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

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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

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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).

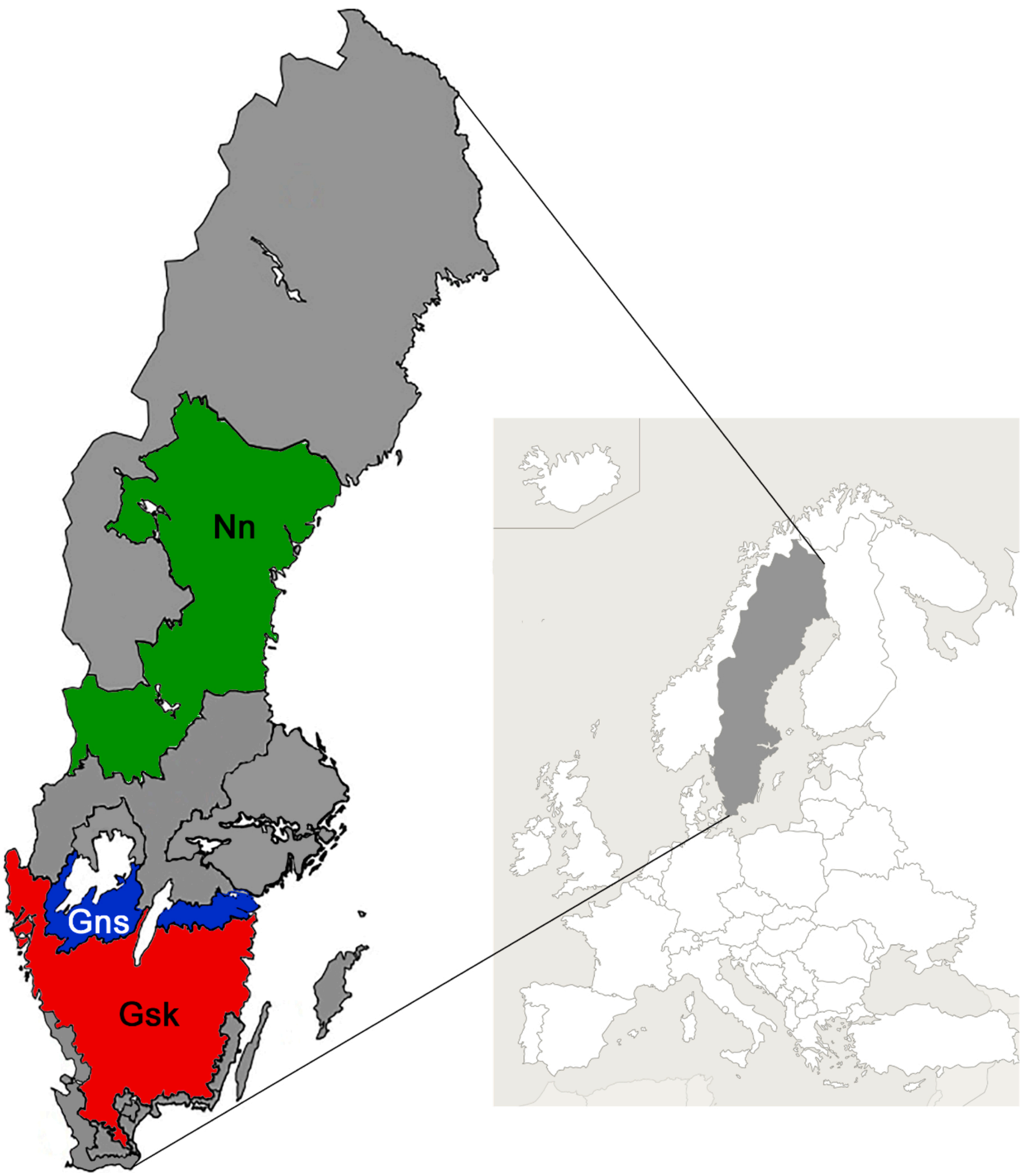

Fig. 1. Localization of three geographical regions in Sweden, forest districts in Götaland (Gsk), plain districts in northern Götaland (Gns), and lower parts of Norrland (Nn) (Swedish Board of Agriculture, 2020a).

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

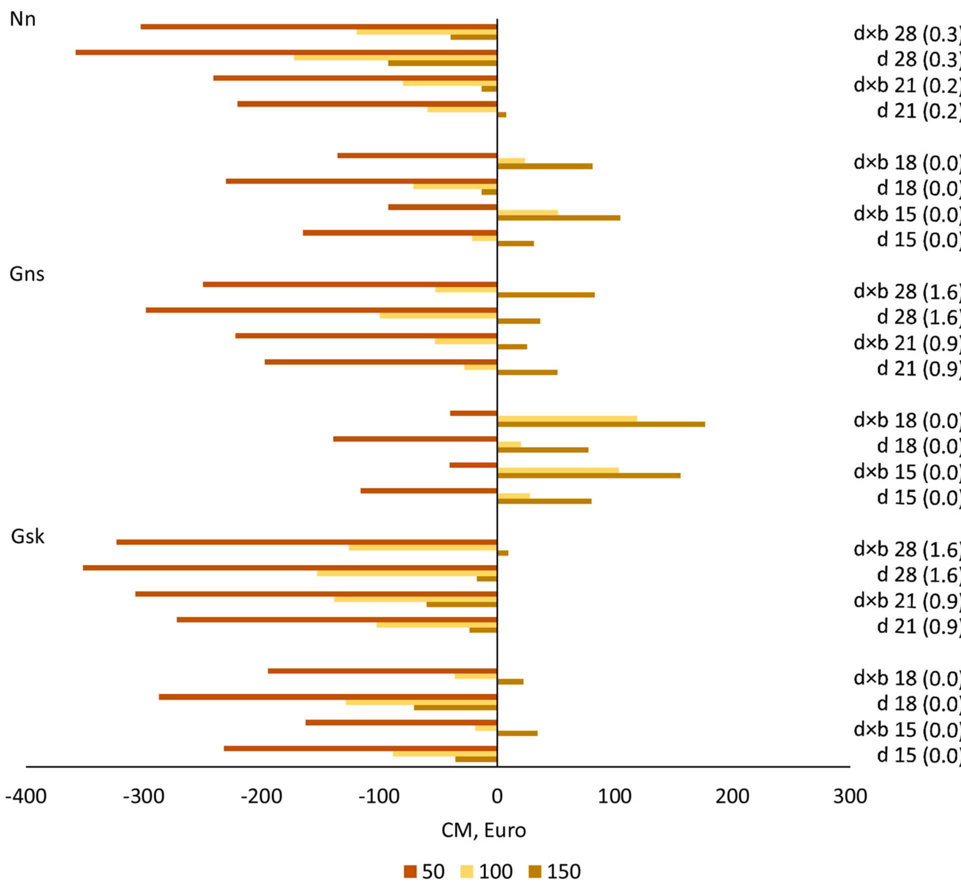

Fig. 2. Basic calculation of contribution margin (CM = contribution to management and risk) in beef enterprise with grazing steers and indoor bulls of varying breed (d is dairy, d x b is dairy x beef crossbreed), in different production system (15, 18, 21, 28 is age at slaughter in months with ha grazed 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 $150 \times 0.9 = 135$ ha and for the same herd size steers reared to 28 months of age, grazing two summers, require $150 \times 1.6 = 240$ 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.

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

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