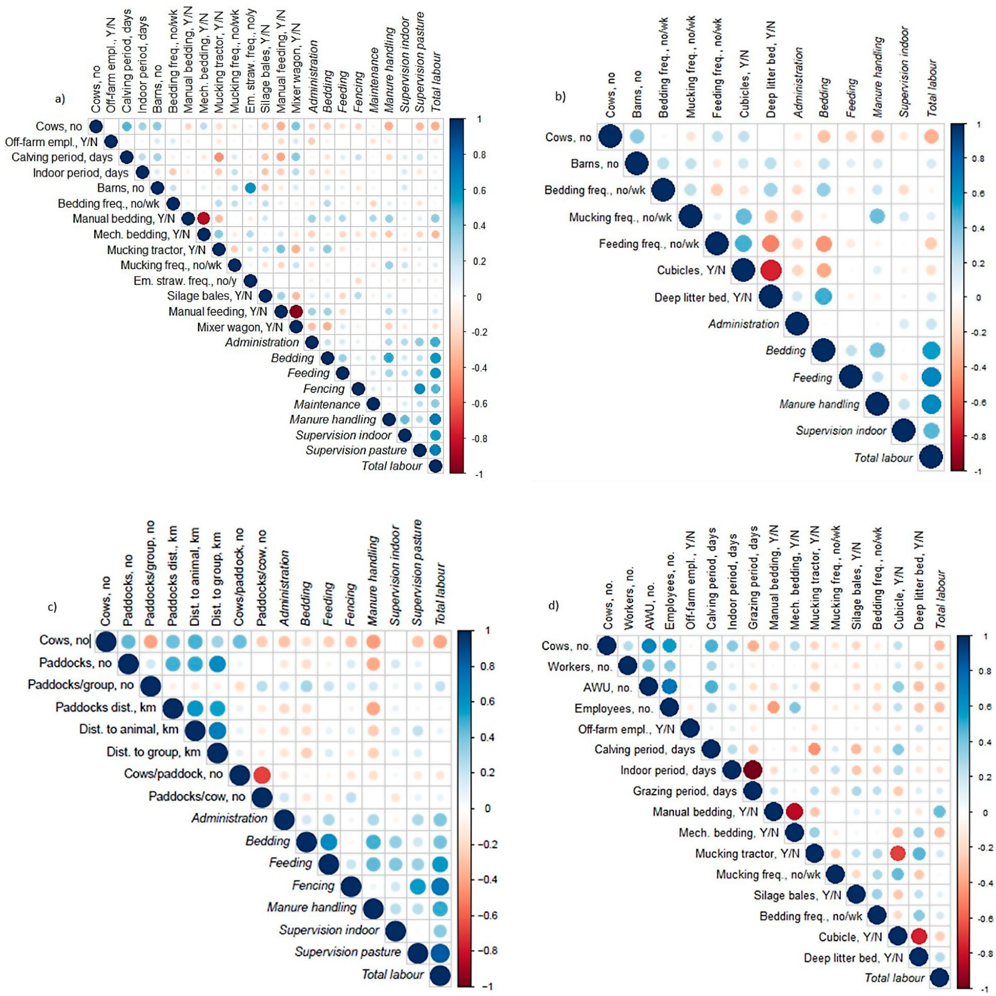

Figure 3. (a–d) Correlation matrixes for on-farm parameters (upright) and daily labour time (Italic) for (a) entire year, (b) calving period, (c) grazing period and (d) indoor non-calving period. Positive correlations are displayed in blue and negative correlations in red colour. Colour intensity and size of the circle are proportional to the correlation coefficients. Y/N = yes/no, freq. = frequency, dist = distance, AWU = annual working unit, off-farm empl. = off-farm work, both for owner and/or employees, mech. bedding = mechanical bedding and, em. straw freq. = emptying straw bed, no of times straw beds are mucked out during the year maintenance = maintenance of buildings and machinery.

combined with other engagement on and off the farm also needs to be considered (Figure 2). The large dispersion in labour time indicates an opportunity for improvements of competitiveness and efficiency in Swedish suckler cow production, where both lifestyle farms and very large, labour effective herds could be motivated.

The annual labour time per cow in the present study decreased along with an increasing herd size, which is in accordance to other studies (Short SD, 2001; Nelson, 2002; Schrade et al., 2005; Bostad et al., 2011; Agriculture and Horticulture Development Board, 2016). Based on all investigated herds, the annual labour time per cow is estimated to 25 hours for herds with 20 suckler cows, 17 hours for herds with 100 cows and 14 hours for herds with 200 cows (Figure 4). The shape of the regression curve for labour demand as a function of herd size (Figure 4) is similar to the one developed

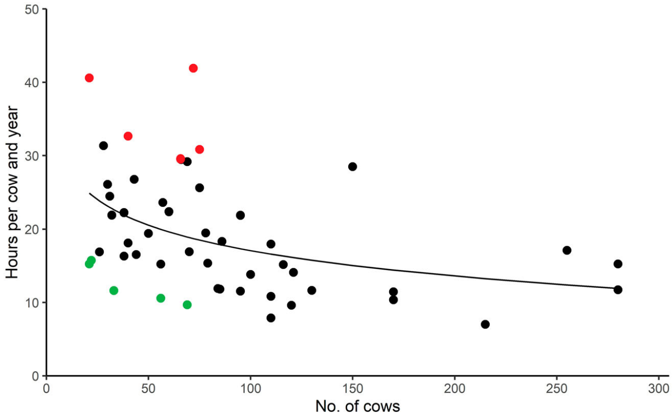

Figure 4. The points show labour time (hours) per suckler cow and year related to size in 49 Swedish beef operations. The logarithmic regression function has the form $y = 40–11.5 \times \log10(x)$, $R^2 = 0.17$, p-value <0.01. Five farms diverging most from the regression line are marked in green colour (below the line, least labour time) and red colour (above the line, largest labour time).

from a Swedish advisor's experiences up to 200 cows, but on a higher level of labour demand (Nelson, 2002). This discrepancy could partly be explained by the fact that our estimate includes labour time for administration, fencing, and maintenance of building and machinery, unlike the Nelson study. For herds larger than 200 cows, the curve from Nelson (2002) continues to fall while the largest herds in the present study have higher labour demand than both Nelson's estimate and the most labour efficient herds with 50–130 cows. The high workload in our largest herds could either indicate a decline in size advantage or be an artefact due to a low number of observations.

For housed beef cattle, a decreasing economies of scale previously has been explained by Bostad et al., (2011) and Finneran and Crosson (2013), who stated that when the optimum herd size has been reached, structural changes are better than scale changes for reaching further efficiency. This is in line with the results of our study, where herd size was positively correlated to number of barns during the calving period. Furthermore, the five small farms (≤ 100 cows) with the least labour time, compared to the regression line (Figure 4), had a median of one barn only, whereas the five small farms with most labour time had a median of two barns.

Although herd size in the present study was negatively correlated with labour demand per cow for the calving period and the indoor non-calving period, no effect of herd size was found on labour demand per cow during the grazing period. Instead, labour demand during the grazing period was more dependent on pasture fragmentation, as it was positively correlated with the time used for supervision on pasture and on fencing. Time spent on supervision of animals, water and fences on pasture was of great importance for the overall workload, as this was the single most time-consuming task across the year (Table 2). The suckler cows in the study grazed many small grasslands, scattered in the landscape between forests and arable land. Swedish livestock usually graze the same paddock continuously throughout the grazing period or is rotated among two or three paddocks with a few weeks' interval. The transport of cows to and between paddocks, and in some cases transports of water, were often over long distances, as well as the workers' transportation during animal supervision. The five small herds (≤100 cows) with the lowest workload per cow, compared to the regression line, had a median distance to the pasture of four kilometre, whereas the five small herds with the largest workload had a distance of seven kilometres. There was also a positive correlation between distance to paddocks with time spent on animal supervision indoors (Figure 3(c)). This could be explained by cattle being ill or needing extra supervision for some other reason, when the farmer is more inclined to keep them at home instead of on pasture if the distance to the paddock is long. Labour efficiency due to a large herd size during indoor periods were counter-acted by scattered location of and long distances to pasturelands during the grazing period. It might seem inconsistent that herd size was negatively correlated with time spent on supervision on pasture on a yearly basis, but not during the specific grazing period. This divergence is most likely because large herds in general have shorter grazing periods than smaller herds.

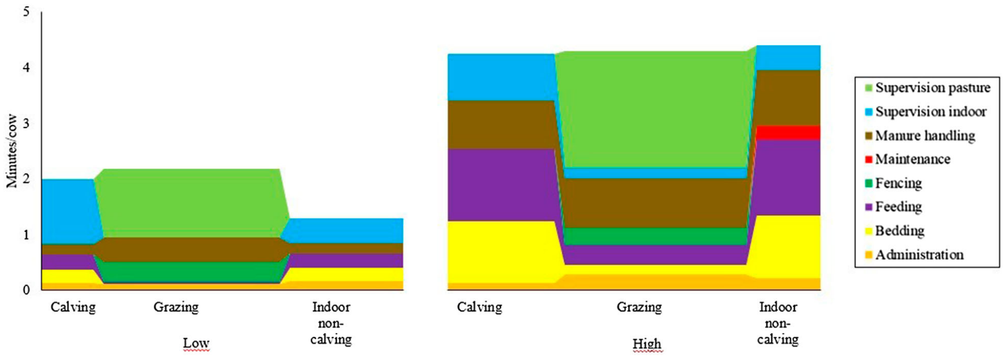

Figure 5. Median labour time (min) per suckler cow and day for the five farms with the least and the largest workload respectively, estimated as the largest deviation downwards vs. upwards from the regression line in Figure 4, in Swedish beef enterprises with ≤100 cows during calving, grazing and indoor non-calving period respectively, allocated into eight various tasks.

Fragmentation of pastureland has been noticed by other studies to decrease labour efficiency (Leahy et al., 2004; Fallon et al., 2006; Cederberg et al., 2018). For example, farmers interviewed by Cederberg et al. (2018) estimated labour time spent on supervision on scattered semi-natural pastures to be double when grazing one-hectare-paddocks compared to when grazing five-hectare-paddocks. Hence, due to variables related both to indoor and grazing periods, there are reasons to believe that the effect of herd size is not as large as was previously expected (Nelson, 2002).

Although there was a general negative correlation between herd size and labour time per cow, some small herds were also shown to have a low labour time per cow. The overall labour demand at the five small herds (≤100 cows) with the lowest workload was about half of the workload at the five small herds with the largest workload (Figure 4). A majority of these small farms with a low labour time per cow worked outside the farm, whereas the ones with a high workload did not. Work with the cattle may have a high opportunity cost for those who have a well-paid job outside the farm, whereas farmers who have no other work than the cattle may lack other income-generating work in certain parts of the year and hence it does not matter if the animal husbandry takes a little longer. When comparing full-time farmers with part-time farmers, Fallon et al. (2006) found part-time farmers to be more labour efficient than full-time farmers. Short SD (2001) also found that part-time lifestyle suckler cow farming could be labour efficient. In the present study we did not find any correlation between proportion of off-farm work and labour time for all the farms studied. Socio-economic factors, such as farmer's need of income-generating occupation, age and time in profession, as well as the quality of farm facilities, were not investigated, but could have influenced the result (Fallon et al., 2006).

Hence, the variation in labour demand suggests that relatively small and labour efficient herds, in combination with off-farm work, may sometimes be a good way to reach a satisfactory work/life balance compared to building up a herd that is very large for Swedish conditions.

In other countries (Leahy et al., 2004; Fallon et al., 2006; Agriculture and Horticulture Development Board, 2016) the labour demand per cow is generally lower than on most of the farms in the present study, but not always lower than the most labour efficient ones. The generally higher labour demand in Sweden may be due to the fact that Swedish production is generally small-scale, having a long indoor period and lacks both a long tradition of suckler cow production and large coherent pastureland. Hence, land structure and climate conditions affect labour demand and other costs, resulting in Swedish farmers having a higher total costs for beef production compared to other countries (Government Offices of Sweden, 2004). It should be noted that the herds in the present study on average were four times larger (88 cows) than the Swedish average suckler cow herd (22 cows); (Swedish Board of Agriculture, 2022). Schrade et al. (2005) reported larger annual labour demand in Swiss suckler cow herds (on average 38 hours routine work per cow including fencing and water supply on pasture) than in the previous study, which can be explained by a large demand in the Swiss alps, i.e. for travelling.

Maintaining a national Swedish suckler cow herd is important not only for food production, but also for preserving the biodiverse semi-natural grasslands, since almost half of that area is grazed by suckler cow operations (Swedish Board of Agriculture, 2021a). A prerequisite for long-term continued suckler cow operations is that they are profitable. During the last decades, structure rationalization has been high in dairy and pig operations, but not in beef production, and especially not in the suckler cow operations (Swedish Board of Agriculture, 2022). Family farm incomes are lower in Swedish beef production than in dairy and pig production (Swedish Board of Agriculture, 2021b). This is partly due to the costs in beef production having increased more than revenues during the last decades and especially the labour costs (Agriwise, 2000, 2022). Labour is one of the largest costs in suckler cow operations, accounting for approximately 20% of the total costs (Agriwise, 2022). Compensation to the owner for labour time and invested capital in beef production is lower than wages paid for employees (Swedish Board of Agriculture, 2021b). Therefore, is it of great importance to decrease labour demand in suckler cow production.

As previously discussed, supervision of animals, water and fences during the grazing period was found to be the most time-consuming task across the entire year, and the fragmentation of the pastures is a reason for the high workload. By creating larger coherent paddocks out of small scattered semi-natural grasslands and adjacent forestland and marginal arable land, the cattle can be kept in larger but fewer groups and the labour time hence be reduced (Holmström et al., 2018, 2021). Such arrangement has proved to be profitable (Holmström et al., 2018, 2021; Kumm and Hessle, 2020).

In spite of a similar structure of pastureland and animal group sizes, supervision of animals during the grazing period had a labour demand 2.5 times larger in the present study than in a previous Irish study (Fallon et al., 2006). This divergence can be explained by the fact that daily inspection of every single animal is mandatory due to the Swedish animal welfare regulation (Swedish Board of Agriculture, 2019). The actual time spent on supervision on pasture might even have been higher. If someone else than the farmers and their employees supervised the animals or fences, for example, a neighbour, this labour was not recorded. Furthermore, farmers commented that they do not always regard animal supervision as work, but leisure time, as they combined the work with walking the dog, etc. We did not ask the farmers whether all animals were supervised daily (as the Swedish law prescribes) or not. If they had, the time spent on supervision on pasture would have been much higher than presented (Högberg, 2021). At present, daily manual surveillance of every single animal is compulsory by the Swedish animal welfare regulation (Swedish Board of Agriculture, 2019). If animal surveillance achieved by digital sensors would be allowed, labour time spent on animal supervision would in future be possible to reduce by using new innovative decision support systems with remote surveillance of animal behaviour and welfare (Högberg, 2021). If supervision of suckler cows could be decreased from daily to twice a week, it would decrease the labour input by between 1.7 and 4.3 hours/cow/year.

Feeding was the most time-consuming task during the indoor non-calving period, similar to results on the farms studied by Schrade et al. (2005) and also finishing beef operations studied by Bostad et al. (2011), where feeding and bedding accounted for the highest labour demand. The tasks took longer time per animal for the suckler cow herds in our study than for the finishing cattle studied by (Bostad et al., 2011), which might derive from different herd sizes and the use of different types of barns and/or degree of mechanization.

The result from this study shows that for total annual labour time, mechanical bedding is of great importance in order to save labour time, which is similar to the results in other studies (Fallon et al., 2006; Bostad et al., 2011; Veysset et al., 2015).

In accordance with previous studies on finishing beef and suckler cows (Fallon et al., 2006; Bostad et al., 2011), we had expected that a higher frequency of feeding, bedding and manure handling would increase the total workload on the farms, but no such effect was found (Figure 3(d)). This is most likely due to a statistically confounding effect of higher frequencies and degrees of mechanization being positively correlated to herd size. A similar (confounding) effect might be in play for the structure of barns. Bostad et al. (2011) found that farm fragmentation increased labour demand in finishing beef production. As previously stated, the five small farms with the least labour time per cow had one barn, whereas the five small farms with the most labour time had two barns as a median. However, no correlation between labour time and number of barns was found on an annual basis when analysing all farms. Probably the size advantage of larger herds counteracted the extra work brought on by using several barns, so that larger herds with many barns still had less labour time than smaller herds. The declining size advantage for very large herds discussed above (Figure 4) could however be partly due to building fragmentation.

We found that the largest daily labour demand occurred during the calving period, which is similar to what Fallon et al. (2006) and Leahy et al. (2004) found in Irish herds. However, our study showed an average daily labour time per cow 10 times higher than Fallon et al. (2006), despite the larger average herd size in the present study. Large Swedish suckler cow herds often have two calving seasons, one during spring and one during autumn, whereas the study by Fallon et al. (2006) mainly was conducted on spring calving suckler-beef systems. The divided calving season is implemented in order to lower the daily work load during the labour-intensive period, to increase the use of the barn and to decrease risks of infection when spreading the calving period (Leahy et al., 2004).

In accordance with the calving period being the most labour-intensive period, we found that the small farms (≤100 cows) with lowest labour time per cow often had a short calving period (61 days compared to farms of similar size having the largest labour demand where the calving period was 121 days). No correlation between length of calving period and labour time could however be found. These inconsistent results are probably due to a confounded effect between herd size and length of calving period as larger herds generally had a longer calving period.

In this study we did not investigate how or if the farms used observation cameras or calving indicator equipment during the calving period, if they grouped the cows according to calving date, or if they practised night feeding, which leads to a higher probability of calvings to occur during daytime (Lowman et al., 1981). All these measures have previously been identified as good labour-saving practices during the calving period (Leahy et al., 2004; Fallon et al., 2006).

The response rate of this study was 20%. There might have been a selection bias due to the number of non-participants, but there was unfortunately no way to compare these with the participants. Our perception of the general reason for non-responding was a lack of time for the farmers.

According to Bostad et al. (2011) to underestimate labour time is more common than to overestimate it. In our study, especially the supervision on pasture and work with fencing might have been under-estimated as previously discussed. Some other tasks might also have been under-estimated. When comparing the on forehand estimates of seldom tasks from the interview, for instance mucking out straw beds, with the recorded actual labour time, some low figures in the former data source was found, indicating under-estimation.

Based on the results, it can be concluded that the median labour demand was 17 hours/cow/year, but varied greatly among farms, not only between herd sizes but also within herd size, with a variation from 7.9 to 41.9 hours. Herd size was negatively correlated with labour time per cow during the calving period and indoor non-calving period, but not during the grazing period when the cows often were allocated into groups and grazing fragmented pastureland. Supervision of animals, water and fences on pasture was the most time-consuming task across the year, whereas the calving period was the most labour-intensive period. The results show that labour demand of housed cattle can be reduced by mechanical bedding and having a short calving period. Even if there is a generally smaller labour demand per cow in larger herds, we conclude that small herds can be as efficient as larger ones.

Acknowledgements

We wish to thank each of the suckler cow farmers and their employees, who participated in the study by filling in the labour time in the app and sending it to us. Adam Flöhr, SLU, Alnarp, is acknowledged for the statistical discussions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

We are also grateful for the funding from Västra Götalandsregionen (grant numbers RUN 2018-00137, MRU 2023-00117), the Rural Economy and Agricultural Society Sjuhärad, the Swedish University of Agricultural Sciences, and Bröderna Jonssons fund .

References

Abeyasekera, S. & Lawson-McDowall, J. (2001). *Computerising and Analysing Qualitative Information from a Study Concerning Activity Diaries* (Chatham: Natural Resources Institute).

Agriculture and Horticulture Development Board. (2016). Beef: Cost of production benchmarks - suckler herds. Accessed 13 June 2022, available at: https://ahdb.org.uk/beef-cost-of-production-benchmarks/suckler-herds.

Agriwise. (2000). Agriwise-SLU. Accessed 9 June 2022, available at: http://www.agriwise.org/Databoken/index_oldfiles_12.aspx.

Agriwise. (2022). Agriwise - Smart kalkylering. Accessed 5 April 2022, available at: https://www.agriwise.se/web.

Bostad, E., Swensson, C. & Pinzke, S. (2011). Labour input in specialist beef bull production in Sweden. *Agricultural Engineering International: CIGR Journal*, 13(3). Accessed 9 May 2018, available at: http://cigrjournal.org/index.php/Ejounral/article/view/1920.

Cederberg, C., Henriksson, M. & Rosenqvist, H. (2018). Ekonomi och ekosystemtjänster i gräsbaserad mjölk- och nötköttsproduktion. Chalmers tekniska högskola, Göteborg: Instutitionen för rymd-. geo- och miljövetenskap.

Eriksson, O. (2022). Coproduction of food, cultural heritage and biodiversity by livestock grazing in Swedish semi-natural grasslands. *Frontiers in Sustainable Food Systems*, 6. Accessed 28 October 2022, available at: https://www.frontiersin.org/articles/10.3389fsufs.2022.801327.

European Commission. (2022). Database Eurostat. Accessed 28 February 2022, available at: https://ec.europa.eu/eurostat/web/agriculture/data/database.

Fallon, R. J., Leahy, H., O'Riordan, E. G. & Ruane, D. (2006). *A Study of Time and Labour Use on Irish Suckler Beef Farms* (Dunsany: Teagasc). Accessed 28 February 2022, available at: https://t-stor.teagasc.ie/handle/11019/1133.

Finneran, E. & Crosson, P. (2013). Effects of scale, intensity and farm structure on the income efficiency of Irish beef farms. *International Journal of Agricultural Management*, 2 (4), 1–12.

Gård & Djurhälsan. (2022). Accessed 5 April 2022, available at: https://www.gardochdjurhalsan.se/.

Government Offices of Sweden. (2004). Genomförandet av EU:s jordbruksreform i Sverige/ Implementation of the EU agricultural reform in Sweden. Accessed 16 November 2017, available at: http://www.regeringen.se/rattsdokument/departementsserien-och-promemorior/2004/01/ds-20049/.

Hanauer, M. (2015). Comparative Ecological and Functional Analysis of Grazing Systems. Regensburg: Der fakultät für Biologie und Vorklinische Medizin; Accessed 5 October 2022, available at: https://epub.uni-regensburg.de/33329/1/Dissertation_Maria%20Hanauer.pdf.

Högberg, N. (2021). *Sensing the worms - automated behaviour monitoring for detection of parasitism in grazing livestock*. Dissertation. Uppsala, Sweden: Swedish University of Agricultural Sciences, available at: https://publications.slu.se/?file=publ/show&id=111607.

Holmström, K., Hessle, A., Andersson, H. & Kumm, K.-I. (2018). Merging small scattered pastures into large pasture-forest mosaics can improve profitability in Swedish suckler-based beef production. *Land*, 7(2), 58. doi:10.3390/land7020058

Holmström, K., Kumm, K.-I., Andersson, H., Nadeau, E., Segerkvist, K. A. & Hessle, A. (2021). Economic incentives for preserving biodiverse semi-natural pastures with calves from dairy cows. *Journal for Nature Conservation*, 62, 126010. doi:10.1016/j.jnc.2021.126010

Kassambara, A. & Mundt, F. (2020). Factoextra: Extract and visualize the results of multivariate data analyses, available at: https://CRAN.R-project.org/package=factoextra.

Kumm, K.-I. (2006). Scenarios for profitable beef and lamb production. ResearchGate. Accessed 15 May 2017, available at: https://www.researchgate.net/publication/242112192_Vagar_till_lonsam_not-_och_lammkottsproduktion_Scenarios_for_profitable_beef_and_lamb_production.

Kumm, K.-I. & Hessle, A. (2020). Economic comparison between pasture-based beef production and afforestation of abandoned land in Swedish forest districts. *Land*, 9(2), 42. doi:10.3390/land9020042

Langemeier, M. R., McGrann, J. M. & Parker, J. (2004). Beef cattle handbook: Economies of size in cow-calf production. Accessed 24 April 2017, available at: http://www.iowabeefcenter.org/bch/CowCalfEconomySize.pdf.

Le, S., Josse, J. & Husson, F. (2008). FactoMineR: An R package for multivariate analysis. *Journal of Statistical Software*, 25 (1), 1–18. doi:10.18637/jss.v025.i01

Leahy, H., Ruane, D. J., O'Riordan, G. E. (2004). An investigation into the impact of farm labour use on Irish suckler beef farms. In: Dublin: 20th Annual Conference AIAEE, pp. 519–530.

Lowman, B. G., Hankey, M. S., Scott, N. A., Deas, D. W. & Hunter, E. A. (1981). Influence of time of feeding on time of parturition in beef cows. *The Veterinary Record*, 109(25–26), 557–559.

Nelson, B.-O. (2002). Kalkylmodell för nötköttsproduktion. Ängelholm: Skogs- och lantarbetsgivareförbundets analysgrupp.

Nitsch, U. (2009). Bönder, myndigheter och naturbetesmarker. Uppsala: Centrum för biologisk mångfald, Swedish University of Agriculture; Accessed 5 April 2023, available at: https://www.slu.se/globalassets/ew/org/centrb/cbm/dokument/publikationer-cbm/cbm-skriftserie/skrift23.pdf.

OECD. (2018). Innovation, agricultural productivity and sustainability in Sweden. oecd-ilibrary.org. Accessed 12 May 2022, available at: https://read.oecd-ilibrary.org/agriculture-and-food/innovation-agricultural-productivity-and-sustainability-in-sweden_9789264085268-en.

Paul, C., Nehring, R., Banker, D. & Somwaru, A. (2004). Scale economies and efficiency in U.S. agriculture: Are traditional farms history? *Journal of Productivity Analysis*, 22(3), 185–205. doi:10.1007/s11123-004-7573-1

Pykälä, J. (2005). Cattle grazing increases plant species richness of most species trait groups in mesic semi-natural grasslands. *Plant Ecology*, 175(2), 217–226. doi:10.1007/s11258-005-0015-y

R Core Team. (2022). R: A language and environment for statistical computing. Accessed 31 May 2022, available at: https://www.R-project.org/.

Redman, G. (2020). *John Nix Pocketbook for Farm Management for 2021* (Leicestershire: Agro Business Consultants Ltd). www.thepocketbook.co.uk.

RStudio Team. (2022). RStudio: Integrated Development for R, available at: http://www.rstudio.com/.

Schrade, S., Keck, M., Schick, M. & Krause, M. (2005). Determination of working-time requirement in suckler cattle farming using a combination of recording methods. Accessed 27 February 2022, available at: https://www.semanticscholar.org/paper/Determination-of-working-time-requirement-in-cattle-Schrade-Keck/c3aab12d821c13a47c7b9aae4ab782bb7de5eb1b.

Setten, G. (2002). *Bonden og landskapet* (Trondheim: Geografisk institutt, Norges teknisk-naturvitenskapelige universitet). Accessed 5 April 2023, available at: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/265231/123952_FULLTEXT01.pdf?sequence=1.

Sheng, Y., Zhao, S., Nossal, K. & Zhang, D. (2015). Productivity and farm size in Australian agriculture: Reinvestigating the returns to scale. *Australian Journal of Agricultural and Resource Economics*, 59(1), 16–38. doi:10.1111/1467-8489.12063

Short SD. (2001). *Characteristics and Production Costs of U.S. Cow-Calf Operations* (Washington, DC: U.S. Department of Agriculture, Economic Research Service). Accessed 24 April 2017, available at: https://www.ers.usda.gov/publications/pub-details/?pubid=47151.

Swedish Board of Agriculture. (2019). SJVFS 2019:18: Statens jordbruksverks föreskrifter och allmänna råd om nötkreaturshållning inom lantbruket/The regulations and general advice of the Swedish Board of Agriculture about cattle farming in agriculture. Jönköping, Sweden. Accessed 6 April 2023, available at: https://lagen.nu/sjvfs/2019:18.

Swedish Board of Agriculture. (2021a). Den vanligaste besättningsstorleken för kor för uppfödning av kalvar är 25-49 kor. Jordbruket i siffror. Accessed 9 June 2022, available at: https://jordbruketisiffror.wordpress.com/2021/11/10/den-vanligaste-besattningsstorleken-for-kor-for-uppfodning-av-kalvar-ar-25-49-kor/.

Swedish Board of Agriculture. (2021b). The farm economics surveys (JEU) 2021. Accessed 16 March 2023, available at: https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2023-02-24-jordbruksekonomiska-undersokningen-2021.

Swedish Board of Agriculture. (2022). Statistics Sweden. Accessed 27 February 2023, available at: https://jordbruksverket.se/om-jordbruksverket/jordbruksverkets-officiella-statistik/jordbruksverkets-statistikrapporter/statistik/2022-07-05-jordbruksstatistisk—sammanstallning-2022.

Veysset, P., Lherm, M., Roulenc, M., Troquier, C. & Bébin, D. (2015). Productivity and technical efficiency of suckler beef production systems: Trends for the period 1990–2012. *Animal*, 9(12), 2050–2059. doi:10.1017/S1751731115002013

Appendix A1

Questionnaire

1) Number of suckler cows, replacement heifers, sires, slaughter animals
2) Number of people working at the farm
3) Number of employed outside family
4) Contracted work at the farm
5) Farmer’s off-farm work
6) Breed
7) Number of weaned calves and time for weaning
8) Time for turn-out to pasture and time for housing
9) Conventional, organic or other concept
10) Kind and number of barns for suckler cows
11) Kind of litter, distribution and frequency of bedding
12) Kind and frequency of roughage distribution
13) Kind and frequency of manure handling, both daily and mucking out deep litter
14) Time and procedure of cleaning the barn(s)
15) Localisation of roughage storage, close by or far away
16) Area arable land and semi-natural pasture
17) Number of pasture enclosure
18) Grazing routines, rotation or continuously grazing
19) Distance from farm centre to pasture enclosures
20) Type of drinking water provision on pasture, hose, surface water or manually filled tanks
21) Age of last building built, and information on any big repairs upcoming this year
22) Estimation of labour time per year for non-recurrent moment, e.g. clipping, pregnancy test, hoof trimming
23) Estimated labour time per year for visits from veterinarian, controllers (e.g. animal welfare, environment protection, EU agri-environmental payment and support), and advisors

Appendix A2,

Table A2, Characteristics in five farms with low workload (green) and five farms with high workload (red) in southern Sweden

	Low workload					High workload				
Farm no	1	2	3	4	5	1	2	3	4	5
Cows, no	33	21	56	69	22	72	21	75	40	66
Off-farm employment, Y/N	Y	Y	Y	N	Y	Y	N	N	Y	N
Barns, no	1	1	1	1	1	3	1	2	2	1
Calving period, days	68	31	88	61	43	121	50	122	91	186
Indoor period, days	181	187	197	175	166	198	181	193	178	186
Grazing period, days	184	178	168	190	199	167	184	172	187	179
Cubicles, Y/N	Y	Y	Y	N	N	Y	N	Y	N	N
Mechanical bedding, Y/N	N	N	N	Y	Y	Y	N	N	N	N
Mucking tractor, Y/N	N	N	Y	Y	Y	N	Y	Y	Y	Y
Empty strawbed frequence/year	1.5	0	0	1	1	2	1	1	0	1
Maximum distance to paddock, km	4	3	11	4	0.8	7	3	23	2	10
Distance to animal, km	2	0	11	2	0	5	1.5	11.5	1	1
Distance to group, km	3.1	1.3	11	5	0	3	1.5	11.5	1	2

Acta Universitatis Agriculturae Sueciae

Doctoral Thesis No. 2024:93

Economies of scale and differences in profitability between different cattle production systems: is this a way to create economically sustainable beef enterprises in Sweden? This thesis examined profitability when creating larger pasture enclosures, differences in profitability between herd sizes and animal production systems across Sweden, labour demand in beef cow herds, and profitability when feeding different grass silages produced under different weather conditions. Economies of scale improved profitability and there were differences in profitability between different cattle production systems shown.

Kristina Holmström received her doctoral education at the Department of Applied Animal Science and Welfare, Swedish University of Agricultural Sciences. Her undergraduate degree was received at the Swedish University of Agricultural Sciences.

Acta Universitatis Agriculturae Sueciae presents doctoral theses from the Swedish University of Agricultural Sciences (SLU).

SLU generates knowledge for the sustainable use of biological natural resources. Research, education, extension, as well as environmental monitoring and assessment are used to achieve this goal.

ISSN 1652-6880
ISBN (print version) 978-91-8046-420-8
ISBN (electronic version) 978-91-8046-428-4